10th Anniversary Celebration
October 31 - November 2, 1999

Classic Reviews

**From Past
Comprehensive Review Courses
In Prosthodontics**

Volume I

SCHOOL OF DENTISTRY · University of MICHIGAN ·

The University Of Michigan
Ann Arbor, Michigan

COMPREHENSIVE REVIEW IN PROSTHODONTICS

The first Comprehensive Review in Prosthodontics was held on November 14-17, 1990. The basic organization of the course involved a series of lectures presented during three consecutive all-day sessions by faculty from the ,University of Michigan, School of Dentistry, and special guest faculty of national and international prominence. Initially the course was designed for graduate students preparing for board examinations, and clinicians that wanted an update on prosthetic dentistry. Over the years however, what has evolved is a series of presentations designed when possible to provide clinicians with evidenced-based information that can be used to support various treatment options in their practices. When scientific fact was lacking, the faculty presented their opinions that were based on extensive clinical experience. Participants attending the course have always been able to ask questions of the speakers regarding their presentations after each lecture.

Since that initial course offering, the review course has been an annual event with either new speakers presenting new topics or speakers from previous years updating their material. The primary focus remains the same with the additional advantage of also providing the practicing general dentist as well as the prosthodontist with a clear understanding of the research and biological reasons for what we do each and every day in managing the prosthetic needs of our patients. Intensive reviews about dental materials, techniques, and the application of new technologies have been the focus of each annual course. Written material for each presentation have been provided in a "workbook" for each participant. These "handout" materials have become an extremely valuable reference source used by practitioners on a daily basis.

In the past nine and this tenth course, fifty-seven (57) faculty have participated, and the success of this program belongs to them. For the 10th Anniversary of the "Comprehensive Review Course In Prosthodontics" we have prepared two volumes of "Classic Reviews" that represent thirty-seven (37) presentations from the past nine years. We hope they prove as helpful to you as they did to those who attend the past courses.

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TABLE OF CONTENTS

Section One - Fixed Prosthodontics

Section One contains information related to fixed prosthodontics. It provides references and background material ranging from the biomechanics in oral rehabilitation to treatment sequencing. Preparation designs and concepts and why and when to use posts and cores are presented in this section. Occlusal concepts and schemes for the natural teeth and the importance of this topic in oral rehabilitation is also detailed. The following authors and the titles of their presentations follow:

Dr. Marion J. Edge

"Occlusion And The Natural Dentition"

Dr. Joseph A. Clayton

"Occlusion For Natural Teeth"

Dr. Carl J. Andres

"Preparation Design Concepts In Fixed Prosthodontics"

Dr. Dan Nathanson

"Post And Cores In Fixed Prosthodontics:

Dr. Kenneth A. Turner

"Treatment Sequencing Of The Prosthodontic Patient"

Dr. Ronald H. Jarvis

"Biomechanics In Fixed Prosthodontics"

Occlusion And The Natural Dentition

Dr. Marion J. Edge

"OCCLUSAL SCHEMES IN FIXED PROSTHODONTICS"

History

Occlusion in Fixed Prosthodontics is based on very sparse scientific evidence. One must remember that the specialty and discipline of Fixed Prosthodontics developed from Removable Prosthodontics as a result of the need for more specialized knowledge in the field. Principles and concepts of removable prosthodontic occlusion were the first rules applied to fixed prosthodontic patients.

The first adopted fixed prosthodontic occlusal concept was that of **Bilateral Balanced Occlusion**......the same as was and is used in Removable Prosthodontic practice. It is important to remember that the evolution of the theory of bilateral balanced occlusion was a direct result of the early explosion in the development of dental articulators and the concomitant development of manufactured denture teeth. The work of Balkwell and Bonwill in the late 1800's and early 1900's on jaw movement and it's geometrical, mechanical and physiological relationships to tooth form and function led to further studies by Gysi on occlusal form and design. Bennett's work relating the intricacies of jaw movement as related to occlusal form gave rise to more refinement of articulator design.

It soon became evident that principles of articulation and occlusal form as so developed did not apply easily to the practice of Fixed Prosthodontics. The work of McCollum and Stallard, followed closely by Stuart, resulted in more sophisticated jaw movement recording and duplicating instruments and articulators. As these mechanical aspects became more precise, it became clear that occlusal principles that worked in the practice of removable prosthodontics very often worked poorly or did not apply at all to fixed prosthodontic patients. As these early "Fixed" prosthodontists watched their rehabilitations fall apart in very short order, they realized that modification of known occlusal principles must be made. Early observations of bilaterally balanced restorations revealed premature wear, mobility of teeth and gingival clefting, especially lingual to the balancing side contacts. A few brave souls, among them Charlie Stuart, began equilibrating these cross-arch balancing contacts away in their patients' mouths and watching the results. This modification seem to give better results and the next step was elimination of the contacts from the wax-ups while still on the articulator. This process gave birth to the concept of **Unilateral Balanced Occlusion or Group Function.**

Early prosthodontists assumed the responsibility for a lot of failures related to poor oral hygiene. Their misplaced guilt fueled efforts to more refine their instrumentation which they blamed wrongfully for their restoration failures. Many clinicians felt that instrumentation had gone as far as it could go, and that the mouth should be used as the "final articulator". Others continued to attempt to refine their instruments and techniques and we shall discuss their discoveries later. The turn away from instrumentation resulted in attempts to create crowns and fixed partial dentures intraorally by direct waxing which proved cumbersome for most clinicians. The development of the functional wax chew-in for complete denture occlusion by Fred Meyer soon led to the adaptation of the technique to fixed prosthodontic patients by Pankey, Mann and others. The spark that ignited this concept and probably unified previous work into the present philosophy was the early writings of C. H. Schuyler on the importance of incisal guidance. Once Schyler's beliefs were applied to the basic work of Pankey and Mann, the concept congealed. The work of these men resulted in a refinement of this occlusal concept, along with the development of the Verticulator articulator, to the point where it is a widely accepted and highly respected philosophy of occlusion. **Group Function Occlusion**, as it shall herein be called, has a definite place in today's practice of Fixed Prosthodontics. It is especially invaluable in those patients for whom the development of cuspid rise occlusion is difficult or impossible to achieve and that brings us back to Charlie Stuart and the mechanical philosophy of occlusion.

The development of precision instrumentation in the mid-1900's reached a plateau with the refinement of the Stuart Articulator and Pantograph jaw movement recorder. As more and more clinicians migrated towards this philosophy, they began to call themselves gnathologists from the Gnathological Study Clubs they formed. Therein, this occlusal philosophy became known as Gnathological Occlusion. During this time, D'Amico's work on naturally occurring occlusal schemes became prominent. Stuart and others had noticed also that certain people who seemed to have relatively few problems with their teeth and jaws had one thing in common, namely, their cuspid teeth discluded their posterior teeth in lateral excursions. This new aspect of occlusal design was quickly and easily incorporated into the gnathological philosophy and soon became widely referred to as **cuspid rise occlusion or cuspid disclusion**. This philosophy today forms the basis of the **Gnathological Concept of Occlusion**. With the advent of more precise, cheaper and easier to use instrumentation, this concept is the most widely used one in the practice of Fixed Prosthodontics today.

In the mid- to late 1900's clinical observations of occlusion began to give way to rudimentary scientific investigation. The work of Lundeen, Gibbs, Hobo and Lee seemed to show that maybe we're not all that different, jaw movement-wise, as patients. Their work showed that in 80% or more of patients, variations in jaw movement was limited to the amount of lateral movement of the condyles and the degree of inclination of the slope of the eminence. These findings resulted in the development of articulators with the ability to closely duplicate these variations and a return to average value settings of the remaining jaw measurements for the most part. For lack of a better term, this relatively infant philosophy of occlusion is referred to as the **Organic Concept of Occlusion.**

Current Concepts of Occlusion

Bilateral balanced occlusion is rarely used as a restorative philosophy in Fixed Prosthodontics today and will not be discussed except to say that it's role in Fixed Prosthodontics should probably be limited to fixed prosthodontic applications on maxillofacial prosthodontic patients.

The remaining three concepts have major differences in design philosophy which bear discussion. Their two major differences involve which teeth contact when the mandible goes into a lateral excursion and the design of posterior tooth contact.

Unilateral balanced occlusion (Group Function) is based on the philosophy that the more teeth that can share a load, the better. In lateral excursions, this concept dictates that working side contact be spread out over as many teeth as possible. A classic example would involve working side disclusive contact including from the central incisor through the last molar, with only the buccal cusps of the posterior teeth being in contact with the opposing arch. The number of teeth involved may be reduced, but contact should always involve three or more teeth in each arch and these teeth should always be adjacent to one another. Incisal guidance is established first as the philosophy dictates that the combination of natural joint anatomy and established incisal guidance dictates posterior tooth form and function. An attempt is made whenever possible to establish centric relation contact at the same vertical dimension as centric occlusion. However, no attempt is made to make the two contacts coincident; rather, an anterior-posterior flat plane is developed in the working fossae to accommodate a "long centric". This allows working cusp contact in the opposing fossae in either centric relation occlusion or centric occlusion. The philosophy allows for no cross-tooth contact on the working side nor contact of any form on the balancing side.

The Gnathological Concept of Occlusion (Cuspid Rise Occlusion), as the name indicates, dictates that the cuspid on the working side disclude all the remaining teeth in working movement, but not immediately! The classic philosophy dictates that there be a 0.001 of an inch space between the opposing cuspids that would, in essence, be migratory contact by the posterior teeth prior to the beginning of the cuspid disclusion in working movements. Very precise posterior occlusal anatomy is mandatory for this action to take place and accurate jaw movement recordings transferred to precision articulators are of necessity. Once the opposing cuspids do contact in working movement, there is disclusion of the posterior teeth on the working and balancing sides. Working side disclusion, however, is small relative to that on the balancing side. Posterior tooth contact is developed as a precise tripodization of contact between the opposing working cusps and corresponding fossae. Through elaborate mechanisms of jaw movement recordings and articulator programing, an attempt is made to develop the restorations so that centric occlusion contact and centric relation contact coincide on posterior tooth closure. Anterior guidance is developed so that all posterior teeth are discluded in a protrusive movement.

The Organic Concept of Occlusion is very similar to the Gnathological concept with notable exceptions. In organic occlusion there is contact of the opposing cuspids in closure which provides for **immediate** disclusion of remaining teeth in working movement. The cuspid teeth are anatomically developed in length and lingual contours to accomplish this. Posterior tooth contact is developed so that centric occlusion and centric relation are coincident at a given vertical dimension of occlusion, but an area of contact is developed buccolingually which is referred to as "wide centric". This "wide centric" is to accommodate any lateral movement of the working condyle in the fossae prior to translation yet not allow contact of the inclines of the cusps and ridges of the posterior occlusal surfaces. Newly designed articulators and simplified jaw movement recorders are used in developing this occlusal scheme.

Anterior Guidance

The importance of anterior guidance in fixed prosthodontics cannot be over emphasized. Anterior teeth are designed to "**uncouple**" the posterior teeth in lateral and protrusive excursions. The extreme importance of this function is based in the physiology of mandibular movement.

Neuromusclature control of the mandible was designed by nature for efficiency of form and function. The muscles of mastication perform different functions at different levels of intensity. Muscle control of posterior teeth functions as a class I or class II lever system which one recalls from physics are the most efficient and powerful of the lever systems. Muscle control of the function of anterior teeth, on the other hand, is that of a class III lever system which is much more inefficient and less powerful. Posterior teeth, therefore, are able to occlude with tremendous force whereas anterior teeth incise with much less force. This physiological order allows the anterior teeth to separate the posterior teeth during function without being harmed from strong muscle closing force.

Lingual anatomy and contour of anterior teeth is designed by nature to harmonize with the slope of the eminence of the temporomandibular joint fossa and the occlusal anatomy of posterior teeth. Lingual surfaces of anterior teeth should provide for immediate disclusion of the posterior teeth in all protrusive and lateral excursions. Deviation from this can cause muscle disharmonies through a phenomenon described by Stuart as "**competitive inhibition**". He postulated that if in an excursive movement a posterior tooth remained or came into contact that a signal was sent back to the brain indicating that the closure muscle controlling that tooth should contract. This results in groups of muscles firing in a competing fashion and not knowing whether to continue or stop because of the confusion of signals. Sore muscles, posterior tooth wear and anterior tooth mobility occur in this situation.

The benefits of anterior guidance are most evident in Angle's class I occlusions. In Angle's class II occlusions where there is essentially no anterior guidance, posterior teeth are generally lost at a very speedy rate. There are very few old class II occlusions needing fixed restorations. In Angle's class III occlusions with the mandible being positioned so far anterior, even posterior muscle pull is weak. In this situation even posterior occluding force is based on a class III lever system. Another benefit in our favor is that Angle's class III patients generally do not make excursive movements.

We must be sure to either preserve or duplicate healthy anterior guidance when treating patients. If existing anterior guidance is not adequate, we must change it. If no anterior guidance exists, we must be able to provide it using the teeth most capable of bearing the load. Preserving or establishing proper anterior guidance will be the most important step in assuring long-term success of fixed restorations.

Complexities in Restoring Various Occlusal Schemes

Any fixed restoration could be made intraorally if one spent enough time working at it. The purpose of an articulator is to reduce chair-time and move the difficulty of constructing a restoration from the mouth to the laboratory work bench. However, this transfer must be in the same spatial relationship as exists in the patient's mouth. Herein lies the main differences between modes of restoration.

An articulator system is only as accurate as the operator using it. More simple articulators require less information be gathered from the patient to be used to set an instrument to duplicate a patient's functions. Therefore, more adjustment must be done intraorally to a restoration to make it harmonize with a patient's occlusion prior to delivery. Complex articulators require that much more information be gathered from the patient to set the instrument properly if one is to expect better accuracy from a restoration that requires little adjustment intraorally. We must realize that all these articulator systems will perform no more accurately than the records with which we use to program them.

PHYSIOLOGIC OCCLUSION

A physiologic occlusion is one which is in **SUFFICIENT HARMONY** with the anatomic and physiologic controls of the mandible so as not to produce pathology within the tissues of the gnathostomatic system.

CRITERIA OF OPTIMUM OCCLUSION

1. VERTICAL STRESS
   Incorporate factors which have to do with the **REDUCTION** of.....

2. HORIZONTAL STRESS
   A. Provide for maximum intercuspation with condyles in centric relation.
   B. Provide for horizontal movement of the mandible until teeth **MOST** capable of bearing load come into function.

FIXED PROSTHODONTIC OCCLUSION

- **Dependent on mandibular movement**
- **Cusp height and fossa depth critical**
- **Determined by:**
  - ~ **Immediate sideshift**
  - ~ **Anterior guidance**

FIVE DETERMINANTS OF MANDIBULAR MOVEMENT

1. Posterior determinants	Right TMJ	Not under control of dentist except.....
2. Fixed joints	Left TMJ	....via oral surgery
3. Anterior guidance	Teeth	Can be modified by Dentist - esthetics and phonetics are limiters.
4. Proprioceptive neuromuscular mechanism	TMJ, pulp and perio tissues - nerve impulses	Modified to a degree by changing the third determinant
5. Emotional stress	C.N.S.	Contributes to bruxism, spasms and TMJ

PURPOSES OF MANDIBULAR MOVEMENT

A. FUNCTIONAL
1. Chewing (Mastication)
2. Swallowing (Deglution)
3. Speech (Phonetics)

B. NONFUNCTION
1. Bruxism
2. Clenching
3. Habits (Pipes, pencil biting, etc.)

FUNCTION VS NONFUNCTION

FACTOR	FUNCTION	NONFUNCTION
Type of muscle contraction	Isotonic	Isometric
Proprioceptive influence or protection	Adaptive arc, tooth interference avoided, conditioned reflex	Skeletal arc, neuro-muscular protective mechanism absent
Mandibular closure position	C.O. or C.R.O.	Eccentric
Pathological effects	None or at least minimal	Pathologic changes vary with different patients
Duration of tooth contact	4 - 10 min/day	4 hours/day
Magnitude of applied force	20 - 40 lbs. PSI vertically - acceptable	Up to 300 lbs. PSI laterally - injurious
Leverage	Class III or class II	Class II or class I

TYPES OF OCCLUSAL ARRANGEMENTS

CONTACT	CUSP - FOSSAE	CUSP - MARGINAL RIDGE
Location of opposing	Occlusal fossae only	Marginal ridges and occlusal fossae
Relation of opposing	Tooth - to - tooth	Tooth - to - two - tooth
Advantages	Forces parallel, near center of tooth, minor lateral stresses. Full mouth rehabs.	Most natural type, 95% of all adults. Used for most small daily restorations
Disadvantages	Rarely found in natural teeth. Warped cusps.	Wedging of functional cusps lead to food impaction in embrasures.

CONCEPTS OF OCCLUSION

Unilateral Balanced	Cusp to Fossae	C.R. or C.R. plus C.O.
Disocclusion	Cusp to Fossae	C.R. or C.R. plus C.O.
Biological Occlusion	Cusp to Fossae	C.R. plus Wide Centric

THE PREVAILING

OCCLUSAL CONCEPTS

Pankey - Mann - Schuyler	Unilateral balanced occlusion; cusp - to - fossae; C.R. plus C.O.
Gnathology	Disocclusion; cusp - to - fossae; C.R.
Biologic	Disocclusion; cusp - to - fossae; C.R. plus Wide Centric

FOUNDATION OF THE PANKEY-MANN-SCHUYLER PHILOSOPHY

1. Meyer - Functional Wax Technique
2. Monson, Bonwill, Von Spee - Spherical concept of Occlusion
3. Schuyler - Anterior Guidance

In General: Instrumentation cannot give an accurate reproductionof the range of mandibular movements of the dentate subject.

THE FUNCTIONALLY GENERATED PATHWAY

A recording of all dimensions of the mandibular posterior tooth border pathways at the correct vertical dimension as directly influenced by the condylar guidance and anterior guidance.

FACTORS	P - M - S	vs	GNATHOLOGY
Articulator:	Pankey - Mann		Fully Adjustable
Dominant Factor:	Anterior Guidance		Condylar Guidance
Facebow:	Arbitrary		Kinematic
Philosophy:	Spherical		Individual
Restoration:	Segmental		Bimaxillary
Occlusion:	CRO + CO		CRO
	Long Centric		Tripodism
	FGP Group Function		Mutually Protective

INDICATIONS FOR GROUP FUNCTION OCCLUSION

1. Preservation of existing group function occlusion
2. *Weakened periodontal support*
3. Absence of anterior guidance
4. Absence of canine teeth
5. Patients with a high FMA
6. Restoration based on P - M - S philosophy

INDICATIONS FOR FGP

1. Restoration of group function occlusion
2. Restoration of working side disclusion
3. Generally for maxillary teeth
4. Ideal for bilateral restorations
5. Suitable for unilateral quadrants and single tooth restorations
6. Basis of the Pankey - Mann - Schuyler concept of occlusal rehabilitation

REQUIREMENTS FOR FGP

1. Anterior guidance
2. Optimal plane of occlusion
3. Well restored opposing occlusal surfaces
4. Stable and well aligned opposing teeth
5. Good neuromuscular co-ordination
6. Absence of posterior interferences
7. No opposing teeth missing

These article summaries offer descriptions of the two most prevalent occlusal schemes, arguments both for and against their respective usage, and what scant scientific evidence is available justifying the use of either scheme over the other. There are also summaries concerning occlusal force determination, complex reconstructions and historical perspectives.

I. Gnathology and Anterior Guidance

Akoren AC Karaagaclioglu L: Comparison of the electromyographic activity of individuals with canine guidance and group function occlusion. J Oral Rehabil (1995 Jan) 22(1):73-7.

The purpose of this study was to investigate occlusal schemes (canine guidance and group function) in relation to masticatory muscle activity. It was performed on 30 subjects, 15 with canine guidance and 15 with group function. Bilateral electromyographic recordings of masseter and anterior temporal muscles were obtained by surface electrodes during gum chewing and sliding laterally from centric relation while the teeth were in contact. The obtained data for both groups were compared statistically. Electromyograms were also evaluated visually. There was no significant difference in results between the occlusal schemes. However, canine guidance showed a narrower chewing model than group function and reduced anterior temporal muscle activity during sliding. This suggests that in the presence of healthy and good supportive canine teeth, canine guidance occlusion will be preferable.

Fitins D Sheikholeslam A: Effect of canine guidance of maxillary occlusal splint on level of activation of masticatory muscles. Swed Dent J (1993) 17(6):235-41.

The effect of canine guidance of a full-arch maxillary flat occlusal splint on the level of activation of the anterior and posterior, temporal, masseter and suprahyoid muscles during maximal clenching, were studied in 14 subjects without craniomandibular disorders. The results revealed that, the level of electromyographic activity of anterior and posterior temporal and suprahyoid muscles during maximal clenching on the occlusal splint in habitual closure was unchanged, as compared to biting in the intercuspal position (ICP), while the activity in the masseter muscle, on average, was increased slightly (13 percent). In contrast, the level of activation of the jaw elevator muscles decreased significantly during maximal clenching on the cuspid ramp of the splint, as compared to the biting in ICP or clenching on the splint. However, the degree of reduction of activity was not symmetrical, and was most pronounced in the masseter muscle of the biting side and in the anterior and posterior temporal muscles of the non-biting side. No significant difference was observed in the activity of the suprahyoid muscles.

Goldstein GR: The relationship of canine-protected occlusion to a periodontal index. J Prosthet Dent 41(3):277, 1979.

A study of 1,000 teeth in 100 different patients with Angle Class I occlusions was conducted. These patients had no previous orthodontic therapy, fixed or removable prosthodontic treatment or occlusal equilibration. The goal of the study was to correlate various occlusal schemes to the presence or absence of periodontal disease.The results of the study were:

-14% canine guided occlusion
-16% progressive disclusion (see next paragraph for definition)
-46% group function occlusion
-24% different right and left occlusions

Progressive disclusion occurs when one or more teeth in addition to the maxillary canine are in occlusion until the cusp tips are reached and then only the maxillary canine and its antagonist touch during lateral movement. Of all the patients surveyed, the ones with the lowest incidence of periodontal disease were those with canine guided occlusions. Each of the patients had similar plaque indices at the start of the survey. These findings correlate with D'Amico's theories that canine guidance provides a stress-breaker type of effect due to lack of posterior tooth contact for bracing and, therefore, a decrease in the total amount of force applied to any one tooth.

Gross MD, Cardash HS: Transferring anterior occlusal guidance to the articulator. J Prosthet Dent 1989 Mar;61(3):282-5.

Anterior disclusion has become accepted as an optimal therapeutic model in the restoration of the anterior dentition. The ability to achieve anterior disclusion is influenced by the anterior determinants of esthetics, phonetics, skeletal relation, tooth position, abutment distribution, and alveolar bone support in addition to the posterior condylar determinants. Temporary restorations are made to incorporate these factors and it becomes necessary to transfer the information to working models of the articulator. A technique is described whereby a wax or silicone index fixed partial denture is made at chairside, duplicating the temporary restoration that is directly transferable to the working casts of the articulator. This technique allows the technician to make final restorations according to the index fixed partial denture, thus incorporating the anterior determinants of occlusion in conjunction with the posterior condylar determinants specific to each patient.

Hobo S and Takayama H: Effect of canine guidance on the working condylar path. Int J Prosthodont 2(1):73, 1989.

Orbits of incisal point and working condyle during right and left mandibular movements were measured under canine guidance and clutch guidance using six degrees of freedom. The results showed that the working condyle path is affected by anterior guidance and exhibits displacement in the sagittal plane. When canine guidance is not coincident with the working condylar path, there is a sagittal displacement of the working path created to compensate for the lack of harmony. When restoring lingual surfaces of maxillary canines, develop lingual contours so the working condyle path exhibits minimal sagittal displacement.

Johnson FS: Variations in organic occlusion. J Prosthet Dent 41(6):625, 1979.

Organic occlusion is a cusp-fossae relationship that utilizes tripoding for stability, tooth to tooth occlusion, coincidence of CO (Centric Occlusion) and CR (Centric Relation) and disclusion of posterior teeth during eccentric jaw motions. The functional elements of this type of occlusion are stamp cusps and shear cusps. The stamp cusps are the maxillary lingual cusps and mandibular buccal cusps. The shear cusps are the maxillary buccal cusps and mandibular lingual cusps. The posterior stamp cusps protect the anterior teeth in CO while the anterior teeth protect the posterior teeth from eccentric, horizontal stresses and grinding during empty mouth contacts. This type of stamp/shear cusp arrangement must always be maintained and may be corrected in Angle Class II and III malocclusions by recontouring the cusps as follows:

Angle Class I (Neutroclusion)

- no posterior interferences during mandibular closure.
- each stamp cusp that leaves its opposing fossa moves eccentrically out of contact and into a groove.
- prevents posterior tooth wear and decreases lateral stresses on posterior teeth

Angle Class II (Distoclusion)

- mandibular premolar cusps are 1/2 tooth distal and molars are 1 cusp distal to normal.

To correct: move mandibular stamp cusps slight distally and buccally while moving maxillary stamp cusps mesially and lingually.

Angle III (Mesiooclusion)

- mesial placement of mandibular teeth by 1/2 tooth in the premolar region and 1 cusp in the molar region.
- anterior teeth are usually end to end.

To correct: move involved maxillary stamp cusps slight mesially and lingually while moving mandibular stamp cusps distally and buccally.

Kerstein RB: A comparison of traditional occlusal equilibration and immediate complete anterior guidance development. Cranio (1993 Apr) 11(2):126-39; discussion 140.

Traditional occlusal equilibration has been advocated by numerous authors as a treatment modality for chronic myofascial pain dysfunction syndrome. However, treatment predictability and reliable clinical success has not been reported by all authors. Some report no correlation between occlusal contacts and chronic myofascial pain dysfunction syndrome. Recent publications and manuscripts have described a new occlusal adjustment technique which is aimed at reducing lengthy pretreatment disclusion time in mandibular excursions. This reduction in disclusion time physiologically and rapidly reduces contractile muscle activity in the masseter and temporalis muscles, which leads to the resolution of numerous chronic myofascial pain dysfunction syndrome (MPDS) symptoms. This new occlusal adjustment process is known as Immediate Complete Anterior Guidance Development (ICAGD). The purpose of this article is to describe the important differences in focus, sequence, and theory between traditional occlusal equilibration and ICAGD.

Kimmel SS: Temporomandibular disorders and occlusion: an appliance to treat occlusion generated symptoms of TMD in patients presenting with deficient anterior guidance. Cranio (1994 Oct) 12(4):234-40.

Temporomandibular disorders (TMD) are of multifactorial origin. If it is determined that the patient's occlusal scheme is a contributing factor to their TMD symptoms, it is accepted that reversible, noninvasive procedures be instituted at the outset of treatment. Splint therapy conforms to this guideline, offering temporary, reversible alteration of the occlusal scheme in order to provide this relief. In a mutually protected occlusion, the posterior teeth accept the occlusal force of closure, while the anterior teeth separate the dentition during excursive movements. The purpose of the disclusion splint described in this article is to eliminate muscle hypertonicity, along with its ensuing problems. This is accomplished by establishing a mutually protected occlusion via the guide planes created by the acrylic portions of the splint, but not compromising the patient's "freeway" space.

Lederman KH, Clayton JA: Patients with restored occlusions. Part I: TMJ dysfunction determined by a pantographic reproducibility index. J Prosthet Dent 1982 Feb;47(2):198-205.

In a population of 50 subjects restored with fixed prostheses, the prevalence of TMJ dysfunction was 38% slight, 20% moderate, and 10% severe for a total of 68% showing some degree of dysfunction as recorded by pantographic tracings quantitated by the PRI. SD varied between categories. Higher PRI scores produced larger SD. The SD was 45 for the reproducible category, increasing progressively in each category, to 12.91 for the severe dysfunction category. The one session (four sets of tracings) used in the study to determine the degree of TMJ dysfunction appeared to be an accurate sample of a subject's PRI score for a given time. Control subject's scores appeared to stay relatively stable (p = .3649) over a period of time (1 to 3 months). While the scores did fluctuate, the category remained essentially the same. Those subjects with higher PRI scores showed the most fluctuation. The results indicated that pantographic tracings quantitated by the PRI can be used as a suitable instrument in epidemiologic studies to determine the prevalence of TMJ dysfunction.

Lederman KH, Clayton JA: Restored occlusions. Part II: The relationship of clinical and subjective symptoms to varying degrees of TMJ dysfunction. J Prosthet Dent 1982 Mar;47(3):303-9.

Fifty subjects restored with fixed restorations were examined by means of pantographic tracings and the PRI in order to determine the prevalence of TMJ dysfunction. In addition to the prevalence of dysfunction, the PRI categorized subjects as to the degree of dysfunction and clinical and subjective symptoms were related to the varying degrees of dysfunction. There were positive relationships 43 between the PRI categories and any dysfunction and many of the variables at the 0.1 level. There were positive correlations (Spearman R) at the 0.5 level between PRI categories and any level of TMJ dysfunction and many variables. The absence of clinical symptoms did not always indicate the absence of dysfunction as determined by the PRI.

Lederman KH, Clayton JA: Patients with restored occlusions. Part III: The effect of occlusal splint therapy and occlusal adjustments on TMJ dysfunction. J Prosthet Dent 1983 Jul;50(1):95-100.

Occlusal interferences can play a significant role in causing TMJ dysfunction. To determine the significance of occlusal interferences, occlusal splints were placed in 10 of these restored patients who had moderate to severe dysfunction. The PRI was used to detect the presence or absence of TMJ dysfunction. The PRI TMJ dysfunction scores were reduced in all 10 patients after use of the occlusal splint. Five of the patients achieved reproducible tracings (no TMJ dysfunction) during the experiment time of 7 months. The occlusion of two patients was adjusted to eliminate the need for the occlusal splint. Patients who wore the splint 24 hours a day showed a significant (0.0004 level) reduction in TMJ dysfunction. Those patients who did not wear the splint regularly or had high levels of stress had PRI scores that varied. This finding indicates that the occlusal splint is not a treatment, as its removal permits reactivation of the occlusal interference. Resolution of dysfunction did not occur until occlusal interferences were removed. The changes in PRI scores to different dysfunction categories (none, slight, moderate, and severe) for the experimental group were significant at the 0.01 level. A control group of five patients had similar pantographic tracings but no other treatment. Their PRI scores varied, but there was no significant change in PRI scores or dysfunction categories. It was concluded that occlusal interferences were active causes of TMJ dysfunction in 10 of 36 patients in a population with restored occlusions.

Manns A, Chan C and Miralles R: Influence of group function and canine guidance on electromyographic activity of elevator muscles. J Prosthet Dent 57(4):494, 1987.

Studied which of the two types of occlusal guidance cause a greater quantitative reduction in the bilateral activity of the elevator muscles. Made splints and split them on both sides distal to the canines. When all three parts of splint was in place, could record right and left laterotrusion with group function. When only the front section was seated, right and left laterotrusive recordings with canine guidance could be made. Laterotrusive position with canine guidance, in contrast to group function, produced significantly lower elevator muscle activity. The reduction in activity with canine guidance suggests that the stomatognathic system is more effectively protected against unphysiologic muscle tension in this position. Canine guidance should probably be included in full-coverage splints.

Reynolds JM: Occlusion organization. J Prosthet Dent 26(1):56, 1971.

Posterior teeth that stay free of wear facets for the longest periods of time allow a terminal hinge intercuspation. In a study of fifty mouths free of cariogenic activity, the dentitions that had maximum intercuspation coincident with terminal hinge relation had only a few small facets of wear. When the posterior teeth occluded centrically and were "discluded" immediately by the anterior teeth in eccentric positions, facets of wear were practically non-existent. The anterior teeth showed less wear on the incisal edge when maximum intercuspation and terminal hinge relation were identical. The study also revealed that the number and extent of facets of wear on all teeth seemed to be closely related to: 1) the length of the slide from terminal hinge relation to maximum intercuspation, and 2) a lack of eccentric "disclusion" of the posterior teeth. The age of the individual appeared to be much less a causative factor.

Scaife RR and Holt JE: Cuspid guidance. J Prosthet Dent 22(2):225, 1969.

The concept of the cuspid protection mechanismbegan in 1919 with the work of Nagao. This was reinforced in 1924 by Shaw, and then gained most of its following after the extensive work of D'Amico in 1958. An objective examination of 1,200 patients was made to determine the natural incidence of a cuspid protected occlusion. The influence of the maxillary cuspids was noted in centric occlusion and in protrusive, left, and right lateral positions. Bilateral cuspid protected occlusion was found in 57 per cent of the subjects, 16.4 per cent possessed a unilateral cuspid protection, and 26.6 per cent had no cuspid protection in lateral excursions. Only 0.4 percent had cuspid contacts in protrusion. 91.5 per cent had cuspid contact in centric occlusion. More research must be undertaken before dentistry has a complete understanding of the natural protective mechanism of the human, whatever its form.

Schwartz H: Anterior guidance and aesthetics in prosthodontics. Dent Clin North Am 1987 Jul;31(3):323-32.

Aesthetic determinants in prosthodontics are related to imprecise and often vague objective and subjective factors. Anatomic and functional studies indicate parameters of form, position, and contour of anterior teeth and the incisal guide angle. The final aesthetic composition is best determined by a continuing, ongoing evaluation designed to help the patients actively develop a perception of their own self-image and aesthetic potential. Incisal guide factors are determined independently of condylar elements. The final occlusal scheme is developed and coordinated with both the condylar and incisal guide elements.

Thornton LJ: Anterior guidance: group function/canine guidance. A literature review. J Prosthet Dent (1990 Oct) 64(4):479-82.

Anterior guidance, which can be categorized as group function or canine guidance, is essential for esthetics, phonetics, and mastication. This article reviews the historical development and philosophies of both occlusal schemes. There is no scientific evidence that supports one occlusal scheme over the other. Where anterior guidance must be reestablished or where it changes, there currently appear to be more authorities who favor canine guidance over group function.

Williamson and Lundquist: Anterior guidance. J Prosthet Dent 49(6):816, 1983.

Purpose of study was to determine the effect of two occlusal schemes on the temporal and masseter muscles. The first occlusal scheme used anterior guidance to eliminate all contact of the posterior teeth in eccentric movements. The second occlusal scheme allowed selective posterior occlusal contact in eccentric movements. Maxillary occlusal splints were used to develop the occlusal schemes. The results showed that posterior disclusion by appropriate anterior guidance reduces the elevating activity of the temporal and masseter muscles. Also, it is not the contact of the canines that decreases the elevator muscle activity, but the elimination of posterior contacts.

Willis WA: The effectiveness of an extreme canine-protected splint with limited lateral movement in treatment of temporomandibular dysfunction. Am J Orthod Dentofacial Orthop (1995 Mar) 107(3):229-34.

This study suggests that a splint design incorporating extreme canine guidance with limited lateral movement may be effective in the treatment of temporomandibular dysfunction (TMD) symptoms. Fifty consecutively treated TMD patients were evaluated with the TMJ Scale before and after treatment. A group of 11 similar patients identified as having TMD, but who declined treatment, were used as a control group.

II. Group Function

DiPietro GJ: A study of occlusion as related to the Frankfort-mandibular plane angle. J Prosthet Dent 38(4):452, 1977.

This 112-patient study correlated canine guidance and group function to the Frankfort-mandibular plane angle. The Frankfort-mandibular plane angle is the angle between the Frankfort horizontal plane and the mandibular plane. It can be extrapolated from an overlay tracing of a lateral cephalogram. Most Frankfort-mandibular plane angles range from 10 degrees to 35 degrees with the mean angle being 24.57 degrees.The results of the study were:

-17.9% of patients had canine guidance
-19.6% of patients had delayed canine guidance
-8.9% of patients had progressive group function
-53.6% of patients had group function

An increased vertical overlap or overbite was correlated to a decreased Frankfort-mandibular plane angle. Conversely, an increased Frankfort-mandibular plane angle is associated with a decreased biting force and therefore might be responsible for increased tooth mobility due to trauma from occlusion.

Jones SM: The principles of obtaining occlusion in occlusal rehabilitation. J Prosthet Dent 13(4):706, 1963.

Two important steps to be recognized in P.M. or any technique: 1) a preliminary equilibration of the occlusion, and 2) the establishment of the incisal guidance. In Pankey-Mann technique: 1) the posterior teeth maintain the vertical dimension while the anterior teeth are being restored. 2) The anterior teeth maintain the occlusal vertical dimension while the posterior teeth are being restored. 3) The incisal guidance, the TMJ's, and the mandibular musculature register a functionally generated path. 4) There is static occlusal contact of all teeth when the mandible is in centric relation to the maxillae. 5) An area of centric occlusal contact is developed to provide freedom of centric in a horizontal direction while the same vertical dimension is maintained. 6) Working side contacts are coordinated with the incisal guidance while non functioning side contacts are eliminated.

McAdam: Factors in canine and group-function occlusion. J Prosthet Dent 35(3):283, 1976.

The primary difference between group function and canine guided occlusal schemes is the manner in which the teeth function during the working lateral movement. Canine guidance and group function guidance occlusions are considered normal; the latter occurs naturally due to occlusal wear. When an entire occlusion is to be restored, either occlusal scheme will serve adequately. Where only a portion of the occlusion is to be restored, the restoration must be consistent with the existing occlusal scheme. Regardless of which occlusal scheme is used, the dentist must maintain it during regular postoperative appointments.

III. Occlusal Force Determination

Budtz-Jorgensen E, Isidor F: Cantilever bridges or removable partial dentures in geriatric patients: a two-year study. J Oral Rehabil 1987 May;14(3):239-49.

The purpose of this study was to compare prosthetic, functional and occlusal conditions in twenty-seven patients treated with distally extending cantilever bridges and twenty-six patients treated with removable partial dentures (RPD) in the mandible. All patients had a complete upper denture. Mean age of the patients in both groups was about 69 years. The patients were under a supervised oral hygiene care throughout the 2-year study period. There were 6.9 +/- 1.7 mandibular teeth left in the bridge group and 7.5 +/- 1.7 in the RPD group and the mean number of posterior teeth (natural teeth/denture teeth/pontics) in occlusion was 4.1 +/- 1.1 and 7.3 +/- 1.4, respectively. During the study period signs and symptoms of mandibular dysfunction became significantly aggravated in the RPD group, P less than 0.05. A balanced occlusion in the muscular contact position was observed in 90% of the patients in the bridge group and in 76% of the RPD wearers. During the study period the need for dental or prosthetic treatment was negligible in the patients treated with bridges. In the RPD group, twenty-two teeth were restored with fillings due to caries and in eight patients major adjustments of the sublingual bar were necessary due to irritation of the oral mucosa. This study has shown that treatment with distally extending cantilever bridges in the mandible is a favourable alternative to treatment with removable partial dentures in elderly patients with a reduced dentition.

Denissen HW Kalk W van Waas MA van Os JH: Occlusion for maxillary dentures opposing osseointegrated mandibular prostheses. Int J Prosthodont (1993 Sep-Oct) 6(5):446-50.

This paper presents a combination of several occlusal concepts designed to contribute to the successful use of maxillary dentures in opposition to osseointegrated mandibular prostheses. To ensure a positive outcome when designing such an occlusion, three factors must be considered: patient satisfaction, maxillary anterior bone preservation, and mandibular arch shortening. It is recommended that for centric occlusion the molars have a lingual contact occlusion, the premolars have a buccal contact occlusion, and the anterior teeth have an open occlusal relationship. For an eccentric occlusion, a balanced articulation is favored instead of mutually protected occlusion.

dos Santos J Jr Blackman RB Nelson SJ: Vectorial analysis of the static equilibrium of forces generated in the mandible in centric occlusion, group function, and balanced occlusion relationships. J Prosthet Dent (1991 Apr) 65(4):557-67.

Mechanical analyses supporting various and prevailing stomatognathic concepts of occlusal function are sparse. This study, using a mechanical model, simulates a system in function and provides a vectorial analysis based on a static equilibrium of forces generated in a mandible at 10 different positions. The positions analyzed were one in centric occlusion and nine in eccentric positions. Four eccentric positions were in a balanced occlusal relationship and five were in group function. Among other conclusions that were drawn, the most relevant seems to be the finding that cusp inclines and condylar path inclination have a profound influence on the forces acting within the joints and dentition.

English CE: Mechanical tooth concepts in implant dentistry. Implant Dent (1993 Spring) 2(1):3-9.

A brief history of mechanical tooth concepts is presented with an update and discussion of the three basic categories of designs presently available. The application of mechanical designs to implant dentistry is covered with a discussion of indications, contraindications, and technical requirements for each of the categories.

Hasegawa S, Bando E, Tanaka B, Tabata T: Occlusion of full cast crown at the intercuspal position. Bull Tokyo Med Dent Univ 1981 Jun;28(2):53-60.

The IP-Checker type MS capable of measuring the height of a crown at the intercuspal position (IP) was invented. The following observations were obtained. 1. The intercuspal position is stable within 5 micrometers. 2. The intercuspal positions shows a higher stability under slight biting than under heavy biting. Under this condition, the teeth show a displacement of about 20 micrometers by the distortion of the periodontal membrane. 3. The crown made by the ordinary procedure is about 30 micrometers higher at the intercuspal position. Therefore, an occlusal adjustment is always necessary. 4. With the current method of occlusal adjustment, adjustment of the crown to a definite height with the maximum error of 10 micrometers is possible in the oral cavity.

Jacobi R, Shillingburg HT Jr, Duncanson MG Jr: Effect of abutment mobility, site, and angle of impact on retention of fixed partial dentures. J Prosthet Dent 1985 Aug;54(2):178-83.

Fixed partial dentures cemented to dies of adjustable mobility were subjected to repeated impacts at three different sites. Immobile abutments retained their prostheses longer than mobile abutments. Impacts that fell between the centers of rotation of the abutments were withstood longer than impacts that fell nearer the ends of the prostheses. This study failed to show a significant difference between the effect of impacts perpendicular to the occlusal plane and impacts angled 45 degrees toward the lingual plane. The results of this study suggest that (1) crowns that anchor rigid prostheses to mobile teeth require greater retentive ability than crowns on relatively immobile abutments and (2) occlusal impacts are best withstood when they fall on the areas of the fixed partial denture over and between the centers of rotation of the abutment teeth. If a fixed partial denture must withstand loading outside these areas, as is the case with cantilevered pontics and some tilted abutments, the retainer furthermost from the anticipated eccentric load must have exceptionally good retention.

Jorneus L, Jemt T, Carlsson L: Loads and designs of screw joints for single crowns supported by osseointegrated implants. Int J Oral Maxillofac Implants 1992 Fall;7(3):353-9.

The problem of screw stability was approached in this study by calculating the maximum occlusal forces in vivo for patients with single implant restorations (which use only one screw to secure the prosthetic reconstruction to the implant). The measurements of occlusal forces together with geometric parameters for the individual patients were used to determine the necessary holding capabilities of the screw joint. Different screw designs were tried in bench test situations and the results were compared with clinical situations. A gold alloy screw with a flat head and high tightening torque (35 Ncm) produced the best results.

Katona TR Goodacre CJ Brown DT Roberts WE: Force-moment systems on single maxillary anterior implants: effects of incisal guidance, fixture orientation, and loss of bone support. Int J Oral Maxillofac Implants (1993) 8(5):512-22.

An engineering model of maxillary single anterior implants was developed to calculate the force-moment systems resulting from occlusal contacts. Analysis of a clinical example showed that flattening the incisal guidance and/or placing the implant in a more upright position reduced the moment and the labial component of the force but increased the intrusive component. The calculations are applicable to the design of implants and may help in the long-term evaluation of clinical success.

Kerstein RB: Disclusion time measurement studies: stability of disclusion time--a 1-year follow-up. J Prosthet Dent (1994 Aug) 72(2):164-8.

Six of seven women were recalled after 1 year to remeasure their right- and left-side working disclusion times. Before the occlusal adjustment technique known as immediate complete anterior guidance development (ICAGD), these patients presented lengthy mean disclusion times (> 1.0 second) and multiple chronic myofascial pain dysfunction syndrome (MPDS) symptoms. After ICAGD, these patients presented with short mean disclusion times (< 0.7 second) and no chronic MPDS symptoms were observed. At 1-year follow-up, there was no statistical difference between present measurements of disclusion time and those of 1 year earlier. In addition, all six posttreatment patients demonstrated no observed chronic MPDS symptoms. However, the symptom of nocturnal bruxism appeared to recur with some chronic regularity. These results suggest that, for this population, disclusion time was stable over the 1-year period of observation, and the short disclusion time appears to allow normal daily muscle function with significantly lessened appearance of chronic myofacial pain dysfunction symptoms.

Kerstein RB: Disclusion time measurement studies: a comparison of disclusion time between chronic myofascial pain dysfunction patients and nonpatients: a population analysis. J Prosthet Dent (1994 Nov) 72(5):473-80.

From a pool of 89 patients, 49 patients were classified as having chronic myofascial pain dysfunction syndrome (MPDS), and 40 were classified as asymptomatic or non-MPDS patients designated as the control group for the study. To achieve balanced sample size in both groups, 40 patients were arbitrarily selected from the MPDS group. All patients from each of the two primary groups were then categorized and assigned to one or more subgroups according to the following criteria: (1) jaw classification, (2) open occlusion, (3) previous orthodontic therapy, or (4) no previous orthodontic therapy. A fifth subgroup composed of only MPDS patients and equally divided into those who had or had not experienced orthodontic therapy was established to determine whether mean disclusion time differences occur between orthodontic and nonorthodontic MPDS patients. All 80 patients were evaluated for disclusion time of their right and left mandibular excursions to determine statistical population comparisons. Statistical assessment of right and left disclusion times for women and men in the MPDS and non-MPDS groups was performed separately for each of the five subgroups. Analysis of the comparisons revealed that in all except two of the subgroups, mean disclusion time was significantly longer in the MPDS patient group than in the non-MPDS group. The two subgroups in which this was not apparent were those with open occlusion and orthodontic patients compared with nonorthodontic patients. These findings suggest that lengthy posterior disclusion time may be of diagnostic importance when the differing etiologic factors of chronic MPDS patients are evaluated.

Laurell L: Occlusal forces and chewing ability in dentitions with cross-arch bridges. Swed Dent J Suppl 1985;26:160p.

The main aims of this thesis were 1) to study the pattern of axially directed occlusal forces developed during chewing and biting in dentitions restored with cross-arch bridges, 2) to find out to what extent these forces are influenced by the amount of periodontal tissue supporting the bridge abutments and 3) to study the chewing ability in subjects supplied with cross-arch bridges. For the purpose of aims 1 and 2 a method was developed which permits measurement of occlusal forces in various parts of as well as over the entire dentition simultaneously. The method is based on the use of strain- gauge transducers mounted into pontics or artificial teeth. Two groups, each comprising 12 subjects, were included in the studies of occlusal forces. In one group, the periodontal support included bilateral molar end abutments. In the other group, molar/premolar end abutments were unilaterally missing and replaced with posterior two- unit cantilevers. In each subject, four transducers were used, bilaterally distributed to represent the posterior and anterior regions and mounted so as to measure forces perpendicular to the occlusal plane. The occlusal forces were measured during activities: 1) chewing and swallowing, 2) biting with maximal strength in habitual occlusion, expressing the voluntary capacity of the jaw-closing muscles, and 3) clenching between two antagonistic teeth, expressing the transient periodontal force withstanding capacity in that region. The chewing ability was studied using a fractional sieving technique in principle according to Helkimo el al (1978) and was compared with the chewing ability of subjects with complete healthy dentitions and complete denture wearers. The mean total chewing force amounted to about 100 Newtons (N) in dentitions with cross-arch bilateral end abutment bridges, compared to about 50 N in dentitions with cross-arch unilateral posterior two-unit cantilever bridges (P less than 0.01). The mean maximal bite force in habitual occlusion amounted to 320 N and 264 N respectively (NS). In the presence of end abutments, the chewing and biting forces were significantly larger in the posterior than in the anterior regions. The local forces on the distal cantilever unit were, however, equal to or smaller than those in the anterior regions and much smaller than have been suggested in the literature.

Laurell L, Lundgren D: Periodontal ligament areas and occlusal forces in dentitions restored with cross-arch bilateral end abutment bridges. J Clin Periodontol 1985 Nov;12(10):850-60.

The aim of the present investigation was to find out to what extent the magnitudes of chewing and biting forces in dentitions restored with cross-arch bilateral end abutment bridges are correlated to the areas of the periodontal ligament supporting the abutment teeth. 12 subjects whose dentitions had been periodontally treated and prosthetically restored participated in the study. The chewing and biting forces were measured in various parts of as well as over the entire dentition simultaneously using 4 strain gauge transducers bilaterally placed in pontics of the posterior (first molar/second premolar) and anterior regions. Based on calculations of the periodontal ligament areas, a new periodontal support index, PSIL, is introduced. This index expresses the relation between the total remaining periodontal ligament area supporting the bridge abutments and total maximal periodontal ligament area if all teeth were preserved as abutments. It is compared with the index of Ante, PSIA, which expresses the relation between the total remaining periodontal ligament area of all abutments and the total maximal periodontal ligament area of all replaced teeth. Within the present group of subjects, PSIL varied from 10 to 44% and PSIA from 17 to 118%. Based on the results of the correlation analyses, it is suggested that in dentitions restored with cross-arch bilateral end abutment bridges, the magnitude of the chewing forces is positively correlated to the areas of the periodontal ligament supporting the bridge abutments, whereas the periodontal ligament areas have no influence on the comparatively larger biting forces. The relevance of the 2 periodontal support indices and the clinical implications of the results of the study are discussed.

Laurell L, Lundgren D: Periodontal ligament areas and occlusal forces in dentitions restored with cross-arch unilateral posterior two-unit cantilever bridges. J Clin Periodontol 1986 Jan;13(1):33-8.

This investigation was undertaken in order to analyse to what extent the magnitudes of chewing and biting forces in dentitions restored with cross-arch unilateral posterior two-unit cantilever bridges are correlated to the area of the periodontal tissue supporting the abutments. 12 subjects, whose dentitions were periodontally treated and prosthetically restored, participated in the study. The chewing and biting forces, simultaneously measured in various parts of, as well as over the entire dentition, were correlated to the periodontal ligament areas of the abutments supporting the bridge constructions. A strong positive correlation ($r = 0.83$; P less than 0.01) was found between the total remaining periodontal ligament area and the mean total chewing force. A positive correlation ($r = 0.57$; $P = 0.05$) was also found between the local remaining periodontal ligament area of the posterior end abutment tooth and the local chewing force in that region. No positive correlation was found between the amount of periodontal tissue support and the magnitude of the forces developed during biting with maximal strength in habitual occlusion either totally or locally, although there was a strong tendency ($r = 0.54$; 24 greater than P greater than 0.5) towards decreasing total maximal bite force with decreasing total remaining periodontal ligament area. A strong positive correlation ($r = 0.74$; P less than 0.01) was found on the end abutment side between the local remaining periodontal ligament area of the end abutment tooth and the local forces in that region during biting with maximal strength over a limited area at a time.

Laurell L, Lundgren D: Distribution of occlusal forces along unilateral posterior two-unit cantilever segments in cross-arch fixed partial dentures. J Prosthet Dent 1988 Jul;60(1):106-12.

Axially directed occlusal forces over unilateral posterior two-unit cantilever segments of cross-arch fixed partial dentures were measured during natural functioning by using built-in transducers, one in each cantilever unit. The mean local maximal occluding and maximal chewing forces were significantly larger over the first (124 N and 64 N) than over the second (21 N and 29 N) cantilever unit. The average intraindividual ratio between the forces over the first and second cantilever unit amounted to 12:1 for maximal occlusion and 3:1 for maximal chewing. Despite the smaller mean total maximal chewing 52 N) than mean total maximal occluding cantilever force (145 N), the resulting axially directed mean bending moments in the joint between the distal abutment crown and the cantilever segment did not differ significantly. This is explained by the larger mean maximal chewing (29 N) than mean maximal occluding (21 N) force over the second cantilever unit. This demonstrated that not only the magnitude of occluding and chewing forces over cantilever segments but also their distribution along the cantilevers is of importance for the magnitude of functional stress created in cantilever fixed prosthesis.

Laurell L , Lundgren D, Falk H, Hugoson A: Long-term prognosis of extensive polyunit cantilevered fixed partial dentures. J Prosthet Dent 1991 Oct;66(4):545-52.

The aim of this retrospective study was to elucidate the long-term prognoses of extensive fixed partial dentures including unilateral or bilateral polyunit cantilevers in patients with healthy but reduced periodontal support. Following periodontal therapy 36 cross-arch fixed partial dentures with two or more cantilever units unilaterally or bilaterally were fitted in 34 patients. In the prosthodontic design, special attention was given to the retention to long parallel preparations, to the dimensions of the framework, and to the occlusal design. After completion of therapy, the patients were enrolled in a regular maintenance care program and followed up for a period of 5 to 12 years. During this follow-up period one abutment tooth was fractured in one patient. One fixed partial denture with extremely reduced periodontal support was lost as a result of complete periodontal breakdown from occlusal trauma. For 33 fixed partial dentures, neither periodontal nor technical complications occurred.

Laurell L Lundgren D: Influence of occlusion on posterior cantilevers. J Prosthet Dent 1992 May;67(5):645-52.

The incorporation of posterior two-unit cantilevers in fixed prosthodontics is generally discouraged because of the assumption that large posterior chewing and biting forces might jeopardize the prosthesis and the abutment teeth. This investigation was performed to study (1) the distribution of chewing and closing forces in dentitions with cross-arch bilateral posterior two-unit cantilever fixed partial dentures and (2) the influence of different occlusal arrangements on the magnitude of these forces along the cantilever segments. Six patients were included in the study. Axially directed closing and chewing forces were measured with miniature transducers bilaterally mounted in pontic units anteriorly and in each of the four cantilever units. In ideal occlusion, occlusal forces decreased considerably along the cantilever segments in the distal direction. Infraoccluding the distal cantilever unit by 80 microns had little influence on the magnitude of the initially small local force in this region, whereas an 80 microns high primary occlusal contact considerably increased the local force over the distal cantilever unit. The clinical implications of the results are discussed.

Lundgren D, Laurell L: Occlusal force pattern during chewing and biting in dentitions restored with fixed bridges of cross-arch extension. I. Bilateral end abutments. J Oral Rehabil 1986 Jan;13(1):57-71.

The pattern of axially directed occlusal forces, i.e. magnitude, distribution, duration and frequency of occlusal forces perpendicular to the occlusal plane, was studied during chewing, swallowing and biting in twelve subjects whose dentitions were periodontally treated and prosthetically restored with fixed, cross-arch bridges whose periodontal support included bilateral end abutments. The measuring devices consisted of four strain gauge transducers bilaterally mounted into pontics of maxillary bridges to represent the posterior and anterior regions. The forces could thus be studied in various parts of as well as over the entire dentition simultaneously. All subjects exhibited a rhythmic chewing pattern with preference of one side as chewing side. Local chewing and biting forces were always larger in the posterior than in the anterior regions and largest in the posterior region of the preferred chewing side. The total chewing and swallowing forces were about 100 Newtons (N) whereas the total maximal bite force in habitual occlusion amounted to 320 N. On average 37% of the total maximal bite force in habitual occlusion was utilized during chewing (and swallowing). The capacity of the periodontal tissues on the preferred chewing side to withstand transient occlusal forces was utilized to an average of 25% during chewing and swallowing and to an average of 57% during biting with maximal strength in habitual occlusion. The mean duration of that part of the chewing cycle during which the teeth were subjected to occlusal forces was 240 ms. The duration of the occlusal forces during swallowing was about three times longer. It is concluded that the periodontal tissues can withstand transient occlusal forces which are much larger than those generally operating during chewing, swallowing and biting with maximal strength in habitual occlusion. However, when the bite force is concentrated to a limited area of the tooth-arch, its magnitude seems to be limited by feedback mechanisms evoked in the periodontal tissues of that region.

Lundgren D, Laurell L: Occlusal force pattern during chewing and biting in dentitions restored with fixed bridges of cross-arch extension. II. Unilateral posterior two-unit cantilevers. J Oral Rehabil 1986 Mar;13(2):191-203.

The pattern of axially (perpendicular to the occlusal plane) directed occlusal forces developed during light tooth tapping in habitual occlusion, chewing, swallowing and maximal biting was studied in twelve subjects whose dentitions were periodontally treated and prosthetically restored with cross-arch bridges with unilateral posterior two-unit cantilevers. The measuring devices consisted of four strain-gauge transducers uniformly and bilaterally mounted in pontics of maxillary bridges to represent the posterior (end abutment and distal cantilever respectively) and anterior regions. Thus, the forces could be studied locally in various parts of the dentition simultaneously as well as totally over the entire dentition. The results demonstrated that the distal cantilever unit, on average, was subjected to forces about or less than half of those over the contralateral end abutment unit irrespective of the activity studied. Furthermore, the cantilever forces either equalled or were ever significantly smaller than those of the anterior regions. All subjects preferred the end abutment side as the chewing side. When the cantilever side was used as the chewing side, which occurred most infrequently, the bolus was usually located in the anterior region. The mean total chewing force (about 50 N) was only about half of that found in a previous study of subjects supplied with cross-arch bridges with bilateral end abutments (Lundgren & Laurell, 1985). Furthermore, on average only 26% of the voluntary muscular capacity was used during chewing, compared with 37% in the 'bilateral end abutment group' referred to. The reasons for the comparably small forces over the distal cantilever unit and the lower muscular utilization during chewing in cross-bridges with unilateral posterior two-unit cantilevers as well as the implications of the findings for the dimension of such bridge constructions are discussed.

Lundgren D, Nyman S, Heijl L, Carlsson GE: Functional analysis of fixed bridges on abutment teeth with reduced periodontal support. J Oral Rehabil 1975 Apr;2(2):105-16.

The present study examines the function of fixed bridges on abutment teeth with reduced but non-inflamed periodontal tissues. Eighteen patients with advanced periodontal breakdown and indication for oral rehabilitation received periodontol treatment and their dentitions were restored with fixed bridgework. The analysis of function performed 2-5 years after insertion of the reconstructions was made by (1) evaluation of the patients' opinion on chewing ability and function of the masticatory system; (2) clinical examination of the border movements of the mandible, the status of the temporomandivular joints and the chewing muscles, and (3) measurements of the bite force indifferent areas of the dentition. The results of the study show that the functional capacity of the type of extensive bridgework discussed is good and that the patients--in spite of severe loss of periodontal tissue--achieve bite force values that are almost comparable to those in individuals with natural teeth. Comparison of the function of fixed bridges and that of removable dentures is also discussed.

Misch CE Bidez MW: Implant-protected occlusion: a biomechanical rationale. Compendium (1994 Nov) 15(11):1330, 1332, 1334 passim; quiz 1344.

The clinical success and longevity of endosteal dental implants are controlled, in a large part, by the mechanical milieu within which they function. The occlusion is a critical component of such a mechanical environment. "Implant-protected occlusion" refers to an occlusal schema that is often uniquely specific to the restoration of endosteal implant prostheses. Implant orientation and the influence of load direction, the surface area of implants, occlusal table width, and protecting the weakest area are blended together from a biomechanical rationale to provide support for a specific occlusal philosophy.

Nyman S, Lindhe J, Lundgren D: The role of occlusion for the stability of fixed bridges in patients with reduced periodontal tissue support. J Clin Periodontol 1975 Apr;2(2):53-66.

The present investigation reports how occlusion may be utilized to establish and maintain stability of fixed bridges in patients with markedly reduced periodontal tissue support. The material consisted of 20 adult patients, aged 27-69, with advanced periodontal breakdown, often in combination with extensive loss of teeth. After periodontal treatment, the patients were rehabilitated with fixed bridges, whose stability was evaluated once a year for 2 to 6 years. The results show that permanent stability of bridgework can be obtained in patients where there is a minimum of remaining periodontal tissue support, even in combination with marked hypermobility of individual abutment teeth. The stability was achieved by proper treatment of the diseased periodontal tissues, and by establishment of stable occlusion in the intercuspal position. When there was a risk of bridge mobility on excursive movements of the mandible, balancing contacts were established for the prevention of migration, tilting and increasing mobility. The study also shows that cantilever pontics can be used to achieve and maintain the stability of fixed bridgework.

Penny RE, Kraal JH: Crown-to-root ratio: its significance in restorative dentistry. J Prosthet Dent 1979 Jul;42(1):34-8.

The definition of the crown-to-root ratio, its manifestation as a clinical problem, and associated problems were reviewed. Treatment possibilities were discussed in terms of plaque control, periodontal surgery, occlusal adjustment by selective grinding, splinting, restorative considerations, and extraction. The original guidelines for crown-to-root ratio in the selection of abutments were found to be exceptionally conservative and treatment limiting. New treatment modalities were considered in light of increased understanding of periodontal inflammation and its control. With inflammation controlled and with a carefully designed occlusion, some degree of mobility may be tolerated, thereby permitting the retention of teeth with minimal alveolar support.

Picton DC, Likeman PR: An investigation of the displacement of fixed bridges and their abutments under occlusal load in Monkeys (Macaca Fascicularis). Restorative Dent 1991 Feb;7(1):8-1.

Previous investigations have established the displacement characteristics of the teeth under axial load in monkeys (Macaca Fascicularis). The methods employed in these investigations have been used to study the displacements under occlusal load of both conventional fixed bridges and cantilever bridges, having different numbers of abutments. Under axial load there was a reduction in displacement when two teeth were splinted together to act as abutments to a fixed bridge compared with the displacements of the individual teeth. Loading on the pontics of the cantilever bridges showed the greatest displacements and caused tipping forces in the abutments. Recommendations that a cantilever bridge should replace only one unit and have not less than two abutments are supported.

Preti G Gassino G Lombardi M Mazzone P: Monitoring of the discrimination threshold for interocclusal thicknesses in rehabilitated edentulous patients. J Oral Rehabil (1994 Mar) 21(2):185-90.

Thirty-seven white Caucasian subjects with unsatisfactory dentures were tested for interocclusal thickness discrimination threshold. New dentures were prepared and the test was repeated on days 1, 4 and 90 (from delivery). Eight patients whose situation was still unsatisfactory were given osseointegrated implant anchored dentures and the test repeated at the same intervals. Results were analysed statistically. Improved denture fit was found to increase interocclusal sensitivity. Decreased sensitivity during follow-up might indicate the need to check denture fit.

Rangert B, Jemt T, Jorneus L: Forces and moments on Branemark implants. Int J Oral Maxillofac Implants 1989 Fall;4(3):241-7.

The placement of fixtures (implants) in relation to the geometry of a prosthetic restoration has a great influence on the mechanical loading of the implant. Based on theoretic consideration and clinical experiences with the Brånemark System, this article gives simple guidelines for controlling these loads. The emphasis is on design rules that can be used in clinical practice. With the Class I lever as a reference, various clinical implant prosthesis situations are discussed and evaluated.

IV. Stress Analysis, Electromyography and Radiography

Duncan RC, Storey AT, Rugh JD, Parel SM: Electromyographic activity of the jaw-closing muscles in patients with osseointegrated implant fixed partial dentures. J Prosthet Dent 1992 Apr;67(4):544-9.

The control of postural and synergistic jaw reflexes involves interrelated sensory input from receptors in the jaw muscles, temporomandibular joint, periodontal ligament, and mucosa. This investigation was done to determine whether a decrease in intraoral sensory afferent discharge significantly altered the onset of the jaw-unloading reflex. The subject population consisted of three groups with 10 subjects in each group. Group 1 had maxillary and mandibular natural teeth and group 2 consisted of edentulous subjects with complete dentures. Group 3 consisted of edentulous subjects with maxillary complete dentures and mandibular complete implant-supported prostheses. The unloading reflex was initiated with a muscle-unloading device and recorded with a storage oscilloscope. A one-way analysis of variance found no significant differences in the unloading-reflex latency for the masseter or temporal muscles among the three experimental groups (p less than 0.05).

Ettala-Ylitalo UM: Effects of occlusal adjustment on the periodontal condition and on the symptoms of masticatory dysfunction in patients treated with fixed prosthesis--a one-year follow-up study. J Oral Rehabil 1986 Nov;13(6):509-19.

A total of fifty-nine patients treated with a fixed prosthesis 4 years previously were recalled for a clinical and radiological examination. The subjects studied consisted of two groups: in group A the teeth of the patients with TMJ symptoms were selectively ground, whereas no grinding was performed in group B. At the first examination, occlusal interferences were found in 43.0% of the crowns and in 29.0% of pontics in group A before occlusal adjustment. At the second examination 1 year later, the percentage of occlusal interferences was decreased in this group (33.0% of the crowns and 25.8% in the pontics). In group B no changes in occlusal interferences were found after the 1-year follow-up period. The results of the investigation suggested that the frequency of interferences related to occlusal adjustment is important and the effect of occlusal adjustment to periodontal condition and TMJ symptoms is beneficial.

Ettala-Ylitalo UM, Syrjanen S, Markkanen H: Occlusal interferences related to dental panoramic radiographic changes in subjects treated with fixed prosthesis. J Oral Rehabil 1987 Sep;14(5):405-14.

Because of contradictory reports between clinical and radiographic findings, occlusal analysis correlated to dental panoramic findings was completed in 147 patients treated with fixed prosthesis. Both occlusal interferences and radiographic changes in the TMJ area and/or in dentition were discovered. Dysfunction and occlusal indices gave statistically significant correlations to radiographic changes (P less than 0.01 and P less than 0.05, respectively) in the TMJ area. Periodontal changes with vertical bone pocket formation and sclerotic lamina dura seem to be early radiographic findings and occlusal interferences were the only means to give a clear-cut correlation to the radiographic changes (P less than 0.001). However, if periodontal tissues with supporting bone structure fail to respond to occlusal trauma, changes in the TMJ area will probably appear. From the clinical changes the deviation on mouth opening, tenderness to palpation of TMJ, and slide from retrusion to intercuspidation (RP-IP) explained most of the radiological TMJ changes when tested by the discriminant analysis. The value of radiographic follow-up of subjects following prosthetic treatment is emphasized.

Glantz PO, Nyman S, Strandman E, Randow K: On functional strain in fixed mandibular reconstructions. II. An invivo study. Acta Odontol Scand 1984 Oct;42(5):269-76.

Six linear strain gauges and one rosette strain gauge were used on one partially dentate subject to study various types of functional deformation in a six-unit conventionally designed fixed mandibular bridge and a five-unit cantilever fixed mandibular bridge. The results of this study show that the clinical straining pattern was complex and different from those recorded in laboratory model studies of the same case. It was therefore concluded that functional deformations of fixed dental appliances can be studied accurately only in clinical experiments. Fundamentally different straining patterns were observed between the conventionally designed bridge and the cantilever one. The clinical significance of these results are discussed in relation to prosthetic treatment with various types of fixed-bridge constructions.

Glantz PO, Strandman E, Svensson SA, Randow K: On functional strain in fixed mandibular reconstructions. I. An invitro study. Acta Odontol Scand 1984 Aug;42(4):241-9.

Six linear strain gauges and one rosette strain gauge were used on three different types of models prepared from one partially dentate subject, to study loading deformation in a six-unit fixed mandibular bridge. The bridge was mounted on each of the models on an adjustable articulator and loaded in a universal testing machine at loading levels ranging from 0 to 491 N. The results showed considerable differences between the three types of model, with regard to both the magnitude of the recorded strains for the individual gauges and the calculated direction of the principal strains under the rosette gauges. The findings indicate that the mechanical properties and the design of the supporting structures have a major influence on the functional deformation of fixed dental appliances.

Wood WW, Gelfant H, Hannam AG: Effect of occlusal reconstruction on the reproducibility of chewing movements. J Prosthet Dent 1981 Aug;46(2):181-4.

The jaw movement patterns of five subjects with reconstructed occlusion were compared with those of 10 normal dentate subjects. The degree of conformity between closing and opening pathways in the intercuspal area and the reproducibility of these pathways within and outside the intercuspal zone were measured with a computer-based system. The mean linear separations between opening and closing pathways and deviations around these pathways for the reconstructed group were consistently smaller than those for the control group. The results suggest that reconstructed subjects use displacement patterns which show less variation than do subjects with natural dentitions.

V. Complex Restorative Considerations

Binkley TK, Binkley CJ: A practical approach to full mouth rehabilitation. J Prosthet Dent 1987 Mar;57(3):261-6.

The concepts of traditional full mouth reconstruction have been reviewed. A practical full mouth rehabilitation technique has been described combining the chairside advantages of the programmed quadrant reconstruction with the laboratory advantages associated with the complete mouth simultaneous rehabilitation.

Brown KE: Reconstruction considerations for severe dental attrition. J Prosthet Dent 1980 Oct;44(4):384-8.

Alternative approaches toward the resolution of difficulties associated with severe attrition are offered. A clinical approach is advocated which first proves the acceptance of an increase in the occlusal vertical dimension before initiating definitive treatment. The various aspects of removable treatment are considered. A sequential approach is suggested in fixed reconstruction which avoids inaccuracies of multiabutment registration and orientation associated with complete arch preparation.

Dahl BL, Krogstad O, Karlsen K: An alternative treatment in cases with advanced localized attrition. J Oral Rehabil 1975 Jul;2(3):209-14.

A combined orthodontic/prosthetic treatment of patients with advanced localized attrition has been described. In one patient the effect of the orthodontic treatment upon the morphological face height has been studied using an X-ray cephalographic technique and the results have been discussed.

Bjornaas T Rygh P Boe OE: Severe overjet and overbite reduced alveolar bone height in 19-year-old men. Am J Orthod Dentofacial Orthop (1994 Aug) 106(2):139-45.

Few investigations have reported convincing evidence of an association between malocclusion and loss of periodontal tooth support. The contradictory findings may in part be explained by the selection of material and by method differences. In many studies not- very-severe malocclusion was compared with not-very-correct occlusion. Only recently have measuring methods been developed that calculate the distance between the cementoenamel junction (CEJ) and the interproximal alveolar bone crest (AC) to the nearest 0.01 mm with acceptable accuracy. The association between overjet > or = 8 mm and the reduction of the bone support as expressed by the distance between CEJ and AC in 21 military recruits was compared with a peer group of 50 recruits with nearly ideal occlusion. The results showed a significant reduction of bone height (mean = 0.96 mm) of the four upper front teeth and of the four lower incisors (mean = 0.35 mm) in the malocclusion group. Similarly, a group of 31 army recruits with overbite > or = 6 mm revealed a significant reduction of bone height of 0.71 mm of the upper front teeth and 0.49 mm of the lower front teeth. Overjet and overbite did not appear in combination in this material. In conclusion, alveolar bone height was reduced in regions with severe malocclusion when compared with corresponding regions in healthy men with near ideal occlusion. The material was military recruits (age 19 years).

Fidler BC Artun J Joondeph DR Little RM: Long-term stability of Angle Class II, division 1 malocclusions with successful occlusal results at end of active treatment. Am J Orthod Dentofacial Orthop (1995 Mar) 107(3):276-85.

The purpose of this study was to examine long-term stability of Angle Class II, Division 1 malocclusions with successful occlusal results at the end of active appliance therapy, search for predictors of relapse, and look for characteristics associated with successful treatment. Records taken before and after treatment and a mean of 14.0 years postretention of adolescent patients treated for a significant Angle Class II, Division 1 malocclusion both with and without tooth extraction were evaluated. The sample was limited to successfully treated cases as judged by subjective evaluation of intercuspation and incisor occlusion of posttreatment study models and included 78 patients. Cephalometric characteristics or postretention occlusion was not considered in sample selection. The mode response was no change postretention for molar, premolar, and canine relationships and relapse of 0.5 mm for overjet and overbite. Maximum relapse was 3.5 mm for molar, premolar, and canine relationship, 3 mm for overjet, and 4.5 mm for overbite. Stepwise backward multiple regression analyses revealed no associations between either pretreatment characteristics or skeletal and dental treatment changes and relapse of overjet. However, relapse of overjet was associated with relapse of molar, premolar, and canine relationships, postretention increase in overbite, postretention proclination of maxillary incisors, and postretention retroclination of mandibular incisors. Active treatment changes included redirection or inhibition of maxillary growth and retraction of maxillary incisors. Mandibular incremental growth was favorable both during and after treatment. It was concluded that successful correction of Angle Class II, Division 1 malocclusions through differential growth adaptation and tooth movement appears to be very stable.

Foster LV: Clinical aspects of occlusion: 1. Occlusal terminology and the conformative approach. Dent Update 1992 Oct;19(8):345-8.

This two-part series aims to familiarize the reader with essential occlusal principles and terminology and to give some guidelines as to which cases are suitable for crown and bridgework. The first article covers occlusal terminology and the conformative approach, whilst the second will describe the reorganized approach. Both papers contain clinical cases which demonstrate how to overcome some of the occlusal problems encountered in this area.

Fradeani M, Bottachiari RS, Tracey T, Parma-Benfenati S , Stein JM, De Paoli S: The restoration of functional occlusion and esthetics. Int J Periodontics Restorative Dent 1992;12(1):63-71.

Severe occlusal destruction, whether it results from attrition, abrasion, or erosion, must be met with definitive diagnosis and treatment. This case report illustrates the step-by-step diagnosis and treatment of a patient with severe occlusal wear. Restoration of a functional occlusion and esthetics involved endodontic treatment, reestablishment of the vertical dimension of occlusion, osseous periodontal surgery, and placement of single-tooth cast glass-ceramic crowns.

Gray HS: Occlusion and restorative dentistry: Part II. N Z Dent J (1993 Jul) 89(397):87-91.

When planning treatment for major reconstruction of a dentition, occlusal factors which can affect the comfortable functioning of the masticatory system are a prime consideration. Anterior guidance and posterior support contribute significantly to the comfortable functioning of the masticatory system. Aesthetic factors are also significant for, in providing anterior guidance, the alignment, lengths, and proportions of incisors are as critical as their shape, colour and surface texture. Finally, treatment does not end with the insertion of the fixed and removable prostheses. Continual maintenance over the years can

Ibbetson RJ, Setchell DJ: Treatment of the worn dentition: 1. Dent Update 1989 Jul-Aug;16(6):247, 250-3: 2. Dent Update 1989 Sep;16(7):300-2, 305-7.

The first article concerns the practical techniques involved in reconstruction of the worn dentition. The authors describe some of the procedures available and assess the appropriateness of 'conformative' versus 'reorganized' approaches to the occlusion. They continue by describing some practical aspects of reconstructive work.

The second article concerns the practical techniques involved in reconstruction of the worn dentition. Part 1 discussed approaches to managing occlusion, and practical techniques for restoring worn anterior teeth. This second article will describe the procedures involved when both anterior and posterior teeth are worn, and then give a guide to the management of the short clinical crown.

Lundeen HC: Occlusal morphologic consideration for fixed restorations. Dent Clin North Am 15(3):649, 1971.

This article deals with some of the occlusal morphology of the fixed restorations for the natural teeth. A very informative article. In order to restore teeth to a stable occlusal relationship, contacts must be fabricated in an harmonious relationship to each other. The evaluation of the occlusal table jaw movements and muscle physiology are important if the fabricated restoration is to survive in the oral environment. This article did a good job in explaining the importance of these factors.

Miller TE : Thielemann's diagonal law of occlusion revisited. Compendium 1991 Feb;12(2):114, 116, 118 passim.

Thielemann's studies of malocclusal relationships and the frequently observed chain reactions created in distant localities led to the formulation of a philosophical approach to occlusion that is also of practical premeditative clinical relevance for the practitioner. Dr. Thielemann presumed to name it a law, and repeated clinical observations apparently support and reinforce his claim. All disciplines of dentistry inevitably encounter and need to know about this aspect of fission-reactive involvement with the common and seemingly innocuous malocclusions. By incorporating the law into the diagnostic, planning, corrective, and therapeutic stages of treatment, the clinician can readily categorize patients for needs assessments and future goals in treatment.

Spalding PM, Cohen BD: Orthodontic adjunctive treatment in fixed prosthodontics. Dent Clin North Am 1992 Jul;36(3):607-29.

The purpose of this article has been to increase the restorative dentist's appreciation for the rationale justifying preprosthodontic orthodontic treatment. When planning prosthodontic treatment, the dentist should embrace a dynamic view of tooth position and determine whether restorative treatment can be enhanced by tooth movement. Improved tooth position can eliminate potentially pathologic occlusion and create a healthier periodontal environment that is easier to maintain. In addition, it permits the dentist to place restorations that often require less natural tooth reduction during preparation, and that are more esthetic, functional, stable, and durable. Orthodontic treatment that accomplishes these benefits may be limited to a partial fixed appliance localized to one segment of an arch or require a more extensive fixed appliance. Addressing more comprehensive orthodontic problems in patients requiring prosthodontic care is best managed through a restorative dentist and orthodontist team approach to treatment.

Stern N, Michman J: Oral rehabilitation of adult class II, division 1 malocclusion complicated by collapse of posterior occlusion. J Oral Rehabil 1977 Jan;4(1):39-44.

The complications and limitations in rehabilitating an adult woman with class II, division 1 malocclusion and posterior occlusal collapse is described with special consideration given to the aspects of time, the patient's personality and socio-economic situation. Fixed restorations were chosen for optimum function, comfort and to enhance the patient's emotional security. The importance of an individual treatment approach is stressed.

Turner KA: Restoration of the extremely worn dentition. J Prosthet Dent 52(4):467, 1984.

The article discusses the diagnosis and treatment planning of patients who suffer from extreme occlusal wear. This condition is defined as the wearing away of one tooth surface by another tooth surface. There are, however, several etiologic factors that can result in excessive occlusal wear:

1. Congenital abnormalities
2. Parafunctional occlusal habits
3. Abrasion
4. Erosion
5. Loss of posterior support

In evaluating occlusal vertical dimension, it is critical to verify the support prior to restoration. The most common cause of decreased occlusal vertical dimension is loss of posterior support. Vertical positioning of more than 1 millimeter apart may indicate a loss of occlusal vertical dimension. Currently, the methods of measuring inter-occlusal distances are diverse, inaccurate and inconsistent. For example, a patient who demonstrates an inter-occlusal distance of six millimeters is more capable of tolerating a slight increase in occlusal vertical dimension than the patient with an inter-occlusal dimension of two millimeters. An arbitrary increase in occlusal vertical dimension should be avoided if a feasible alternative exists. This can be accomplished through the use of removable occlusal splints and followed by fixed provisional restorations. There are various modalities that can aid in the successful treatment of patients with a worn dentition. A team approach that uses inter-specialty expertise can aid in the longevity of the restoration for the patient.

Warren K, Capp NJ: Occlusal accuracy in restorative dentistry: the role of the clinician in controlling clinical and laboratory procedures. Quintessence Int 1991 Sep;22(9):695-702.

This paper describes the clinical and laboratory stages necessary to ensure the occlusal precision of fixed restorations. The important diagnostic stages, including elimination of mandibular dysfunction the occlusal analysis and waxing of diagnostic casts, and the diagnostic use of provisional restorations, are outlined. The importance of having the clinician control all stages of laboratory work, including die trimming, mounting working casts on an articulator, the determination of both anterior and posterior tooth form, and the final occlusal adjustment of the restorations, is emphasized.

Weiland FJ: The role of occlusal discrepancies in the long-term stability of the mandibular arch. Eur J Orthod (1994 Dec) 16(6):521-9

To assess the influence of occlusal discrepancies on the long-term stability of orthodontic treatment, the dental casts, and cephalometric records of 40 patients were evaluated, pretreatment, post-treatment, and at least 9 years post-retention. Post-treatment and post-retention casts were mounted in a semi-adjustable articulator in RCP. In addition to arch dimension measurements, discrepancies between RCP and ICP were measured in three spatial planes using a condymeter. Arch width and length decreased significantly after retention. The position of the lower incisors was relatively stable, whereas the lower molars moved forward substantially. Lower anterior irregularity increased after treatment. As a consequence, 60% of the cases had unsatisfactory lower anterior alignment after retention. The long-term records generally showed a trend towards moderate crowding. The amount of slide decreased over time and had a statistically significant, though clinically only moderate, influence on the increase in lower anterior irregularity.

VI. Historical Perspectives

Jankelson B: Neuromuscular aspects of occlusion. Dent Clin North Am 23(2):157, 1979.

Dentistry has relied upon mechanical repetitiveness to define an occlusal position for many years. But, since the operator positions the patient in this position, it is muscularly strained, or is it a relaxed position (as it is claimed to be)? To answer this question, clutches, central bearing and pantographs have been used to evaluate the muscles at the time of positioning. However, all of these pieces of equipment in and of themselves cause muscular disruption. A more ideal measurement of a relaxed muscle state can be achieved using TENS (Transcutaneous Electrical Neural Stimulation) to relax the muscles via the V and VII nerves. Then, a K3 mandibular kinesiograph and a myomonitor are connected to record changes that occur during positioning. According to these findings, CR (centric relation) was found to be a neuromuscularly strained position and further found that TMJ syndrome is a function of CO (centric occlusion) not coinciding with a relaxed neuromuscular position. Myocentric occlusion is, however, a neuromuscularly relaxed position that frequently coincides with CO but NEVER coincides with CR.

Schuyler LH: An evaluation of incisal guidance and its influence on restorative dentistry. J Prosthet Dent 9(3):374, 1959.

Incisal guidance of the lingual surface of the six maxillary anterior teeth is the key to a harmonious relationship of natural dentition in functional occlusion. In complete dentures, maxillary and mandibular anterior teeth rarely contact one another while almost all natural dentition offer this contact. Complete dentures are made to provide three point balancing contact for stability. Balancing contacts in natural dentition are non-essential and may even be deleterious by causing alveolar bone loss in posterior teeth. In addition, balancing contacts may cause TMJ disorders. To this end, balancing contacts in natural dentition should always be eliminated in teeth that are periodontally involved or in cases of TMJ dysfunction. When restoring a patient, maintenance of incisal guidance is critical . If a patient originally had contact between the maxillary and mandibular anterior teeth, these teeth will super-erupt to regain this contact if it is not restored correctly. In addition, anterior contact will take added stress off the posterior teeth. Finally, when establishing occlusion, allow for slight freedom of anterior-positioning movement as well as freedom in the intercuspated position. This can be achieved by placing thin (0.5 to .075 mm) pieces of tin foil in front of the condylar balls of the articulator and then grinding the teeth. Then, remove the foil and grind the teeth in this position. This allows for the aforementioned freedom.

Sharry JJ: An essential questioning of occlusion. Part II. J. Prosthet Dent 30(4):509, 1973.

Do cusps meet tightly in opposing fossae or loosely when the jaw occludes from an open position? The answer in this article states that the physiological adaptability allows muscles to guide the jaw into "pin-point" position to avoid "trouble". Pousselt felt that ligaments were the ultimate guides. Boucher suggested that muscles were responsible for limiting jaw movements at least in the waking states. Muscle contraction varies from day to day and that seems to account for the variability of jaw movements. The operator is given two choices when trying to determine occlusion. The first is to take an average of several recordings and use that reading for occlusal registration. The second is to accept one static movement and build in arbitrary "looseness" to include all other excursional movements. Pantographs allow the visualization of jaw movements in two planes: sagittal and coronal. However, pantographs do not include a third plane which would allow for a shift in Bennett movement and help create an area of centric relation. Overall, the author feels that the preferred therapy is to provide an "area of centric" of approximately 0.3 mm rather than have a tight intercuspation.

Stuart CE: Occlusion for natural teeth. J Prosthet Dent 14(4):716, 1964.

In forming a gnathic organ occlusion, the entire organ system must be viewed. Bones, muscles, joints and associated organs, and, of course, the teeth all play a vital role in this concept. The isolated theories of determining jaw relationships from only viewing tendon groups or muscle groups has been discarded in this article. Muscles in coordination with the joints and nerve receptors in the teeth, aid in jaw closure according to the author. The teeth can function in the zone of several skull positions. Within this zone, there are mesial and distal limitations. Molars and premolars have two types of occlusion: stamping and shearing cusps. Maxillary lingual cusps are stamp cusps and occlude in fossae. Shearing cusps do not occlude in fossae. Natural occlusal patterns allow stamp cusps to move in and out of fossae without occlusal contacts on central or eccentric positions.

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Functional analysis is the diagnosis of occlusal disharmony or malocclusion and the production of occlusion that will be efficient in both the physiological and functional sense. The masticating mechanism must be viewed as a whole in order to have proper analysis of occlusion. What was once considered normal has now been expanded to accommodate a wide range of anatomic variation. In order to properly evaluate occlusion, the path of closure needs to be examined. Temporomandibular discrepancies can be addressed accordingly at this time during the evaluation process. Next, the amount of freeway space should be determined. Afterwards, a facebow analysis will facilitate the transfer and mounting of the maxillary cast to the articulator for a static registration. Failure to obtain a true relaxed centric relation of the jaws will cause a resultant malocclusion during setup procedures. Additional therapies such as orthodontics and periodontics play a vital role in helping create an efficient masticatory plane that allows the maintenance of healthy periodontia as well as adequate temporomandibular joint function.

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Occlusion For Natural Teeth

Dr. Joseph A. Clayton

OCCLUSION FOR NATURAL TEETH

A CONCEPT OF OCCLUSAL INTERFERENCES

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This review of previous research on occlusal interference, was prompted by the increase in current literature to ignore them (McNamara et al,1995). If one looked at the history of occlusion their have been different groups that provided the leadership in the promulgation of occlusion. Dentists in general want to be lead. They want someone to tell them how to do it. Occlusion probably started with prosthodontists on dentures. Balanced occlusion made some sense to stabilize dentures. A group calling themselves gnathologists started to research jaw movement and occlusion for the dentate patient. For years gnathologists were the leaders in occlusion. During their reign the change from a balanced occlusion to a mutually protected canine guided occlusion was made. Balanced occlusion on natural teeth caused problems. As periodontics grew they recognized the role occlusion played in the treatment of periodontal disease. For many years the periodontist advocated occlusal splint therapy and occlusal adjustments. Occlusion was becoming a part of TMJ dysfunction as a primary cause. Over the past several years the area of TMJ dysfunction, Temporomandibular disorders, Craniomandibular disorders grew rapidly and the role of occlusion as an etiologic factor has been questioned. The role of occlusion in restoring occlusion has still maintained it's importance, however, the two areas have been entertwined and there is confusion. The peripheral areas of dentistry got involved in TMD and CMD through the stress-psychological roles. Nondentists, as they have been labeled, got into this area. Occlusion was a problem for them since they knew very little about it and the easiest ways to deal with it is to try to discredit occlusion's role in TMJ dysfunction. This is where we are today. All of the previous research has been discarded based on today's research protocol that has developed over this time. Also, the protocol will continue to improve and today's so call perfect research will be discarded in a few years. This is the wonder of progress. However, research must be judged according to the decade in which it was done. All of it has some merit. The purpose of the article is to present the research on occlusion that was developed in support of occlusion and its role in dentistry and TMJ dysfunction. It cannot be discarded solely because on today's research protocol. It was done by very intelligent and clinically capable individuals. The individual researcher or/and his integrity is involved and makes the research valid. These are the "experts" of their time.

Occlusion means different things to different groups in dentistry (Clayton, 1995). Arguments start immediately because individuals have different ideas when occlusion is mentioned. This has been emphasized in research involving the role of orthodontics as an etiological factor in TMD. Orthodontist deals with malocclusion. They have been classified. Malocclusion deals with tooth and bone positions such as crossbites, open bites, Class I, II, III with divisions, overjet, etc. The restorative dentist and periodontist recognized occlusal interferences (OI). Occlusal interferences were in the occlusal form of the teeth and were related to jaw movements dictated by the TMJs. Over the years, research has shown that OIs can cause muscular response. OIs can cause muscles to be hyperactive. Muscle hyperactivity can lead to muscle dysfunction. Muscles under dysfunction loose their coordination, hid the OIs and make restoring of the occlusion difficult. The muscle response to OIs can cause pressure in the TMJs which can also trigger a muscular response. Pressure in the TMJs can also cause changes in the joints. Previous research has shown that interferences in CR and particularly a lateral slide; balancing; working and protrusive interference; and a restrictive anterior and canine guidance can cause hyperactive muscular responses.

When OIs and malocclusions are brought together, we can have OIs without malocclusions. We can have malocclusions without OIs. We can have OIs on malocclusions. These combinations have lead to the confusion in studies concerning OIs and malocclusion. They are lumped together. They should be considered separately.

The same is true for disorders of the masticatory system. New names have been given to larger groups of disorders such as Craniomandibualr disorders (CMD) which encompasses all of the disorders. There are various disorders under this term. OIs start by causing muscle dysfunction or pain dysfunction. This has been termed TMJ dysfunction. There are deranged disk disorders. There is bruxism. There are TMJ disorders. There are traumatic occlusion disorders etc. To lump these all together adds to the confusion. Now the debate centers around whether OIs cause CMD. OIs cause muscle dysfunction which can lead to other disorders in the masticatory system.

The definition of OIs can be controversial in itself. The restorative dentist can record the border movements as dictated by the TMJs without muscle dysfunction. Occlusal surfaces can be made to be in
harmony with the border movements. OIs can be defined as tooth parts that deflect the jaw closure away from the border movements. CR is a border position. Tooth surfaces that deflect the jaw closure in CR are OIs. A pantograph can record these border movements. Muscles under dysfunction become uncoordinated and cannot reproduce these border movements. The pantographic reproducibility index (PRI) was developed to quantitative the uncoordinated movement sign of muscle dysfunction.

The confusion about OIs role in TMJ dysfunction because studies on subjects with TMJ dysfunction do not find OIs. However, the protective role of the muscles has hid the OIs. The occlusion can program (train) the muscle to close around the OIs, if they can, and protect the teeth. This programming is very strong and may not be disrupted without occlusal splint therapy (OST). The sole purpose of the OST is to disengage the teeth and let the muscles unlearn the learned response. Then the OIs can be located. Studies on OIs in TMJ dysfunction subjects should be proceeded with OST. Splints must be worn 24 hours a day and be adjusted as the jaw position changes. The time involved to get rid of the muscle dysfunction is dependent on the individual subject's condition.

Another confusing area to some is the fact that everyone with OIs does not have TMJ dysfunction. This is because every individual has a tolerance level and an adaptive capacity to their OIs. The tolerance level and adaptive level can change to where the existing OIs can cause muscle dysfunction. Stress affects the tolerance level and adaptive capacity. The "Suddenness" of the OI interference is important. Adaptation may be more complete to a slowly developing OI whereas a sudden placement of an OI may overload the adaptive capacity. It is not so much the OI as the subject's response to the OI. Also, it is not so much the stress as it is the subject's response to stress. The individual difference must be considered. Bell put it in prospective when he said "an occlusal interference, it activated by emotional tension, may become etiologic ally important". There is a lot of "gray areas" when considering OIs as a cause of TMJ dysfunction.

The area of occlusion has been made more confusing by a series of articles by Mohl on the "Devices for the diagnosis and treatment of temporomandibular disorders." These reviews of literature articles discard all devices that are available for diagnosis and treatment of TMD. Nothing except biofeedback has enough research to support the claims. The PRI, EMG and all other "devices" were discarded for lack of research support. They established the clinical examination as the "golden rule." The clinical examination is subjective and is not quantitated. Therefore, their "golden rule" is not a research tool so how can they do research? It gives individuals a good place to hid and make them feel good because there is nothing we can use to diagnosis or treat TMD.

Todays research protocol has it's double blind, controls, specificity, etc. It is assumed that if a person follows the protocol the research has to be good. However, there are no research tools with numbers that can be analyzed by statistic because they were all discarded by Mohl's (1990) committee. Today's research then is at fault like previous research. Research that uses subjects "without" TMD are suspect because their is no device to measure this. The visual analog scale (VAS), although it has 100 units, is still a subjective tool because subjects guess where the pain is and can be biased.

As stated above, this article will present past research on the role of occlusion and OIs. The best devices of the time, Helkemo dysfunction index, PRI, EMG, were used. In spite of the overwhelming criticism, these studies are valid and useful.

INFLUENCE OF OCCLUSION ON JAW MOVEMENT

Brill et al, 1962, studied the influence of occlusal patterns of movements of the mandible. Fifteen edentulous subjects ages 37 to 75 were used. Seven were males and eight females. They had good ridge form. One maxillary and two mandibular dentures were made for each subject. Both had teeth set to the retruded position and could be worn by the subjects. On one of the lower dentures, the posterior teeth were set-back 3 mm. The subject would have to protrude the jaw to achieve CO, the "P" denture. The other was the "M" denture. The subject was instructed to tap lightly 25 times on the "M" denture. The contact position was observed. Subjects were examined for muscle, TMJ and ridge area pain.

All subjects closed into the "M" denture with light or hard muscle activity. The forward position was achieved with the "P" denture only with hard tapping. With light tapping they closed in the posterior position. Only 10 subjects had symptoms. No ridge soreness was seen. Muscle symptoms were noted in 5 subjects, but none were aware of muscle symptoms for the week. When the "M" denture was placed, the symptoms disappeared in a week. Movement patterns of the jaw can be changed to accommodate a protruded occlusal position.

Dewe-Mathews, 1975, studied the effect of tooth guidance on function in relationship to the border position recorded graphically. One 58-year-old subject was used. No dysfunction was observed clinically or with the PRI. The posterior teeth needed restorations. The occlusion was restored to a point centric at CR and CR and CO coincided. Immediate canine guidance separated the posterior teeth. In the mouth the tooth guided occlusion coincided with the guided border movements. Interchangeable occlusions were made. The subject wore a maxillary occlusal interference free occlusal splint before the study began. The subject had been wearing gold temporaries from another study that had interferences in CR and lateral slide into CO. A removable interference was made and recordings were taken immediately, and at two, seven and seventeen days. The occlusal interference was removed and jaw movement recordings were made at six and eight days. The recording of jaw movements were made on two frontal and two horizontal tables attached to labial clutch attached to the teeth so the teeth could contact. Test foods were chewed.

The border tracings were reproducible. The recorded CR-CO slide was 0.5 mm forward and 0.7 mm left of CR. The Tracing with the teeth in contact moved around the OI and away from the border tracings. When the OI was removed, the subject jaw still moved (chewed) as if the interferences were still there. This pattern was gone in 2 days. The OI prevented the function to the border recordings and caused muscle dysfunction. OIs can cause the muscles to develop a learned pattern, avoidance pattern.

Nielson et al, 1987, studied the alteration in proprioceptive reflex control in subjects with Craniomandibular Disorders (CMD). The control group had seventeen subjects with no symptoms of TMD, normal occlusion and craniofacial morphology. This group had 11 men and 6 women ages 22 to 42 years. The patient groups had 33 patients with palpated muscle pain. There were 9 males and 24 females ages 18 -46 years. None had TMJ pain.

The kinesiograph was used to track the jaw position. Subjects opened wide 10 times. They were asked to hold a position a target position in the less than 50% (4-10 mm) and greater than 50% (17-26 mm) opening from the incisors. The results suggest that neuromuscular control of mandibular position is altered by muscle pain. Mandibular positional sense depends on sensory feedback from receptors and their reflex control on muscles. Other studies showed that patients with malocclusion and TMJ had difficulty reproducing mandibular positions. This study suggests that pain in the muscles disrupt the propreceptive-reflexive pathway for precise control of positions.

Jemt, 1982, studied the effect to two different occlusal designs on the chewing pattern. Patients had full arch maxillary implant prostheses. There were five subjects (2 men and 3 women) ages 39 to 70 years. They all had natural or restored mandibular teeth. One of the occlusal designs had a distinct canine protection (however the drawings showed a restrictive canine guidance). After 4 months, adaptation the jaw movements were recorded with light-emitting diodes (LED). The occlusion was changed to group function (drawing shows a correctly designed canine guidance) and was recorded 5 months later. Two had the occlusion changed back to canine restriction and recorded

6 months later. There were no differences between the two design recordings. The canine restricted guidance had a steeper path. The correctly designed canine guidance felt more comfortable to the subjects and there were fewer contacts. The effect of the food also changed the recorded pattern. The occlusion affects the terminal occlusal pattern by decreasing the angle in the restricted canine guidance and more tooth contacts would occur for adaptation.

The occlusal pattern can influence the chewing pattern. The less restricted guidance showed a greater degree of movement and a higher mandibular velocity.

Barghi et al, 1987, assessed the correlation between timing of joint clicks and the loss of posterior teeth. One hundred and fifty males and females ages 27 to 79 years old were examined for audible TMJ clicking sounds. They had tooth losses for at least 5 years. Questionnaires recorded the history and symptoms of TMJ disorders. Five openings were used to check repeated clicking. Subjects with posterior teeth were used as controls. The two groups had different TMJ clicking (34.6% vs 23.9%). The type of click was different. The group with missing teeth had 17.8% early opening clicks and more late opening and early closing clicks (55.7%). Clicking on the same side as the missing teeth was statistically significant. There was a high incidence of TMJ clicking in patients with missing posterior teeth, a loss of posterior support.

Robinson, 1946, in a cadaver study showed that the tissue found in the TMJ was not the type found in stress-bearing areas. Therefore, it is reasonable to assume the there should be no appreciable stress in the TMJs. The cadavers were 44% edentulous and 66% with teeth. Heavy forces in the TMJ would be transmitted to bone as pressure and bone would change. Reflex connections prevent the occurrence of destructive forces. The temporal muscle equilibrates the forces (physiologic) in amount and placement. This is reflexively controlled through proprioception. Stress is reflexly controlled. The coordination between all muscles concerned is so fine that their resultant force is applied where needed in the dental arch. Heavy forces are transmitted between teeth and are dissipated through the periodontal membrane to bone as tension.

In abnormal situations, muscles under dysfunction lose their coordination and forces can be applied in wrong area. The occlusion can cause the muscles to move the jaw abnormally and stress the TMJ. The proprioceptive response in the joint can cause muscles to reposition the condyles and/or disk to relieve the stress.

Heavy forces should occur between the teeth through stable centric stops. Anatomy and histology of the TMJs indicate that they are non-stress-bearing areas. Stress in the TMJ can cause the bone, disk, ligaments to change and malposition the condyles up, down, forward or back. Incline tooth contacts can disturb stress distribution to cause joint and periodontal disease. Stresses in the mandible are regulated by a positional and masticatory reflex. Pathology in the joints and teeth could be caused by abnormal reflexes. The disk is composed of specialized connective tissue and repair can occur if the conditions responsible for the pathological process are corrected. Treatment of the TMJ is by correcting the causes of the abnormal reflex and stress.

DEVICES FOR RECORDING MUSCLE DYSFUNCTION AND TMD:

Helkemo, 1974, developed a quantitative clinical dysfuncion index intended for use in the estimation of the functional status of the masticatory system. Three indices are used: 1) clinical dysfunction index (CDI) evaluates 5 groups of symptoms of impaired range of movement, impaired function of the TMJ, pain on movement, pain in the TMJ and pain in the masticatory muscles; 2) anamnestic dysfunction index based on data from the interview; and 3) index of occlusal state based on the evaluation of the occlusion as to the number of teeth, number of occluding teeth, interferences on occlusion and articulation. The index provided numbers for statistical evaluation.

The Helkemo dysfunction index (HDI) was used to study 321 Lapps ages 15 - 65 years. There were 156 men and 165 women. The population had 30% impairment of mobility. The CDI showed 41% had mild, 25% had moderate and 22% severe symptoms. The anamnestic index showed 31% mild and 26% severe symptoms. The index for occlusal state showed 14% moderate and 86% severe occlusal disturbances.

The index was developed for epidemiologic population studies on the prevalence of signs and symptoms of TMJ dysfunction. As a result the index is not as good for a dentist to use in everyday practice. It is, however, recognized as the "gold standard" clinical dysfunction index to use in research. It is still being used today to evaluate clinical signs and symptoms of TMJ dysfunction.

Shields, Sindledecker, Clayton, 1978, evaluated the PRI against the Helkemo dysfunction index (HDI). In the development of the PRI the HDI was the best clinical dysfunction index in use. Forty-six subjects with varying degrees of dysfunction and occlusal problems were used. The study followed the double blind protocol. One operator (JMS) took the dysfunctional pantographic recordings. Another operator (LDS) evaluated the subjects with the HDI. A third operator (JAC) scored the PRI tracings. The three operators were trained and calibrated in their procedures. They knew nothing about the subjects or what each others evaluation showed until the end of the study. Each subject has two sets of PRI recordings taken. The second set of tracings discriminated among the dysfunction groups ($P < 0.1$). The paired comparisons indicated a significant ($P < 0.05$) difference between the groups with the moderate HDI group. An analysis of covariance showed the PRI correlated well between the moderate and slight or no dysfunction. The PRI scores were adjusted after this study to the present PRI dysfunction categories. The PRI categories are 0 - 15 reproducible, no dysfunction; above 15 was non reproducible, 16 - 30 slight, 31 - 60 moderate and 61 - 144 severe dysfunction. ; PRI scores could range from 0 to 144. At least two sets of tracing should be taken to assess the dysfunction. Four sets of tracings that are averaged are used in research.

The results of this study indicate that the PRI can be used clinically to aid in detecting TMJ dysfunction and muscle incoordination. The PRI relates to muscle pain as determined by the HDI and was related to the subject's occlusion. The PRI can be used by dentists in an everyday practice to detect the presence or more importantly the absence of muscle dysfunction. Muscle dysfunction (incoordination) is one of the first symptoms to occur and the last to disappear in TMJ dysfunction development and treatment. The PRI correlation's to the presence of pain (avoidance pattern) and occlusal interferences and was more sensitive than the HDI.

Crispin, Myers, Clayton, 1978, studied the effects of occlusal splint therapy and occlusal adjustments on the PRI. Nine men and 17 women ages 21 to 50 years were selected at random and divided into 3 groups by their PRI scores. Five nonreproducable (TMJ dysfunction) subjects and 5 reproducible (no dysfunction) subjects were used as a control group. Eleven subjects were the experimental group that received occlusal splint therapy and occlusal adjustments. There were four recall periods 30 days apart to record the PRI scores. For the first two periods, the subjects wore splints and the splints were adjusted as needed. To be sure the subjects were wearing the splints, the occlusion was adjusted during the third period. The subjects were without the splints the last 2 weeks of the fourth period. Four dysfunction pantographic recordings (PRI) were made at each recording session.

Maxillary occlusal interference free occlusal splints were used with stable centric stops and immediate canine guidance. Splints were worn 24-hours and adjusted as the jaw position changed. The occlusal adjustment reduced the slide in centric first and then the balancing and working excursions. The control subjects were recorded every 30 days but nothing else was done to their teeth. The recorder and the scorer of the PRI recordings were two operators under double blind protocol.

There were 516 sets of PRI recordings that were analyzed. There was a rapid drop in the PRI scores in the experimental groups over the first 30 days and then the drop continued through the occlusal adjustment to the reproducible (no dysfunction) range. The control group PRI scores fluctuated over the 120 days but remained in the same starting category. Analysis of covariance showed the change in the experimental group were statistically significant at the .001 level and the controls were not. This study showed that the PRI scores changed with the change in the occlusion, occlusal splint therapy and occlusal adjustment. As a result the PRI can be used to determine the success of occlusal treatments. OIs cause hyper muscle activity that leads to muscle dysfunction. Under dysfunction, the muscles loose their fine coordination and the jaw movements become incoordinated. The PRI is a scale that quantities this incoordination and the degree of muscle dysfunction. The PRI, therefore, records muscle dysfunction in TMJ dysfunction. Few subjects under stressful times had a spike in the PRI scores.

Clayton et al, 1994, reported on a 6 - 15 month study of control-like subjects and the PRI scores. Twenty volunteer, dental students and staff, were used. The PRI was recorded with the Pantronic (Denar, Teledyne-Water Pic, CO). Eleven were recorded for 15 months and 8 for 6 months. There were 150 PRI recordings sessions with 4 PRIs recorded for a total of 600 PRI recordings to be analyzed. A clinical dysfunction index (CDI) (Clayton) was recorded at each session. Nothing else was done on the subjects. The data showed that time has no statistically significant effect ($P < 0.05$) on the PRI or CDI. The PRI did, however, increase slightly during stressing times. Time alone has no effect on the PRI. Stress or changes in the OIs is needed to cause a change. There were no false positive or negative PRI scores over a 15 month time period.

Lederman and Clayton, part I, 1982, used the PRI to study the prevalence of TMJ dysfunction in a group of subjects with their occlusions restored in the graduate clinic. Fifty subjects, 23 men and 27 women, 25 to 75 years of age were studied. They had at least four posterior quadrants of teeth restored with fixed partial dentures. The double blind research protocol was followed between the recorder (KHL) and the scorer (JAC). Both were trained and calibrated in their respective areas of the PRI. Four sets of PRI recordings were taken on each subject

A total of 68% of the subjects had some degree of PRI dysfunction, 38% (20) slight, 20% (10) moderate and 10% (5) severe dysfunction. The standard deviation were reproducible 2.96, slight 4.08 moderate, 9.42 and severe 12.91. As the dysfunction became more severe, the incoordinted movement increased and the S.D. increased. The results of this study showed that pantographic tracings quantitiated by the PRI can be used in epidemiologic studies of the prevalence of TMJ dysfunction.

Lederman and Clayton II, 1982, used the same 50 subjects to relate the clinical sign and symptom of TMJ dysfunction to the PRI. Twenty-three variables were analyzed statistically. At the 0.1 level (chi-square) the PRI compared to headaches, muscle sensitivity, number of wear facets, working interferences, protrusive interferences and total number of interferences. No correlation was seen for a slide in centric or balancing interference since the restorative procedures were designed to eliminate them. The HDI was used for a clinical dysfunction index. There was a strong positive correlation between the presence of dysfunction determined by the PRI and HDI. The PRI scores increased in 70% of the subjects who had no subjective complaint. Most were in the slight dysfunction category that is not easily recognized by the patient or the dentist and shows the clinical sensitivity of the PRI. The clinical and subjective symptoms were not as reliable as PRI scores in detecting TMJ dysfunction.

Lederman and Clayton III, 1983, used the PRI to determine the effect of occlusal splint therapy (OST) and occlusal adjustment (OA) on the treatment of TMJ dysfunction. Ten subjects with uncoordinated mandibular movements and clinical signs and symptoms received OST and OA. Five subjects with a wide range of PRI dysfunction were used as control subjects. They received no occlusal treatments. Four PRI records were used at each session to determine the average PRI score. The null hypothesis that OST had no effect on the PRI TMJ dysfunction was rejected at the 0.0004 level. There was no significant change in the control group. All 10 experimental subjects showed a statistically significant reduction of the PRI TMJ dysfunction. OST can be used to reduce TMJ dysfunction. Subjects not wearing the splints 24 hours a day did not have the PRI scores reduced to the reproducible category. Subjects who had the occlusion adjusted after the PRI was reproducible could eliminate their splints. The PRI scores can be used to determine the success of OST and OA. The PRI can be used to determine the presence or absence of the muscle dysfunction symptoms of TMJ dysfunction.

STUDIES ON OCCLUSAL INTERFERENCES

Ramfjord, 1961, used EMG to study the relationship between occlusion and pain. Thirty-two patients (20 male and 12 female) with most of their teeth were used. Twenty-seven had TMJ and muscle pain and five only muscle pain of 1 month to 10 years duration. Clinical and EMG analysis were performed before and after occlusal adjustment of interferences in CR and lateral and protrusive movement. Gross OIs in CR and balancing were adjusted first. Clinical criteria for completion of adjustments were absence of CR slide, lighter balancing side contacts and smooth gliding movements. Patients were followed for 3 years.

All patients had bruxism and varying severity of OIs. Slides of 0.5 - 4 mm between CR-CO were common. Most were lateral slides away from the painful joint. Over one-half had OIs and pain on the balancing side. One patient got relief on adjusting working side canine guidance. All patients were completely free of pain and discomfort at the end of the study. Only 8 of 20 patients had minimal muscle activity before relaxing exercises and 12 of 32 patients could not relax before occlusal adjustment. They did not have a resting range. Most muscle activity was in the posterior temporal muscle on the painful side.

All had balanced and minimal muscle activity after the adjustment. Tapping the teeth detected OIs. CO closure caused hyper muscle activity and more activity on the initial contact side. Swallowing caused the most disturbed EMG pattern before adjustment and improved after adjustment. Muscle response was inharmonious before and became harmonious after adjustment. Balancing side interferences caused the most hyper muscle activity and muscle splintting.

TMJ dysfunction and related muscle pain were eliminated by OA. CR-CO slide was most common trigger of muscle spasm. The slide is more significant in swallowing than chewing. Rest position was normal with ideal occlusal relations.

Roth, an orthodontist, 1973, studied occlusal interferences common in TMJ dysfunction with nine subjects. All had had full-banded orthodontics. They ranged from 15 to 25 years of age and had been out of orthodontics 6-7 months. All were considered well-treated by orthodontic standards. Seven of the nine had symptoms and two were symptom free controls. Three were males and six were females. Five had four bicuspid extracted. Occlusal splints were used. The hinge axis, pantograph recordings and CR registrations were used to mount casts on a Sturart articulator. The occlusal interferences were located and adjusted on the casts and then the mouth. A mutually protected occlusion with stable occlusal stops in CR and immediate gentle canine guidance was established. All other contacts were interferences

Seven subjects had varying degrees of symptoms and the severity was subjectively graded. All had balancing interferences. The subjects with the severest symptoms had the most centric deviation with balancing and protrusive interferences. Pain and clicking correlated to balancing interferences. All had a complete relief of symptoms after occlusal adjustment, most in 24 hours. There appears to be a close association between the severity of pain-dysfunction symptoms and balancing interferences. Occlusion is significant

Kohno et al, 1988, studied patients with pain in the TMJ's, defective interior guidance and pain in the sternocleidomastod muscles (SCM). Ten patients, three with bilateral and seven with unilateral pain in the SCM muscles were studied. Nine also had pain or discomfort in neck muscles, masseter, temporal and trapezius muscles. Their occlusion had defective lateral guidance and balancing OIs. The SCM muscles had pain on the same side as the defective guidance. The treatment was to provide anterior guidance. They were pain free after several weeks. Defective anterior guidance can cause balancing interferences and opposite side SCM muscle pain. The pain was more in the insertion of the muscle.

Beard, 1988, studied the effect of mock and real occlusal adjustments. A previous study by Goodman (1976) reported 64% of their subjects had a total remission of their muscle dysfunction symptoms with a mock adjustment. Ten subjects with PRI recorded muscle dysfunction were used. Two served as controls. The protocol of Goodman was followed. All adjustments were made on non-occluding areas. At the third visit subjective and objective symptoms (PRI) were recorded.

Maxillary occlusal interference free occlusal splints were made and worn for 3-10 months. A total of 82 PRI recordings of the muscle uncoordination of muscle dysfunction were taken.

After the mock adjustments 80% reported a favorable subjective response. However, the PRI muscle dysfunction scores were reduced in 30%, increased in 30% and was unchanged in 40%. During splint therapy all subjects had significant PRI score reduction while the controls were unchanged. The mock occlusal adjustments did not totally reduce the muscle incoordination symptoms of muscle dysfunction.

Kiveskari et al, 1992, studied the relationship between occlusal interferences (OI) and CMD over six years in two groups of children, 96 in the 5 year and 64 in the 10 year group. An annual clinical exam was done by one author unaware of the occlusion. Muscles and joints were palpated and joint sounds on mandibular mobility were recorded. Occlusal analysis was made in RP-IP distance, RP contacts, mediotrusion, post canine lateratrusion and protrusion. Children randomly received either a mock or real occlusal adjustment once a year for 30 minutes. OI free children had bilateral contacts in RP, less than 1 mm slide, and no lateral or protrusive posterior contacts.

The adjustments had little impact after 12 months. The number of OI's were reduced. The number of OI free children was greater in the adjusted group. An association between OI's and CMD did not become significant until the fourth, fifth and sixth years. Occlusal adjustments were not harmful. The results showed an association between OI's and CMD. The results do not support the precepts that the association is only in the minds of the clinicians and occlusal changes result from CMD.

Clayton and Lederman, 1980, looked at whether the incident of TMJ dysfunction could be reduced by occlusal adjustment. Eighteen subjects were randomly selected from TMJ dysfunction group as detected by the PRI. After the PRI was recorded, the occlusion was adjusted to get rid of a slide in CR, working, balancing, and protrusive interferences on posterior teeth. Repeat PRI's were recorded five minutes after the adjustment and one week later. Fourteen of the eighteen subject's (77.7%) PRI scores were reduced to the no dysfunction PRI range as a result of the occlusal adjustment that removed OI's. The other four required occlusal splint therapy and then occlusal adjustment to reduce the PRI muscle dysfunction scores. All 18 subjects had CR interferences, seventeen had working and three had balancing interferences. Eight subjects had improperly designed (too abrupt or steep) canine guidance's. OI's were a significant cause of TMJ dysfunction. The PRI measures the incoordination symptom of muscle dysfunction of TMJ dysfunction.

Abd Al-Hadi, 1993, reported on a survey of 600 asymptomatic students at Mosul University, Iraq. There were 311 men and 289 women ages 18 to 22 years. A clinical exam was made to: angles classification, horizontal overlap, balancing side contacts, presence of TMD (Okeson's textbook) and chewing side preference for gum.

There were 50% with one or more symptoms of TMD. Abnormal joint sounds (AJS) and muscle tenderness (MT) were most frequent followed by AJS, MT and joint tenderness (JT) and AJS only. Chewing was on the affected side. Angle's classifications were not significant. TMD occurred more in the group function than canine guidance. Of the 210 subjects with balancing interferences 125 had TMD symptoms. A 0 to 2 mm horizontal overlap was not significant. A 2.5 and 3.5 mm overlap was associated with TMD. TMD increased sharply after 6 mm overlap.

There was no difference between male and female. TMD was more prevalent on the chewing side, and with balancing interferences and increased horizontal overlap. TMD was low in canine guidance and Cl II D1 occlusions.

Egermark - Eriksson et al, 1987, studied children and adolescents in regards to occlusion and mandibular dysfunction. There were 402 children ages 7, 11 and 15 years. Four years later 120 (7 & 11 year olds) were randomly selected and at 5 years, 135 15 year olds. A questionnaire was used for mandibular dysfunction, oral parafunction, chewing habits and headaches. Clinical signs were impaired mobility, pain on palpation of the TMJs and muscle and pain on movement. Emphasis was placed on OIs and wear on a five point scale. Psychological traits were evaluated by their teacher and 20 year olds evaluated themselves.

Changes in OIs were rare. More than half of the 11 year olds and older had unilateral contacts in RCP and a lateral slide. There was no difference between male and female. Canines was more worn in males. Both signs and symptoms increased slightly in frequency and severity but were mild. The unilateral RCP contacts had a positive correlation with subjective and clinical dysfunction and TMJ sounds in the younger but not older subjects. Lateral deviations correlated to TMJ sounds in all age groups. Dental wear increased markedly on the anterior teeth. Wear and bruxism correlated in the younger groups only.

Karlsson et al, 1992, studied the effect of nonworking interferences on masticatory movements and signs and symptoms of dysfunction. Twelve dental students (5 women and 7 men) ages 22 years were used. All had near complete dentition, no balancing interferences and no bruxism. Balancing interferences were placed for one week. A clinical exam of tender muscles and TMJ or pain with mandibular movements and a functional analysis in IP-RP and lateral movements were made. The visual analog scale (VAS) was used to indicate severity of joint sounds, fatigue or stiffness, jaw opening, pain on movement, locking and pain in face or jaw (0 = no symptoms). The balancing interferences were added with etched composite to the lingual cusp of the first and second molars. Subjects chewed paraffin wax for 12 seconds.
Recordings, computerized, were made before, after one week and after removal of the balancing interference (BI).

The VAS before and one week after placing did not show any differences. The subjective experience was varied. Four did not notice the BI in lateral excursions and four were severely disturbed (VAS 67 to 100). Six reported mild and two reported severe irritations. Three reported minor and four moderate to severe chewing problems. Four reported problems the entire week and eight had problems the first few days. Eight subjects had increased muscle tenderness to palpation at the end of one week. Four had muscle tenderness on the opposite side of BI, three same side and one both sides. Mandibular movements changed after insertion of BIs. All dimensions increased significantly. After one week adaptation occurred. Removal of the BIs did not change the recorded variables. One subject had problems after removal of the BI and requested several adjustments before he recovered. The study shows that OIs can cause muscle problems and some subjects can adapt. Muscle incoordination may be the cause of the muscle tenderness.

Even with all these effects recorded by balancing interferences, the authors in the discussion suggested "a need to change the concept of canine protected occlusion to a new 'concept of balancing-side protection.'"

Occlusal interferences have varying influences on different individuals and adaptation can occur on some in one week.

Johnston Jr, 1988, reported on a comparison of postorthodontic subjects CR-CO slide and an untreated population. Sophomore students (357) were surveyed by questionnaires. Ninety-two had undergone comprehensive orthodontic therapy. Untreated controls were selected from every third untreated student. The mean age was 25 years and 95% were males. Each wore a maxillary splint for two weeks. Casts mounted on a whip-mix articulator provided the measure from CR-CO with lines on canines and premolars. All measurements were duplicated (blindly) by two observers.

The mean CO-CR difference for orthodontically treated patients had the same frequency as the untreated controls. Half of both groups had slides larger than 0.75 mm. The two groups were not statistically different. The averages were higher than other studies. Some studies reported 1.3 - 1.6 mm difference between CR-CO at band removal. The study suggests CR-CO difference may be normal.

Korioth and Hannam, 1990, using 3-dimensional computer-assisted modeling studied the forces that vertical and lateral contacts on teeth could cause in the TMJs. Five points of optimal contact were used. Nine pairs of muscles were simulated. It was possible to model muscle-generated tooth loads on working and balancing sides.

Canine guidance alone produced the lowest force values of the condylar loads. Group function with simple balanced contacts produced the highest values overall at the load point and both condyles. Change in angle on the tooth force influenced the condylar force. As the occlusal load moved to the balancing side, the more the load on the balancing side condyle. The canine guidance alone had the lowest loads in the condyles.

Beard and Clayton, 1980, studied the effect of occlusal splint therapy alone. Twenty subjects ages 18 to 47 were treated with maxillary occlusal interference free occlusal splints. There were 15 experimental subjects with TMJ dysfunction as determined by the PRI and 5 subjects, 2 with TMJ dysfunction served as controls. The OST continued until the subjects were free of TMJ dysfunction as determined by the PRI. The time needed was from 1 to 10 months and the splints were adjusted as needed. There was immediate canine guidance and all mandibular teeth contacted the splint in centric. A double blind protocol was used between the recorder and scorer of the PRI. The control subjects were recorded at the same sequence but nothing was done to their occlusion.

All 15 subjects were made free of their TMJ dysfunction with the splint therapy. Nothing else was done to their occlusion. The occlusal splints were removed and over time the PRI score increased into the TMJ dysfunction range again. The splints disengaged the occlusal interference and the TMJ dysfunction went away. The splints were removed and the occlusal interferences were again in contact and the TMJ dysfunction returned. This indicates that occlusal interferences were the cause of the TMJ dysfunction.

Jarabak, an orthodontist, 1956, studied three groups to determine the effect of occlusion on muscle activity: 1) four subjects with good occlusion and free of TMJ dysfunction; 2) seven orthodontic subjects who had clicking after intermaxillary elastics; and 3) eleven subjects with broken down occlusions with clicking, pain and trismis. The EMG activity of the temporal muscle was used. Occlusal splints were designed for mandibular displacement, lost vertical dimension and build-up of occlusion. The occlusal splints caused the muscles to relax, therefore, muscle spasms were caused by the occlusion of the teeth. Recordings 5 minutes after the splints were removed showed that the hyper muscle activity had returned. The temporal muscles were thrown into a functional imbalance, spasms occurred and clicking returned. Muscle spasms in the temporal muscles disappeared when occlusal interferences were removed with the splints and returned again when the splints were removed and the occlusal interferences were engaged again.

Solberg et al, 1975, studied the short-term effect of occlusal splint therapy on bruxers by measuring the masseter muscle activity with portable EMG. Eight patients (6 females and 2 males) who were confirmed bruxers by a history of grinding were used. Their ages were 22 - 24 years. They had one or more symptoms of TMJ dysfunction. Patients had been through a behavior modification study that was transitory. Patients wore portable EMG with unilateral masseter muscle recordings during sleep. Maxillary splints with flat posterior centric stops and canine guidance were used.

There was an immediate reduction of muscle activity after the splint disengaged the occlusal interference and remained low until the splints were removed. Once the occlusal interferences were engaged again, all but one of the patient's EMG level returned to the pre-splint levels. Occlusal adjustments may be needed to maintain the lower muscle activity. There appears to be a relationship between occlusal interferences and the degree of muscle activity.

STUDIES ON GUIDANCES

Williamson and Lundquist, 1983, studied the effect of occlusal schemes on the temporal and masseter muscles. Occlusal schemes that would reduce or cause the least muscle activity would be desirable. Five women, four with a history of dysfunction and pain were used. Maxillary acrylic resin splints were used to establish an arbitrary anterior guidance. The mandibular cusps contacted flat areas. The anterior guidance was adjusted so that all of the posterior teeth discluded in eccentric movements.

Electromyography (EMG) recordings were made of the right and left temporal muscles. After the first scheme was recorded, the anterior guidance was adjusted until the posterior teeth touched in eccentric movements. There was an increased EMG muscle activity when the posterior teeth contacted without the splint. With the splint and lateral contact with lower canines, there was an immediate decrease in EMG activity in the temporal and masseter muscles in the four subjects with TMJ symptoms. When the anterior guidance was removed and the posterior teeth contacted in centric movements, the muscle activity did not decrease.

Only when posterior disclusion was established by anterior guidance can the elevating muscle activity be reduced. The anterior guidance can reduce hyper muscle activity.

Shupe et al, 1984, studied the effect of canine and group function guidance on jaw muscles. Five men and 4 women ages 23 - 41 years with healthy dentitions were studied. Three different guidance's on maxillary occlusal splints were used: 1) flat canine guidance (0.9 mm. posterior clearance); 2) steep canine guidance (2.4 mm clearance); and 3) group with molars and premolars also in contact. EMG activity was recorded on the masseter and anterior temporal muscles during clenching, grinding and chewing.

The canine guidance (steep) reduced the muscle activity more than the less steep and group function designs during all activities. Working side posterior contact increased muscle activity. To reduce muscle activity, the canine guidance design is best.

Miralles et al, 1987, studied the influence of protrusive movement of the EMG activity of the elevator muscles. Four males and four females ages 22 to 32 years with healthy occlusion and no dysfunction were used. Seven had a slide in centric of more than 1 mm. Maxillary occlusal splints with stable posterior contacts and full anterior, canine to canine, guidance were used. The lateral guidance was from the canine area. After wearing the splints for 4 days, the anterior guidance was sectioned into 3 pieces to provide 3 different protrusive guidance's. EMG (bilateral) recordings were made on the masseter and anterior temporal muscles. Each subject was recorded in six different movements and splint designs.

The EMG muscle activity was highest without the splints in the intercuspal position. The occlusion caused the hyper muscle activity. All the anterior guidance designs decreased the muscle activity. The temporal muscle was more active without the splint indicating the role of the temporal muscle to position the jaw around the occlusal interferences. Therefore, the temporal muscle activity was reduced most by the splints. The least muscle activity was shown when the protrusive guidance was with the mesial incisal edges of the mandibular incisor only. This concentrated the force over a smaller periodontal membrane area and caused an earlier muscle inhibition.

This study shows that occlusal interferences and anterior guidance design can affect muscle activity. An immediate canine guidance in lateral movement and a single contact with the mandibular incisor in protrusive movement relaxes the muscles the most. The goal of the design of the occlusion and guidance should be to relax the muscle and not cause hyper activity that could lead to dysfunction.

Butler and Zander, 1968, studied cuspid protected and group function restored occlusions. Two subjects were used. Bridges containing transmitters were used to record tooth contacts. EMG was used to observe muscle activity. There was a CR switch in a mandibular bridge to record CR contacts. Lateral contact switches were placed on the lingual surfaces of the maxillary canine. One subject had a natural canine guidance and the other group function. They were restored with the same guidance's for the first month. They wore the other type the second month. The subjects were adjusted to CR and restored to CR.

There were inhibitions of EMG activity in closing muscle with lateral contacts. The chewing patterns were no different in EMG patterns. The teeth contact patterns were different. There were fewer lateral contacts with the canine protected occlusion. There is a protective mechanism for the muscles and TMJ that could prevent damage to tissues. There were contacts in the border CR both during chewing and swallowing. This differed from other studies because these subjects were restored to CR. This study shows that subjects will function to CR if the occlusion permits, there are no CR interferences. The more lateral contacts in the group function occlusion indicates an altered movement pattern. Lateral contacts caused a pause, a cessation of EMG activity during closing.

Lateral contacts can help to program a closure pattern. Once the pattern is learned, the lateral contact on the canine guidance was less frequent. The canines do not have to contact with every closure. They contact occationally to reinforce the learned pattern.

Manns et al, 1987, studied the influence of group function (GF) and canine guidance (CG) on EMG activity of elevator muscles. Four men and 2 women ages 17 to 35 years with no dysfunction were used. Bilateral EMG recordings were made of the masseter and anterior temporal muscles. Occlusal splints were made with canine guidance, CR contacts and no protrusive or balancing contacts. To produce the group function, the canine guidance was adjusted. The splints were worn for 5 days for adaptation. The splint was then split into 3 pieces distal to the canines. The pieces were cemented in place with zinic oxide and eugenol cements. All 3 pieces in place was GF and with just the anterior segment CG.

The GF occlusal reduced the EMG muscle activity 47%. The temporal muscle was reduced the most. The CG occlusion reduced the EMG muscle activity the most 27%. 100% was full activity so 47% reduced less than 27%. All muscles showed a significant reduction in EMG activity with CG. Most reduction was in the temporal muscle. Mechanoreceptors are sensitive to pressure and can inhibit muscle activity. This is a protective reflex. In GF the pressure is distributed over a greater periodontal membrane area, more teeth, with CG the pressure is concentrated and less pressure is needed.

Our goal in occlusion is to reduce the muscle activity and CG does this more than GF.

Belser and Hannam, 1985, studied the physiological behavior when natural group function was changed to canine guidance and then to balancing interferences. Three women and 9 men ages 23 to 45 years were used. Each had wear on the teeth to produce a GF occlusion on the working side and some balancing interferences. There were no signs or symptoms of TMJ dysfunction. To produce the CG cast copings were made for the canines and had minimal immediate disclusion. Acrylic overlays were made for the maxillary right first molars to simulate working and balancing eccentric contact for clenching.

EMG activity was recorded on the anterior and posterior temporal and masseter muscles. Jaw movement was recorded by a kinesiograph. Recordings were made in an hour of clenching and chewing. When the natural GF was changed to CG there was a general reduction in elevator muscle activity in lateral clenching. The chewing pattern was the same. Balancing interferences caused a significant alteration in muscle activity and coordination in lateral clenching.

The results suggest that canine guidance does not alter muscle activity in chewing, but significantly reduced the muscle activity during parafunctional clenching. Balancing interferences dramatically alter the temporal muscle activity during clenching. This may affect the nature of the reaction force in the TMJ.

Scaife, 1969, examined 1,200 basic trainees ages 17 - 25 years. They all had natural dentition. Angle classifications were made and wear facets wee noted. Bilateral canine guidance was found in 57% of the 1200 subjects, 16.4% had unilateral CG and 26.6% had no canine guidance. In protrusion 99.4% had incisor guidance. Cuspids contacted in CO 91.5% of the time for immediate disclussion. Wear facets were seen in subjects without canine protection.

Mathews, 1987; Shea 1989; Gross and Hirsh, 1985 all studied the effects of changing the guidance angles either on the bearing surfaces or at the canine area. All found that when the guidance angle was increased, it reached an angle at which the guidance became restrictive, the muscles responded like those with muscle dysfunction.

Gross and Hirsh used 0°, 20° and 63° on the clutch bearing surface. There was no restriction for 0° and 20° while there was with the 63°.

Mathews changed the bearing surface angle 20°, 35°, 50° and 65°. Five women and one man ages 27 - 43 years were used. Three subjects had some TMJ dysfunction symptoms and three did not. The effect on muscle activity was recorded with a modified PRI score. There was a general increase in muscle activity as the angle was changed from 20° to 65° until there was a statistically significant difference between 50° and 65°. The most change occurred between 35° and 50°

Mandibular border movements can be disrupted by steep guiding inclines. This guidance could be considered as occlusal interference if it increased or restricted muscle activity. This research suggest that there may be a critical angle for each individual.

Shea used 10 subjects with varying PRI dysfunction. The guidance's were moved from the bearing area to the maxillary canine area. The guidances were attached to a maxillary clutch and contacted the natural mandibular canines. The guidance was changed in 5° increments from 20° to 45°. A modified PRI was used to record the muscle reactions.

The mandibular movements can be effected, like muscle (TMJ) dysfunction by steep canine guidance. A statistically significant increase in PRI muscle activity occurred between 20° and 35° canine guidance angulation. For the no dysfunction groups the angle could be steeper between 35° to 45°. In 80% of the subjects as the angulation increased and became more restrictive, the working movement was restricted in the TMJ. In 90% of the subjects, as the canine guidance increased the jaw movement was deflected away from the border tracings.

No common critical angle was found and was individual for different subject requirements. Subjects with muscle dysfunction were affected sooner with the increasing angle. Improperly designed canine guidance can be restrictive and act on muscles like posterior occlusal interferences

Gross and Nemcovsky, 1993, studied the effects of increasing the clutch angulation on the Pantronic border recordings. Seven subjects without symptoms of TMD were used. Maxillary clutch had 20°, 30° 45° and 60° angulations. There was a statistically significant decrease in the immediate side shift (ISS) as the guidance angle increased. The progressive side shift decreased when the angle increased from 45° to 60°. Both of these decreases show a restriction of lateral movement (ISS and PSS) as the guidance angle was increased. The plot tracings shown in figure 8 showed a gradual restriction in the lateral movement as the guidance was increased.

These studies shows that the guidance for lateral movement can be increased too far and restrict lateral movements. This causes the muscles to respond adversely as they try to make smooth lateral movements, an anterior or canine guidance interference from a improperly designed guidance. Anterior and canine guidance, if designed improperly, can act on muscles like an occlusal interference.

SUMMARY AND CONCLUSIONS:

The article present <u>SOME</u> of the studies on occlusion and occlusal interferences. It is not all inclusive.

Their value is determined by each individual practicing dentistry. Some times present day research protocol was not followed because it was not know at the time. They provide the best research at the time. The researchers were knowledgeable and had enormous clinical experience. This should add value to their research.

Studies designed to determine whether something exists needs only one positive. Studies designed to determine if something does not exist needs to have many, many more subjects, maybe every subject in a population.

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Preparation Design Concepts In Fixed Prosthodontics

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The review of the literature related to preparation design concepts in fixed prosthodontics has been organized using the following outline:

1. Historical Perspectives
2. General Topics
3. Biologic Considerations - Pulpal
4. Biologic Considerations - Periodontal
5. Mechanical Considerations
6. Esthetic Considerations
7. The Need For Fixed Prosthodontics
8. Preparation Design For Individual Teeth

Summaries of specific articles providing information in accordance with the above outline are presented to support the topic of discussion.

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Dr. Andres: Basic Concepts of Tooth Preparation Design for Fixed Prosthodontics.

The Need for Fixed Prosthodontics. Restoration of **Function** and **Appearance.**

Historical Perspective.

Diagnosis: Treatment Options.
<u>History</u>
<u>Comprehensive Clinical Examination</u>: Extraoral/intraoral hard and soft tissue status.
<u>Essential Preoperative Information</u>: Radiographic, full mouth periapical views. Mounted casts.
<u>Optional Additional Preoperative Information</u>: Kinematic axis location. Mandibular movement analysis. Photographic records.

The Choice of Restoration Type
Full coverage/Partial coverage
and the choice of **Restorative Material:** Metal/Metal-Ceramic/All Ceramic must address the need to restore the functional and appearance requirements for each individual patient.

Both the restoration type and the material utilized in its fabrication must satisfy
Three Essential Criteria

1. **Biologic**
2. **Mechanical**
3. **Esthetic**

Ref (Dykema/Goodacre/Philips. Rosenstheil/Fujimoto/Land)

The **Decision Making** process in the choice of the design of preparations of individual teeth for fixed prosthodontics a number of factors need to be considered.

1. **Role**
2. **Position**
3. **Condition**
4. **Dimensions**

Role
<u>Single Tooth Restoration</u>
<u>Fixed Partial Denture Retainer</u>
<u>Removable Partial Denture Abutment.</u>
Position
<u>Anatomic location</u>-Maxilla/Mandible--> Partial coverage cold visibility
<u>Intra-arch position</u>-Rotations/tipping/contact point relations.

Inter-arch relations-Jaw relationship Crossbite (reverse horizontal overlap)/
overeruption occlusal plane anomalies.

Conditions
Congenital/Developmental defects in tooth structure
Amelogenesis Imperfecta
Acquired defects. Abrasion, Erosion, Attrition, Previous restorations.
Caries
Periodontal status
Dimensions
Anatomical location Maxilla/Mandible E&D thickness vary
Age Pulp size young/old patients
Race
Enamel, Dentin thickness, Pulpal size exhibit variation within all these subgroups
Clinical crown length width size and shape.

Ref (Shillingburg, Grace)

Threshold of Restorability
Preoperative Operative, Endodontic, Periodontal, Surgical adjunctive procedures may be required to bring an individual tooth to a threshold of restorability prior to actual tooth preparation in order to satisfy the Biologic, Mechanical, and Esthetic criteria required of the final restoration.

The proposed role, the position, condition and tooth tissue dimensions will all play a part in the preoperative prescription of these procedures and will be designed to facilitate a more optimal preparation.

Basic Concepts of Preparation Design for Individual Tooth Preparations in Fixed Prosthodontics.

Biologic
Mechanical
Esthetic.

Biologic Considerations
- **A. Pulpal**
- **B. Periodontal**
- **C. Adjacent/Opposing Teeth.**

Biologic Considerations: Pulpal.
Vital teeth are subject to pulpal insult during preparation.
Temperature. Excessive heat generation can lead to pulpal irritation and must be avoided. Water spray, etc. High speed esp., but also low speed without water.
Refs Morrant/Zacchary, Cohen.

Desiccation. Can lead to severe pulpal irritation
Ref Brannstrom

Age factors. Young pulps are larger. The thickness of remaining dentin has been shown to be inversely proportional to the pulpal response to tooth preparation.
Ref Seltzer and Bender.

Using the minimal practical convergence angle between the walls of the prep and developing a conservative margin as coronally placed as possible will reduce pulpal complications.
Ref Rosensteil Fujimoto Land.

Endodontic complications post fixed pros.
Ref Jackson et al JPD 1992 in a retrospective study reported that irreversible pulpal involvement was seen in 5.7% of their sample of teeth that were crowned in a vital condition.

Biologic Considerations: Periodontal
Gingival tissue Pre and per-operative management of gingival tissue health is essential for effective tooth preparation and impression making. Clear field. Adequate tooth reduction to prevent overcontouring of the final restoration
Ref Goodacre/Stein DCNA/Jameson

Margin location and configuration/geometry

Location - subgingival margin placement deleterious to gingival sulcular health and identified as a major factor in contributing to periodontal disease.
Refs Waerhaug(classic)/Silness
But quality of fit of restoration at margin as significant a factor as location in maintenance of gingival health. Ref Richter and Ueno

Configuration - Various shapes proposed. The featheredge not acceptable. Refs Rosenstheil, Fujimotor, Land/Tylman/Dykema Good, Phil. Shoulder, shoulder with bevel, chamfer have been studied by many authorities. Controversy exists as to the marginal gap developed post cementation and conflicting opinions appear in the literature.
Ref Rosner used a trigonometric argument to advocate the superior fit of the shoulder and bevel design.
Ref Pascoe finding evidence that shoulder finish lines offered better fits than shoulder and bevel.
Ref Byrne in a recent study 1992 found that the three configurations listed above did not effect the fit of cemented crowns.

Biologic Considerations

Adjacent teeth

Adjacent teeth damaged especially interproximally are more subject to caries.

Opposing teeth

Adequate occlusal reduction is required to allow sufficient space for developing a functional occlusal scheme in the finished restoration.
Ref Rosensteil Fujimoto Land/Dykema Goodacre Phillips.

Mechanical considerations

Key Factors: Retention and Resistance Form

Retention: Definition

The quality inherent in the prosthesis acting to resist forces of dislodgement.
Ref Glossary of Pros. Terms.

Retention Forma nd Preparation Design

Dislodgement occurs along the path of insertion (POI) of the prosthesis
One POI allows one path of withdrawal (POW)
Retention is primarily a phenomenon of the geometrical design of the preparation.
Ref Shillinburg

After porcelain fracture and caries loss of retention is a major cause of restoration failure.
Ref Walton

Aspects of Preparation Design Affecting Retention

Taper (Convergence) of prep
Surface area of prep
Surface roughness
Grooves, pins, boxes

Taper - Taper determines the POI. Multiple POIs retention. Near parallel walls, low convergence angels create limited paths of insertion or withdrawal.
Rosensteil When preparations are designed with minimal practical taper they increase shearing stresses rather than tensile stresses on the cement layer and offer greater resistance to the unseating forces thus increasing retention.
Ref Shillingburg
The taper of a preparation has a direct effect on the magnitude of retention
a 10° taper being half as retentive as a 5° taper
Ref Jorgenson/Hovijitra
Ideally a taper of 5-6° is recommended
Ref Rosenstiel/Shillingburg
Clinical studies reveal a much wider range of 13-23°.
Ref Ohm Silness/Mack

Surface Area of the Preparation
Long axial walls are more retentive than short axial walls. For the same convergence angles molars are more retentive than premolars.
Ref Reisbick and Shillingburg

Surface Roughness
Controversy exists as to the beneficial effects of a rough tooth preparation. Effects do not seem to be significant enough to warrant recommendation as a method to enhance retention.

Ref Smith/Rosensteil/Dykema.

Rounding the internal line angles of a preparation reduces build up of internal stresses in the cement layer and increases castability.
Ref Nicholls/Dykema/Shillingburg

Grooves, pins, boxes
Grooves, pins and boxes are substituted in partial veneer restorations or in severely damaged teeth to augment retention. Retentive contribution in the order of box maximal, groove and pin least.
Ref Shillingburg/Dykema

Resistance: Definition
The features of a tooth preparation that enhance the stability of a restoration and resist rotation from the seated position.
Ref Glossary of Pros. Terms.

Resistance Form and Preparation Design
Resistance prevents dislodgement of the restoration by forces directed in an apical, oblique or horizontal direction.
Resistance must be designed into the preparation by forming walls to block the anticipated movement.
Ref Shillingburg
Rotation occurs around the gingival margin. Rotation is prevented by areas of the tooth prep that are placed primarily under compression, so called resistance areas.
Ref Hegdahl Silness

Aspects of Preparation Design Effecting Resistance Form
Convergence angle
Height and Diameter
Type of preparation

Taper
Increasing the convergence angle and rounding line angles decreases resistance form.
Ref. Hegdahl Silness/Shillingburg

Height and diameter
Short preparations with a large diameter reduce resistance form due to unfavorable leverage.

Type of Preparation
Full coverage restorations offer greater potential for developing a more ideal resistance form in the preparation by offering more perpendicular walls to resist dislodgement by unseating forces. The incorporation of pins grooves and boxes aid in increasing resistance potential in the design of partial coverage restorations.
Ref Shillingburg/Dykema

Esthetic Considerations in Preparation Design

Choice of Restoration - Esthetic aspects of preparation design.
The choice of **Restoration Type:** Partial coverage/ Full coverage and the choice of **Restorative Material:** Metal/ Metal-Ceramic/ All Ceramic must address the need to restore the esthetic requirements for each individual patient.

Partial Coverage

Proximal margin - Mesial placement critical to prevent visibility.
Facial margin - In mandibular preparations metal display is unavoidable as the occlusal surface of the mandibular teeth can be seen during speech.
Maxillary facial margins are more easily hidden.

Full Coverage

Metal Ceramic Restorations

Facial reduction - biplane, adequate depth for porcelain application.
Incisal reduction
Margin placement/Emergence Profile - Large unacceptable embrasures spaces require more apical placement to develop an acceptable Emergence profile.
Ref Stein./Croll
Collarless crowns require very definite smooth flat shoulders without any bevel.
Goodacre.

All Ceramic Restorations
Magnitude and direction of occlusal forces need to be considered.
Size and shape of dental pulp.

Shoulder margin /Location and depth consistent with emergence profile requirements for maximal esthetic results.

Ceramic Occlusal Coverage
Increased tooth reduction
Anatomical tooth reduction
Patient habits
Opposing occlusion.

Abbate MF, Tjan AHL, Dent, Fox WM. Comparison of the marginal fit of various ceramic crown systems. J Prosthet Dent. 1989;61(5)527-531. This study evaluated the marginal fit of four ceramic crown systems, 1) metal ceramic crowns with a metal margin, 2) metal ceramic crowns with a porcelain facial margin, 3) Cerestore crowns, and 4) Dicor crowns. The tooth preparation for the metal ceramic crowns was designed with a 1.3mm slanted margin with approximately 120-degree slope and a lingual chamfer. The margins for the all ceramic crowns were a 120-degree shoulder with rounded axio-gingival line angle approximately 1.3mm in width. There were 10 tooth preparations with their correspondent analog crowns for each one of the four experimental groups. The 40 crowns were cemented with a zinc phosphate cement. The cement thickness at the marginal openings were measured by using a video-enhanced measuring microscope with a digital micrometer and image intensification on a high-resolution television screen. Discrepancy values were computed as averages of the measurements obtained. Six measurements from the facial and six from the lingual surface were included to average the overall discrepancy. The data were analyzed with a one-way analysis of variance. There was not statistical difference at $p>0.05$ in marginal fit among the four crown systems ($F=1.91$ 39,3). The four crown systems demonstrated acceptable marginal openings in the range of 56 to 81μm. Cerestore crowns had the lowest marginal discrepancies and Dicor crowns had the greatest. The all-ceramic crowns exhibited various cracks under laboratory conditions. Suggestions were made for avoiding clinical fractures.

Acoria CJ, Dewald JP, Vitasek BA, Wagner MJ. Effect of undercut placement on crown retention after thermocycling. J Oral Rehab. 1990;17:395-402. The objectives of this study were: 1) to investigate various retentive designs for crown preparations; 2) to examine the short-term effectiveness of glass ionomer cements; 3) to determine the mode of failure and location of cement residue for each retentive design; and 4) to evaluate the effect of thermocycling on the integrity of the luting agent and its capacity to retain crowns in several retentive modes. Forty-eight extracted human premolar teeth were used for this study. Half of the samples were thermocycled, and the others were kept at 37 C. Undercuts were made with a round bur in tooth surface or the wax pattern or in both. Then, samples were cemented with glass ionomer and tested with Instron machine for these variables: non-cycled and cycled with no undercut, casting undercut, tooth undercut, combined undercut. Conclusions: Thermocycling was not a significant factor in cement failure. Location of the coves or undercuts in castings or tooth structure increased significantly the retentive strength of glass ionomer cemented crowns. The pattern of cement residue suggested that the bond between cement and metal was greater than between cement and tooth.

Ante IH. The Fundamental Principles of Abutments. Michigan State Dental Society Bulletin, April 12, 1926. Why we should insert an artificial restoration? For restoration of structures, teeth and associate parts. For restoration of function of digestion, speech, expression, mastication, insalivation, deglutition. For prevention of further injury as a result of extraction by the insertion of good appliances to prevent: drifting, exfoliation, excessive stress, excessive wear, stagnation. Factors which go to make up a correct restoration: 1) surgical diagnosis to determine the procedure necessary to maintain health, 2) technical diagnosis to determine the proper procedure and design, and 3) physiological essentials: number of teeth present, degree of mobility, stress of occlusion, teeth which are to occlude with the restoration, alignment of the abutment teeth and the amount of the restoration, length and thickness of a root and the amount of bony attachment, peridental attachment of the abutment teeth. An abutment is a supporting structure at the end of a bridge or partial denture. There are two classes of abutments retaining and supporting abutments. Retaining abutment retains the bridge or attachment in place as well as supports it, while a supporting abutment supports the bridge but not retain it. Contraindications of abutments: a loose tooth, one with periclasia or badly tilted, a granuloma at its apex, infective condensing osteitis, fistula, resected root, or fractured root. Considerations: 1) remove all existing pathological conditions, 2) design the restoration to prevent needless sacrifice of tooth tissue, gingival irritation trauma, 3)produce good esthetic appearance, and 4) properly inserted and maintained.

Assif D, Azoulay S, Gorfil C. The degree of zinc phosphate cement coverage of complete crown preparations and its effect on crown retention. J Prosthet Dent. 1992;68(2):275-278. The investigators examined the amount of retentive area covered by cement under complete coverage crowns and its effect on retention. Sixty crowns of self-cured acrylic resin were prepared on 60 identical brass dies and were divided into six groups of 10 crowns each according to different cement applications. The results showed that retention was dependent on the amount of retentive area covered by the cement. The amount of cement in the occlusal part of the cementation space did not affect retention. The cement on apical half of the tooth ensured both retention and good marginal adaptation.

Banks RG. Conservative posterior ceramic restorations: A literature review. J Prosthet Dent. 1990;63(8):619-626. Conservative ceramic restorations have much to offer to improve appearance and strengthen posterior teeth. The advent of resin bonding makes possible many designs for inlays, onlays, and partial coverage crowns. This review discuss conventional porcelain. Optec HSP porcelain, Dicor, and Cerapearl with emphasis on strengthening mechanisms, principles of preparations, accuracy of fit, indications and advantages.

Bass EV, Kafalias MC. Systematized procedure of crown preparation. J Prosthet Dent, 1989;62:400-5. This article suggests a regimented method of tooth reduction for metal ceramic crowns. There are ten steps for proper tooth reduction, utilizing nine different types of burs and varying between low and high speed handpieces. A special emphasis is placed on surface roughness of the preparation. The Roughness Index is defined as the distance from the highest point to the lowest point on the roughest surface. Die spacer is seen as a necessity for cement space and the ability to seat the casting during cementation. Tungsten carbide finishing burs should be used on the gingival margins because it produces a Roughness Index of $5\mu m$.

Bernal G, Jones RM, Brown, DT, Munoz CA, Goodacre CJ. The Effect of Finish Line Form and Luting Agent on the Breaking Strength of Dicor Crowns. Inter J Prosth 1993;6(3):286-290. This study was done to determine if different luting agents produce variations in all-ceramic restoration strength (Dicor) and if the use of resin cement and associated bonding procedures would counteract the negative effect of certain finish line designs. One hundred and five (105) extracted human maxillary first molars were prepared following five different finish line designs. Dicor crowns were fabricated and luted on the teeth using zinc phosphate, glass ionomer, and resin cements. Restorations luted using the visible light cured resin cement and associated bonding procedures produced significantly higher strength compared to those luted with zinc phosphate and glass ionomer cements, Those restorations luted with zinc phosphate and glass ionomer cements yielded the same strength. No difference was found between restoration strength for the five different finish line designs when light-activated resin cement and associated bonding procedures were used.

Brannstrom M. Dentinal and pulpal response II. Application of on air stream to exposed dentine short observation period. Dental Aktieselskabet of 1934.D34. The purpose of this study was to establish by histologic methods whether a continuous stream of air directed on exposed dentine gives rise to any changes in the odontoblast layer or the rest of the pulp. At the same time note was taken of the presence and duration of pain and any changes in the sensitivity of the dentine. After preparation of the cavities one tooth of each contralateral pair was chosen by lot as the test tooth and the cavity exposed to the air stream at room temperature for 30 seconds. Five minutes later both teeth were extracted. Results. The duration of the pain was the same as the duration of air blast. In cases where the air stream was applied for 45 seconds or five minutes, the pain subsided after 15-45 seconds. Histologic examination showed that in all cavities exposed to the air stream the odontoblast layer was reduced and a number of odontoblast nuclei were observed in the dentinal tubules. This phenomena were not evident in any of the control cavities. No evidence of these reactions was found beneath any of the control cavities in the contralateral teeth. Discussion. It would appear that the air stream causes increased evaporation at the apertures of the dentinal tubules, which in turn results in a outward movement of the contents of the tubules. It would seem that the pain and the movement of the contents of the tubules cease simultaneously, a possibility that is consistent with the theory that the sensitivity of the dentine is due to hydrodynamic irritation of the nerves of the pulp.

Burgess JO, McCartey JG. Anterior retainer design for resin-bonded acid-etched fixed partial dentures. J Prosthet Dent 1989;61:433-6. Electrolytically etched castings of varying designs were cemented to prepared enamel. The load required to displace these castings was compared with the load required to displace anterior and posterior three-quarter crowns cemented with zinc phosphate cement. Electrolytically etched castings with grooves, half grooves, pins, a labial wrap, and no additional resistance feature (lingual plate only) were cemented to properly etched enamel. All specimens were loaded in tension from the lingual surface with an Instron testing machine at a crosshead speed of 0.05in/min. Specimens with proximal extensions (3/4 crowns, full grooves, or labial wrap) required significantly more load for displacement than the other groups. This study demonstrated the need for proximal resistance form when designing retainers for resin-bonded acid-etched fixed partial dentures.

Byrne G. Influence of Finish-Line Form on Crown Cementation. Inter J Prosth. 1992;5(2):137-144. The finish-line forms were designed in 3 types: shoulder, beveled shoulder and chamfer by preparation on ivorine maxillary incisor. First, a 1mm wide beveled shoulder finish-line with a cavosurface angle of 140 degrees was prepared on the facial surface with 0.5mm chamfer on the lingual surface. Then it was replicated producing 15 epoxy resin teeth. The same tooth was modified, converting the shoulder bevel into a 1mm wide chamfer and replicated into 15 epoxy resin teeth. Finally, the chamfer was converted into a shoulder with 90 degree cavosurface angle and was also replicated. Each epoxy resin die was duplicated and poured in dental stone. Each finish-line was divided into 3 groups; group 1 was seated on its stone dies, group 2 was seated on epoxy resin without cement, and group 3 was seated on epoxy resin with Zinc phosphate cement. All of them were sectioned and the gap measured. Results showed that finish-line form does not affect the fit of cemented crowns.

Catovic AM. Comparative investigation of dynamic loading of prepared and intact human premolars. Quintessence International 1992;23(6): 435-438. An Epidemiologic investigation shows that fractures are the third most frequent cause of tooth loss, after caries and periodontic. This study was to obtain data on the dynamic strength of premolar teeth. Experiments were performed in three groups of teeth; <u>1st</u> intact teeth, <u>2nd</u> teeth prepared for partial veneer crowns with flat occlusal surfaces, and <u>3rd</u> teeth prepared for partial veneer crowns with rounded occlusal surfaces. Loading procedure was performed in a modified Amslers high frequency pulsator. The greatest dynamic strength was exhibited by the intact specimens. Highest dynamic stress withstood was about 300N.

Crispin BJ. Marginal placement of esthetic veneer crowns. Part I: Anterior tooth visibility. J Prosthet Dent. 1981;45(3):278-282. The purpose of this study was to determine the percentage of subjects in a random population in which anterior crown margins could be placed supragingivally and not be visible. An analysis of anterior tooth visibility was performed on 425 subjects and scored for the amount of anterior visibility on normal smile and on exaggerated smile. Results: 1) Normal smile. Maxillary anterior teeth: The incisal sections was almost always visible, with the middle section being covered in 4.2% to 8.4%. Gingival margins would not show in 44% of the canines, 33.7% of the lateral incisors and in 50% of the central incisors. Mandibular anterior teeth: The incisal section did not show in 18.7% to 21.4% of the subjects. The middle section did not show in 57.7% to 65.4% and the gingival section did not show in 88.2% to 93.4% of the subjects. 2) Exaggerated smile. For the middle and incisal section few subjects were scored as not showing. The percentage of gingival sections not visible dropped to about one half than the normal smile. In mandibular anterior teeth the gingival section was still scored as not showing in 51.3% to 64.7% of the subjects. Conclusion: Routine subgingival margin placement of the anterior crowns for esthetics may be unnecessary.

Croll BM. Emergence profiles in natural tooth contour. Part I: Photographic observations. J Prosthet Dent. 1989;62(1):4-10. Photographic data revealed that in natural teeth, straight emergence profiles are the norm with a few exceptions.

Doyle MG, Munoz CA, Goodacre CJ, Friedlander LD, Moore BK. The Effect of Tooth Preparation Design on the Breaking Strength of Dicor^R Crowns: Part 2. Inter J Prosth. 1990;3(3):241-248. This study compares the strength of Dicor crowns fabricated for teeth prepared with 5° and 15° of total occlusal convergence, 2mm of occlusal reduction, and three finish line forms (1.2mm shoulder with a sharp axiogingival line angle, 1.2mm chamfer, and 0.8mm chamfer). Maxillary first premolar artificial teeth were prepared according to the study designs with the finish lines curving slightly occlusally on the proximal surfaces. The preparations were reproduced in base metal alloy and Dicor crowns fabricated. The metal ceramic restorations in Part 1 were used as controls. Restorations made for 0.8 chamfer and 15° convergence angle were the strongest (56.20 kg). The weakest restorations were those that were made for 1.2mm chamfer and 5° convergence angle (42.26 kg) and regardless of finish line form or depth. Tooth preparations with 5° of total occlusal convergence produced restorations that were weaker than tooth preparations with 15° of total convergence.

Doyle MG, Goodacre CJ, Munoz CA, Andres CJ. The Effect of Tooth Preparation Design on the Breaking Strength of Dicor^R Crowns: Part 3. Inter J Prosth. 1990;3(4):327-340. This study measured certain dimensions of the twelve all-ceramic tooth preparations used in Parts 1 and 2 to determine if any designs features could be related to recorded differences in restoration strengths. The feasibility of accomplishing the various preparation designs based on pulp size and the amount of tooth structure remaining was also evaluated. The authors concluded that ten degrees was the most desirable total occlusal convergence, based on both restoration strength and the amount of tooth reduction. A shoulder finish line with a sharp axiogingival line angle is preferred because it produces greater restoration strength than either a shoulder finish line with a rounded axiogingival line angle or a chamfer line. They also recommended that the finish line posses as little cervical inclination as possible since this design was related to increased restoration strength.

Eames WB, O'Neal SJ, Monteiro J, Miller C, Roan JD Jr, Cohen KS. Techniques to improve the seating of castings. Dentists may have observed, not infrequently, that most cast restorations do not seat completely. An attempt to compromise the fit by occlusal and internal adjustment, with the inherent possibility of cement-margin failure, may be frustrating to the dentist. This study of over 200 castings describes methods for eliminating the effect of internal discrepancies which cause a rebound effect, requiring occlusal reduction and adjustment of faulty margins. Human teeth were prepared in vitro, using methods that were correlated with clinical conditions as nearly as possible. The experimental variables were degree of convergence (taper) of full crown preparations, effects of several types of commonly used cements, effects of occlusal venting, relief of the castings by aqua-regia acid etching and provision of the die spacing before fabrication of the wax pattern. The advantages of relieving the die or etching the crown are that castings are seated more completely because internal stress areas are substantially relieved, that more space is provided for the thickness of cement, and that retention is increased by 25%.

Eissmann HF, Radke A, Noble WH. Physiologic Design Criteria for Fixed Dental Restorations. Dent Clin No. Amer. 1971;15(3):543-568. Physiologic Contouring is done to minimize plaque retention by exposure of the largest possible area of the clinical crown and gingiva to the natural cleansing action of 1) food flow pattern, 2) musculature, 3) mechanical devices (toothbrushes). "Natural concavities are arranged to expose the gingiva to stimulation...and interproximal contact areas must be extended from the incisal embrasure to the interdental papilla where the facial and lingual surfaces or embrasure are opened proportionately. Placement of gingival margins. Margins are ideally placed on tooth surfaces that are fully exposed to a cleansing action. Also the contour of the restoration should accommodate an optimum cleansing action. Lastly, the transition from restoration to tooth structure should be as smooth as possible. Indiscriminate placement of subgingival margins should be avoided. One inviolable rule is: margins must not be placed at or near the alveolar crest. Interproximal tooth contact.

First, they contribute to the stability of the dental arch. Second, they prevent impaction of food substance into the interproximal area. Third. the occluso-gingival length of the contact may influence food retention. Fourth, cosmetic and phonetic considerations may also affect the design of contact areas. Physiologic pontic contour. Success of a pontic will rely on 1) favorable contour and consistency of gingiva, 2) smallest area of tissue contact, 3) lack of definite concave or convex curvatures of pontic and ridge, 4) a gentle contact of tissue and pontic and lastly, 5) choosing a highly glazed, high fusing porcelain that will maintain the smoothest possible surface. The sanitary-contoured pontic offers the most favorable balance of comfort, support and hygiene and is considered as a standard concept for pontic design and termed the "physiologically-contoured" pontic.

El-Sherif M, Jacobi R. The ceramic reverse three-quarter crown for anterior teeth: Preparation design. J Prosthet Dent 1989;61:4-6. The preparation design proposed attempts to overcome the weaknesses of the laminate veneer by providing more space for the porcelain and greater surface area for retention and resistance while avoiding the sacrifice of tooth structure required by full-coverage ceramic crowns. High-strength ceramics and dentin-bonding agents make this restoration feasible. The enamel is removed from the facial, mesial, and distal surfaces, and from the incisal one fourth of the lingual surface. The finish line is a heavy chamfer so that the porcelain will meet the enamel in a butt joint. Bulk reduction is carried out with a round-end tapered diamond stone, followed by a similarly shaped carbide bur to produce a smooth surface and distinct finish line. The axial walls are in dentin. Proximal grooves used in conventional partial veneer crowns are omitted. This new preparation of the ceramic reverse three-quarter crown for anterior teeth offers a way to improve the appearance with slight to moderate structured damage. Advantages and indications of the new design are discussed.

Felton DA, Kanoy BE, Bayne SC, Wirthman GP. Effect of in vivo crown margin discrepancies on periodontal health. J Prosthet Dent. 1991;65(3)357-364. This study examined the relationship in vivo between marginal adaptation of dental castings and periodontal tissue health. Forty-two crown restorations cemented in 29 randomly selected patients were selected for this study using three criteria as follows: 1) the artificial crowns or FPDs were made at the University of North Carolina School of Dentistry, 2) the restorations were in service for a minimum of 4 years, and 3) the margins were located in the subgingival crevice. Replica impressions of the facial margins of each tooth were made with a low viscosity vinyl polysiloxane impression material. The stone dies were recovered and sputter-coated with AuPd for SEM observations. Periodontal and restorative indices were recorded for each tooth. Facial pocket depths were measured with a No. 15 periodontal probe. Crevicular fluid volume was measured with a Periotron. The facial margin adaptation was determined with a sharp explorer. The criteria for describing the marginal adaptation was: a) explorer tip is held perpendicular to long axis of tooth when moving apically, b) explorer tip is held at 45 degree angle to crown long axis when moving occlusally. The marginal discrepancies for all restorations varied from 5 to 430μm (mean 160μm). The SEM micrographs reveled minimal correlation between the perceived marginal adaptation with the explorer and the actual measured MD determined by the SEM. This investigation demonstrated that the discrepancy between the margin of the restoration and the margin of the prepared tooth has a greater potential influence on the periodontal health than the actual restoration in the subgingival crevice. This means that an increase in marginal discrepancy between the casting and prepared tooth resulted in an increase of gingival inflammation measured by a gingival index and crevicular fluid volume. This investigation also supported the concept that the clinical evaluation of gingival margins within the subgingival crevice is occasionally misleading with current instrumentation.

Ferencz JL. Maintaining and enhancing gingival architecture in fixed prosthodontics. J Prosthet Dent. 1991;65(5):650-657. The main problem of alterations in gingival architecture is mostly related to tooth preparations. It has been well documented that the health of the periodontal tissues must be achieved prior to initiation of restorative procedures. There are some factors in fixed prosthodontics that affect directly the periodontal health, such as margin placement, tissue damage during tooth preparation, the role of the provisional restorations, tissue injury during impression procedures, crown contour, pontic design, and embrasure design. Margins of any preparation have to be located supragingival whenever is possible in order to prevent factors that can affect the periodontal tissue. In subgingival preparations margins located close to epithelial attachment produce more harm than margins further away. Subgingival crown margins generally result in a less favorable periodontal condition than margins at the gingival crest or above and subgingival margins placed near the bottom of the sulcus are potentially more damaging than margins placed closer to the crest. The etiology of this inflammatory process may be related to the injurious nature of the subgingival operative procedures, restorative materials themselves, marginal gaps, and roughness of the luting agent. Preparations of the teeth below gingiva at speed of 200,000 rpm causes trauma of varying severity to the sulcular epithelium and frequently to the subepithelial connective tissue. During initial tooth preparations, it is important not to prepare the tooth to its full depth within the sulcus. Margins that are less invasive within the sulcus can be capturated accurately when fabricating provisional restorations. Referring to impressions materials the placement of retraction and cotton strings into the gingival sulcus cause injury to the sulcular epithelium, and the chemical agent with which the cord has been impregnated, the force used in packing the cord and the length of the time the cord is left in place within the sulcus.

Overcontouring of the crown tends to encourage the retention of plaque and the ensuing development of inflammation. Pontics represent oral hygiene problems, ideally, there should be no contact or slight contact against mucosa, surface should be flat or convex, also, pontics should be the same length as the adjacent teeth. The interproximal papilla responds rapidly to overcontouring of the embrasure region. The ideal size of the interproximal embrasure is one that permits the introduction of cleaning aids for the removal of plaque in this most vital area.

Friedlander LD, Munoz CA, Goodacre CJ, Doyle MG, Moore BK. The Effect of Tooth Preparation Design on the Breaking Strength of Dicor^R Crowns: Part 1. Inter J Prosth. 1990;3(2):159-167. The purpose of this study is to evaluate the strength of Dicor crowns fabricated for teeth prepared with 10° and 20° of total occlusal convergence, 2mm of occlusal reduction, and three types of finish lines (1.2mm shoulder with sharp axiogingival line angle, 1.22mm shoulder with rounded axiogingival line angle, and a 0.8mm chamfer), and to compare the strength of Dicor with metal ceramic control preparations. Model teeth were prepared with 2mm occlusal reductions and following the dimensions designed for the study. The preparations were reproduced in base metal alloy and Dicor crowns were fabricated for each die. Occlusal loading was then applied using Instron machine. The tooth preparation with a 1.2mm shoulder finish line, sharp axiogingival line angle and 10° of total occlusal convergence produced the strongest Dicor crowns (88.6 kg). The weakest restorations were observed when a 0.8mm chamfer finish line was used (66.8 kg) regardless of total occlusal convergence. Metal ceramic crowns were significantly stronger (247.45 kg) than the strongest Dicor crowns.

Goodacre CJ. Gingival Esthetics. J Prosthet Dent. 1990;64(1)1-11. Achieving the most desirable gingival appearance enhances the esthetic result achieved with fixed prosthodontic restorations and is most often realized when gingival health is optimized before treatment. The best way to enhance gingival health and minimize trauma is to avoid contact of the gingiva with restorative materials. Partial veneer crowns can be used to avoid contact with facial gingival tissue. Supragingival finish lines can also meet esthetic demands. It has been shown that in 33% of the people studied, the gingival aspect of their most visible anterior teeth did not show during a normal smile. Further, some patients will accept supragingival margins even if they are visible, and many patients prefer the potential of optimal gingival health over esthetics. For those patients who display the cervical aspect of their teeth, it is possible to avoid gingival contact and meet esthetic requirements by using collarless metal ceramic restorations with finish lines located at the gingival crest. Subgingival finish lines are required in some situations to gain sufficient retention, cover existing restorations or fracture sites, eliminate caries, or achieve a better esthetic result. In order to maintain gingival health in the presence of subgingival finish lines is necessary to consider the following factors: Patients with existing periodontal abnormalities often have exaggerated responses to the slightest tissue insults. It is imperative that optimal tissue health be established before fixed prosthodontic procedures. The epithelial attachment is the most vulnerable of all the supporting structures. Subgingival finish lines should be terminated at least 0.5mm short of the epithelial attachment. The restoration must be a continuation of normal tooth contour and not be overcontoured, a condition that promotes plaque accumulation and resultant gingival inflammation. Retraction cord can be placed in the sulcus to displace the gingiva laterally and apically. Hand instruments with flat blades can also be used to retract the gingiva of or in addition to retraction cords. Provisional restorations should be well adapted to the finish line and has a smooth surface. Provisional fixed partial dentures must exhibit pontic and cervical embrasure forms that provide access to the soft tissue by oral hygiene aids. Provisional restorations should be in position as short time as possible preferably no more than 2 or 3 weeks. The quality of the definitive restoration must provide an environment that promotes long-term maintenance of optimal gingival health. The restorations should have good marginal fit because marginal defects permit plaque formation and have been associated with reduced periodontal bone levels. Facial, lingual, and interproximal surfaces should be normally contoured and should not impinge on the soft tissue because overcontouring promotes plaque accumulation. Minimal soft tissue contact of the pontic is advantageous. Embrasures should be opened as much as practical to permit access with oral hygiene aids. Postplacement observations of oral hygiene adequacy are needed to promote longevity of the definitive restoration.

Grosso FP, Carreno JA. Partial or full coverage restorations: A survey of prevailing criteria. J Prosthet Dent 1978;40(5):628-30. A survey was designed to (1) determine the prevailing consensus as to whether partial or full coverage restorations conserve more tooth structure and provide better esthetics and retention, (2) determine the ideal location, if any, for establishing gingival margins of restorations, and (3) obtain information regarding the criteria used by different centers of dental education for determining clinical acceptability of a preparation. Seventeen types of restorations were selected, and preparations were made on 12 different teeth. The restorations included inlays, onlays, full coverage, three quarter crowns, and pinledges. The teeth were selected for their frequent use as abutments for replacement of one, two, or more missing teeth. Preparations were ideal with normal mesiodistal and faciolingual dimensions, favorable crown-to-root ratio, and normal alignment in the dental arches. A questionnaire was designed so that each preparation could be judged for clinical acceptance, including the amount of tooth reduction and the extent of the cavosurface margins. The questionnaire also addressed the matter of supragingival and subgingival placement of margins for both partial and full coverage preparations. Other considerations were esthetics, ease of preparation, retention, failure rate, amount of exposed margins, and conservation of tooth structure for both types of coverage. A set of unprepared and prepared teeth, together with five questionnaires, was sent to each dental educational center in the nation. Over 100 questionnaires were returned from nearly 30 schools. The information obtained was organized on a geographic basis to determine whether regional factors influence clinical acceptability. The data were interpreted and compared on the basis of these regions and nationally. Based on the results of this study, the following conclusions were reached: (1) Definite regional differences exist in the criteria used in determining the clinical acceptability of preparations; (2) Such differences are more pronounced in partial coverage restorations; (3) Supraginigval margins are favored slightly for both partial and full coverage restorations; (4) Full coverage restorations were selected by a substantial majority as offering the best esthetics, ease of preparation, greater retention, less exposed margins, and a lower rate of failure.

Harrison JD. Effect of retraction materials on the gingival sulcus epithelium. J Pros Dent 1961;11(3)514-521. Three dogs were used as the experimental animals. Retraction materials used were untreated, string and string saturated with (1) 1:1000 epinephrine, (2) 8% epinephrine, (3) 100% alum, (4) 8% zinc chloride, or (5) 40% zinc chloride. The lingual sulcus was used as a control in each instance. Results of animal experimentation with dogs may be interpreted as valid in meaning for man. However, the tissue reaction is generally less severe in dogs than in man. Conclusions. On the basis of these findings, the following points concerning the use of retraction materials in patients may be concluded: 1) Mechanical and chemical retraction materials used with elastic impression materials do injure the gingival sulcus epithelium. The injuries, excluding those caused by the zinc chloride concentrations, healed within 7 or 10 day periods and may be considered temporary. 2) Untreated string is a safe retraction material for periods from 5 to 30 minutes and is recommended when bleeding or seepage is not a problem. String saturated with 1:1000 epinephrine is a safe retraction material for periods from 5 to 10 minutes and is recommended when bleeding or seepage is a problem. 3) String saturated with 8% epinephrine or 100% alum solution may be used when heavier bleeding or seepage must be controlled. They are recommended for 5 and 10 minute retraction periods. 4) String saturated with 8 or 40% zinc chloride is not recommended as a retraction material.

Hegdahl T, Silness J. Preparation Areas Resisting Displacement of Artificial Crowns. J Oral Rehabilitation 1977;4:201-207. Pyramidal preparations gave larger resisting areas than conical ones. Factors that influence resisting areas are diameter or side length, convergence angle and height. An increase in preparation height, diameter or side length will increase resisting areas. On the other hand, an increase in convergence will reduce resisting areas. So when preparing teeth for full crown restorations rounding of angles should be avoided. The use of large convergence angles results in small resisting areas and should be avoided.

Hoffman JM. Modern Concepts in Crown Preparation. NYSDJ August/September 1991;32-35. The author discusses the type of preparation to be selected (sub-gingival, supra-gingival and hybrid), the type of provisional restoration to be used and the philosophic concept of removing all the enamel when using a sub-gingival type of preparation. Then he reviews the preparation procedures. In the sub-gingival preparation he advise to switch to slow speed after bulk removal and to avoid using a flame-shaped bur when creating the bevel (that will be too thin) substituting it with a fine football. He also advocates a 360 degrees shoulder to avoid creating a difficult to read transition area.

Hovijitra S, Robinson F, Brehm T. The Relationship Between Retention and Convergence of Full Crowns When Used as Fixed Partial Denture Retainers. Journal/Indiana Dental Assoc. 1979;58(4):21-24. The purpose of this study was to measure the relationship between retainer convergence angle and fixed partial denture retention, and the amount of retention gained if two single crowns are joined by a connector as in a three-unit FPD, and to find out if the additive retention value of two single crowns equals that of the FPD after connection. Four sets of stainless steel dies were made with convergence angles of 2°, 5°, 7°, and 10°. These dies were fastened in the bottom half of a flask using removable pins. The upper half of the flask was designed to fit the bottom half at the periphery and contained two die holes with the same convergence angles as the dies. Instron machine was then used to apply and measure the loads. The authors found that an inverse relationship existed between convergence angles of a preparation and retention. The two abutments simulating fixed partial denture required more force necessary for separation than the corresponding single retainers.

Hunter J, Flood M. The restoration of endodontically treated teeth. Part 2. Posts. Australian Dent J. 1989;34(1):5-12. Posts are normally used to aid core retention and provide tooth support. A direct relationship between the quantity of sound tooth structure and tooth strength and care is required when preparing teeth to accept posts. Post configuration is more important than post length because accurate post fit is important to maximize both retention and support, direct fabrication techniques using matched post/reamer systems are recommended. The author suggests: all anterior and premolar teeth which are to receive crowns following root canal therapy should have at least one post placed. Most "non-vital" molar teeth should also be prepared for subsequent crowns by placing at least one post.

Hunter AJ, Hunter AR. Gingival margins for crowns: A review and discussion. Part II: Discrepancies and configurations. J Prosthet Dent. 1990;64(6):636-642. Making a casting involves a series of controlled compensations for the dimensional changes occurring throughout the process. While there is variation regarding the maximum acceptable marginal discrepancy, there is little argument that poorly fitting margins are a frequent finding. Large discrepancies are clinically significant, since they facilitate plaque retention. Margins incorporating slip joint geometry have usually been favored as a method of minimizing seating and sealing discrepancies. However, many of these discussions largely ignored the effects of the cementing medium and the clinical applicability of slip joint geometry is based on questionable assumptions with regard to casting accuracy and seating. The use of horizontal margins combined with procedures that improve crown seating. Theoretically, horizontal designs allow the smallest discrepancies after cementation provided the casting is accurately made and seated. Some dentists prefer covering areas of enamel cleavage at the preparation margin by incorporating a short, low angled bevel, but deep extension into the gingival crevice should be resisted. Significant advantages in preparation geometry or finishability should not be claimed for these designs.

Jackson CR, Skidmore AE, Rice RT. Pulpal evaluation of teeth restored with fixed prostheses. J Prosthet Dent. 1992;67( ):323-325. Fixed prosthetic procedures result in possible and probable insult to the pulpal tissues of the tooth. Preparation of the tooth involves cutting dentin and odontoblastic processes. Impression techniques in current use necessitate drying the dentin surface. Temporary self-curing resin, temporary and permanent cements can irritate the pulp. A recall of 130 patients yielded 603 teeth for study. All these teeth had received treatment with fixed partial dentures performed by prodoctoral students during the years 1983 - 1988. Each tooth was evaluated for pulpal health, periodontal health and clinical acceptability of the restoration. Among these teeth, 437 were vital when crowned and 166 had undergone root canal therapy before restoration was cemented. (1) Of the 437 teeth that were vital when restored, twenty-five (25) 5.7%) either subsequently had or now needed root canal therapy. (2) No significant relationship was found between the location of the tooth, sex of the patient, or the involvement of the tooth in a fixed partial denture versus a single crown, and irreversible pulpal involvement. 3) The low rate of pulpal involvement in this study shows that proper techniques cause little or no permanent injury to the pulpal tissues. 4) The results of this study do not support the idea that modern techniques of preparation and restoration are injurious to the pulpal tissues.

Jackson CR, Skidmore AE, Rice RT. Pulpal evaluation of teeth restored with fixed prostheses. J Prosthet Dent 1992;67:323-5. This study evaluates the effects of complete coverage fixed prosthesis on pulpal health of the teeth. OF the 603 examined who had received prosthetic treatment during the years 1984-1988, 166 had undergone root canal therapy before placement of the restoration, leaving 437 that were crowned while vital. Of these, 25 (5.7%) either subsequently had or now needed root canal therapy. A chi-square analysis of the data revealed no significant difference for crown or fixed partial denture abutments, posterior versus anterior, or male versus female factors.

Jacobi R, Shillingburg HT Jr, Duncanson MG Jr. A comparison of the abrasiveness of six ceramic surfaces and gold. J Prosthet Dent. 1991;66(3):303-309. Six different ceramic surfaces and a type III gold alloy were secured in an abrasion machine opposing extracted teeth to determine their relative abrasiveness and resistance to wear. The ranking of restorative materials from least abrasive to most abrasive were: polished gold alloy; polished cast ceramic; polished porcelain; polished and shaded cast ceramic; polished and glazed porcelain; cerammed skin shaded and then unshaded cast ceramic. The ranking of materials from most wear-resistant to least wear-resistant was: cast ceramic cerammed gold alloy, cast ceramic cerammed and shaded, porcelain polished, porcelain glazed, cast ceramic polished and shaded, and cast ceramic polished. Overall, type III gold was the least abrasive. Glazed porcelain was more abrasive than polished porcelain. Dicor shading porcelain had approximately the same abrasiveness as VMK 68 porcelain when glazed. Dicor cast ceramic material without shading was the least abrasive ceramic material but the most subject to wear. The cerammed skin of Dicor cast ceramic material was the most abrasive and wear resistant of the ceramic surfaces.

Jameson LM. Comparison of the volume of crevicular fluid from restored and nonrestored teeth. J of Prosthet Dent. 1979;41(2)209-214. The crevicular fluid volumes between restored and nonrestored teeth were compared on 32 patients randomly selected between the ages of 12 and 60. The fluid was collected by means of a standardized time sequence and an orifice technique using sterile filter paper strips. Sublinical inflammatory changes associated with subgingival full coverage restorations can be objectively and quantitatively measured using standardized techniques and a Gingival Crevicular Fluid meter. The existence of a measurable inflammatory response associated with full coverage subgingival margins would seem to support the view of supragingival margin placement. Full coverage restorative procedures necessitate proper diagnosis, adequate tooth prep, proper use of dental materials, and final crown contours with physiologic form which are also congruent with existing root formation.

Jameson LM, Malone WFP. Crown contours and gingival response. J Prosthet Dent. 1982;47(6):620-624. The objectives of this paper is to: 1) evaluate the current methods of measuring gingival response to restorative procedures and materials, 2) evaluate the design theories of crown contours, and 3) evaluate the guidelines for gingival margin placement. Subjective indices such as color, texture and probing are prone to the dentist's subjective interpretation of periodontal response. A more objective method involves measurement of crevicular fluid flow since it is observed that: 1) crevicular fluid flow increases with an increase in inflammation, and 2) fluid flow is easily studied before advanced clinical signs are seen. Also it was noted that subgingival extension of the margins causes more inflammation. The closer the crown margin is placed to the base of the gingival sulcus the more severe the inflammation. Overcontouring especially in the cervical third and interproximal surfaces is harmful to gingival health. It was suggested that tooth reduction at the gingival margin should be enough to provide adequate space for the restorative materials to avoid overcontouring. Also exposed furcations must be fluted to eliminate places for plaque retention and promote cleansability.

Jorgensen K. The relationship between retention and convergence angle in cemented veneer crowns. Acta Odont Scand 1955;13:35-40. A report is given of some investigations on the relationship between the retentive force and the angle of convergence in cemented veneer crowns. The relation is shown to be a hyperbola with the formula (y-(-a)) x X = K, where y is the retention in grams per millimeters squared, X the convergence angle, and a and K constants. The retention is substantially increased by a very slight scratching of the surfaces that are to be cemented.

Kaufman EG, Coelho DH, Colin L. Factors influencing the retention of cemented gold castings. J Prosthet Dent. 1961;11(3)487-502. Studies of some of the factors which influence the retention of cemented gold alloy castings are reported. The tests were made on metal dies with controlled variations in height, angle of convergence, and diameter. Castings were fabricated by use of a controlled technique, and the resultant casting cemented to die assemblies were subjected to unseating forces on a tensile strength testing apparatus. The difficulties encountered in seating the casting completely led to a study of the effect of a planned opening in the castings as an escapement for excess cement. Conclusions were drawn. 1) The resistance to unseating a cemented casting increases as the opposing walls approach parallelism. 2) The increase in retention is less marked with an increase in height. 3) An analysis of the retention of tooth preparations with the same degree of inclination demonstrates that each unit area of this surface has comparable retentive ability, regardless of the other dimensions of the preparation. 4) There is a linear increase in retention as the preparation increases in diameter. 5) In a convergent preparation, the areas closer to the gingival termination contribute the greater proportion of the retention. 6) Castings do not seat completely during the cementation procedure, and this discrepancy is clinically significant. The intervening cement layer at the occlusal surface is excessive under nonperforated castings, thus violating marginal relationships. This is a more critical problem in preparations where the walls approach parallelism and appears to be related to the degree of adaptation of the two parts. 7) The use of a planned occlusal opening for a casting allows more nearly complete seating, greater ease of placement, and an increase in retentive ability.

Kent WA, Shillingburg HT Jr, Duncanson MG Jr. Taper of clinical preparations for cast restorations. Quintessence Inter. 1988;19(5):339-345. Taper of preparations done by an experienced operator ranged from 8.6° to 26.6°. The overall mean was 14.3°.

Laforgia PD, Milano V, Morea C, Desiate A. Temperature change in the pulp chamber during complete crown preparation. J Prosthet Dent. 1991;65(1):56-61. This study observed the temperature changes in the pulp chamber during tooth preparation for a complete crown. Twelve extracted morphologically intact human teeth were chosen: four canines, four premolars, and four molars. Six teeth, two of each, were cooled during tooth preparation with an air-water spray while the other six were air-cooled. Minimal reduction of dentin using an air-water spray coolant resulted in a lowered temperature in the pulp chamber. Application of air coolant resulted in a temperature rise in the pulp chamber.

Löe H, Dr. Odont, Silness J. Tissue Reactions to String Packs Used in Fixed Restorations. J Pros Dent. 1963;13(2):318-323. The effect of commercial pack containing epinephrine and cotton strings soaked in 8% zinc chloride was studied histologically after the insertion of retraction cord into 13 gingival pockets of 2 normal dogs. They concluded that the force normally used for packing strings into the pocket should be reduced so as not to destroy the upper most Sharpey's fibers. Both 8% zinc chloride and a commercial pack necrotize the epithelial cuff and the adjacent layer of the subepithelial connective tissue. The new epithelium proliferates from the gingival margin and the wound is lined with epithelial cells in 6 to 9 days. Complete healing will take place provided the healing processes are not disturbed.

Loey RE, Myers GE. The retentive qualities of bridge retainers. JADA 1968;76:568-572. Five different clinical preparations were made on ivorine maxillary canine teeth. Preparations were: complete crown preparation, three-quarter crown preparation with incisal and proximal retention grooves, three-quarter crown similar to the above with a pinhole 2.5mm deep, placed in a recess at the crest of the cingulum, pinledge preparation with three tapered pinholes 2.5mm deep, and a parallel pin preparation with three pinholes on the lingual surface in the same positions as those in the pinledge preparation. Castings were cemented with zinc phosphate cement. Castings were withdrawn from their individual dies three times without cement and three times after cementation. Conclusions: the retentive values increased with surface area of the preparation, the addition of a cingulum pin to the anterior three-quarter crown increased the retention, the retention values obtained for the canine with tapered pins and the canine three-quarter crown with a cingulum were similar, the standard three-quarter crown retainer had lower retention values than the pinledge with three tapered pins, the pinledge retainers with three tapered pins were higher than the values for the parallel pin preparation with three cylindrical pins, the highest retention values were obtained with the two complete crown restorations, the retention values of uncemented castings gave no indication of the retention values obtained after cementation.

Long D, Smith BGN. The effect of contact area morphology on operative dental procedures. J Oral Rehab. 1988;15:593-598. In spite of extreme caution, tooth protection methods, and current emphasis on conservative cavity preparations, incidence of damaged to adjacent teeth is still very high. In this study, 94% of tooth surfaces out of 54 teeth adjacent to MOD cavities were damaged by burs. The authors suggest the need for further investigation in protective methods and instruments used in MOD and full crown preparations to avoid damage to adjacent teeth.

Mack PJ. A Theoretical and Clinical Investigation Into the Taper Achieved on Crown and Inlay Preparations. J Oral Rehab 1980;7:255-265. In the study, investigation was done with the distance between eye and tooth preparation, and monocular or binocular. Results showed that angles of taper in clinical investigations from every crown preparation were greater than the recommended ideal. The average of the clinical full crown measurements was 16 degree 34 minutes, less than the average for inlay preparation (21 degree 59 minutes), while the recommended ideal was 5 degree. Finer tapers are achieved when the preparation of axial on opposing walls is undertaken at the furthest distance from the tooth. Fine tapers are achieved when monocular vision is employed to prepare inlays or crowns anterior to the canine, and when binocular vision is employed to cut extracoronal preparations distal to the canine, or to align multiple extracoronal retainers.

Maxwell AW, Blank LW, Pelleu GB Jr. Effect of crown preparation height on the retention and resistance of gold castings. Gen Dentistry, May/June 1990;200-202. The success of a cast restoration depends largely on adequate retention and resistance, but achieving this is often a problem for dentists. Accepted techniques for improving the retention and resistance of a restoration include increasing the surface area, parallelism of opposing walls, and occlusogingival preparation height. The purpose of this investigation was to determine the minimum crown preparation height necessary for retention and resistance of full-coverage cast restorations on tooth structure dies. Roots of single-rooted extracted nonendodontically treated teeth were prepared to a standardized 6° angle of convergence of opposing walls and occlusogingival heights of 5mm (control), 3mm, 2mm and 1mm. Retention and resistance tests were performed on copings using an Instron tensile-testing instrument. It is concluded that an occlusogingival preparation height of 3mm with a 6° taper is the minimum necessary for adequate retention and resistance for gold castings.

McMullen AF III, Himel VT, Sarkar NK. An In Vitro Study of the Effect Endodontic Access Preparation and Amalgam Restoration Have Upon Incisor Crown Retention. J of Endodontics 1990;16(6):269-272. This study intended to determine whether the crown retention of endodontic access preparation leads to a significant reduction. Eighteen extracted human maxillary incisors had PFM crowns fabricated. Crowns were cemented, retention measured, recemented, access preparations cut, and retention once again measured. Then, crowns were recemented and accesses restored with dental amalgam and new retention measured. The results suggest that recementing crowns secondary to endodontic access and restoring the access with amalgam regains and even surpasses the original retention. For example, crowns cemented with zinc phosphate cement and restored with amalgam, a 126% increase over original retention was measured. Crowns cemented with polycarboxylate cement and restored with amalgam, a 237% increase over original retention was measured.

Moopnar M, Faulkner KDB. Accidental damage to teeth adjacent to crown-prepared teeth. Aust Dent J 1991;36:136-40. Iatrogenic damage to adjacent teeth can be expected regardless of care and operator skill during crown preparation. The tongue, the cheek, and lips might come into contact with the high speed cutting instrument unexpectedly. The water mist of the hand piece, closeness of the adjacent teeth, and difficulty in approaching the tooth to be prepared can lead to tooth structure damage which may develop carious lesions due to impairment of plaque removal. 370 casts with 652 registerable proximal surfaces adjacent to teeth with full crown preparations were examined. Involved proximal surfaces were classified visually according to the amount of tooth structured damaged and by its location on the teeth. The preparations were performed by undergraduate dental students, experienced dentists and postgraduate students, and academic and hospital staff. 9 (by undergraduates), 94 (by academic and hospital staff), and 267 (by private practitioners) proximal surfaces were evaluated by the authors with a 93 percent of agreement. Of the 652 tooth surfaces examined, 171 showed no damage from cutting instruments. 321 present slightly damage and 160 presented obvious damage. Distal surfaces were more prone to become damaged. No incidence differences were observed on damaged tooth surfaces of upper and lower jaws. Finally, preventive techniques and protective instruments and devices such as matrix band and small tapering burs to protect adjacent teeth were suggested. Microfill composite material was suggested to repair damaged enamel surfaces.

Morrant GA. Dental instrumentation and pulpal injury. Part II: Clinical considerations. J of the British Endodontic Society. 1977;10(2):55-63. Efficiency of burs. Preliminary results indicated that of ten different manufactures of flat tissue burs, only half were efficient, however of these none was outstanding over the others. Of the inefficient burs, the common fault was a tendency to stall. It was noted that when rotation was resumed, after momentary stall, there was a peak rise of temperature. It seems probable that stalling is one of the causes of charring of dentine. Diamond points. Schuchard and Walkins in 1967 confirmed that diamond stones of similar dimensions to carbide burs ran at higher temperature than the burs and were less efficient in cutting tooth structure. It is a common experience that diamond stones clog with debris which tends to become compacted to a high degree. The instrument then presents a greater surface contact to dentine producing greater frictional heat. Harkkness showed that this can reduce the cutting efficiency by about 60%. Speed and pressure. At ultra high speed and low torque, the pressure which can be applied is limited. Although the temperature generated by these instruments may be high, the quantity of heat may be low. Conversely, it should not be forgotten that instruments being run a low speeds in conventional handpieces may generate a large amount of heat at a lower temperature. If this cannot be dissipated it will generate a high local temperature. Mode of use. It is preferable to remove tooth substance or restoration over a wide area at first and then the base should be approached more gradually thereby allowing the spray to penetrate to the surface being prepared. This will prevent a localized concentration of heat being generated by a bur. Caution is needed in the sinking of pin holes for pin retained restorations. Coolant. Langeland stated that a coolant is of paramount importance because it prevents dehydration and temperature raise. Clinical investigation. 209 buccal cavities were prepared in premolars to be extracted for orthodontics reasons. the cavities were prepared using diamond points or tungsten burs with and without waterspray. Summary of pulp changes. It can be seen that there is a much greater incidence of reactions in the dry groups in the histological reaction. Diamond points appear to stimulate a greater frequency of reaction than tungsten carbide burs. Dentine changes. Combining diamond and carbide in the wet groups, nearly 70% show no heat marking of dentine, 24% were moderately affected and 9% were burnt. In the dry groups only 25% showed no heat marking. Conclusion. It is fundamental of all operative procedures that they should leave the tooth and the patient in at least as good a state as that in which we found them.

Morris ML. Artificial Crown Contours and Gingival Health. J Prosthet Den 1962;12(6):1147-1156. Melvin Morris presents the concerned with the problem of minimizing gingival irritation as related to the axial contours of artificial crowns. Current philosophies teach that artificial buccal and lingual contours should protect the gingival crevice from food impaction. He further discussed that the theory of the artificial bulge in the crown is an inaccurate view of gingivocoronal anatomy and physiology. This rationale produces crowns that are contoured in excess of anything seen in nature and causes, rather than prevents, gingival inflammation. The rationale of muscular molding and cleansing, rather than that of food impaction, more adequately explains clinical phenomena and is a more accurate guide for the construction of gingivally tolerated full crowns.

Nicholls JI. Crown retention. Part I. Stress analysis of symmetric restorations. J Prosthet Dent 1974;31(2):179-184. Conical shape preparations receive concentrated stress on the corner of the preparations and this can be a cause of cementation failure.

Ohm E, Silness J. The convergence angle in teeth prepared for artificial crowns. J Oral Rehab 1978;5:371-5. Teeth for artificial crowns were prepared by students in their last clinical year. The teeth were prepared with a buccal and partly approximal bevelled shoulder, whereas the remaining part of the finishing line was of the chisel edge type. Measurements of convergence angles were made from stone dies (Vel-mix) produced from impressions with thiokol rubber material (Permlastic). The stone dies had been used to produce full crowns with an aesthetic facing of synthetic resin. Ninety-three dies were prepared for vital teeth and 97 for rootfilled teeth. In rootfilled teeth a cast gold postcore is routinely made and cemented prior to impression making. The crowns were made for anterior teeth and premolars in the upper as well as the lower jaw. The different tooth types were almost equally represented. The analysis of the results showed that differences between vital and rootfilled teeth existed. Within each of these two groups, however, no major differences between the various tooth types occurred. The results of the measurements showed that for vital teeth the mean size of the convergence angles varied between approximately 19 and 27°. For rootfilled the mean values varied between about 12 and 37°. The values both for vital and rootfilled teeth are considerably larger than those usually recommended for the preparation of teeth for artificial crowns.

O'Leary TJ, Miles S. Severe periodontal destruction following impression procedures. J Periodonto. 1973;44(4):43-48. This article documents severe postoperative problems in two patients after the use of electrosurgery and rubber base impression material. The two reports are markedly similar. Electrosurgery had been carried out to remove a small amount of soft tissue and control hemorrhage. Rubber base material was then used to secure an impression. After the procedure they developed cellulitis and pain. A radiograph confirmed the presence of radiopaque material in the affected area. Flaps were retracted and a large amount of granulomatous tissue and silver-gray foreign matter was removed. The exact nature or the foreign material could not be identified. Histologic diagnosis revealed chronically inflamed gingiva and foreign body reaction. Both patients had extensive bone loss. The author speculates how these problems occurred: 1) The surgical current may have involved areas here blood vessels emerged from the bone, causing retraction or coagulation necrosis of the vessels. Subsequent injection of the impression material into crevicular areas and seating of the impression tray may have forced the material into the bony channels where the blood vessels had been altered. 2) The operators penetrate to the bone with a bur or instrument during the crown preparation. The subsequent pressure in injecting the impression material and seating the tray may have forced impression material into the gingival tissue and bone. 3) The pressure employed in injecting the material and seating the tray forced the material through the soft tissues.

Parker MH, Malone KH, Trier AC, Striano TS. Evaluation of resistance form for prepared teeth. This article evaluated the resistance form of preparations for which castings have been done in a large dental laboratory. Evaluation was by tooth groups: incisors, canines, premolars, and molars. A total of 294 preparations were evaluated (90 incisors, 25 canines, 72 premolars, and 107 molars). Resistance form was shown by 96% of the incisors, 92% of the canines, 81% of the premolars, and only by 46% of the molars. Results also indicate that groove placement enhanced resistance to dislodgement, but the sample was not large enough to be statistically significant.

Pascoe DF. Analysis of the geometry of finishing lines for full crown restorations. J Prosthet Dent. 1978;40(2):157-162. Pascoe in 1978 analyzed the geometry of finishing lines for full crown restorations. He stated that the geometry exhibiting the least marginal discrepancy was the shoulder with slightly oversize casting. It is significantly better than the oversize bevel, the control shoulder, or the control bevel.

Perel ML. Axial crown contours. J Prosthet Dent. 1971;25(6):642-649. The objective of this article is to document the effects of tooth contours on the gingiva by altering it either by undercontouring or overcontouring tooth surfaces. Mongrel dogs were used as subjects. The buccal surfaces of the right side, lingual surfaces of the left side and the labial surfaces of the anterior lower teeth were prepared to altered contours. The convexity including the height of contour, was removed and the apical termination was 0.5mm above the marginal gingiva. The soft tissue was not disturbed in the course of preparation or sacrifice. Those teeth that were overcontoured involved buccal surfaces only. A class V preparation was filled with acrylic resin and overbuilt in a convex manner 2mm beyond the normal curvature. The similarity of the labial surface of lower anterior dog teeth to those of human definitions allowed for their use to simulate erosion. Effect of undercontour was insignificant and this study questions the need for deflecting suragingival contour. The undercontoured axial surfaces does not alter the tight adaptation of the gingival collar which may be because of more mechanical stimulation during mastication. Also the presence of incorrect tooth contours may not disturb healthy gingiva. Thus the protective mechanism of the gingiva may be within the gingiva itself. Effect of overcontour is observed with the presence of a soft plaque material which favors the concept of an area of stagnation. This produced inflammatory and hyperplastic changes in the marginal gingiva as early as 4 weeks.

Potts RG, Shillingburg HT, Duncanson MG. Retention and resistance of preparations for cast restorations. J Prosthet

Dent 1980;43(3): 303-308. The purpose of this study was to evaluate the effect of preparation designs on the retention and resistance of cast restorations. Displacement of crown restorations occurs because the design of the tooth preparation does not resist the forces that are placed against the restoration. Retention prevents the removal of the restoration along the path of insertion. Resistance prevents the dislodgement of the restoration by forces directed in an apical or oblique direction and prevents any movement of the restoration under occlusal load. Five preparation designs were used: 3/4 partial veneer crown without axial grooves, 3/4 partial veneer crown with axial grooves, 7/8 partial veneer crown without axial grooves, 7/8 partial veneer crown with axial grooves, and a complete crown without axial grooves. Zinc phosphate cement was used according to a standardized protocol. The Instron machine was used with a cross-head rate of 0.05 inches per minute. The retention test used tensile force and the resistance test used a dislodging force that was oblique to the path of insertion. There was no statistically significant difference in retention offered by the addition of grooves. There was no statistically significant difference in extending axial surface coverage from the 3/4 to the 7/8 partial veneer crown. There was a statistically significant difference in retention between the partial veneer and full veneer crowns. There was a statistically significant difference among the resistance values for all of the preparation designs. The authors state that the placement of axial grooves adds little to the total surface area of the preparation, and that factors other than the total surface area should be considered when explaining the significant increase in retention of full veneer crowns. The primary function of proximal grooves in the partial veneer crown preparation is resistance. The extension of the axial coverage of the restoration onto the surface on the same side from which the forces are being directed enhances resistance.

Pruden WH II. Fixed partial dentures and operative dentistry. J Prosthet Dent. 1971;26(1):302-306. Discussions on the merits of partial coverage versus full coverage have been stimulating interest at dental meetings. The indications, advantages and disadvantages of various types of restorations and retainers are discussed in this article, with the emphasis of careful diagnosis and treatment planing. Generally, partial coverage preparations are considered the most conservative preparations since they remove the least amount of tooth structure and cause the least degree of trauma to the pulp and soft tissues. Pins are valuable and effective means of obtaining added retention for castings. Full coverage is the only successful method of treatment for badly broken down teeth.

Purton DG. Form, Fit and Location of the margins of full crowns. This literature review debates the use of a round shoulder (deep chamfer) preparation placed at or above the gingival margin for all crown types. Many margin forms have been suggested in the dental literature. Due to the improvement in investing materials, accuracy in fitting of casting can be easily achieved. Complete seating of castings can be achieved by internal oversizing of castings. Except for PJC crowns, the round shoulder is the best alternative in regard to margin designs. It is easy to prepare (using the proper burs), easiest to identify clinically on teeth and in the impression, and convenient to locate and wax to a die model.

Richter WA, Ueno H. Relationship of crown margin placement to gingival inflammation. J Prosthet Dent 1973;30(2):156-161. In this study 12 full crown restorations on permanent first molars were placed with both subgingival and supragingival margins adjacently placed on the same crown. Of these only 3 showed evidence of gingival inflammation after 3 years of clinical service. A comparison of the two margin locations using four different methods of evaluation revealed no difference in the health of the gingiva, in the change in sulcus depth, in gingival contour and in plaque accumulation, thus suggesting that the fit and finish of full crown restorations may be more significant to gingival health than the location of the finish line. However, despite the results the authors felt that slight differences that were noted invariably favored the supragingival placement, that should be used whenever acceptable.

Robbins JW, Burgess JO, Summitt JB. Retention and resistance features for complex amalgam restorations. JADA 1989;118:437-442. This article reviews the literature concerning the retention and resistance features and makes recommendations for their use in amalgam restorations. Methods of obtaining retention and resistance form which amalgam restorations has been used as a restorative material in large posterior restorations include pins, slots, amalgam inserts, and ledges. The authors concluded that amalgapins and circumferential slots have their greatest indication in teeth with short clinical crowns and in cusps that have been reduced 2-3mm for coverage with amalgam. The use of both vertical and horizontal pins may be limited by inadequate access; in these cases, alternate devices should be used. The literature suggests that distribution of resistance features to all areas of the preparation is necessary for maximum effectiveness. Pins, amalgapins, slots, ledges, and boxes may be used independently in many clinical situations. However, the effectiveness of these resistance and retention features can be maximized when used in combination and properly distributed.

Roberts DH. The failures of retainers in bridge prostheses. Brit Dent J 1970 February: 117-24. Various factors in any specific bridge design are: age of the patient, length of the clinical crown, angulation of the teeth, caries, the periodontal condition and the skill of the operator. The relative failure rates of the various types of major retainers (the pontic is rigidly attached to the retainer) indicate that in fixed-fixed and complex bridge work the full crown should normally be considered the retainer of choice. The posterior three-quarter crown when used for fixed-fixed bridge work will attain above average retention and may be considered as a major retainer. For a minor retainer (the pontic connector is usually in the form of a dove tail), the relative failure rates in the posterior region indicate that the three-quarter crown is the retainer of choice but an MOD-inlay may be considered for esthetic reasons. From failure rates of minor retainers in the anterior region it would be best to use a Class III inlay or an anterior three-quarter crown.

Rosenstiel E. The retention of inlays and crowns as a function of geometrical form. Brit Dent J 1957 December: 338-94. The retention of an inlay or crown depends on whether there is only one path of placement, or one degree of freedom. Because of the presence of elastic forces and the impossibility of accurately machined cavities, a minimal amount of taper is necessary. However, a deviation of five degrees from parallelism is liable to lower the crowns retentive value. A quantitative assessment of retention should consider the physical properties of the tooth, restoration, and cement. It should be possible though, to assess the degree of retention in a preparation by ensuring that only one path of insertion exists. The length of the restricted portion of this path can serve as a relative measure of the retention of otherwise similar preparations.

Rosner D. Function, Placement, and Reproduction of Bevels for Gold Castings. J Pros. Den. 1963;13(6): 1160-1166. The difference between the size of a casting and the wax pattern may be in the range of 1.0%. This variation is a significant error, and it is responsible for the difficulty in completely seating restorations during cementation. A correctly formed bevel at the margin reduces the marginal defect due to incomplete seating. Although the horizontal distance between the restoration and the bevel on the tooth is equal to the amount of displacement of the restoration from complete seating, a parallel bevel minimizes the thickness of cement between the internal surface of the casting and the bevel on the teeth. The function, placement and reproduction of the bevel surfaces are discussed in this article.

Saunders WP, Saunders EM. Effect of Noncutting Tipped Instruments on the Quality of Root Canal Preparation Using a Modified Double-Flared Technique. J of Endodontics 1992;18(1)32-36. Root curvature was determined for all fifty-one extracted human first molar teeth with intact crowns. Molars were prepared for root canal in the mesial root of lower molars, or the mesiobuccal root in maxillary molars, in one of three ways. In group I, the root canals were instrumented using a modified double-flared technique with noncutting tipped files, in group II, the same files were used with a step back technique. Group III was prepared with conventionally tipped files using the step back technique. A low viscosity polyvinyl siloxane impression material was injected into the prepared root canals and the specimens were decalcified, dehydrated, and cleaned. Prep was evaluated subjectively according to, shape of root canal, shape of terminus, presence of ledging, presence of perforation, standard of debridement, branches of main canal untouched, debris apically, and overall standard of preparation. Group I had better overall preparation than those in group III. The use of a modified double-flared technique with noncutting tipped files was shown to be an effective method for the preparation of current root canals.

Saunders, EM, Saunders WP. The heat generated on the external root surface during post space preparation. Inter Endodontic J 1989;22:169-173. The heat generated on the external root surface of human premolar teeth during post space preparation was measured in vitro. The rise in temperature was recorded at a point 6mm from the apex of the tooth using a thermocouple attached to a chart recorder. The temperature rise was greatest when the removal of gutta-percha was combined with post channel preparation. The result showed that the use of engine-driven drills to prepare post channels in teeth may generate temperature rises that may cause periradicular tissue damage, and caution should be considered during their use.

Schmitt SM, Brown FH. A rationale for management of the dentogingival junction. J Prosthet Dent 1989;62(4):381-385. A clinical problem arises when an attempt is made to determine where the true sulcus ends, the epithelial attachment begins, and how to easily visualize the contour and extent of its dentogingival junction. Potential damage to marginal gingival from tooth preparation, tissue retraction, and the restoration itself are minimized when restorations are used that do not extend into the gingival crevice. They used concept of sulcular landmark, which is No. 3-0 black braided surgical silk is placed in the sulcus. The silk serves a number of purposes: 1) it will be a sulcular landmark and indicate the location and contour of the dentogingival junction; 2) it will act as a mechanical barrier to rotary instrumentation; and 3) during preparation and impression making, any debris or impression material left in the sulcus will be eliminated when the silk is removed.

Shillingburg HR Jr. A Partial Veneer Restoration. Australian Dent J. 1972;17(6):411-417. A partial veneer restoration is a restoration that saves tooth structure. Four principles must be observed in tooth preparation: conservation of tooth structure, retention and resistance, integrity of restoration and optimum extensions. Basically, three-quarter crowns were used with grooves. Grooves should parallel the long axis on posterior teeth and the incisal half of the labial surface on anteriors that allows them to extend farther apically. The resistance to lingual displacement comes from proximal grooves by a definite lingual wall to the groove. Modified anterior preparation was developed by Burgess called "Pinledge." There were three modifications for posterior teeth. The first of these is the seven-eights crown which frequently used for maxillary molars with the mesio-buccal surface intact. The second modification is the proximal half crown which is especially useful for a tilted mandibular molar used as a fixed abutment. The distal surface, rather than the buccal, has been left intact. Grooves paralleling the anterior preparation are cut in the distal half of the buccal and lingual walls. The final modification is the reverse three-quarter crown used for the tooth that leans lingually, so proximal grooves are placed to the lingual and the lingual surface has been left intact.

Shillingburg HT Jr, Grace CS. Thickness of enamel and dentin. JSCDA 1973;41:33-52. A total of 132 extracted maxillary teeth and 127 extracted mandibular teeth were selected for this study. The teeth were embedded in a clear casting resin. Each block was trimmed so that its surfaces were flat and parallel to the 4 respective axial surfaces of the tooth embedded in it, then, cut on a section machine. Anterior teeth and premolars were sectioned in the mid-sagittal plane. Maxillary molars were sectioned with two buccolingual sections, with each cut passing through two cusp tips. Mandibular molars were sectioned with two mesiodistal sections to enable measurement of enamel and dentin thickness of the cusp tips. The thickness of enamel and dentin for the groups of the teeth are presented in 13 tables, giving the dimensions for mesial, facial, distal, and lingual surfaces at 1mm. The thickness of root structure is given for 4 points at 3mm.

Shillingburg HT Jr, Hobo S, Fisher DW. Preparation design and margin distortion in porcelain-fused-to-metal restorations. J Prosthet Dent 1973;29(3)276-284. Four Labial finish lines were tested to determine what effect their configurations have on the stability of labial margins of porcelain-fused-to-metal restorations during the stage of porcelain firing. These finish lines were 1) chamfer, 2) heavy chamfer with bevel, 3) shoulder with bevel, and 4) shoulder. The shoulder finish lines, with and without a bevel, were found to produce significantly less distortion in labial margins of porcelain-fused-to-metal restorations than do chamfer finish lines with and without a bevel.

Shiloah J, Schuman N, Covington J, Turner J. Periodontal hazards of retained impression materials. Quintessence Inter. 1968;19(2):143-147. The purpose of this study was to review the commonly used impression materials and to illustrate some clinical complications and microscopic characteristics associated with their use. When reversible hydrocolloid is used, the main hazard in its use involves burns caused by using the material that is too hot. The catalytic agent of polyether (2.5 dichlorobenzene sulfonate), frequently producing contact dermatitis. Polysulfide rubber impression material may contain lead in a form which could present problems of gingival irritation and toxicity. Addition type and condensation type silicon impression materials rarely caused local or systemic reactions. The by-product molecule is usually ethyl alcohol, which causes little in the way of gingival irritation because the relative amount is very low and evaporates uneventfully. All the complications with the impression materials that were observed were associated with tooth preparations placed subgingivally. The epithelial attachment may be separated from the tooth surface during tooth preparation paving the way for deep penetration of the impression material. Further, proper registration of these preparations require retraction of the gingival margins and forceful injection of the impression materials into the crevices.

Silness J. Periodontal conditions in patients treated with dental bridges. III. The relationship between the location of the crown margin and the periodontal condition. J Peridont Res. 5: 225-229. 1970. The periodontal condition of 385 lingual abutment tooth areas with varying location of the retainer margins was compared with that of 385 contralateral tooth surfaces which were caries-free and devoid of fillings. A supragingival position of the crown margins seemed to be the most favorable location, whereas retainer margins at and below the gingival crest interfered significantly with gingival health, the weak link seeming to be the luting material at the cervical junction between the artificial crown and the tooth.

Smith BGN. The effect of the surface roughness of prepared dentin on the retention of castings. J Pros Dent 1970;23(2)187-198. Altering the roughness of a prepared dentin surface within a range of 5 to 120μm doesn't significantly affect the retention of cemented cast crowns.

Sorensen JA. A standardized method for determination of crown margin fidelity. J Prosthet Dent. 1990;64(1):18-24. Fidelity refers to the faithfulness of reproduction of the tooth preparation margin with the restoration. A scientific method for measurement of crown margin discrepancy should be consistent, reproducible and have standardized points of measurement. This may be accomplished by sectioning the crown-die complex and viewing in cross section. A biologically oriented rationale emphasizes the factors that affect accumulation of plaque and the microbiologic environment around crowns. The samples were sectioned faciolingually and mesiodistally. Plastic overlays were used to determine vertical and horizontal marginal discrepancies of emergence profiles of margins. Three observers found out that by using this method an interobserver variance was 9mm for vertical discrepancy and 10mm for horizontal discrepancy. In a biologic standpoint with subgingival margin placement, it was stated that a crown margin emergence profile that is continuous with the root surface is most desirable. Also, an undercontoured margin is more desirable than an overcontoured margin because access for removal of excess cement during cementation and for patient plaque removal is greater with an undercontoured margin.

Sorensen A, Engelman MJ. Effect of post adaptation on fracture resistance of endodontically treated teeth. JPD 1990;64:419-24. This in vitro study examined the effect of different post designs and the amount of post-to-canal adaptation on the fracture resistance of endodontically treated teeth. 40 freshly extracted maxillary central incisors were randomly assigned to four groups of 10 teeth and were stored in saline solution. Endodontic treatment was performed and post space prepared with a No. 3 peeso reamer to within 4mm of the apex. Cast post and cores and crowns were luted with zinc phosphate cement on a static loading device. The teeth were embedded in acrylic resin and then loaded in a Instron testing machine at 130 degrees to the long axis until failure. Authors conclude that: parallel-sided posts presented a lower frequency of fracture and involved less tooth structure. Maximum adaptation to the canal with tapered posts significantly increased the mean failure threshold. Tapered posts involved greater tooth fracture oriented apically and lingually. Recommend use of taper post design.

Stein RS, Glickman I. Prosthetic Considerations Essential for Gingival Health. There is a close interrelationship between prosthesis and the establishment and maintenance of periodontal health. In the final analysis the value of prosthesis is measured in terms of the response of the periodontal tissues. Careful construction of the prosthesis is necessary to provide maximum benefit to the gingiva.

Waerhaug J. Effect of Rough Surfaces Upon Gingival Tissue. J D Res 1956;35(2)323-325. This study used diamond point to grind the subgingival enamel surface, making deep furrows and high ridges in order to determine whether or not a decided rough surface below the gingival margin will prevent healing and act as a permanent irritant. The result was that subgingival calculus or plaque was found on the experimental side more than on the control side and there was complete readaptation of a new healthy epithelial cells into all the large and small indentations in the enamel surface. This shows that it is not the rough surface that irritates, but the bacteria or their toxins. The rough surface seems to facilitate the retention of bacterial plaque.

Waerhaug J. Histologic Considerations Which Govern Where the Margins of Restorations Should Be Located in Relation to the Gingiva. Institute of Dental Research, Norwegian State Dental School, Josefinegaten 32, Oslo pg 161-177. It is better to finish the restoration above the gingival margin. Subgingival restorations are the major etiologic factors in periodontitis.

Wagman SS. The role of coronal contour in gingival health. J Prosthet Dent 1977;37(3):280-287. An important objective in replicating tooth contours of a full-coverage restoration is the control of bacterial plaque. This is accomplished by eliminating surface concavities or convexities that hamper the natural rubbing action of the lips, cheeks and tongue that debrides the surfaces of a tooth and its gingiva. Also the position of a tooth in the arch in relation to its neighboring teeth and also its axial alignment in relation to the supporting structure may produce areas of stasis and accumulation of bacterial plaque. Furthermore, morphology of the free marginal gingiva when shaped in a thick roll, accumulates plaque. This happens when gingiva recede and/or after gingival surgery around a tapered root with thick bone and gingival tissue. The ideal shape of the subgingival convexity should extend facially or lingually approximately one half the thickness of the gingivae at the height of its attachment. The crevice tends to be at an angle to the long axis of the tooth, being protected by the cervical ridge of enamel. The facial and lingual surfaces should have gradual curvatures in all directions to maintain physiologic rubbing and cleaning functions of the lips, cheeks and tongue. The same is true with interproximal contour of adjacent teeth in that moving tissues can clean or help facilitate patient performing oral hygiene procedures. Finally, it was also stated that undercontour is better than overcontour where clinical judgement is vague.

Walton JN, Gardner FM, Agar JR. A survey of crown and fixed partial denture failures: Length of service and reasons for replacement. J Prosthet Dent. 1986;56(4):416-421. Walton, et.al. in 1986 reported a survey of crown and fixed partial denture failures, length of service and reasons for replacement in 270 patients. They concluded that the mean length of service observed in their study was 8.3 years. Caries was the most common cause of failure, affecting 22.0% of the units failed and leading to the necessity for replacement of 24.3% of the units. Mechanical problems accounted for 69.5% of the failed units as opposed to 28.5% for oral disease. Resin veneer metal crown provided the longest service of all crown type observed (13.9 years) and failed most frequently because of worn or lost veneers. Metal-ceramic crowns also showed a relatively short period of service at 6.5 years needing replacement primarily because of porcelain failure or poor esthetics.

Weed RM, Baez RJ. A method for determining adequate resistance form of complete cast crown preparations. J Prosthet Dent. 1984;52(3)330-334. Tooth preparations with inadequate resistance form often contribute to dislodgement of complete cast crowns. Before crown preparations are made, factors such as length, diameter, and occlusal convergence angle must be evaluated. Generally these factors have been considered in relation to retention form only. A diagram with various degrees of occlusal convergence, which takes into consideration the length and diameter of complete crown preparations, was designed as a guide to assist the dentist to obtain adequate resistance form. To test the validity of the diagram, five groups of complete cast crown stainless steel dies were prepared (3.5mm long, occlusal convergence 10, 13, 16, 19 and 22 degrees). Gold copings were cast for each of the 50 preparations. Displacement force was applied to the casting perpendicularly to a stimulated 30 degree cuspal incline until the casting was displaced. The hypothesis that the diagram could be used to predict adequate or inadequate resistance form was confirmed by this study.

Zena RB, Khan Z, von Fraunhofer JA. Shoulder preparations for

collarless metal ceramic crowns: Hand-planing as opposed to rotary instrumentation. J Prosthet Dent 1989;62:273-7. This study was undertaken to determine whether hand-planing the gingival facial floor improved the overall fit and marginal adaptation of a collarless metal ceramic crown. An extracted caries free maxillary central incisor was prepared conventionally with high speed rotatory instrumentation. Separate impressions were made of the tooth with custom trays and poured in stone. Crowns were constructed and cemented with silicone impression material as the luting agent. The silicone films were captured in stone and sectioned. Film thickness was measured at six points on the buccal and lingual surfaces. The tooth was then modified at the gingival floor by hand-planing the margin to a smooth, flat finish, and the above procedures repeated. It was found that the fit of crowns as measured by the cement film thickness was significantly better ($p<0.005$) at the facial margin, facial, lingual incisal, and lingual surfaces for the hand-planed margins.

Zinner ID, Miller RD, Panno FV. Clinical management of abutments with intracoronal attachments. J Prosthet Dent. 1992;67(6):761-767. A method of preparing teeth to accommodate intracoronal attachments is presented. The resulting prosthesis incorporates a fixed partial denture with physiological contoured crowns and a removable partial denture with precisely determined path of insertion. These techniques discuss 1) abutment alignment, 2) guiding planes, 3) retainer housing, 4) abutment preparation, 5) retainer height, 6) supplementary retention aspects to stress the importance of surveyed diagnostic casts and coordinated tooth preparations for artificial crowns to facilitate treating complex cases.

Post And Cores In Fixed Prosthodontics

Dr. Dan Nathanson

Post And Cores In Fixed Prosthodontics

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An understanding of the importance of post and cores in fixed prosthodontic therapy is essential for the successful oral rehabilitation of a patient. Specific literature citations have been selected for review that deal with the following subjects:

1. Pin retained amalgam cores versus cast gold cores
2. Comparisons of intact endodontically treated teeth with and without endo-post enhancement
3. Tooth fracture
4. Comparisons of restorative techniques in endo-treated teeth
5. Retention of post crowns
6. Dowel form and tensile force
7. Retention of endodontic dowels.
8. Analysis of stress distribution by posts
9. Restoring endodontically involved teeth.
10. Dowel design
11. Reinforcement and coronal coverage
12. Survey of post procedures
13. Effect of ferrule design on fracture
14. SEM study of posts cemented with unfilled resin
15. Significance of retention in post and core restorations
16. Prefabricated posts
17. Root fractures with posts

Lovdahl PE, Nicholls JI: Pin retained amalgam cores vs. cast gold dowel cores. J Prosthet Dent 1977; 38:507

Pulpless teeth were treated endodontically in vitro. They were restored in two fashions: one group was restored with cast gold dowel-cores and the other group with pin amalgam buildups. A third group remained unrestored and maintained the anatomical crown with its access cavity preparation.

Teeth were loaded to failure at an angle in a testing device. The two restoration methods (cast gold dowel core vs. pin amalgam) were not significantly different, but the non restored control teeth had double the resistance of failure as compared to the two restored groups.

Guzy GE, Nicholls, JI: In vitro comparison of intact endodontically treated teeth with and without endo-post reinforcement. J Prosthet Dent 1979; 42:39.

Intact endodontically treated teeth were restored with parallel posts in vitro. A control group was also treated endodontically but remained unrestored. Loading to failure showed no differences between the two groups either in mode of failure or magnitude.

The authors explain the observed results by pointing out that bending loads applied to a tooth may cause tension and compression forces on opposing surfaces of the tooth, but a vector diagram demonstrates a zero moment force at the center of the tooth (neutral zone). An endodontic post therefore, is not an efficient method to reinforce a tooth against angular stresses.

Trabert KC, Caputo AA, Abou-Rass M: Tooth fracture: a comparison of endodontic and restorative treatments. J Endodont 1978; 4:341.

In this in vitro study the authors tries to correlate various restorative factors with increased resistance to fracture of pulpless teeth. They simulated trauma via an impact test and found that central incisors restored with stainless steel posts had a higher resistance to impact. But the use of larger posts decreased the tooth's resistance to trauma.

The most important factors to achieve resistance against impact according to this study are: 1. mesio-distal tooth diameter; 2. tooth length; 3. width of preparation. The wider the preparation, the less resistance to impact observed. There seems to be a strong correlation between the amount of remaining sound tooth structure and the tooth resistance of fracture.

Kantor ME, Pines MS: A comparative study of restorative techniques in pulpless teeth. J Prosthet Dent 1977; 34:405.

Extracted human teeth were treated endodontically and restored with various core-dowel options. Teeth were loaded to failure. While a cemented steel rod was found to provide higher resistance to fracture, teeth restored with cast dowel-cores were significantly less resistant to fracture than the control unrestored teeth.

Colley IT, Hampson EL, Lehman ML: Retention of post crowns. Br Dent J 1968; 124:63.

This is one of the original studies that determined the superior retention properties of parallel posts. A parallel sided serrated post at a length of 5.5 mm was more retentive than a tapered post that was 8.0 mm long. Surface texture was also found to be significant. At 3.5 mm length, serrated posts are more retentive (2 to 3 times) than smooth posts that are longer.

Johnson JK, Sakamura, JS: Dowel form and tensile force. J Prosthet Dent 1978; 40:645.

The authors tested the retention of parallel sided dowels in comparison to tapered dowels.

That established that parallel sided dowels are 4.5 times more resistant to tensile forces than tapered dowels.

Standlee JP, Caputo AA, Hanson EC: Retention of endodontic dowels: effects of cement, dowel length, diameter and design. J Prosthet Dent 1978; 39:401.

Three prefabricated posts (smooth tapered, parallel sided serrated and parallel sided threaded) were compared for retention as a function of shape, length and diameter. The resistance to axial displacement was higher for the threaded post and least for the smooth tapered post.

Surprisingly, the diameter had no effect on retention apparently due to the fact that most canals are irregular in shape and are never perfectly cylindrical. Post length is directly related to retention with longer posts providing significantly better retention.

The authors also established that threaded posts typically failed by dentinal fracture (i.e., longitudinal split in root) whereas parallel sided passive posts dislodged with cement adhering to post and smooth tapered posts failed at the post-cement interface.

Standlee JP, Caputo AA, Collard EW, Pollack MH: Analysis of stress distribution by endodontic posts. Oral Surgery 1972; 33:952.

In this study different post shapes were analyzed for stress distribution via photoelastic method. Tapered posts produced the highest shoulder stresses and exhibited a wedging effect. Hence, the conclusion that tapered posts may be stressful to teeth.

Ross RS, Nicholls, JI, Harrington, GW. A comparison of strains generated during placement of five endodontic posts. J of Endo 1991; 17:450.

Five endodontic posts were tested in vitro for strains generated on the outer root surface during various stages of post placement. The posts included: ParaPost Plus (non threaded), Flexi-Post, Vlock Post, Kurer Fin Lock Anchor and Radix Anchor. Strains were detected for all posts during the various stages, i.e., cementing of the non threaded post and tapping or cementing of the active posts. Kurer Fin Lock Anchor and Radix Anchor exhibited the highest strains.

Caputo AA, Standlee JP: Restoration of endodontically involved teeth. <u>in</u> *Biomechanics in Clinical Dentistry*, Quintessence Books, 1987, p. 185-203.

The authors cover a wide spectrum of issues related to biomechanical aspects of endodontic posts. These range from design factors to materials, methods of preparation and cementation, etc.

Sorensen JA, Martinoff JT: Clinically significant factors in dowel design. J Prosthet Dent 1984; 52:28.

The authors reviewed the dental records of approximately six thousand patients of nine general practitioners and came up with 1273 endodontically treated teeth. Various statistics were performed to correlate type of stabilization/restoraion with success rates. The authors reported the following success rates observed: cast parallel sided posts (cast Para-Post) - 100% success rate; Para-Post with amalgam or composite core build-ups - 97% success rate; custom tapered cast post and cores - 87% success rate; endodontic treatment without dowel - 90% success rate.

A correlation was also found between dowel length and success rate. Dowels equal in length to the crown had a 97% success rate. Dowels with a length of 1/4 the crown had a 75% success rate.

Sorensen JA, Martinoff JT: Intracoronal reinforcement and coronal coverage: A study of endodontically treated teeth. J Prosthet Dent 1984; 51:780.

This study is based on a retrospective survey of 9000 patient records and involves 1273 endodontically treated teeth.

The authors divided the teeth into 6 groups according to anatomical location (maxillary and mandibular anteriors, premolars and molars). They tried to correlate the use of dowels with increased resistance to fracture in different groups. The authors found no significant increase in tooth structure resistance to fracture due to the use of dowels in any of the anatomic groups.

Goldstein, GR, Hittleman E. Survey of post procedures. New Yory State Dent J 1992; 32:5.

The authors conducted a survey among highly qualified general practitioners and board certified prosthodontists to determine their preferences in use of post and cores.

Despite evidence from in vitro studies that tapered posts are less retentive and may cause more root fracture than parallel posts, 58 out of 104 general practitioners (56%) and 13 out of 23 surveyed boarded prosthodontists (65%) who use cast posts, still utilize tapered posts.

The authors conclude that possibly there is no problem with tapered posts in vivo despite evidence derived from in vitro testing.

Sorensen JA, Engelman MJ, Mito W: Effect of ferrule design on fracture resistance of pulpless teeth. J Dent Res 1988; 66:343.

In an attempt to evaluate the effect of ferrule design on fracture resistance of extracted teeth, six groups were created with various ferrule designs. Cast parallel posts were used and all teeth were crowned.

Ferrule design either at the cast core-tooth junction or the crown margin-tooth junction had no effect on resistance to fracture. But extending the coronal tooth structure one mm above the crown preparation shoulder doubled the fracture resistance of the tooth.

The authors conclude that crown lengthening should be considered whenever coronal tooth structure is compromised to the gingival level.

Goldman M, DeVitre R, White R, Nathanson, D: An SEM study of posts cemented with an unfilled resin: J Dent Res 1984; 63:1003.

This study relates to a post cementing method that utilizes canal smear layer removal and a low viscosity resin cement to secure the post.

SEM photos showed the effect of smear layer removal with EDTA (17%) and NaOCl (5.25%) leaving the canal dentin clean and the dentinal tubules open. The low viscosity resin cement flows into the tubules by capillarity to considerable depth and can provide "passive" retention system for endodontic posts.

Nathanson D, Dias K, Ashayeri N: The significance of retention in post and core restorations. Pract Perio and Aesthet Dent 1993; 5:82.

A technique for endodontic post cementation with a low viscosity resin cement is described. The technique is applicable to prefabricated or cast posts and offers high retention in spite of being passive. It involves smear layer removal from canal prior to cementing with resin. A comparison of 3 cementing methods for retention of prefabricated posts was reported. The low viscosity resin cement had the highest retention, followed by a glass ionomer cement and a composite resin cement. The authors concluded that a passive cementing technique that offers good retention may minimize harmful stresses in the root.

Deutsch AS, Musikant BL, Antenucci G, Giusti P: Adaptation of a prefabricated post to dentin. J Prosthet Dent 1985; 53:182.

Flexi Post, a threaded post with a split shank (to absorb insertion stresses) was examined in 20 extracted single rooted teeth. The teeth were sectioned longitudinally and examined. The findings included:

- The split shank displaced inwardly
- The self-tapping action of the threads was gradual
- The post was completely enclosed in cementing medium
- Only the threads engaged the dentin
- The shaft of the post and the "second tier" were separated from the dentin by approximately 0.1 mm of cement, while the threads engaged the dentin.

DAN NATHANSON

Millstein PL, Yu H, Hsu CS, Nathanson D: Effects of cementing on retention of a prefabricated screw posts. J Prosthet Dent 1987, 57:171.

This study evaluated the retention of Flexi-Post (EDS) in extracted teeth using various cements including three composite resin cements and Z.O.P. as control.

Zinc phosphate cement produced the highest retention and was the least sensitive to use (or lack of use) of lentulo spirals. The three composite resin cements gave better retention when cement was spun into canals. A significant portion of Flexi-Post's retention derives from threading the post into the root dentin.

Boyarsky H, Davis R. Root fracture with dentin retained posts. American J Dent 1992; 5-11.

This in vitro study examined the incidence of incomplete root fractures in extracted teeth subjected to different treatments.

Eight extracted mandibular canines were treated either with pulpectomies (control group, n=20) or endodontic therapy with lateral condensation of gutta percha (n=60). The root canal treated teeth were restored with Flexi Posts (n=20), Vlock dentin-retained posts (n=20) and no post (n=20). All teeth were placed in red stain for 5 days then sectioned at 4 levels and the sections microscopically evaluated for fractures.

None of the control group teeth (pulpectomy only) were fractured. Some incomplete fractures were observed in the other groups. The incidence of incomplete fracture (10%) was the same in all other groups, leading the authors to the conclusion that the two active posts tested are not more likely to cause tooth fracture than conventional endodontic therapy alone.

Nayyar A, Walton RE, Leonard LA: An amalgam coronal radicular dowel and core technique for endodontically treated teeth. J Prosthet Dent 1980; 43:511.

A technique introduced by the authors suggests the use of amalgam for a coronal-radicular build-up in lieu of a separate post and core. This technique requires adequate remaining sound tooth structure with one (or preferably two) walls of dentin. The technique calls for removal of gutta percha from pulp chamber and several mm in canals. Using a fast setting amalgam (condensed with aid of a matrix band), a crown preparation may be completed in a relatively short session.

A follow up for 4 years of 400 teeth treated by this technique showed no failures due to the coronal restoration method.

Treatment Sequencing Of The Prosthodontic Patient

Dr. Kenneth A. Turner

"TREATMENT SEQUENCING OF THE PROSTHODONTIC PATIENT"
Kenneth A. Turner, D.D.S.
October 1993

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Biomechanics In Fixed Prosthodontics

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BIOMECHANICS IN FIXED PROSTHODONTICS

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Biomechanics re: Endodontically Treated Teeth

1. Photoelastic analysis of stress transfer by endodontically treated teeth to the supporting structure using different restorative techniques

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A photoelastic model was used to examine the influence of different types of restorations placed following endodontic therapy, emphasizing the way in which forces applied to the occlusal surface were dispersed to the supporting structures of the teeth. Stresses were photographed in the polarized light field. Findings indicate that distribution and patterns of stresses vary depending on the direction of the loads and the nature of the involved restorative procedures. (J Prosthet Dent 1989; 61:535-43).

2. Load transfer of posts and cores to roots through cements

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This study evaluated differences in load transfer when cast posts are fixed to roots with different cements. Cast posts and cores were cemented with 40 endodontically prepared teeth by using four different cement mediums. The load exerted on the root surface through the post was evaluated using a strain gauge. The increased flexure after cementation was statistically analyzed. In conclusion, there was load transfer from post to root structure when posts were cemented, but no difference was found between cementation mediums. (J Prosthet Dent 1989; 62:298-302).

3. Stress distribution surrounding endodontic posts

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This study compared the stress distribution during insertion and function of three prefabricated endodontic posts with different designs using the criteria of post length and diameter. Test blocks of photoelastic material were prepared with simulated endodontic canals. Three posts for each design, diameter, and depth were cemented. Each specimen was examined and photographed without load, with 135 Newton (N) compressive force, and with 90 N and/or 135 N oblique force applied at 26 degrees by use of a circular polarscope. Para-Post and Para-Post Plus posts produced similar, evenly distributed patterns of stress using the criteria of diameter, depth, and load. Flexi-Post posts produced asymmetric stress patterns with concentration of stress at each thread. During compressive loading and after cementation alone, Flexi-Post posts displayed significantly higher shoulder stresses and substantially greater stresses along the coronal surface of the post's length than Para-Post and Para-Post Plus posts. Apical stresses were similar for Flexi-Posts, Para-Post, and Para-Post Plus posts during compressive loading. (J Prosthet Dent 1990; 64:412-8).

4. Stress analyses of four prefabricated posts

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A two-dimensional photoelastic stress analysis method was applied to study the relative magnitude of stress and concentration induced by four commercially available posts for endodontically treated teeth. Three types of threaded posts; V Lock, Radix Anchor, and Flexi-Post, and one nonthreaded prefabricated post, the Para-Post Plus post were tested. Stress was recorded at installation, at vertical and inclined load, and the threaded posts were compared with the nonthreaded post. At installation and on loading, stress was induced where posts were in contact with the model. Higher apical stresses were demonstrated for the Para-Post Plus post whereas the threaded posts concentrated stress where they engaged the model through threads or flanges. (J Prosthet Dent 1992;67:30-3).

5. Effect of core materials on stress distribution of posts

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Severely damaged endodontically treated teeth require the use of a post and core for the retention of the restoration. The choice of material for a post and core and their stress -producing characteristics must be considered by the clinician. Two-dimensional photoelastic analysis of birefringent models was used to investigate the influence of different core materials on the stress distribution of nonthreaded cylindrical posts. Cast posts and cores and prefabricated posts with amalgam and composite resin cores were compared with posts without cores at installation and under two loading conditions. The findings indicate a significant difference between posts with and without cores. It appears that the stiffer core materials can shift the load from the apex to the coronal region. (J Prosthet Dent 1992; 68:416-20).

6. Effects of posts on dentin stress distribution in pulpless teeth

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A finite element analysis was carried out to study the roles of posts in reducing dentin stress in pulpless teeth. Two-dimensional plane strain models of the midlabiolingual section of a human maxillary central incisor were first analyzed. The results showed that the gold alloy post reduced maximal dentin stress by as much as 30%. However, the integrity of the dentin was compromised and the effects of the post were likely to be exaggerated in such models. In an effort to correct for these problems, plane stress models with side plates and axisymmetric models were analyzed. Posts were found to reduce maximal dentin stress by only 3% to 8% when the teeth were subjected to masticatory and traumatic loadings in these latter models. Although posts reduced maximal dentin stress by as much an 20% when the teeth were loaded vertically, teeth such as incisors and canines normally are not subjected to vertical loadings. Thus the reinforcement effects of posts seem to be doubtful in these teeth. (J Prosthet Dent 1992;68:421-7).

7. Root fracture in endodontically treated teeth related to post selection and crown design

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Standardized plastic analogues simulating an endodontically treated maxillary central incisor root were used to investigate the resistance to root fracture in endodontically treated teeth. Three different posts and core systems were used: 1) cast post and core, 2) Para-Post Plus post, and 3) Flexi-Post post. The core build-up material selected n this study was Ketac Silver material, after which a crown preparation was made on each analogue. Two types of preparations were used; a wide chamfer margin (butt joint) and a wide chamfer margin with a 1.0 mm circumferential bevel. An overcasting was fabricated and was permanently cemented an each preparation. Assemblies were subjected to an increasing lingual oblique force until fracture occurred. Results were tabulated using the analysis of variance (F-test) and Student's t-test. Beveled preparations with a concomitant final restoration provided a significant increased resistance to root fracture. Furthermore, vertical fracture occurred twice as often with nonbeveled preparations. (J Prosthet Dent 1992;68:428-35).

8. The retentive and stress distributing properties of split threaded endodontic dowels

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A threaded, parallel-sided endodontic dowel that has a longitudinal split was tested to determine its retention and stress distribution properties. Photoelastic stress analysis revealed high installation stresses unless the dowels were counter-rotated. Axial loading created stresses at the threads, with elevated coronal and apical stresses. Even higher coronal stresses were recorded with inclined loads, and shorter dowels generated greater stresses than longer dowels. The retentive values were generally lower than those in comparable studies (J Prosthet Dent 1992; 68:436-42).

9. The resistance to tensile, compression, and torsional forces provided by four post systems

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This study measured the force required to displace four different endodontic posts (an experimental, Para-Post, Flexi-Post, and V Lock) when tensile, torsion, or compressive forces were applied. Extracted mandibular premolars were decoronated at the cementoenamel junction, the roots were divided into groups of similar size, and the pulpal tissue was removed. The canals were enlarged, cleaned, and filled with gutta percha. Post preparations were made, and the posts were cut and cemented into the post spaces with resin cement. The roots were notched with a separating disc and lowered into a metal tube filled with acrylic resin. Two Minim pins were placed into the coronal dentin paralleling the post. Composite resin cores were made around the coronal 4 mm of the posts and the two pins for 10 specimens from each group. The specimens were placed into a standardized fixture and a load applied until failure. The tensile load required to pull the experimental post and resin was significantly less than the load required to remove the threaded posts. Flexi-Posts provided the greatest resistance to torsion and tensile loading. The compressive load required to fracture the core over the V-Lock post was significantly greater than the other post systems. (J Prosthet Dent 1992; 68:899-903).

Biomechanics re: The Tooth

1. Effect of a dilacerated root on stress distribution to the tooth and supporting tissues

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The configuration of the root of a prospective abutment tooth has a significant influence on its potential load-bearing capacity. Dilaceration is an angulation in the root or crown. Thin abnormality may also affect the stability and longevity of an abutment. Finite element stress analysis was used to investigate the effect of a root dilaceration on stress distribution to the tooth and its' supporting structures. A normal and a dilacerated single-rooted tooth under three loads (axial, disto-oblique and mesio-oblique) were analyzed and compared. The results indicated that a dilaceration concentrates the stresses in the supporting structures and may be taken into consideration as a risk factor in abutment selection. (J Prosthet Dent 1991; 65:771-77).

2. Stresses at the dentinoenamel junction of human teeth – A finite element investigation

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A three- dimensional, linear, elastic finite element model of a maxillary first premolar from longitudinal ground sections was developed to investigate stress variation in the enamel and dentin adjacent to the dentinoenamel junction (DEJ). The effect of regional variation in the contour of the DEJ on the stress patterns for enamel and dentin was also analyzed. The normal (compressive or tensile) and shear stresses in the dentin and enamel surfaces of the DEJ were computed for a vertical load of 170 N acting on the entire occlusal surface of the model. The normal stresses in dentin and enamel were maximized on the occlusal surface of the model and diminished along the buccal and lingual surfaces of the DEJ. However, the magnitude of the normal stresses increased at the cervical enamel, which also showed increased values for shear stress distribution. The normal and shear stresses were markedly affected by the contour of the DEJ and at the thickness of enamel in the occlusal third on the buccal and lingual surfaces. The results suggested that because the mechanical interlocking between enamel and dentin in the cervical region is weaker than in other regions of the DEJ, enamel in this region may be susceptible to belated cracking that could eventually contribute to the development of cervical caries. (J Prosthet Dent 1991; 66:451-59).

3. Effect of cavity depth on stresses in a restored tooth

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Restorative procedures commonly replace lost tooth structure, but redistribution of functional stresses after treatment is not fully understood. Many restorative methods are dictated by the integrity of the remaining tooth structure, because sparse tooth structure can lead to fracture. It is essential to prevent fractures by having a clear concept of the designs for cavity preparations, and to anticipate the stresses of mastication on the remaining tooth structure. Knowledge of various internal parameters of cavity designs would facilitate selection of the appropriate cavity preparation for a specific clinical situation. Three cavity designs and restorations were examined in this study for stresses using the finite element technique. After placement of restorative materials, the dentin experienced a dramatic change in stress gradient immediately below the pupil wall, and this response was magnified in deeper cavity preparations. Enamel also exhibited major alterations in the stress gradient in all three designs of cavity preparations. The combination of the changes can cause cracks in the remaining tooth structure, leading to cusp fracture immediately adjacent to the deepest portion of the cavity. (J Prosthet Dent 174-83).

4. The wear of enamel opposing shaded ceramic restorative materials: An in vitro study

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The wear rate of intact human enamel opposed by Olympia porcelain gold, Dicor, Ceramco porcelain, and externally shaded Dicor and Ceramco was investigated with an artificial oral environment. The enamel-material couples were subjected to 300,000 masticatory cycles at a maximal occlusal force of 13.4 N while they were continuously bathed with 37 C deionizod water. Both the enamel and material surfaces were analyzed by use of a three-dimensional surface monitoring computer program, AnSur, to record the removal of the material and the maximal loss of vertical height. The enamel opposing the externally shaded materials abraded two to five times more than that opposing the unshaded materials and 10 to 15 times more than enamel opposing gold. The wear rates for enamel opposing the gold and unshaded Dicor were similar both in the removal of material and in the loss in vertical height. (J Prosthet Dent 1992;68:42-8).

Biomechanics re: Fixed Prosthetic Restorations

1. Fixed cantilever splints on teeth with normal and reduced periodontal support

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Photoelastic models were used to visualize stresses developed in teeth and supporting bone by cantilever fixed partial dentures where the most distal abutments had either crater or trough osseous defects. The effects of splinting the periodontally involved teeth to one or more additional sound teeth were studied. It was shown that for a cantilever fixed partial denture with either normal periodontal support, or a distal abutment with a moderate degree of mobility and bone loss, the following can be concluded: (1) occlusal forces on a cantilever fixed partial denture were significantly distributed to only the three teeth closest to the loaded cantilever, (2) optimum stress reduction occurred with the splinting of a periodontally compromised tooth to two periodontally sound teeth. Increasing the number of splinted abutments did not result in a proportional reduction of stress in the periodontium, and (3) no significant cross-arch sharing of occlusal loads was seen. (J Prosthet Dent 1991;66:737-42).

2. Flexion characteristics of four-unit fixed partial denture frameworks using holographic interferometry

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Flexion of a metal/ceramic fixed partial denture (FPD) framework under function can cause fracture of the porcelain or deterioration of the cement seal. This study evaluated the flexion under compressive load of a four-unit mandibular FPD replacing the second premolar and the first molar. Testing was accomplished with elapsed time holographic interferometry, using 39 porcelain fused-to-metal frameworks cast with a silver-palladium alloy. The results demonstrated that solder joints at the junction of the premolar and molar pontics flexed under a reduced compressive load and exhibited a higher failure rate than other connector designs. (J Prosthet Dent 1992;67:609-13).

3. Influence of occlusion on posterior cantilevers

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The incorporation of posterior two-unit cantilevers in fixed prosthodontics is generally discouraged because of the assumption that large posterior chewing and biting forces might jeopardize the prosthesis and the abutment teeth. This investigation was performed to study (1) the distribution of chewing and closing forces in dentitions with cross-arch bilateral posterior two-unit cantilever fixed partial dentures and (2) the influence of different occlusal arrangements on the magnitude of these forces along the cantilever segments. Six patients were included in the study. Axially directed closing and chewing forces were measured with miniature cantilever units. In ideal occlusion, occlusal forces decreased considerably along the cantilever segments in the distal direction. Infraoccluding the distal cantilever unit by 80 um had little influence on the magnitude of the initially small local force in this region, whereas an 80 um high primary occlusal contact considerably increased the local force over the distal cantilever unit. The clinical implications of the results are discussed. (J Prosthet Dent 1992;67:645-52.)

4. Three-dimensional finite element stress analysis of a cantilever fixed partial denture

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A three-dimensional mathematical model was generated, representing a three-unit cantilever fixed partial denture and its supporting mandibular structures. First and second premolars were used as abutments with one posterior cantilever pontic. A 5 lb. vertical load was applied to the pontic. Vertical and horizontal stresses were analyzed by means of a three-dimensional finite element stress analysis technique. The results showed that a cantilever pontic creates considerable compressive stress on the abutment nearest to the pontic and produces tensile stress on the abutment farthest from the pontic. (J Prosthet Dent 1992;68:243-48.)

5. Stresses induced by different loading around weak abutments

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Stresses and deflections of abutments induced by various loadings were analyzed with a two-dimensional finite element model. The biomechanic system consisted of the mandibular posterior three-unit fixed partial denture (FPD). Four different loading types were analyzed: (1) a distributed force of 600 N; (2) concentrated nonaxial and (3) axial 300 N forces at the marginal ridge of the molar; and (4) a concentrated vertical 300 N force at the center of the pontic. All computations were conducted for three different alveolar bone levels. The premolar exerted a greater pressure during occlusal loadings (except axially) on the alveolar bone than the molar. According to the stresses induced in the alveolar bone, the most critical loading was the distributed force. With diminishing periodontal support, stresses elevated in the biomechanic system and critical increases more noted for the concentrated nonaxial load on the molar. (J Prosthet Dent 1992:68:879-84.) .

Biomechanics re: Stomatognathic System

1. Orthodontic Therapy for the restorative patient. Part 1: The Biomechanic aspects

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The integration of interspecialty treatment before the restorative and prosthodontic efforts of the dentist can eliminate conditions that have the potential to jeopardize successful completion of the proposed treatment. Adult dentitions that have deteriorated because of neglect, fear, caries, extractions, or trauma can be restored to stability, health, function, and esthetics. In "Part 1, The biomechanic aspects, the orthodontic paralleling of proposed abutment teeth displays premolar (buccolingual) and molar (mosiodistal) uprighting procedures that achieve improved force distribution to these teeth. Molar intrusion (occlusoapical) to improve an occlusal plane distribution of adverse forces to the proposed opposing fixed partial denture is discussed. These vexing problems facing successful reintegration of the altered states of occlusal relationships frequently can be answered by the incorporation of preprosthodontic corrections. (J Prosthet Dent 1989;61:268-76.)

2. Biomechanical model of the human mandible: A hypothesis involving stabilizing activity of the superior belly of lateral pterygoid muscle

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A new biomechanical analog for the human mandible is proposed. The biomechanics of the human mandible can be explained by a simple support model, where muscular forces are produced by the masseter, medial pterygoid, temporal, and superior lateral pterygoid muscle components, and reaction forces are produced by the occlusal surfaces and condyle. All forces are resolved into components orthogonal and parallel to the temporal articular plant (articular eminence). In this model, one component of muscular forces in parallel to the temporal articular plane. The influence of the inclination of the occlusal plane, the inclination of the temporal articular plane, the position of the resultant of the occlusal reactions, and the relative contribution of the different jaw elevator muscles an the parallel and orthogonal components are evaluated according to a computer model of the system. The muscular force parallel to the temporal articular plane may be produced by the superior lateral pterygoid muscle, which during clenching acts an a stabilizer of the mandibular condyle to prevent posterior dislocation and compression of nonarticular tissues. (J Prosthet Dent 1992;68:829-35.)

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Section Two - Maxillomandibular Relationships, Their Recording And Articulators

Section Two contains information related to the relationship of the mandible to the maxillae, joint anatomy, and ;orientation, how to record the jaw relationships, and the transfer of the recorded information to an instrument of choice. All of oral rehabilitation begins with this information regardless of whether the patient is edentulous, partially edentulous, or has a full compliment of teeth with the need for some restorative therapy. The authors and the titles of their presentations related to this section's topics are:

Dr. Donna L. Dixon

"Articulations And The Prosthodontic Patient"

Dr. Stephen J. Riedy

"A Review Of The Articulator"

Dr. Charles C. Kelsey

"Review Of Maxillomandibular Relationships"

Dr. Joseph A. Clayton

"Pantographic Recording Of Mandibular Movements"

Articuation And The Prosthodontic Patient

Dr. Donna L. Dixon

ARTICULATION AND THE PROSTHODONTIC PATIENT

DEFINITIONS OF CENTRIC RELATION

The centric relation record is the most important and the most difficult maxillomandibular relation record to make.[1] Centric relation is currently defined as: a maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks, with the complex and the anterior-superior position against the slopes of the articular eminencies. This position is independent of tooth contact, and it is clinically discernible when the mandible is directed superiorly and anteriorly and restricted to a purely rotary movement about a transverse horizontal axis. This term previously referred to the most posterior relation of the mandible to the maxillae at the established vertical dimension of occlusion.[2]

Historically, the term "centric relation" has meant different things to different people. Sheppard[3] and Shanahan[4] felt that the centric relation of the mandible to the maxillae occurred when an individual swallowed. Baer[5] believed that this position was coincident with the physiologic rest position. Page[6] and Rader[7] said that there was no practical way of locating this position.

Shpuntoff and Shpuntoff[8] wrote an article regarding the determination of the centric relation position using electromyography. They suggested that a single channel high gain differential electromyograph may be used to determine the physiologic rest position and centric position. When studying 215 normal adults they found the characteristic electromyograph coincided with the centric position in these individuals. They suggested that the many methods of recording the centric relation position may be studied and compared by using the electromyographic technique.

Hickey[9] believes that the centric relation position is the only position from which even occlusal contact can be established in all other mandibular positions. He believes, therefore, that a recording of this position is necessary when fabricating complete dentures. Kingery[10] explained that there are two requirements of a centric relation record: 1) it must record a correct horizontal relationship of the mandible to the maxillae; and, 2) equilibration of vertical contacts of the denture-supporting areas must occur.

If pathology of the joint is not present, this relationship is reproducible.

Centric relation, in a normal individual, is thought of as ligamentous position. All muscles attached to the mandible must be relaxed to achieve a repeatable centric relation record. There are three requirements for making such a centric relation record: 1) to record the horizontal relation of the mandible to the maxillae; 2) to apply equal vertical pressure; and, 3) to keep the completed record in a condition where it will not distort until the casts have been mounted. It is necessary that the recording medium is a constant consistency. The medium must not resist the forces exerted by the muscles.[1] It has been emphasized that centric relation is not a resting mandibular position, but that it definitely is repeatable.[9,11] Such a record should be made at the appropriate vertical dimension of occlusion.[9]

RECORD BASES

Graser in 1978[12] and Klein and Soni[13] in 1979 agreed that the jaw relation record is only as accurate as the bases on which the recording is made. Elder[14] stated that record bases: 1) must have borders that are adapted similarly to the finished base; 2) must be rigid; 3) must be dimensionally stable; 4) must be fabricated quickly, easily, and without undue expense; 5) must not have an undesirable color; and, 6) must be able to be used as a base for setting denture teeth.

Tucker[15] in 1966 added other requirements to Elder's list of six. He said that these bases must take advantage of desirable undercuts. They must not abrade the casts upon removal and replacement; and, they must bond with the material used to block out the undercuts.

Elahi and Abdullah[16] looked at the effect of five different fabrication techniques on the dimensional stability of record bases. The most discrepancy noted at the mid palatal area of the base to the maxillary casts occurred with the technique where the autopolymerizing resin was applied to the cast and then was immersed in water in a pressure pot undisturbed for three minutes. The least discrepancy in the mid palatal area occurred with a technique where a humidor with monomer vapor was used during the polymerization process.

In 1994 Loney[17] discussed a way of making stabilized record bases for implant-retained overdentures. The technique that he described involved the use of elastomeric caps that are incorporated into the record base, which could be used for retention of the base over the implant components. This, therefore, simplifies the registration of the jaw relationship by generating stability.

In 1978 Graser[12] described the procedure for making completed bases for complete denture jaw relation records. He stated that is easier to record the maxillomandibular relation with these bases because they have the retention and stability of the completed denture. A disadvantage to using completed bases is that there is an increase in time and expense.

RECORD CATEGORIES-DIRECT RECORDINGS

Centric relation records may be grouped into four categories. These four categories are: direct interocclusal records, intraoral and extraoral graphic recordings, functional recordings, and cephalometrics.[18] The direct interocclusal recording is also referred to as the physiologic method[1] or the static recording method.[11] In the 1700's Pfaff first described the technique.[19] It is necessary that the patient's proprioceptors and tactical sense are functioning normally to make an accurate record using this method. It is also necessary that the dentist's visual acuity and sense of touch are functioning normally. Three factors that influence interocclusal direct records are: 1) the amount of pressure exerted on the displaceable tissue in the joints and the equalization of such pressure; 2) the patient's comfort that, in turn, depends on the stability of the record bases; and 3) the number of reference points used to make the record. For instance, a record made using cusp tips is more acceptable than one where only wax or monoplane teeth are used. Such direct records are indicated when the maxillae and mandible are abnormally related and supporting tissues are displaceable, when an abnormally large tongue is present, and when abnormal mandibular movements occur.[1] Hickey[9] wrote that these records were relatively easy to make and that he preferred this type of record due to it simplicity. The direct interocclusal record was the most commonly used recording method until the end of the 19th century.[18]

Hanau[20] was one of the first people concerned with pressure equalization when completing direct interocclusal records. When writing about pressure equalization, he coined the term "Realeff". This word is formed by the beginning letters of "resilient and like effect". Wright[21] and Block[22] agreed that no pressure should be applied when making a record using the direct method. Schuyler[23], Payne[24], and Trapozzano[25] stated that light pressure should be used when making a direct record. Greene[26] invented a Pressometer in an attempt to equalize the pressure when recording the centric relation position by the direct method. Kingery[10] discussed two fundamental principles that contribute to the success of the direct recording method: 1) the dentist's ability to recognize the centric relation position; and, 2) understanding that the recording medium directly influences the pressure developed in the recording and the subsequent equilibration of the recording.

In 1979 Akerly[27] described a tripodal method of recording centric relation. He further classified this type of method as a direct method of recording this jaw relationship. This was a minimum pressure technique that can be quickly and accurately verified. A series of three chrome-cobalt tacks were placed in the mandibular occlusion rim. The jaw relation record is completed and the tacks make an indentation into the maxillary occlusion rim as the registration is being made.

Shanahan[28] used a physiologic approach to recording centric relation records. He placed cones of soft wax on the mandibular occlusion rim, and the patient was asked to swallow repeatedly. He felt that during swallowing, the tongue forced the mandible into the centric relation position. The cones of soft wax were then moved and centric relation was recorded.

GRAPHIC RECORDINGS

The next type of recording is the graphic method. This method records a tracing of the mandibular movements in <u>one plane</u>. The apex of a tracing made in this manner indicates the most retruded relationship of the mandible to the maxillae; and, from this retruded relationship, lateral movements may take place. These methods may be accomplished either intraorally or extraorally, depending upon where the recording device is placed. Extraoral tracings are larger than intraoral tracings; therefore, the apex is more easily seen on these tracings. The earliest graphic recording techniques were based on studies completed by Balkwill.[29] The first needle point tracing was completed by Hesse and this technique was improved about twenty years later by Gysi.[30] Gysi's tracer was an extraoral tracer.[31] Sears took the Gysi tracer and used lubricated rims for the movements to be accomplished easier. Sears[32] placed the needle point tracer on the mandibular rim, and on the maxillary rim he placed the plate. He cemented the rims together for removal. When completing a graphic tracing, it is important that twelve factors are considered: 1) the record bases may become displaced if the central bearing point becomes "off-center" when the mandible moves into excursive positions; 2) if a central bearing device is not used, more resistance to horizontal movements occurs with the occlusion rims; 3) it is very difficult is locate the center of the arches (so that the forces may be centralized); 4) when a patient's tissues are easily displaced, it is very difficult to achieve a stabilized record base; 5) ridges that have no vertical height also cause difficulty in stabilization of a record base; 6) large tongues result in difficulties in record base stabilization; 7) recording devices may not be compatible with normal physiologic mandibular movements; 8) the tracing is considered unacceptable with a blunted apex- only sharp or pointed apexes are considered acceptable; 9) if double tracings occur, this usually indicates that the movements were not coordinated or recordings were made at a different vertical dimensions of jaw separation (if double tracings occur, then it is necessary to make additional tracings); 10) it is necessary to perform the graphic tracing at the predetermined vertical dimension of occlusion; 11) graphic methods record eccentric relations; and 12) such graphic methods of recording are thought to be the most accurate visual means of recording centric relations with a mechanical instrument. It must be remembered, however, that all graphic tracings are not totally accurate.[1] Hanau[33] did not believe that the graphic recording was the most accurate record, but he finally conceded that the Gysi tracing was satisfactory to verify records. He still believed that universal usage was not appropriate.

Extraoral tracings are also referred to by two other names: Gothic arch tracings and arrow point tracings. Intraoral tracing devices are referred to as combination central bearing points with needle point tracings.[11] Yurkstas[34] also wrote about the intraoral tracing procedure. He referred to the many objections or criticisms of this procedure by prosthodontists. Trapozzano[25] was one individual who criticized the procedure. He did not believe that central bearing points equalize pressure. Trapozzano said that this equalization of pressure will result only if two conditions are present: 1) normal ridge relationships- resulting in an ability to place the central bearing point in the center of the foundational basis; and, 2) firm mucosa. Payne[24] stated that any type of apparatus placed intraorally may cause discrepancy in recordings.

Yurkstas[34] evaluated the wax record and the intraoral tracing regarding reproducibility. Thirty-five edentulous patients participated in his study. Their occlusal vertical dimensions were held constant throughout the experiment. This author emphasized that many variables occur that can affect the results of a recording procedure. In the wax recording procedure, it was found that the consistency, the hardness of the wax, the bilateral homogeneity, the amount of occlusal contact, and the presence (or absence of) anterior freedom significantly influence the dentist's ability to duplicate the records. For the intraoral tracing procedure, the central bearing point location, and the inclination of the central bearing point in relation to the tracing plate and the inclination of the tracing plate relative to the underlying bearing surfaces all play important parts in being able to duplicate the records. The results of this study led Yurkstas to recommend that centric relation records be made with accurate base plates, under very little pressure, and that the pressure be centralized and distributed equally or uniformly to the underlying tissues.

Stansbery[35] then introduced a technique that used a curved plate mounted on the maxillary rim. The central bearing screw was attached to a mandibular curved plate; and, after the extraoral tracing was completed, plaster was introduced between the plates to form a biconcave registration. Hall[36] also used this type of technique, however, he used compound instead of plaster for the record.

Later, in the 1940's & 1950's the central bearing point was used to produce a Gothic arch tracing. Hardy[37] and Pleasure[38] described the use of the Coble Balancer. Hardy[37] and Porter[39] used a round bur to make a depression at the apex of the intraoral tracing, and this enabled the patient to hold the bearing point into the depression while the plaster was injected and was subsequently setting.

Phillips[40] recognized that lateral movements would cause interferences of the occlusion rims and this could cause a distorted record. He developed a plate for the maxillary occlusion rim and a tripoded ballbearing mounted on a jackscrew for the mandibular occlusion rim. The occlusion rims were removed; and, after the patient had produced what he thought to be an appropriate extraoral tracing, he softened compound and inserted this between the trial bases. This innovation by Phillips was called the central bearing point; and, as stated earlier, this central bearing point produced equalization of pressure on the supporting tissues.

Silverman[41] decided that he would solve the problem of obtaining an "exact" centric occlusion. He decided that he would do this by incorporating a biting point on an intraoral centric bearing device along with his method of measuring the vertical dimension by means of tattooing the alveolar ridges. He mounted the bridge portion of the intraoral central bearing device on the mandibular wax occlusion rim, and the stylist portion was attached to the maxillary baseplate. The wax rim was removed from the baseplate. He stated that he placed the central bearing device centrally, and in approximately the second premolar to first molar area, to avoid tipping the bases. The patient then was told to bite or repeatedly tap the upper pin against the mandibular base. He did not ask the patient to close lightly. In fact, the patient was told to bite very hard- with dynamic pressure. Because such a hard biting force was used, he believed that the closing musculature placed the mandible in the most retruded functional position. After the patient bit with this pressure, a mark was made on the disk, and this is what was called the "biting point". The biting point was accentuated with a round bur, permitting the patient to lock into this depression. Silverman noted that the resultant biting point was at the apex of the Gothic arch tracing with some individuals, anterior to the apex with some, and posterior to the apex with others. The record that he made with the indentation point was used for mounting purposes whether or not it corresponded to the Gothic arch apex. Boos[42] stated that the centric relation position is not always at the apex of the Gothic arch tracing.

In 1962 Walker[43] completed a study to investigate two methods of recording the centric relation position. The two methods were the physiologic (or swallowing method) and the graphic (or needle point tracing method). In his graphic method he used an extraoral stylist attached to the maxillary occlusion rim. He considered that the jaws were in centric relation when the stylist was at the apex of the tracing. The physiologic method he investigated used the act of swallowing to register the centric relation position; and, to obtain this record, metal studs were embedded in the mandibular occlusion rim. An analyzing instrument was used to measure the differences between the various relationships recorded at five points in space. Twenty-one edentulous subjects participated in the study. The graphic method did not locate the mandible in the same position as did the swallowing or physiologic method. The mandible was found to be in a more posterior relationship to the maxillae when recordings were made using the graphic method. Walker studied the physiologic position because Niswonger[44] stated that during swallowing, the mandible travels from rest position to the centric relation position and back to the rest position again. Those people who did not believe in recording centric relation during swallowing or by using the physiologic method were known as "mechanistics".[43] Some people in the mechanistic school of thought felt that it was unscientific to record centric relation without finding the hinge axis of the mandible.[45,46] The conclusion that Walker[43] reached in his article was that swallowing was found to be unreliable for the registration for centric relation; however, swallowing could be valuable when determining various habitual positions of the patients' mandibles.

In 1976 Hunt and Yoxsimer[47] wrote regarding the displaceability of occlusion rims to which clutches were attached to complete a pantographic tracing. These authors described the technique of using "vacustatics" to stabilize the clutches.

In 1967 Schoen and Stewart[48] conducted an experiment to compare the accuracy of temporary (autopolymerized) record bases and permanent (heat processed) bases regarding differences in generated centric relation records. In this experiment an intraoral tracing was made with a temporary base and the other with a permanent base (on the same patient). Five denture wearing patients participated in this study. Results from this study indicated that there were no significant differences in relationship records obtained by using either temporary or permanent record bases.

In 1996 Obrez[49] completed a clinical study investigating the effect of masticatory muscle pain on the maxillomandibular relation and range of mandibular motion. Five healthy adults participated in this study. In this study muscle pain was induced by infusion of five percent hypertonic saline solution into the central portion of the masseter muscle. Isotonic saline solution was used as a control and the subjects were blinded to the type of substance given. The results from this study demonstrated that the Gothic arch tracings in healthy volunteers with induced tonic masticatory muscle pain were reversibly altered. This study also suggested that pain has a bearing on the static and dynamic occlusal contact relationships. The experimental muscle pain also significantly affected the location of the posterior mandibular position where the border movements were accomplished.

FUNCTIONAL RECORDINGS

Functional or "chew-in" records were another way described to record centric relation. These were first discussed in the dental literature around 1910. All functional methods of recording centric relation require that the record base be very stable. If this record base is dislodged, the record will not be accurate. Patients must have good neuromuscular coordination to participate in such a recording procedure, and they must also be capable of following instructions.[1] Needles[50] mounted studs on maxillary occlusion rims, and these studs cut arrow tracings into compound rims formed on the mandibular arch. After the rims were removed from the mouth, they were reassembled with the functional grooves in place. Patterson[51] was also known for promoting the use of functional records. Patterson cut a trough in the maxillary and mandibular occlusion rims, and these troughs were filled with a plaster mixture. Again, the patient was asked to move his mandible, and continue the motion until the appropriate curvature had been formed on the rims. This was said to equalize pressure and provide uniform contacts in all excursive movements. Meyer[52] also developed a functional technique where soft wax occlusion rims were used and wax paths were formed in these rims during functional movements. Afterwards, a plaster index was made of this wax path, and teeth were set opposing this generated plaster index.

In the 1930s House[53,54] described a technique of recording mandibular movement and registering the centric relation position of the mandible using an engraving method. To complete the functional registration using the House technique the dentist first makes shellac trial denture bases with attached wax occlusion rims. A preliminary jaw relation record was obtained and the maxillary cast and the occlusion rim was mounted on the House articulator. Wax was then placed in the premolar and molar regions bilaterally on the mandibular occlusion rim. It was then replaced by a block of impression compound. These compound blocks had an occlusal surface simulating an average curve of Spee and curve of Wilson. Four triangular shaped studs with cutting edges were then placed in the maxillary wax occlusion rims opposite these blocks. The new occlusion rims were then inserted intraorally and the patients carried out mandibular movements. During these movements, the studs engraved four separate needlepoint Gothic arch recordings into the blocks of compound. This was what was called a "chew-in" recording. One of the casts was then remounted. According to the new Gothic arch recording, the condylar elements of the articulator were then adjusted. Swanson[55] suggested that the House technique was very desirable but it needed some improvements: 1) an accurate recording of the terminal hinge axis with a face bow; 2) the jaw relation records should be made on intimately adapted denture bases or on the final impressions; 3) it would be better to use the central bearing screw when doing the chew-in recordings so that the vertical dimension of occlusion could be maintained; 4) the recording should be made with a soft material rather than a hard material; and, 5) the recordings should be used with an articulator capable of simulating jaw movement and that possesses fossae that can be molded.

Swanson[55] then described a procedure where he improved upon the House technique using the TMJ technique. The TMJ kinematic facebow was used to locate the hinge axis, the recording plates were attached to impressions rather than stabilized trial denture bases, and a central bearing screw was incorporated into this technique. Using TMJ fossae and tray acrylic resin, a recording was made. The molded fossae with the TMJ articulator are then formed from the generated Gothic arch tracings.

In 1972 Hemphill, et al[56] recognized that many variables enter into recording procedures. He examined the Needles-House and Patterson techniques of functionally generated recordings to determine whether any differences in centric relation registrations occurred if the recording surfaces contacted with equal pressure at the beginning of the procedure or if they were recorded with unequal pressure bilaterally at the beginning of the procedure. Nine patients participated in this study. Three sets of acrylic resin baseplates were made for each patient. Functional registrations were then made with unequal pressure on the recording surfaces; and, using tubes and calipers, measurements were completed on right and left sides of the rims. From this study it was apparent that clinical procedures used for registering tentative jaw relation records must be carefully checked for equalized pressure because neither of the two methods studied corrected the error that was experimentally induced.

One of the most famous promoters of functional records was Boos.[42] He developed the Gnathodynamometer. Using this instrument (which later became known as the Boos Bimeter), he determined the vertical and horizontal position where maximum biting force could be generated. This Bimeter was mounted on the mandibular occlusion rim, and it has a central bearing point that occluded against a plate on the maxillary rim. Plaster registrations were also used intraorally with the Bimeter in place and with the patient exerting biting pressure. Boos claimed that the optimum occlusal position and the position of the maximum biting force are coincident. He felt that all registrations should be made under this biting force that would displace the soft tissue. He felt that this displacement would also occur in function.[57,58]

In 1959 Boos[59] wrote that centric relation records should be made with no pressure or torsion. He advocated the use of materials such as plaster or zinc oxide/eugenol paste. He said that wax or compound would tend to tip or displace the mandible because these materials required that force be exerted to obtain an appropriate recording.

CEPHALOMETRIC RECORDINGS

Pyott and Schaffer[60] described the use of cephalometrics to record centric relation. These radiographs were used to determine centric relation and the appropriate vertical dimension of occlusion. This practice, however, never gained wide spread usage.

MUSCLE CONDITIONING

In 1956 Boos[61] prescribed an exercise whereby the muscles of mastication could be conditioned; thus, enabling the patient to relax before jaw relation records were completed. An article by Nasr and Griffiths[62] described the procedure where exercise therapy was also used before recording jaw relationships. The purpose of exercise therapy, they explained, was to eliminate habitual eccentric reflexes and to train the patients to close in the centric relation position. The exercise appliance they described was either an acrylic resin splint or a modified denture that the patient is able to wear. The exercise that the patient is asked to do consists of opening the mouth wide and touching the posterior border of the maxillary denture with the tip of the tongue. This exercise is supposed to be repeated several times over a three minute period. They further stated that the exercise should be repeated three times daily. These authors reported that the exercise should be continued for two to seven weeks; and, by doing this exercise, the patient learns to close his/her jaws in the centric relation position. Recording of this position, therefore, becomes easy for both the patient and the dentist.

TIME OF RECORDING

In 1975 Shafagh, et al[63] showed the position of the condyle in centric relation for dentulous patients was different when examined in the morning and again in the evening. Because Shafagh, et al demonstrated this, in 1992 Latta[64] began an investigation to evaluate the effect of circadian periodicity on the ability to reproduce centric relation records for the edentulous patient. Thirty patients participated in the study, and these patients were divided into three groups.

Their dentures were remounted twice on the same day. The dentures for ten patients were remounted twice in the evening; the dentures for ten patients were remounted twice in the afternoon; and, for ten patients, the dentures were remounted once in the morning and again in the afternoon. Significant differences between time groups occurred, and this shows that circadian periodicity does affect the recording of centric relation for edentulous patients. This may imply that dentures made in the morning would fit best in the morning. Those made in the afternoon would fit best in the afternoon.

RECORDS FOR THE PARTIALLY EDENTULOUS PATIENT

For removable partial denture fabrication, it is not always necessary to make a jaw relation record. If the casts can be hand articulated, then this appointment may be eliminated. When a jaw relation recording appointment is necessary, however, this recording must be completed free from any pressure. Pressure would cause compression of the patient's tissues with resultant baseplate displacement. This displacement, in turn, would cause errors in mounting the casts.[65]

In 1954 Beckett[66] wrote an article regarding occlusal registrations for removable partial dentures. He stated that the vertical dimension of occlusion is greater in the finished partial dentures than that observed when the record is made. He decided that this was because the occlusion rims used to make the recording displace the resilient mucosa, thereby increasing the vertical dimension of occlusion. From this he decided that all partial denture occlusion relations would belong to one of four types. These types are classified as type A, B, C, and D. Type "A" partially edentulous individuals would exhibit sufficient occlusal contacts to allow the dentist to articulate the maxillary and mandibular casts without occlusion rims. Beckett advocated the use of occlusion rims with the other three types of patients because insufficient occlusal contacts existed to properly hand articulate the casts. He suggested that plaster be used for these centric relation records. He advocated that occlusal pressure should be transmitted to the teeth adjacent to the distal extension areas of the occlusion rims with occlusal rests so that soft tissue displacement would not occur.

In 1978 Akerly[67] described a technique that used the altered cast impression for a distal extension removable partial denture and the functional occlusal registration together to record the jaw relation position.

Freilich, et al[68] discussed principals for selecting the type of interocclusal record for articulation of partially edentulous casts. Other authors[69,70] have suggested that a tripod of three widely spaced contacts should exist between two casts when mounting them. Freilich, et al[68] mentioned that when making an interocclusal record for a partially edentulous individual, it is important to provide support or stability that the casts of the remaining dentition do not have. These authors described using an occlusion rim made on the partially edentulous cast that is then made to function as a substitute for the tooth stops with the record base in the mouth. The baseplate wax or the occlusion rim may be used alone to record the imprints of the opposing teeth; but, most often, other materials are placed on the occlusion rim for the recording of the jaw relationship. They mentioned that this recording material is often Aluwax. They described a situation where an occlusion rim may be present in one arch over an opposing distal extension segment in the opposite arch. Some type of rigid-setting recording material may then be introduced, between the arches, that contacts the occlusion rim on one arch and the edentulous ridge on the other. This material should be soft when introduced intraorally.[71-73] A material used in this manner has been termed a "mucostatic recording material".[68]

In 1976 Lundquist and Fiebiger[73] discussed ways of mounting maxillary and mandibular partially edentulous diagnostic casts based on Kennedy's classification system. Methods discussed for mounting casts for the Class I and II patient were based on patients who had no periodontal involvement of the anterior teeth that were present. The procedure these authors described consisted of placing a leaf gauge between the anterior teeth while guiding the patient's mandible toward the centric relation position. When the centric relation position was found, record bases we inserted intraorally, and a plaster recording medium was used to register the position. In Class II patients the authors advocated that acrylic resin be placed over the dentulous side while making the record. With Class III partially edentulous patients, the authors discussed that the preferred method for registering the jaw relationship was by using acrylic resin over the teeth present and the leaf gauge. If an extensive edentulous space is present, however, baseplates must also be used with some type of plaster recording material. Class IV patients, or with any other class including periodontally involved or missing anterior teeth, the authors discussed that the material of choice to be used is dependent upon the neuromuscular control of the patient and the location and number of teeth remaining. They stated that impression plaster or acrylic resin are the materials of choice if good neuromuscular control is present. If this control is not apparent, then some type of thermoplastic material should be used. They also mentioned that it is necessary to verify all centric relation records.

RECORDS FOR THE MAXILLOFACIAL PATIENT

In 1975 Curtis, et al[74] wrote regarding the maxillofacial patient and the special problems the dentist may encounter in attempting to record jaw relationships. These authors wrote about two factors that may affect maxillofacial patients: 1) radiation therapy; and, 2) the physiological trauma that cancer patients face following therapy. After radiation treatment, a gradual reduction in the blood supply to the muscles and joint structures may occur, and an increased fibrosis of these structures may follow. Trismus and restricted movements of the mandible may ensue. This may certainly complicate the use of any type of intraoral tracing device and may limit the border movements of the mandible. They further explained that in cleft palate patients, the recording base may move upward in the anterior area under pressure. In maxillectomy patients, the base would also move, however, it would move upward on the side of the defect. Because the magnitude of this displacement of the bases may vary, the dentist may encounter differing problems regarding stability of the base and the necessity to equalize the pressure during the jaw relationship recording procedure. With maxillary deficiencies it was noted that you do not have mandibular movement restrictions; however, with mandibular resection patients, movement restrictions are very apparent. They noted that with completion of a lateral mandibular resection, the remaining portion of the mandible will drift toward the area of resection and the remaining portion will also retrude and rotate. Lingual cusps on the mandible are retruded inferiorly. The normal hinge movement of the mandible parallel to the sagittal plane is no longer possible with these patients. Force of closure and tactile discrimination is also compromised. To test these clinical observations, the authors examined patients with mandibulectomies and lateral resections. This was a pilot study; therefore, definite conclusions were not possible. The results of this clinical study suggested that this type of patient cannot make definitive protrusive or lateral excursive movements. The functional movement for these patients is a diagonal pathway of closure to maximum intercuspation. Perhaps the unilateral action of the suprahyoid musculature may account for this pattern of mandibular movement.

ECCENTRIC RELATION RECORDS

Eccentric relation records are defined as "...any relationship of the mandible to the maxilla other than centric position."[1] Rahn[1] stated that methods for recording eccentric relation positions may be classified similar to the methods used for recording centric relation records: 1) functional or "chew-in" procedures; 2) graphic methods; and, 3) tactile or interocclusal record methods. He further wrote that the best time to make eccentric records is after all the teeth have been arranged for try-in and the centric relation record has been verified. Eccentric relation records made with soft materials tend to generate a steeper condylar inclination than records obtained with a more resistant material.

In 1929 Gysi[75] wrote that lateral checkbites made with either wax or compound are unreliable, and such records could lead the prosthodontist into great error when fabricating prostheses. Craddock[76] found that interocclusal records made on the same edentulous patient by the same dentist were more consistent than records made on the same patient by different dentists. The differences, however, were still great. He also found that eccentric records made with wax on dentulous patient were very unreliable and were practically worthless.

Eight factors contribute to the accuracy of eccentric records: 1) the distance that the condyles translate when the record is being made; 2) the resistance of the recording material; 3) the stability of the record bases; 4) the ability of the patient to cooperate; 5) the adjustability of the articulator; 6) the dimensional accuracy of the recording material; 7) the interpretation of the record and articulator manipulation by the dentist; and, 8) the accuracy with which the articulator calibration may be interpreted.[77]

Frazier[77] initiated a study to determine the repeatability of eccentric records by the dentist, to evaluate the consistency of records made by three different dentists on the same patient, and to evaluate the consistency of articulator adjustment by four dentists using the same articulator with the same interocclusal eccentric record. Ten patients participated in the study, and complete maxillary and mandibular dentures were fabricated for them by five dentists. Each dentist treated two patients. A plaster interocclusal recording material was used in the procedure to mount the casts in a centric relation position. The artificial teeth were arranged for try-in and the centric relation record was verified. The dentist who made the dentures then made three protrusive, three right lateral, and three left lateral interocclusal records using plaster. Then the two other dentists made three protrusive, one right lateral, and one left lateral plaster record for the same patient within a two hour period. After the records were made, each dentist adjusted the articulator to accept the records; and, the calibrations were read and recorded by a dental assistant. The data were collected and statistically analyzed. Results from this study indicated that each dentist was very consistent with himself for a given patient but was not as consistent with other dentists using the same patient. Inconsistencies that occur in the making of eccentric records are primarily caused by the record making itself and not the dentist's ability to adjust the articulator. It was suggested that interocclusal eccentric records are repeatable enough to render them useful as a basis of treatment for the edentulous patient.

ACCURACY OF RECORDING MATERIALS

In 1960 Berman[78] wrote that it is very questionable that dental waxes make accurate interocclusal records. He tested various waxes and found all of these waxes offered some resistance to closure and he believed that the recording materials should offer no resistance to closure. He advocated the use of zinc oxide eugenol impression paste to make jaw relation records for fabrication of complete denture prostheses.

Lassila in 1986[79] compared several interocclusal recording materials in an attempt to find the most suitable material for making interocclusal records. The materials studied were silicone putty, polyether elastomer, zinc oxide eugenol paste, eugenol-free zinc oxide paste, acrylic resin, and baseplate wax. Resistance to closure, volumetric changes of the materials during the polymerization, and dimensional stability during storage were studied. He noted that resistance of the acrylic resin increased rapidly in the beginning, although it took it quite a long time to polymerize. Silicone was found to be very highly resistant to closure. The author stated that silicone, therefore, was not very suitable for interocclusal registrations for gingiva-supported prostheses. He mentioned that wax is difficult to use because its resistance to closure is very high even at temperatures near its melting point. He mentioned that acrylic resin and zinc oxide paste were very sticky, and this adhesive property could be a problem with interocclusal registration for fixed restorations; however, with removable dentures or removable partial dentures, this stickiness may be advantageous. He mentioned that if it was necessary to store recording materials before mounting, this may be problematic. Zinc oxide materials may be stored in stable conditions; however, they are susceptible to changes in relative humidity.[80] The elastomeric recording materials, he said, remain stable for a long time, and their contraction due to volatility is slight if they are stored in tightly sealed plastic bags. If these elastomers encounter moisture, considerable dimensional change may occur.[79]

In 1992 Breeding and Dixon[81] studied the compression resistance of four interocclusal recording materials. During this investigation the deformation of different thickness of three vinyl (poly)siloxanes and one polyether interocclusal recording material was studied when these materials were subjected to a consistent compressive force. During the study, all the recording materials were compressed clinically significant distances during the constant load. One of the (poly)siloxanes was significantly more resistant to compression than the other materials at the thickness of 5, 10, and 20 mm. This material was Blu-Mousse (Parkell).

In 1994 Millstein and Hsu[82] examined five brands of vinyl (poly)siloxane recording materials regarding their dimensional stability and associated weight change. All brands studied were found to be accurate and dimensionally stable over a 48 hour period of time. The negligible weight change did not affect the dimensional stability of the materials.

In 1994 Chai, et al[83] studied the surface hardness and dimensional stability of several intermaxillary registration materials. These authors found that the dimensional stability of a polyether registration material was significantly lower than that of the vinyl (poly)siloxane materials that were tested. The dimensional change of all the materials was acceptable.

RECORDING MATERIALS AND MOUNTING ERRORS

In 1981 Mullick, et al[84] stated that an ideal interocclusal material/technique combination for making intraoral recordings would allow the placement of fabricated prostheses intraorally with no occlusal adjustment. He further decided that the reasons for occlusal inaccuracies, caused by the interocclusal record, may be divided into three main groups: 1) anatomic and physiologic characteristics of the patient; 2) dentist induced causes; and, 3) properties of the material used to make the record along with technical manipulation of the record during use. This purpose of the Mullick, et al[84] study was to determine the vertical assembly error in mounting dentulous casts on an articulator as effected by the following three things: 1) materials, 2) distance between prepared and opposing teeth, and 3) dentist variability. Stone casts obtained from a patient with a complete dentition were mounted on an articulator. All posterior teeth, except for those in the maxillary left quadrant, were prepared on the cast to simulate full veneer crown preparations. Vertical displacements of the casts on either the right or left side were measured in increments of 0.0001". A zinc oxide eugenol paste, Aluwax, four types of silicone putties, and one polyether material were used. The materials were placed bilaterally between the casts and the articulator and the instrument was closed to incisal pin contact. Measurements were made 5 minutes later. The first measurement was made before record removal, the second measurement was made after the records were removed, trimmed, and the casts were replaced into the trimmed record. Three individual dentists repeated the test 10 times for each material on both the right and left sides. It was found that Aluwax was the most variable and least reliable of all the materials studied. The five elastomers consistently resulted in the least amount of errors, and the two different thicknesses of elastomeric records studied resulted in significantly different mounting discrepancies.

In 1991 Müller, et al [85] also studied cast mounting errors. They examined vertical errors in mounting dentulous casts on an articulator as effected by three things: 1) the interocclusal registration material; 2) storage time of completed interocclusal records; and, 3) the points from which the measurements were made. Maxillary and mandibular casts, with posterior tooth preparations, were mounted on an articulator. The anterior guide pin was raised 3mm so that an interocclusal space was created between the posterior teeth. The following interocclusal recording materials were tested: impression compound, impression compound combined with zinc oxide eugenol paste, Beauty Pink wax, Beauty Pink wax combined with zinc oxide eugenol paste, a polyether material, zinc oxide eugenol paste, and gypsum. The materials were placed between the casts at a constant closing pressure. The condymeter was used to make measurements representing deviations from the original position of the casts. After storage of the records (30 minutes, 6 hours, and 24 hours) other measurements were made with the condymeter. It was decided that for clinical procedures, all of the materials tested may cause not only vertical but also three dimensional dislocation of mounted casts. It was suggested that if anterior teeth are present, and the jaw relation will be registered at the maximal intercuspation position, then a material should be chosen that creates only a small deviation at the molar region. It was stated that the polyether material tested was the material of choice for this situation because there was no clinically significant differences found among the storage periods tested. Furthermore, is was suggested that a corrected wax also creates an acceptable deviation if it is used after a short storage time of 30 minutes or less.

Breeding, et al[86] then developed a methodology to measure the three dimensional accuracy of interocclusal recording materials using a computerized axiograph. This developed methodology was then used to compare the accuracy of three different interocclusal recording materials. The three materials tested were an acrylic resin, a thermoplastic material, and a vinyl (poly)siloxane. It was found that the thermoplastic resin generated mounting errors that were significantly greater than those errors generated by the other two materials tested.

ARTICULATOR CLASSIFICATION

In 1963 Weinberg[87] classified articulators in four categories: 1) arbitrary; 2) positional; 3) semiadjustable; and, 4) fully adjustable. He explained that when an arbitrary articulator is used, individual variations are not taken into consideration. A general curve of the occlusal plane is established with these instruments. When describing positional articulators he mentioned the Stansbery tripod. Users of such an articulator believe that the static or positional relationship of the mandible in centric relation, protrusive, and each lateral position may be obtained. Positional articulators, he explained, are designed primarily for fabrication of complete dentures. One example of a semiadjustable instrument is the Hanau model H articulator. A facebow transfer and centric relation record are used to orient casts on an articulator such as this. These instruments are also primarily designed for complete denture fabrication. Weinberg stated that because of the relative mobility of complete denture bases, a semiadjustable articulator is adequate. He further stated, however, that fixed restorations require a greater degree of accuracy in the lateral excursive movements than complete dentures. It is suggested that the shortcomings of semiadjustable articulators must be understood, and that more adjustable instruments would be indicated for fabrication of fixed prostheses to reduce the degree of occlusal correction necessary during intraoral insertion.

Articulators were also classified in 1972 in *The International Workshop on Complete Denture Occlusion.*[88] Class 1 instruments were called holding instruments. It was stated that these are capable of accepting a single static registration only, and are suited for maximum intercuspation restorations. It was explained that Class 2 instruments permit horizontal and vertical motions but do not orient the motion to the temporomandibular joint. These instruments were said to be useful for the mounted position; however, the eccentric movements these instruments offer provide no advantage because they are not registered and are therefore inaccurate. Class 3 instruments were described as those that simulate condylar pathways by using averages or mechanical equivalents for all or part of the motion. These instruments were said to allow for joint orientation of the casts, and may be either arcon or non arcon articulators. Such articulators, it was explained, fulfill the requirements for complete denture fabrication. Class 4 articulators were described as instruments that accept 3 dimensional dynamic registrations, and allow for joint orientation of casts. These articulators were called the instruments of choice for complete intraoral reconstructions.

CHOOSING AN ARTICULATOR

Celenza[89] described an articulator as a mechanical holding device that is most conveniently used when relating opposing casts. He suggested that two simple, general categories be used to classify the different types of articulators: 1) those that permit eccentric movements; and, 2) those that do not. He stated that if centric relation is the registration position used, then an articulator that accepts a face bow transfer should also be used because all centric relation positions fall on the terminal arc. When using a noneccentric movement articulator, it is necessary to adjust all eccentric pathways intraorally. Registration of the centric relation position must be used as a starting reference position with eccentric movement instruments. He stated that a reason for using an instrument that allows eccentric movements is so that occlusal adjustments may be minimized and to preserve anatomic details of the teeth. Celenza referred to eccentric movement articulators as "precision" articulators. He stated that these instruments duplicate all eccentric pathways so that a precision centric position may be developed and maintained, and so that eccentric "irritants" will not be introduced. He said that there is no doubt that many patients benefit from the occlusal arrangements generated from such articulators; however, he also mentioned that many patients do well without them. He discussed that when selecting an articulator, the dentist must first determine the type of occlusal scheme to be used. Celenza stated that if maximum intercuspation is to be used for restoration of the patient's occlusion, then it is necessary to only make a registration of that position with the remaining teeth in contact. Working casts, therefore, are not joint-oriented because this not a border position. If the centric relation position, however, is recorded, it would advantageous to use a joint-oriented technique for mounting (such as a face bow transfer). He suggested that if this is accomplished, eccentric pathways should be dynamically registered using a pantograph, a stereograph, check bite method, determined by mechanical equivalents, or adjusted entirely intraorally. He suggested, therefore, that if this is to be done, a fully adjustable articulator should be used. He definitely felt that three dimensional eccentric registrations reduce chairside adjustment of occlusion. Celenza stated that a "centric relation system" should be used in complete denture fabrication techniques; however, it is inappropriate to complete precise 3 dimensional eccentric registrations because of tissue resiliency.

Hobo, et al[90] also offered several rules for matching the articulator with the dental treatment to be performed. These authors stated that for most single restorations, a fixed condylar path instrument will produce an acceptable result (a non adjustable articulator). It is desirable, they said, to have a shallow condylar inclination (preferably approximately 20°) because the error produced with a condylar inclination such as this will almost always be a negative one. Therefore, there will be greater tolerance in excursive movements than necessary. If the practitioner is knowledgeable regarding errors that may occur in occlusion using this type of instrument, such errors may be quickly adjusted chairside. They stated that when multiple restorations or fixed partial dentures are being fabricated, then there is a greater need for accuracy in instrumentation. If it is not necessary to restore vertical dimension of occlusion, and if no occlusal disease or immediate side shift is present, then a semiadjustable articulator may be used for such restorations. It is necessary to use lateral interocclusal records to set the condylar inclinations on these semiadjustable instruments. These authors suggested that fully adjustable articulator coupled with the use of a hinge axis transfer and a pantographic tracing or a 3 dimensional intraoral recording be used for extensive restorative treatments. This includes restoration of opposing quadrants, reconstruction of the entire occlusion, and/or for patients with significant side shift occurring during lateral movements. Use of a fully adjustable instrument it is particularly desirable when restoration of vertical dimension of occlusion is necessary or when there is occlusal disease present. They did not suggest that a small non adjustable hinge articulator be used at any time!

In 1963 Weinberg[91] described a gnathologic type of instrument where three dimensional guidance of the working condyle is reproduced. He stated that this is the instrument of choice among the fully adjustable articulators, and this articulator can be adjusted with accurate 3 dimensional pantographs or with eccentric interocclusal records. He stated that the semiadjustable articulators are clinically adequate for complete denture fabrication, and he explained that this type of instrument is based on clinical averages. He further explained that to reduce the amount of intraoral correction necessary with restorations, the use of a fully adjustable instrument that will accept lateral interocclusal records may be desired.

Stuart[92] stated that the use of any particular articulator was not the only factor in successfully achieving an optimal occlusion. He referred to optimal occlusion as "organic occlusion". He described the Stuart articulator and said that the Stuart articulator actually had the same potential for movement as the jaws. This articulator uses frictionless condylar recording; and he felt that the use of frictional devices to record mandibular movements was inappropriate. The mandibular movement recorder used with the Stuart articulator is known as a pantograph. Stuart referred to his articulator as an "analog computer". Using this articulator, the static and moving relations of the mandible may be replicated. The development of occlusion with this articulator allows the mandible to position itself where the patient's muscles, joints, and nerves dictate, with out regard for tooth guidance. He stated that Stuart articulators provide reliable and accurate preservation of the centric relation position due to the rigidity of the instrument. He believed that full iinterdigitation of the cusps must occur in the centric relation position. He believed that an articulator is only valuable if it is used with accurate casts, appropriate interocclusal records and proper jaw-writing records.

Guichet[93] stated that the dentist should never consider restoration of the occlusion out of harmony with the condylar paths of movement. He stated that when the restoration of a patient involves at least the last two or three teeth in a quadrant, the Denar pantograph and fully adjustable articulator offers treatment advantages. He stated that when occlusal restoration of a patient involves only one or a few teeth, such restoration can usually be developed by relying on anatomical guidelines established by the non involved teeth with a functionally generated path technique, or by using minimal laboratory procedures with appropriate chairside adjustment upon insertion of the restoration.

Lundeen[94] wrote about the Lee Pantograph System that was used to record the condylar border movements of several hundred subjects. From this data a computer analysis method analyzed the movement patterns of certain selected subjects. If was found that the average protrusive condylar pathway angle was 45°. The average lateral balancing side pathway was 55°, and the Bennett movement average was 0.75 mm. He then described a simplified mandibular movement recorder that was not used to directly program an articulator. He stated that articulator adjustments may be accomplished very quickly by the use of preformed condylar motion analogs.

In 1973 Bellanti[95] completed a study to measure the discrepancies that can exist in articulator capability due to incomplete movement simulation. He concluded that semiadjustable articulator produced an error that may result in the need for more than a minimal amount of eccentric occlusal adjustment, or, in fact, uncontrolled amounts of disclusion of fabricated fixed prostheses. He suggested that an articulator is needed with a wide range of intercondylar width adjustment, and with adjustable fossa walls, to accurately reproduce the effects of the side shift.

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A Review Of The Articulators

Dr. Stephen J. Riedy

PURPOSES OF AN ARTICULATOR

1) To hold opposing casts in a predetermined fixed relationship

2) To open and close

3) To produce border and intra-border diagnostic sliding motions of the teeth similar to those in the mouth

USES OF AN ARTICULATOR

1) To diagnose dental occlusal conditions in both the natural and artificial dentitions.

2) To plan dental procedures that involve positions, contours, and relationships of both natural and artificial teeth as they relate to each other.

3) To aid in the fabrication of dental restorations and lost dental parts.

4) To correct and modify completed restorations.

CLASSIFICATION OF ARTICULATORS

WEINBERG'S CLASSIFICATION (1963)

1) Non adjustable articulator - an articulator that does not allow adjustment to replicate mandibular movements.

2) Semiadjustable articulator - an articulator that allows adjustment to replicate mandibular movements in the sagittal plane but not in the horizontal plane.

3) Fully adjustable articulator - an articulator that permits adjustment in all planes to replicate three dimensional movement of recorded mandibular motions.

MINIMAL REQUIREMENTS OF AN ARTICULATOR

1) It should hold casts in the correct horizontal relationships.

2) It should hold casts in the correct vertical relationships.

3) It should provide a positive anterior vertical stop (incisal pin).

4) It should accept a face-bow transfer record.

5) It should open and close in a hinge movement.

6) It should allow protrusive and lateral jaw motion.

7) The moving parts should move freely and be accurately machined.

8) The non-moving parts should be a rigid construction.

CLASSIFICATION OF ARTICULATORS

HEARTWELL AND RAHN CLASSIFICATION

Class I - Instruments that receive and reproduce stereograms (pantograms).

Class II - Instruments that will not receive stereograms.

TYPE 1 - HINGE

TYPE 2 - ARBITRARY

TYPE 3 - AVERAGE

TYPE 4 - SPECIAL

CLASSIFICATION OF ARTICULATORS

INTERNATIONAL PROSTHODONTIC WORKSHOP

CLASSIFICATION OF CAST RELATORS (1972)

CLASS I - Simple holding instruments capable of accepting a single static registration. Vertical motion is possible.

CLASS II - Instruments that permit horizontal as well as vertical motion, but do not orient the motion to the temporomandibular joints.

Sub - A - Eccentric motion permitted is unrelated to patient motion.

Sub - B - Eccentric motion permitted is based on theories of arbitrary motion.

Sub - C - Eccentric motion permitted is determined by the patient, using engraving methods.

CLASS III - Instruments that stimulate condylar pathways by using averages or mechanical equivalents for all or part of the motion. These instruments allow for joint orientation of the casts and may be arcon or nonarcon instruments.

Sub A - Instruments that accept static, protrusive registrations and use equivalents for the rest of the motion.

Sub B - Instruments that accept static lateral protrusive registrations and use equivalents for the rest of the motion.

CLASS IV - Instruments that will accept three dimensional dynamic registrations. These instruments allow for joint orientation of the casts.

Sub A - The cams representing the condylar paths are formed by registrations engraved by the patient.

Sub B - Instruments that have condylar paths that can be angled and customized either by selection from a variety of curvatures, modifications, or both.

GARIOT INSTRUMENT

-In 1805, J.B. Gariot designed the first hinge articulator

-the instrument has a metal plate which serves as a vertical stop

STEPHAN ARTICULATOR

-developed in 1921

-similar in design to the Gariot hinge articulator

-fixed condylar inclination and allows for arbitrary lateral movement

-has a fixed vertical dimension

FOURNET ARTICULATOR

-a one-dimensional articulator that has no lateral movement

-utilizes the Cook mounting jig

-casts are arbitrarily mounted, with a paralleling technique

-the instrument possesses a vertical sliding movement perpendicular to the horizontal plane, as well as a hinged movement

HANAU CROWN AND BRIDGE ARTICULATOR 29-0

-a posterior pin and cam guidance mechanism can be set to simulate working and balancing side excursions of 15 degrees

-has a fixed protrusive movement of 30 degrees

-manufactured by the Hanau Engineering Co. from 1934 to 1971

GYSI SIMPLEX

- introduced in 1914 by Alfred Gysi
- a mean value articulator
- used extra oral graphic tracings and a particular condylar path plate
- condylar paths are inclined 30 degrees and the incisal guidance is fixed at 60 degrees

GYSI IMPROVED NEW SIMPLEX

- uses average movements
- condylar inclination is 30 degrees, with a Bennett movement of 7.5 degrees
- incisal table adjusts from 0 to 30 degrees
- a Gothic arch tracing can be performed with this instrument

BONWILL ARTICULATOR

- Bonwill (1858) constructed an instrument based on observations that a 4 inch equilateral triangle defined the distance between the condyles and the symphysis
- the first articulator that simulated movement of the mandible in eccentric positions

THE MAXILLOMANDIBULAR INSTRUMENT

- designed in 1918 by George Monson
- was based on his spherical theory of occlusion
- the instrument has set screws that can vary the instrument's radius
- the upper member moves antero posteriorly and mediolaterally, according to the spherical theory

THE HOUSE ARTICULATOR

- developed by M.M. House in 1927
- it will not accept a facebow transfer
- the instrument is adjusted by a Needles-House chew in
- the dimensions of the instrument satisfied Bonwill's principles
- employs a rotary grinder on the upper member for milling in a 40/1000 inch elliptic area

THE PRECISION COORDINATOR

- an arcon type of articulator that has curvilinear condylar guides
- the incisal pin is curved to allow for changes in the vertical dimension
- a milling device, built into the articulator, can be varied from 0 to 0.04 inch
- developed by W.H. Terrell in the early 1930s

NEW CENTURY/MODIFIED NEW CENTURY ARTICULATOR

-developed by George B. Snow in 1906

-an improvement of the Gritman articulator

-has adjustable condylar paths

-has rotation centers, 4 inches apart, in accordance with Bonwill's theory

-designed to accept a facebow mounting

THE ACME ARTICULATOR

-made by George B. Snow as an elaboration of his 1906 New Century

-the condylar paths are straight and the condylar inclination is adjustable

-the guiding mechanisms are on the upper member

HANAU MODEL H 110

-introduced by Hanau in 1926

-designed primarily for complete dentures

-a non arcon instrument

-condylar guidance adjustments in the saggital and horizontal planes

HANAU H2

-a non arcon instrument with the condylar guidance controls attached to the lower member of the articulator

-a fixed intercondylar distance of 110 mm and it accepts a facebow transfer

-the mechanical incisal guide table is adjustable in the saggital and frontal planes

DENTATUS ARL ARTICULATORS

-designed in 1944

-it is a semi adjustable articulator that is a shaft type of instrument with a fixed intercondylar distance and a straight condylar path

-it can receive a hinge axis facebow transfer

GYSI TRUBYTE ARTICULATOR

-this instrument uses average movements

-the condylar guides are inclined 30 degrees with a Bennett movement of 7.5 degrees

-the incisal guide table adjusts from 0 to 30 degrees

-locking pins, rather that mounting plates, are used to attach casts

HANAU MODEL M KINOSCOPE

-developed by Rudolph Hanau in 1923 as a research instrument

-this instrument has double condylar posts on each side

STANSBERY TRIPOD

-developed by C.J. Stansbery of Los Angeles in 1929

-there is no mechanical equivalent or representation of condyles

-the articulator represents positions, not movements

-there are 3 individual turrets and slots on the tripod

-there is a milling device on the lower member with an eccentric pulley

PHILLIPS OCCLUSOSCOPE

-devloped by George P. Phillips of Washington, D.C. in 1938

-no facebow transfer

-the articulator is adjusted by either intraoral or extraoral records

-the lower member has two adjustable units that represent the temporomandibular joints

-this articulator does not have an adjustable incisal guide

PAGE'S TRANSOGRAPH

-developed in 1952

-it is a split axis instrument designed to allow each condylar axis to function independent of the other

-it accepts positional registrations of varying distances on the lateral path, a kinematic location of the horizontal axis, and centric relation registrations of varying thickness

HANAU MODEL 130-21 ARTICULATOR

-this is one of a series (University Series) of 24 models

-this instrument has the condylar element in the upper member and is a split axis instrument

-it is adjustable to varying intercondylar distances

-this instrument will accept all positional records, but cannot duplicate pantographic tracings

THE TELEDYNE ARTICULATOR

-developed by Richard Bev in 1975

-it has a fixed intercondylar distance

-an arcon instrument with adjustable medial and rear walls and adjustable horizontal condylar guidances

DENAR MARK II

-introduced in 1975 as a simpler arcon instrument

-the horizontal condylar inclination can be adjusted from 0 to 60 degrees

-it has an immediate side shift adjustment of 0 to 4 mm plus a progressive side shift of 0 to 15 degrees

-can be programmed using anatomical averages, positional records or with a mini recorder

THE PANADENT ARTICULATOR

-this instrument uses a series of statistically selected 3-dimensional analogs of condylar axis motion

-the analog fossae feature curvilinear protrusive and balancing pathways with the medial wall angulation of six degrees. There are 5 pins with different Bennett shifts.

-it is designed to be set with an extraoral quick analyzer

HAGMAN BALANCER

- designed by H.C. Hagman in 1925
- requires no facebow transfer or interocclusal records for mounting casts
- its use is based on the spherical theory of occlusion
- the instrument is similar in concept to Monson's
- Hagman advocated a kinematic axis transfer with an orbital pointer
- classified as a nonarcon type instrument

THE TMJ ARTICULATOR

- designed by Kenneth Swanson in 1965
- utilizes a stereographic recording
- custom fossa analogs are generated from the recordings, which are claimed to produce an accurate analog of the patient's temporomandibular joint function

STUART ARTICULATOR

- a fully adjustable arcon articulator developed by Dr. Charles Stuart in 1955
- the upper member of the articulator has two sets of cams. These guide truncated spheres located on the lower member.
- the articulator settings are programmed by using pantographic tracings from the patient

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Review Of Maxillomandibular Relationships

Dr. Charles C. Kelsey

Review of

MAXILLOMANDIBULAR RELATIONSHIPS

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October 16, 1993

1. Orientation of the maxillary master cast on the articulator with a face or ear bow.

   (Actually not a maxillomandibular relationship)

2. Vertical Maxillomandibular Relation - determination of occlusal vertical dimension (OVD).

3. Horizontal Maxillomandibular Relation - defining and recording centric relation.

4. Registration of the condylar path inclination.

REFERENCES ON THE ORIENTATION OF THE MASTER CAST ON THE ARTICULATOR USING AN ARBITRARY FACEBOW

General Review:

1. Brandrup-Wognsen T. The face-bow, its significance and application. J Prosthet Dent 5:618, 1953.

   Excellent history of the development of the face bow, beginning with Bonwill in 1860. "We are justified in stating that Snow's face bow (1889), in spite of its very simple construction, was epoch-making in prosthetic dentistry."

2. Christiansen R. Rationale of the face-bow in maxillary cast mounting. J Prosthet Dent 9:388, 1959.

   Publication of the author's award-winning presentation (Academy of Denture Prosthetics) on this subject. Defended the arbitrary method, and favored condyle palpation for locating the transverse horizontal axis.

Accuracy of Arbitrary and Hinge Axis Location

1. Schallhorn RG. A study of the arbitrary center and the kinematic center of rotation for face-bow mountings. J Prosthet Dent 7:162, 1957.

   70 subjects - found a close relationship of the arbitrary axis to the terminal horizontal axis (THA). 95% of the arbitary point locations were within a 5mm radius of the kinematic center of rotation. Justified the use of an arbitrary point - on a line 13mm from the posterior center of the tragus to the outer canthus of the eye.

2. Walker PM. Discrepancies between arbitrary and true hinge axes. J Prosthet Dent 43:279, 1980.

Made 444 true hinge axis locations (222 subjects) and compared to various arbitrary locations. Found that any chosen arbitrary location would not reliably represent the true anatomic hinge anatomic axis.

3. Simpson JW, et al. Arbitrary mandibular hinge axis location. J Prosthet Dent 51:819, 1984.

Compared selected arbitrary hinge axis locations with the kinematic axis locations on 50 subjects. Demonstrated significant differences between the location of an "experimental arbitrary axis point" and those of Beyron, Gysi, and Bergstrom relative to the kinematic axis. The "experimental" point more closely consistently approximated the kinematic axis than the other arbitrary points. Suggested that the use of the "experimental" point, a point on Camper's line, 10mm from the superior border of the tragus, is more accurate the the other arbitrary points.

4. Bosman AE. *Hinge Axis Determination of the Mandible.* Tandheelkundige Monografieen XVI. Leiden, Stafleu and Tholen BV. 1974.

Excellent review of early investigations of mandibular hinge movement - 18th century.. Good review on hinge axis, moving axis, gnathology, 2 independent axes, arbitrary axes, and accuracy of the hinge axis location.

5. Bowley JF, Bowman HC. Evaluation of variables associated with the transverse horizontal axis. J Prosthet Dent 68:537, 1992.

Measured effect of THA deviation on the vert. and horiz. orientation of U and L members on a lab artic. model.
1. Superior-anterior THA deviation produced the most sig. changes in the lower member.
2. Inferior-posterior THA deviation produced very small shift of the lower member

6. Bowley JF, et al. Reliability of a facebow transfer procedure. J Prosthet Dent 67:491, 1992.

Evaluated the ability of the operator to accurately mount the max. cast once the THA was located. Three operators made between mountings were found between trials with all three methods.

Anterior Point(s) of Reference

1. Wilkie ND. The anterior point of reference. J Prosthet Dent 41:488, 1979.

Excellent review on subject. Discusses five commonly used anterior points of reference and reasons for the use of each.

2. Ash MM, Ramfjord S. *An Introduction to Functional Occlusion.* W. B. Saunders Co. p.130, 1982.

Suggests where the vertical location of the maxillary incisal edges should be for most accuracy when using an ear bow. Similar to diagram in Brandrup-Wognsen article.

3. Gonzalez JB, Kingery RH. Evaluation of planes of reference for orienting maxillary casts on articulators. JADA 1968; 76:329-36.

   Demonstrates a method to compensate for the error induced when using the axis-orbital and the Frankfort Plane (FP) as the 3rd point of reference.

4. Pitchford JH. A reevaluation of the axis-orbital plane and the use of orbitale in a facebow transfer record. J Prosthet Dent 1991; 66:349-55.

   Neither Frankport Plane nor the axis-orbital plane is parallel to the "esthetic reference plane." Showed that the edges of the maxillary central incisors should be 36mm below the condylar plane for.best accuracy. In 1866,Balkwill found that the incisal edges of the mandibular should be 35 mm below the condylar plane.

Accuracy of the Ear Bow:

1. Teteruck WR, Lundeen HC. The accuracy of an earpiece face-bow. J Prosthet Dent 16:1039, 1966.

   Found that 59.4% of arb. points by ear bow are within 6mm of the THA. Estimated that with a modification, this could be increased to 75.5%.

2. Palik JF,et al. Accuracy of an earpiece facebow. J Prosthet Dent 53:800, 1985.

   Eight subjects - most arb. pts. were <u>anterior</u> and <u>inferior</u> to the THA. More discrepency found in the ant.-post. direction. Conclusion - Earpiece bow measurements are <u>not</u> statistically repeatable. Authors suggested that the moveable tissue in the meatus is a factor in this finding.

Potential Error in Face or Ear Bow Use on the Asymmetrical Head

1. Preston JD. A reassessment of the mandibular transverse horizontal axis theory. J Prosthet Dent 1979;41:605-13.

   Excellent history and development of the theory and practice of the THA location. Addresses controversies, including the two- axis theory and facial asymmetry.

2. Stade EH, Hanson JE, Baker C. Esthetic considerations in the use of facebows. J Prosthet Dent 1982; 48:253-56.

   A method to compensate for problems relative to facial asymmetry. Suggests the use of the "esthetic reference position" and bubble guages. for leveling the bow or fork.

3. Shannon JL, Rogers WA. Communicating patients' esthetic needs to the dental laboratory. J Prosthet Dent 1991;65:526-28.

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Indicated the importance of rest position relative to the determination of OVD. He held that individual rest position remains constant throughout life. (Swerdlow,#15)

2. Turrell AJW. Clinical assessment of vertical dimension. J Prosthet Dent. 28:238, 1972.

Excellent review of all methods used up to 1972. Urges the use of accurate pre-extraction records.

3. Fayz F, Eslami A. Determination of occlusal vertical dimension J Prosthet Dent 59:321, 1988.

Excellent review of method up to 1988.

4. Smith DE. The reliability of pre-extraction records for complete dentures. J Prosthet Dent 25:592, 1971.

Describes five methods for making pre-extraction records 1.Sorensen Profile Scale,.2. cardboard profile 3, interfrontal distance, 4. use of measurement between tattos on the gingiva, and 5. nose-chin distance measured with a ruller. Conclusion-no statistically significant difference between methods.

5. McGee GF. Use of facial measurements in determining vertical dimension. J. Am. Dent. Assoc. 35:342, 1947.

A prescribed series of facial measurements to determine OVD

6. Pyott JE. Centric relation and vertical dimension by cephalometric roentgenograns. J Prosthet Dent 4:35,1954.

An early proponent of the use of cephalograms for determining OVD for edentulous patients.

7. Shanahan TE. Physiologic vertical dimension and centric relation. J Prosthet Dent 6:741, 1956.

Advocated the recording of OVD and CR by using a regimen of swallowing.

8. Silverman MM. The speaking method in measuring vertical dimension. J Prosthet Dent 3:193, 1953.

A strong advocate for using phonoetics to determine.OVD. Used the term "closest speaking space." (CSS).

9. Howell PGT. Incisal relationships during speech. J Prosthet Dent 1986; 56:93-99.

Studied 97 subjects. Used a mandibular Kinesiograph. Found a trend for a relationship between "closest speaking space" and vertical overlap of incisors. Concluded that the use of this method is <u>not definative</u> as previously assumed.

10 Rivera-Morales WC, Mohl ND. Variability of closest speaking space compared with interocclusal distance in dentulous subjects. J Prosthet Dent 65:228-32,.1991.

Used a Kinesiograph on 30 subjects. CSS was found to have a high correlation to vertical overlap of the anterior teeth, but the results did not support the use of sibilant sounds for the establishment or evaluation of OVD.

11. Boos RH. Intermaxillary relation established by biting power. J.Am. Dent. Assoc. 27:1192, 1940.

Developed the Bi-Meter based on the theory that muscles function at maximum force of contraction when there is a "critical point" between the origin and insertion. This was called the "power point". In more than 300 subjects, each had a point of maximum power in the vertical dimension. The author determined that OVD=power point -1.5mm.

12. Lytle RB. Vertical relation of occlusion by the patient's neuromuscular perception. J Prosthet Dent 14:12, 1964.

Used a screw-jack device that could be opened and closed between the max and mand arches. This method is based on an assumption that the patient invariably finds, w/i 0.5mm, the most comfortable OVD.

13. Timmer LH. A reproducible method for determining the vertical dimension of occlusion. J Prosthet Dent 22:621, 1969.

Similar to Lytle's device. - The patient gains experience by going from excessive opening to excessive closure. This is repeated until a constant "critical zone" is identified for the correct. OVD.

14. Potgieter PS, Monteith B, Kemp PL. The determination of free-way space in edentulous patients: a cephalometric approach. J Oral Rehabil. 10:283: 1983.

Describes a technique for determining OVD using cephalometrics.

15. Swerdlow H. Vertical dimension literature review. J Prosth Dent 15:241, 1965.

Good literature review on the "concept of constancy of face height."

16 Thompson JR. The rest position of the mandible and its significance to dental science. J. Am. Dent. Assoc. 33:151, 1946.

Claimed that rest position is not affected by either the present of absence of teeth. Agreed with the concept of"constancy of face height."

17. Atwood DA. A cephalometric study of the clinical rest position of the mandible. Part I. The variability of the clinical rest position following the removal of occlusal contacts. J Prosthet Dent 6:504, 1956.

Cephalometric study shows that rest position is not constant.

18. Tallgren A. Changes in adult face height due to aging, wear, and loss of teeth and prosthetic treatment. Acta. odont. scandinav. 15:1, suppl. 24, 1957.

Longitudinal study - rest position not constant in individuals.

19. Lambadakis J, Karkazis HC. Changes in the mandibular rest position after removal of remaining teeth and insertion of complete dentures. J Prosthet Dent 68:74, 1992.

Serial lateral cephs on 24 subjects, before extraction, 10 days after extraction, one year and two years after extraction. Conclusions: 1. Confirmed the concept of the variability of rest position. 2. Suggests that rest position is unreliable for establishing OVD.

20. Unger JW. Comparison of vertical morphologic measurements on dentulous and edentulous patients. J Prosthet Dent 1991; 64:232-34.

Longitudinal study using cephs - data from 20 years, Conclusion : OVD decreases with age.

** See Douglas JB, Meader LM, Kaplan A, Ellinger CW. Cephalometric evaluation of the changes in patients wearing complete dentures. A 20 year study. J Prosthett Dent 69:270. 1993. Study similar to Unger (#20),with similar conclusions.*

21. Swerdlow H. Roentgencephalometric study of vertical dimension changes in immediate denture patients. J Prosthet Dent 14:635, 1964.

Used cephalograms made before and after extraction, and found that the swallowing method resulted in a decreased OVD.

22. Silverman SI, Vertical dimension record: A three dimensional phenomenon. Part I. J Prosthet Dent 53:420, 1985.

Determined that the swallow method often results in a decreased OVD. Suggested that when determining OVD for an edentulous patient, use only the mand. record base with a properly made occlusion rim.

23. Tryde G, McMillan D.R, Christensen J, and Brill N. The fallacy of facial measurements of occlusal height in edentulous subjects. J. Oral Rehab. 3:353, 1976.

Determined that dots on the skin of the chin used for measuring rest position move less than the mandible.

24. Ekfeldt A, Jemt T, and Mansson L. Interocclusal distance and measurement comparing chin and tooth reference points. J Prosthet Dent 47:560, 1982.s

Studied 9 dentate students - used light-emitting diodes, cameras, and computer analysis. Concluded that marks on the skin are not valid for use in determining rest position and OVD.

25. Feldman S, Leupold RJ, and Staling LM. Rest vertical dimension determined by electromyography with biofeedback as compared to conventional methods. J Prosthet Dent 40:216, 1978.

Used EMG biofeedback to determine rest position. The readings came consistantly within 1.2mm of the mean for rest vertical determined by conventional methods. Authors considered this method valid and useful.

26. van Mens PR, de Vries H. Interocclusal distance determined by electromyographic biofeedback compared with conventional methods. J Prosthet Dent. 52:443, 1984.

Similar study to previous reference, but authors suggested this method is "of little use.

27. Wagner AG. Comparison of four methods to determine rest position of the mandible. J Prosthet Dent 25:506, 1971

1. Measurement of rest position —— Best
2. Phonetics (m-m-m) ———— Increase OVD
3. Swallow method ———— Decrease OVD

28. Kleinman AM, Sheppard IM. Mandibular rest levels with and without dentures in place in edentulous and complete denture-wearing subjects. J Prosthet Dent 28:478, 1972

50 subjects - When used rest position for determination of OVD, there was an error of increasing the OVD too far in more than one half of the patients.

29. Sheppard IM, Sheppard SM. Vertical dimension measurements J Prosthet Dent 34:269, 1975.

Ceph study - With <u>edentulous</u> mandible, rest position is not suitable for determining OVD.

30. Lyons MF. An electromyographic study of mastication muscle activity at increased occlusal vertical dimension in complete denture wearers. J Prosthet Dent 1988; 60:346-48.

Found that it is possible that discomfort from complete dentures with excessive OVD might not be related to increase muscle activity.

31. Mack MR. Vertical dimension A dynamic concept based on facial form and oropharyngeal function. J Prosthet Dent 1991;66:479-85.

Author uses unusual methods for determing OVD. Included are the adaptation of the Golden Proportion and stresses the importance of the location of the occlusal plane.

32. Rivera-Morales WL, Mohl ND. Relationship of occlusal vertical dimension to the health of the masticatory system. J Prosthet Dent 1991;65:547-53.

Excellent current review – Patients may adapt to moderate increases in OVD without it being detrimental to the masticatory system.

33. Weinberg LA. Vertical dimension. A research and clinical analysis. J Prosthet Dent 47:290, 1982.

Excellent review on this entire subject!

CONDYLAR POSITION IN CENTRIC RELATION

1. Celenza FW, Nasedkin JN. *Occlusion: The State of the Art.* Quintessence Publishing Co., Inc. Chicago, Berlin, Rio de Janerio, Tokyo. 1978.

Excellent reference on this subject. Illustration of consensus of conference participants relative to location of the condyles in the centric relation position.

2. Dawson PE. *Evaluation, Diagnosis, and Treatment of Occlusal Problems* 2nd ed. The C.V. Mosby Company, St.Louis, Baltimore, Toronto. 1989.

Defines centric relation and explains his method for achieving and recording this mandibular position.

REFERENCES ON MAKING THE CENTRIC RELATION RECORD

1. Zarb GA, Bolender CL, Hickey JC,.Carlsson GE. *Boucher's Prosthodontic Treatment for Edentulous Patients* 10th ed. The C.V. Mosby Co., St. Louis 1990, Chapters 11-13.

Chapter 13, p.282 - excellent practical approach on the subject relative to complete denture prosthodontics.

2. Yurkstas AA, Kapur KK. Factors influencing centric relation records in edentulous mouths. J Prosthet Dent 14:1054, 1964.

Study of the use of wax for making the centric relation record. Found that most repeatable results were achieved when the wax was placed in the premolar and molar area, softened uniformily on both sides, and stressed that the anterior occlusion rims must <u>not contact</u> during closure.

3. Lassila V. Comparison of five interocclusal recording materials. J Prosthet Dent 55:215, 1986.

Tested properties of 6 materials used for recording the CR position. The only wax studied was Baseplate wax. Wax was considered unreliable because of "considerable" cooling contraction. The author.suggested wax can be made more reliable by leaving it at the site of registration.

4. Berman MH. Accurate interocclusal records. J Prosthet Dent 10:620, 1960.

Stressed the need for <u>minimal</u> pressure when closing into the registration material. Investigated the properties of 8 waxes and one ZOE product. Found all waxes offer some resistance.

5. Trapozzano VR. Occlusal records. J Prosthet Dent 5:325, 1955.

Held the position that the use of a central bearing point will not produce equalized pressure. Felt that the static wax intraoral CR record is more accurate.

6. Grasso JE, Sharry J. The duplicability of arrow-point tracings in dentulous subjects. J Prosthet Dent 20:106, 1968.

15 subjects studied. Found variability of the apex position of the needlepoint tracing over a 29 day period. The changes in the mediolateral direction were greater than the anterior-posterior position.

"Myo-Monitor centric"

7. Strohaver SA. A comparison of articulator mountings made with centric relation and myocentric records. J Prosthet Dent 1972;28:379-89.

Six methods of mounting casts. - Conclusions:

1. Myocentric position most variable mounting.

2. Also produced the most protruded relationship of the mandibular cast to the axis. (THA)

8. Remien JC. "Myo-Monitor centric": An evaluation. J Prosthet Dent 1974;31:137-45.

10 Patients - 3 Myo-Monitor CR records at each of three appointments.

1. Axis anterior and inferior to the THA.

2. Mandible. anterior to its position in CR and CO.

3. Tooth contact usually anterior to the axis.

9. Dao TTT, Feine JS, Lund JP. Can electrical stimulation be used to establish a physiologic occlusal position? J Prosthet Dent 1988;60:509-14.

1. Stimulation does not cause reflex of the jaw closing mm. Acts only in the periphery without participation of the CNS .

2. No evidence that reflex jaw closure can be used to establish a physiologic occlusal position.

DETERMINING THE CONDYLAR PATH INCLINATION

1. Craddock FW. The accuracy and practical value of records of condyle path inclination. J.A.D.A. 38:697, 1949.

Evaluated a series of 54 consecutive wax records and made 240 articulator adjustments of condyle path inclinations. Concluded that the use of such intraoral wax record is invalid and unreliable.

2. Posselt U. Registration of the condyle path inclination by intraoral wax records: Variations in three instruments. J Prosthet Dent 10:441, 1960.

Determined the most accurate condylar distance in protrusive for recording the path inclination:

1. 2mm - best physiologically.

2. 6-8 mm - best for mechanical reasons.

3. Compromise - 4mm.

3. Posselt U. Registration of the condyle path inclination by intraoral wax records--its practical value. J Prosthet Dent 11:43, 1961.

Considered intraoral wax record can be of value.

4. Dubois BL, Condylar guidance inclination changes. J Prosthet Dent 16:44, 1966.

1. Condyles forward 6mm - accurate and desireable.

2. Condylar path inclination may change in first 3 months after placement - perform a clinical remount using a new protrusive record.

5. Curtis DA, Comparison of protrusive interocclusal records to pantographic tracings. J Prosthet Dent 62:154, 1989.

Average inclination by Pantogram — 30 degrees.
Using wax for protrusive record —— less than 30 degrèes.

6. Zamacona JM,.et al. Study of the sagittal condylar path in edentulous patients. J Prósth Dent 68:314, 1992.

55 patients – recorded condylar path with Gerber's face bow and graphic registrations for extraoral tracings.
Found that the angulation varies greatly on each side from one individual.

SOME DEFINITIONS OF CENTRIC RELATION

Compiled by C.C. Kelsey 10/93

1. A maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterior-superior position against the slope of the articular eminences. This position is clinically discernible when the mandible is directed superiorly and anteriorly and restricted to a purely rotary movement about a transverse horizontal axis.

   Glossary of Prosthodontic Terms.
   5th ed., 1987.

2. The most retruded physiologic relation of the mandible to the maxillae to and from which the individual can make lateral movements. It is a condition which can exist at various degrees of jaw separation. It occurs around the terminal hinge axis. 2. The most posterior relation of the mandible to the maxillae at the established vertical relation.

   Glossary of Proshtodontic Terms.
   3rd ed., 1968.

3. Centric relation is the most posterior position of the mandible relative to the maxillae at the established vertical dimension.

   Boucher's Prosthodontic Treatment for Edentulous Patients, 10th ed. The C.V. Mosby Co., St. Louis 1990, p.283

4. The relation of the mandible to the maxillae when the condyles are in the uppermost and rearmost position in the glenoid fossae. This position may not be recordable in the presence of dysfunction of the masticatory system.

   International Workshop on Complete Denture Occlusion. Ann Arbor, MI 1973, pg 76..

5. Centric relation may be defined as the relationship of the mandible to the maxilla when the properly aligned condyle-disk assemblies are in the most superior position against the eminentia, irrespective of tooth position or vertical dimension.

Dawson, P.E.:*Evaluation, Diagnosis, and Treatment of Occlusal Problems,* 2nd ed. The C.V. Mosby Company, St. Louis, Baltimore, Toronto 1989.p 29.

6. Centric relation (CR) is a maxilla to mandible relationship in which the condyles and disks are thought to be in the midmost, uppermost position. The position has been difficult to define anatomically but is determined clinically by assessing when the jaw can hinge on a fixed terminal axis (up to 25mm). In CR the condyle-disk assemblies are aligned and in the superior position against the articular eminences.

Major M. Ash, Personal communication, 2/90.

7. Centric relation is a clinically determined relationship of the mandible to the maxilla when the condyle-disk assemblies are positioned in their most superior position in the mandibular fossae and against the distal slope of the articular eminence.

Major M. Ash, Personal communication, 10/91

8. Centric relation is a clinically determined position of the mandible placing both condyles into their anterior uppermost position. This can be determined in patients without pain or derangement in the TMJ.

Sigurd P. Ramfjord, Personal communication, 9/91.

9. The most superior position of the mandibular condyles with the central bearing area of the disk in contact with the articular surfaces of the mandibular condyles and the articular eminences.

Gilboe, D.B.: Centric relation as the treatment position. J Prosthet Dent 50:685, 1983.

(This definition accepted by G.A.Zarb in *A Textbook of Occlusion,* Mohl, N.D., Zarb, G.A., Carlsson, G.E. and Rugh, J.D., eds. Quintessence Publishing Co., Inc. 1988, p.89.)

10. ...the condyles are in the CR position, located most superioanteriorly in the mandibular fossae and braced against the posterior slopes of the articular eminences, with the discs properly interposed (musculoskeletally stable).

Okeson, J.P., *Management of Temporomandibular Disorders and Occlusion,* 2nd. The C.B. Mosby Company, St. Louis 1989, p261.

11. Retruded jaw position (centric relation) ...is described as the jaw position at which the condyles are in close apposition with the articular tubercle (emimence) and where condyles and interarticular discs are correctly aligned (i.e. a 'close-packed' position) at an acceptable vertical dimension of occlusion.

Klineberg, I., *Occlusion: Principles and assessment.* Wright. Butterworth- Heinemann Ltd Linacre House, Jordan Hill, Oxford, 1991, p 14.

From
THE GLOSSARY OF
PROSTHODONTIC TERMS
1993

Centric Relation:

A maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterior-superior position against the slopes of the articular eminences. This position is clinically discernible when the mandible is directed superiorly and anteriorly and restricted to a purely rotary movement about a transverse horizontal axis.

Centric Occlusion:

The occlusion of opposing teeth when the mandible is in centric relation. This may or may not coincide with the maximum intercuspation position.

Maximum Intercuspation:

The complete intercuspation of the opposing teeth independent of condylar position.

Pantographic Recording Of Mandibular Movements

Dr. Joseph A. Clayton

Pantographic Recording Of Mandibular Movements

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An understanding of the importance of mandibular movements is essential in the oral rehabilitation of patients. Recording the movement potentials of the patient and determining the health of the joints and supporting muscles of the mandible is a major part of the study of mandibular movements. Specific literature citations have been selected for review of this subject area that deal with the following topics:

1. Why record mandibular movements
2. Historical literature
3. Recording areas of function and pantographic tracings
4. Styli - Table relationship for research and setting of articulators
5. Accuracy of articulator settings from pantographic recordings
6. Pantographic reproducibility Index
8. Contrary articles to PRI
9. Electronic pantograph - Pantronic

PANTOGRAPHIC RECORDING OF MANDIBULAR MOVEMENTS

Joseph A. Clayton, D.D.S.,M.S.

WHY RECORD MANDIBULAR MOVEMENTS?

Almost everyone would agree, that the occlusion should be restored in harmony with functional movements. However, mandibular movements for setting an articulator can not be recorded during function. So the next best means would be to record the area in which function occurs, the mandibular border movements. A pantograph records these border movements and the functional area. The more we can record this area and transfer it over to the articulator the more the occlusion can be restored in harmony with function. If less is recorded then more occlusal errors (occlusal interferences) may be developed in the restorations as they are made on the articulator. The errors would have to be corrected in the mouth.

Occlusal adjustments take time, therefore, the recording of mandibular border movement with a pantograph saves time. There is also some question as to whether the occlusion can be adjusted correctly in the mouth because of the protective nature of the neuromuscular system. A dentist is responsible for occlusal interference placed in the mouth.

Weinberg LA. An evaluation of basic articulators and their concepts Part IV. fully adjustable articulators. J PROSTHET DENT 1963; 13: 1038-54.

Pantographs are extremely accurate in duplicating three-dimensional motion. Theoretically, no occlusal errors are produced.

I. HISTORY:

McCollum BB, Stuart CE. A research report. South Pasadena, Calif: Scientic Press, 1955: 34-88.

They studied articulator movements compared to patient movements. They developed an instrument to record jaw movements in 3 planes. This became the prototype for the development of pantographs. It had curved anterior styli, the horizontal styli were on the hinge axis, and the posterior styli moved with the mandible. The instrument was literally built for and on the patient.

They had clutches that let the chewing surfaces of the teeth contact. They started tracing at tooth contacts and opened 10mm. All tracings retraced. They recorded function (chewing) to the border tracings. Different bearing surfaces did not change the tracings.

Lucia VO. Modern gnathological concepts. St. Louis: C.V. Mosby Co., 1961:293.

Balanced occlusion for restorations on natural teeth were found to be unnecessary and could be harmful. Gnathology started out with balanced occlusion as the concept of choice. This required a detailed recording of mandibular movement. Thus the desire to develop a recording device. Balanced occlusion in these days, early 1930's, was good for dentures.

After they observed the damage that balanced occlusion did in mouths, it was discarded and the canine guidance, mutually protected concept was developed. With this concept, there was less of a need to "track all the line" recorded by the pantograph. This opened the door for new types of pantographs to develop.

Guichet NF. Applied Gnathology. Why and how. Dent Clin North Am 1969; 13: 687-703.

A new pantographic system, Denar Pantograph, was developed that reduced the complexity of pantograph procedures and the time involved.

Shotwell JL, Kotowicz WE, Clayton JA. Ability of edentulous subjects to reproduce mandibular border tracings. J PROSTHET DENT 1980; 44: 379-83.

The results of this study showed that many edentulous subjects, utilizing stabilized baseplates to support a pantograph, were capable of making reproducible mandibular border movements.

Beard CC, Donaldson, K, Clayton JA. Comparison of an electronic and mechanical pantograph. Part I: Consistency of an electronic computerized pantograph to record articulator settings. J PROSTHET DENT 1986; 55: 570-74.

This study compared articulator settings of mechanical (Denar Corp) pantograph and the Pantronic. Dentists with a lack of recording experience did not cause excessive fluctuations in Pantronic recordings. The Pantronic recorded articulator settings that were consistent with that of the mechanical pantograph.

Stuart CE. Use of the Stuart articulator in obtaining optimal occlusion. Dent Clin North Am 1979; 23: 259-70.

Dr. Stuart maintained that his frictionless condylar recordings were the only way that full mandibular border movements could be copied. He claimed that other devices and "upside - down molar writings are little more than useless gestures made to imitate pretended accuracy."

Donaldson K and Clayton JA. Comparison of mandibular movements recorded by two pantographs. J PROSTHET DENT 1986; 55: 51-8.

This study compared the articulator settings made from the Denar and Stuart pantographs. The mean data showed a 0.007mm difference between the two and this was not statistically significant. The Denar and Stuart pantographs recorded mandibular movements within a mean difference of less than 0.1mm. They produce identical articulator settings.

Mensor Jr MC. Instrument selection and mandibular movement recording procedures. J PROSTHET DENT 1973; 30: 659-63.

The pantographic and stereographic methods of recording mandibular movements are comparable.

II. RECORDING AREAS OF FUNCTION (CHEWING) AND PANTOGRAPHIC TRACINGS

The question is continually raised, "Why record the border movements with a pantograph? People don't chew to the borders." Studies have been done to relate the area of chewing with the border movements.

Clayton JA, Kotowicz WE, Zahler JM. Pantographic tracings of mandibular movements and occlusion. J PROSTHET DENT 1971; 25: 389-96.

Subjects can function to the border tracings recorded by a pantograph provided tooth guidance does not deflect functional movements away from the border tracings.

Posselt U. Sagittal condylar guidance. Odontologisk Revy 1960; 11: 32-6.

He attached a pantograph (McCollum Gnathograph) to the teeth so the occlusal surfaces could contact. He changed the tooth guidance, flat and curved and the condylar path recordings were identical. Patients chewed and the recordings were also identical, chewing strokes contacted these tracings.

Butler JH, Zanders HA. Evaluation of two occlusal concepts. Amer. Equilibration Soc Compend 1969; 9: 144-51.

The occlusion was restored and adjusted to centric relation (retruded position). Subjects contacted this border position during chewing.

Dewe-Mathews GJ. Observations of graphic tracings of functional mandibular movements [Master of Science Thesis] Ann Arbor, Michigan, University of Michigan, 1975.

This study, with the pantograph attached to the teeth, showed that occlusal interference can deflect the jaw movements away from the border tracings. The muscles learn an avoidance pattern. They chewed around an interference. The interference was removed and the patient's jaw moved for a period of time as if the interference was still there. Occlusal interferences can program jaw closure and movements. The true border movement may not be recorded if the muscles are under the influence of occlusal interferences and muscle dysfunction.

III. STYLI - TABLE RELATIONSHIP FOR RESEARCH AND SETTING OF ARTICULATORS.

The arrangement of the styli of a pantograph can affect the graphic recordings. Artifacts can be created in the recordings. If conclusions are being made from the tracings (Graphics) then the styli-table arrangement is critical. If the tracings are to be used to set an articulator (pantograph) then the styli-table set-up is not critical. The misunderstanding was created with the development of the Denar Pantograph. The posterior tables move and the styli are stationary. The original pantograph (Stuart) was developed for research and to draw conclusions from the tracings. The posterior styli moved with the mandible and the tables were stationary.

Clayton JA. Border positions and restoring occlusion. Dent Clin North Am 1971; 15: 525-42.

Recordings were made with a pantograph attached to the teeth so that the occluding surfaces were free. Records were made with teeth in contact and at increased openings. Different bearing surfaces were used. If the styli-table relationship is correct, the tracings are the same. Chewing was also recorded in relationship to occlusal interferences.

Lepera F. Understanding graphic records of mandibular movements. J PROSTHET DENT 1967; 18: 417-24.

This article describes the effects of the positioning of the styli-table elements in the condylar region on the nature of the tracings of mandibular movement. "Graphics" and "Pantographics" were identified.

Cohen R. The relationship of anterior guidance to condylar guidance in mandibular movements. J PROSTHET DENT 1956; 6: 758-67

Recordings were made with the Gnathograph and transferred to the Gnathoscope. Tracings were made with flat, convex and concave clutch surfaces. On the articulator the posterior tracings were identical. The anterior tracings were not because the styli were not curved or "zeroed".

IV. ACCURACY OF ARTICULATOR SETTINGS FROM PANTOGRAPHIC RECORDINGS.

The early articulators (Stuart) designed to be set from a pantograph had fossa elements that were grounded to "track" or reproduce the exact movements. With the introduction of the new concept of occlusion and the Denar Pantograph and D5A fully adjustable articulator, the articulator could be set (programmed) to various parts of the pantographic tracings. The accuracy of these settings became a topic for research.

Watt DA. A study of the reproducibility of articulator settings from graphic records of mandibular movements. Dent Practit 1968; 19: 119-22.

Various observers set the articulator from the same pantographic tracings. The differences observed between setting by different observers were great enough to make the author conclude that the high probability of error made the instrument unacceptable.

Coye RB. A study of the variability of setting a fully adjustable gnathologic articulator to a pantographic tracing. J PROSTHET DENT 1977; 37: 460-65.

The variability encountered in setting a fully adjustable articulator to a pantograph was studied. The adjustment for the top wall, rear wall and the vertical axis showed some variability. There was inherent system variability. Mechanical and operator errors were involved.

Winstanley RB. Observations on the use of the Denar pantograph and articulator. J PROSTHET DENT 1977; 38: 660-72.

The reproducibility of articulator settings were related to the experience of the operator. Eighteen participants were used. This study showed that most of the articulator adjustments were reproducible with a reasonable degree of accuracy. The rear and top wall settings gave the most variability. Familiarity increased the accuracy in reproducing the settings.

Curtis DA, Sorensen JA. Errors incurred in programming a fully adjustable articulator with a pantograph. J PROSTHET DENT 1986; 55: 427-29.

The mean differences from known values were low for condylar inclination, progressive side shift and immediate side shift. Experienced dentists did better than inexperienced dentists. Errors were high in both groups for top wall and rear wall settings.

V. PANTOGRAPHIC REPRODUCIBILITY INDEX (PRI).

When patients develop TMJ dysfunction, the muscles lose their coordination. They are uncoordinated in moving the jaw. The ability, or lack of ability, of a patient to reproduce the lateral border movements on pantograph tracings reflects this incoordination. Therefore, pantograph tracings could be used to detect muscle dysfunction, incoordination. The PRI was developed to score dysfunctional pantographic tracings.

Clayton, JA, Crispin BJ, Shields JM, Myers GE. A Pantographic Reproducibility Index (PRI) for detection of TMJ dysfunction. J Dent Res 1976; 55: 161 (Abstract).

When patients were asked to repeat the lateral border movements 3 times to each side, there was a difference in reproducibility. This seemed to be related to muscle dysfunction. The PRI is a scale that was developed to quantitate the difference between the normal and abnormal reproducibility.

Shields JM, Clayton JA, Sindledecker LD. Using the pantographic tracings to detect TMJ and muscle dysfunction. J PROSTHET DENT 1978; 39: 80-7

The PRI was evaluated against an established clinical dysfunction index Helkemo Dysfunction Index (HDI).

Crispin BS, Myers GE, Clayton JA. Effects of occlusal therapy on pantographic reproducibility of mandibular border movements. J PROSTHET DENT 1978; 40: 29-34.

Occlusal splint therapy and occlusal adjustments were used on subjects with high PRI to determine their effect on the PRI scores, or TMJ dysfunction. There was a statistically significant difference (.01 level) reduction in the PRI as a result of occlusal therapy. No significant change occurred in the controls.

Lederman KH, Clayton JA. Patients with restored occlusion. Part I: TMJ dysfunction determined by a pantographic reproducibility index. J PROSTHET DENT 1982; 47: 198-206.

The PRI was used in an epidemiologic study of a population to determine the degree of TMJ dysfunction

Lederman KH, Clayton JA. Restored occlusion. Part II: The relationship of clinical and subjective symptoms to varying degrees of TMJ dysfunction. J PROSTHET DENT 1982; 47: 303-10.

Various aspects (23) of TMJ dysfunction symptoms were evaluated with the PRI. Clinical and subjective symptoms were not as reliable as PRI scores in detecting TMJ dysfunction, especially slight dysfunction

Beard CC, Clayton JA. Effects of occlusal splint therapy on TMJ dysfunction. J PROSTHET DENT 1980; 44: 324-35

Occlusal splint therapy reduced the PRI scores to no TMJ dysfunction. The splints were removed and nothing else was done. The TMJ dysfunction returned and the PRI scores increased again.

Clayton JA. A pantographic reproducibility index for use in diagnosing temporomandibular joint dysfunction: A report on research. J PROSTHET DENT 1985; 54: 817-31

This article summarizes the research that has been done to validate the PRI as a scale in detecting TMJ dysfunction. Over 200 patients had been studied and more than 2300 tracings had been scored.

VI. CONTRARY ARTICLE TO PRI.

Monteiro AA, Clark GT. Relationship between mandibular movement accuracy and masticatory dysfunction symptoms. J Craniomandib Disorders: Facial & Oral Pain 1987; 4: 237-42.

A light-emitting diode (LED) mandibular tracking system was used to record mandibular movements in muscle dysfunction and normal patients. Poor lateral movement reproducibility separated the two groups. Pain intensity and functional imitations showed low correlations.

Mohl ND, McCall Jr WD, Lund JP, Plesh O. Devices for the diagnosis and treatment of tempromandibular disorders. Part I. Introduction, scientific evidence, and jaw tracking. J PROSTHET DENT 1990; 63: 198-201.

This committee's review concluded the claims that jaw-tracking devices have diagnostic value for TMD is not completely supported by scientific evidence. Longitudinal evidence of the natural history and long-term effects, is any, of high PRI symptomatic individuals are needed.

VII. ELECTRONIC PANTOGRAPH: PANTRONIC (DENAR CORP.).

Clayton JA, Beard CC, Donaldson K, Meyers GE. Clinical consistency of recordings among dentists using an electronic pantograph (Abstract). J Dent Res 1983; 62: 200.

Twenty subjects were recorded with the Pantronic by seven novice to experienced operators. 97% of the ISS were within 0.3mm, 97% of the PSS were within 3° and 100% of the PRO were within 3°. The Pantronic gave recordings that were consistent over time and between operators.

Clayton JA, Beard CC, Donaldson K, Meyers GE. Clinical evaluation of electronic pantograph with mechanical pantograph (Abstract). J Dent Res 1983; 62: 200.

Twenty subjects were recorded with the mechanical pantograph (Denar Corp.) and the Pantronic. The articulator settings from the mechanical pantograph and Pantronic settings were compared. 93% of the ISS were within .3mm, 92.5% of the PSS were within 4° and 87% of the PRO were within 6°. The recording from the two methods were comparable.

Clayton JA, Beard CC, Donaldson, K, Meyers GE. Clinical evaluation of electronic pantograph in relation to posterior axes (Abstract). J Dent Res 1983; 62: 200.

Pantronic recordings were made from one subject with the Pantronic oriented 5mm and 10mm from the THA in all directions. Recordings made from the 5mm area were within the standard error. The 10mm area recordings exceeded the standard error by 0.15mm ISS, 3° PSS and 0.5° PRO.

Clayton JA, Beard CC. An electronic, computerized pantographs reproducibility index for diagnosing temporomandibular joint dysfunction. J PROSTHET DENT 1986; 55: 500-05.

An electronic computerized pantograph (Denar Pantronic) for recording the settings for articulators was developed. The computer was programmed to score the PRI and print out a number (PRI) and the degree of dysfunction. This was validated against the PRI recorded by the mechanical (Denar) pantograph.

Beard CC, Clayton JA. Electronic PRI consistency in diagnosing temporomandibular joint dysfunction. J PROSTHET DENT 1986; 55: 255-59.

The Pantronic PRI was consistent over time. It is more consistent than the mechanical pantograph PRI. Eleven different operators, experienced and novice, showed that experience need not cause P-PRI fluctuations in a dysfunction-free patient. Fluctuations are caused by the TMJ dysfunction muscle symptoms.

Kim KH, Chung SC. A study on pantronic PRI for diagnosing TMJ dysfunction. J Korean Acad Oral Med 1986; 11: 45-55.

This study compared the PRI to the Helkemo index (HDI) and evaluated the consistency of the Pantronic PRI. The Pan-PRI was more sensitive than the HDI. The Pan-PRI was consistent within each session and among sessions.

Anderson GC, Schulte JK, Arnold TG. An in vitro study of an electronic pantograph. J PROSTHET DENT 1987; 57: 579-80

The retrievability of articulator settings by the Pantronic (Denar Corp.) was studied directly on an articulator. The Pantronic was accurate and reliable in recording ISS, PSS and CI. The reliability and validity of the rear and top wall setting improved with increased immediate side shift settings.

Pelletier LB, Campbell SD. Comparison of condylar control settings using three methods: A bench study. J PROSTHET DENT 1991; 66: 193-200

The Pantronic (Denar Corp.), mechanical pantogaph (Denar Corp.) and simplified mandibular motion analyzer (Whip-Mix and Denar) were compared on a bench study. The best to worst method of recording the immediate side shift was Pantronic; polyether interocclusal records; mechanical pantograph, simplified mandibular motion analyzer (Panadent);; simplified mandibular motion analyzer (Whip-mix and Denar) and zinc oxide interocclusal records

Mandilaris CB, Beard CC, Clayton JA. Comparison of the intercondylar distance and the interfacial width as used with the electronic pantograph. J PROSTHET DENT 1992; 67: 331-34.

There has been concern in the Pantronic (Denar Corp.) that the intercondylar distances is not transferred to the articulator. The interfacial width can be used by measuring between the reference point on the posterior tables. This study of 45 subjects indicates that the use of 15mm from tissue surface to condyle center is more accurate than the 12.5mm used on the mounting studs..

Section Three - Periodontal And TMD Considerations In Prosthodontic Therapy

Section Three contains information related to the importance of the health of the periodontal structures to prosthodontic therapy. A literature reviews have been prepared by an outstanding periodontists. The bone and periodontal membrane provides the foundation for the support of the teeth. Prosthodontists and restorative dentists must be aware of the methods of periodontal evaluation and the classic periodontal indicators of health and disease. The biologic width and the junctional epithelium, margin location, crown contour, overhangs, and material science are all directly related to periodontal health and prosthodontic success. Pre-requirements for pre-prosthetic periodontal surgery must be well-known to the practitioner as therapy is planned. When to use crown lengthening procedures is equally important. The examination, diagnosis and treatment of temporomandibular joint dysfunction must be well understood by prosthodontists and restorative dentist who are preparing to embark on the oral rehabilitation of a patient. Topics related to these two major areas of prosthodontics are contained in the reviews by the following authors:

Dr. Robert B. O'Neal

"Periodontal Considerations In Prosthodontic Therapy"

Dr. Christian S. Stohler

"Examination, Diagnosis, And Treatment Of TMD"

Peridontal Considerations In Prosthodontic Therapy

Dr. Robert B. O'neal

The University of Michigan
School of Dentistry
Department of Periodontics/Prevention/Geriatrics
Topic: Periodontal Considerations in Prosthodontic Therapy

Dr. ROBERT B. O'NEAL

Periodontal Considerations in Prosthodontic Therapy

Content:

1. Periodontal Evaluation.
2. Correction of soft tissue abnormalities.
3. Crown lengthening procedure.
4. Ridge augmentation procedures.

Definition

Biologic Width: The soft tissue which is attached to the portion of the tooth coronal to the crestal alveolar bone.
Emergence Profile: The shape of the teeth relative to its gingival housing.

Classic Periodontal Indicators

1. Clinical Changes
2. Radiographic Evaluation
3. Clinical probing
4. Documentation

Location of the Restoration Margin Depends on:

1. Esthetics
2. Need for additional retention of the restoration
3. Degree of personal oral hygiene
4. Susceptibility of the individual to root caries
5. Morphologic characteristics of the marginal gingiva
6. Susceptibility of the marginal gingiva to irritants
7. Degree of gingival recession
8. Severe cervical abrasions

Biologic Width

The distance from junctional epithelium to the alveolar crest. It includes J.E. and supracrestal C.T. attachment, usually it remains constant (2.04 mm).

Gargiulo et al., J. Periodont., 32:261, 1961
Dragoo et al., Int. J. Perio. & Rest. Dent.,1:9, 1981
Lang, JP, 1972
Kennedy, JCP, 1985
Miyasto, JCP, 1977
Stetler & Bissada, JP, 1987

Junctional Epithelium

Clinical vs. Histologic Probe Location

Spray & Garnick, JP, 1978
Stern, JP, 1987

The plaque free zone: fact or myth

Margin Location

Silness (J Periodontal Res, 1970)
- Prefer supragingival margins

Orkin et al (J Prosth Dent, 1987)
- Restorations in subgingival group had a 6 times higher chance of bleeding and 7 times higher chance of recession

Richter et al (J Prosth Dent, 1973)
- Well fitted crown, no difference between sub- and supragingival margins

Muller (JCP, 1986)
- No difference between the margin placement

Wilson (JPRD, 1981)
- Margin should be placed in the intracrevicular space

Materials

Waerhaug (JP, 1953)
- No difference in reaction between gold, porcelain or acrylic

Stores et al (JP, 1969)
- Amalgam, silicate & resin. Depends on smoothness of the material

Silness (J Periodontal Res, 1970)
- Compare full vs. partial crown
- Full had more soft deposits, more gingivitis, deeper pockets whether or not patients had been given OHI
- Partial crown - No difference between given or not given OHI

Waerhaug (J Dent Res, 1975)

Hadavi & Caffesse (JCNA, 1987)

Crown Contour

Overcontoured vs. Undercontoured

Perel (J Prosth Dent, 1971)

Yuodelis et al (J Prosth Dent, 1973)
- The greater the degree of facial and lingual bulge, the more plaque retained in the cervical region
- The flatter, the less plaque

Erlich et al (J Prosth Dent, 1980)
- Over or under (1mm) - contour of crowns didn't make any difference (regarding pockets, OHI)

Overhang

Gilmore et al (JP, 1971)

Highfield et al (JCP, 1978)

Jeffcoat et al (JP, 1981)

Hakkarainen & Ainamo (J Clin P, 1980)

Spinks et al (JP 1986)
- Diamond tip was faster and smoother to remove overhang

Renggli et al (Helv Odontol Acta, 1972)
- Sub- always had more plaque accumulation than supragingival crown or restoration
- Teeth with restorations always had more plaque than teeth without restorations.

Donaldson (JP, 1973)
- Found 10% of patients with temporary crown had recession of 1mm or more
- Therefore, suggested to have crown margin to at least 1mm into crevice as a precaution against recession. (Healthy tissue does not recede)

Marginal Ridge

Hancock et al (JP, 1980)
No significant relationship between contact type & pocket depth
Kepic & O'Leary (JP, 1978)
When plaque control was good, there was no difference in periodontal breakdown
Koral et al (JP, 1981)
Open contacts were not associated with more localized bone loss
Jernberg et al (JP, 1983)
Found less debris at open contact

Pre-requirement for pre-prosthetic periodontal surgery

1. Good initial therapy
2. Good patient oral hygiene
3. Periodontal Charting

1. Correction of soft tissue abnormalities

Ideally, the qualities of the gingiva can be summarized as follows:

a. The gingival margin should be free from any sign of inflammation
b. The gingival margin should be keratinized, stippled, and firmly attached
c. A clear demarcation between A.G. and mucosa
d. The band of A.G. should be adequate in width
e. Minimal probing depth

2. Crown lengthening procedures

Purpose of crown lengthening

1. Improved esthetics
2. Correct occlusal plane
3. Marginal integrity
4. Structural durability
5. Adequate retention and resistence form

Posterior teeth with pins and grooves require at least 3.5-4.0 mm. of prepared tooth for adequate crown retention. Anterior teeth require approximately 6mm of vertical prepared tooth for adequate retention.

Willey, J., Prosthet. Dent., 35:526, 1976
Kaufman et al., J. Prosthet. Dent., 1:487, 1961

The clinician can proceed with restorations three to four weeks after gingivectomy. When an apically positioned flap is required, eight to ten weeks must elapse before the flap has firmly reattached to the alveolar bone.

Biologic Considerations During Crown Lengthening Procedures

1. Amount of remaining attached gingiva
2. Biologic width of attachment
3. Root dimension
4. Root structure
5. Furcation location

Methods for Crown Lengthening

1. External-bevel gingivectomy
2. Apically positioned flap
3. Apically positioned flap with osseous surgery
4. Orthodontics active or passive eruption
5. Coronal positioning of the gingival margin

Ridge Augmentation

Purposes for Ridge Augmentation

1. Prevention of ridge resorption
2. Correction of soft tissue crater
3. Increased ridge length for placing implant

Technique for Ridge Augmentation

Grafts

- Connective tissue graft
- Sclera grafts
- Synthetic bone grafts (Periograf,® Alveolgraf,® Calcite,® Interpore 200®)

Barrier Membranes

- Gore-Tex® -
- Biomend
- Guidor

PERIODONTAL CONSIDERATIONS IN PROSTHODONTIC THERAPY
October 18, 1993

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I. Biological Width

***1. Gargiulo AW, Wentz FM, Orban B: Dimensions and relations of the dentogingival junction in humans. *J Periodontol* 32:261, 1961.**

30 Human jaws were used that were donated by Dr. Kronfeld. A total of 325 surfaces were measured and all specimens were clinically normal. Areas measured included: A. depth of sulcus, B. length of attached epithelium, C. most apical point of epithelial attachment from CEJ, D. distance from the base of the sulcus to the CEJ, E. distance of the CEJ from alveolar bone and F. distance from the most apical point of the epithelial attachment to the alveolar bone(connective tissue). Specimens were grouped based on phases of passive eruption. **From all the phases tested the most constant measurement was 1.07 mm for the connective tissue attachment. The length of the junctional epithelium was highly variable (0.1mm to 1.4mm).**

2. Ingber JS, Rose LF, Coslet JG: The "biologic width"--a concept in periodontics and restorative dentistry. *Alpha Omegan* 70:62-65, 1977.

This article basically summarizes Gargiulo's article. The decision to restore or extract a mutilated tooth is based upon: 1) the crown to root ratio after the tooth is restored, 2) the position of the tooth in the arch relative to its strategic value, 3) predictability of treatment procedures and the clinician's ability to execute them, 4) esthetics, 5) whether the peridontium or adjacent teeth will be compromised as a result of periodontal surgery which may produce an unsatisfactory anatomic deformity in the involved area and 6) the ability to maintain the periodontium in a state of health after the restorative procedures. In summary, the authors state that **a minimum dimension of 3mm coronal to the alveolar crest is necessary to permit healing and proper restoration of the tooth.**

3. Block, PL: Restorative margins and periodontal health: A new look at an old perspective. *J Prosthet Dent* 57:683-689, 1987.

Review article. He talks about biologic width and suggests a new name **"subcrevicular attachment complex."** The most accurate anatomic structure from which to take measurements for margin placement is the healthy, stable gingival margin. It is clinically visible, unlike the biologic width and should replace the latter as the landmark of **choice for placing dental margins. Surgical crown lengthening will be necessary when a restoration will end at or below the alveolar crest.**

II. Width of Keratinized Gingiva

4. Lang NP, Loe H: The relationship between the width of keratinized gingiva and gingival health. *J Periodontol* 43:623-627, 1972.

This study undertook to examine the width of the facial and lingual keratinized gingiva and to determine how much gingiva is adequate for the maintenance of gingival health . After 6 weeks of supervised OHI the gingival health of 32 dental students was assessed with the GI system. Sites were stratified and compared with one having <2mm keratinized gingiva at a site and the other site >2mm keratinized gingiva. It was demonstrated that gingival health is compatible with a very narrow gingiva. **However, in areas with less than 2mm keratinized gingiva inflammation persisted in spite of effective oral hygiene.**

5. Kennedy JE, Bird WC, Palcanis KG, Dorfman HS: A longitudinal evaluation of varying widths of attached gingiva. *J Clin Periodntol* **12:667-675, 1985.**

32 patients with bilateral areas of inadequate attached gingiva on facial of homologous contralateral teeth were followed for 6 years. Treatment consisted of SC/RP, OHI and maintenance at 3-6 month intervals or as needed. A free gingival graft was placed on one side while the other side was the unoperated control. Inadequate keratinized gingiva (KG) was about 1.4mm. Areas of inadequate KG did not demonstrate additional recession or further loss of attachment. On experimental sides the KG increased to 5.5mm at 6 years. Patients who had discontinued participation in the study revealed a re-establishment of gingival inflammation on the control side but not the graft side.

6. Stetler KJ, Bissada NF: Significance of the width of keratinized gingiva on the periodontal status of teeth with submarginal restorations. *J Periodontol* **58:696-700, 1987.**

58 teeth in 26 patients divided into 2 groups according to width of KG at the midfacial of test teeth. Cut-off was 2mm of KG. Groups were further subdivided into paired teeth, one of which had a full coverage restoration and the other didn't. The findings were: 1) teeth with subgingival restoration and narrow zones of KG showed statistically significant higher gingival scores than teeth having submarginal restoration with wide zones of KG although clinically this difference may not be so significant - GI score of 1.73 vs. 2.27. 2) **Teeth without subgingival restorations showed no statistical difference between narrow and wide zones of KG.**

III. Ideal Margin Location/ Contours

7. Silness J: Periodontal conditions in patients treated with dental bridges.
J. Periodont. Res **5: 60-68, 1970.**

73 bridges in 73 patients were split into 2 groups. One group got OHI the other did not. Average pocket depth was not different between groups. More gingivitis was detected if subgingival margins were placed. Periodontal conditions were better if patients got OHI. 33% of crown margins were sub gingival and 33 % were at the FGM.

****10. Newcomb GM: The relationship between the location of subgingival crown margins and gingival inflammation.** *J Periodontol* **45:151-154, 1974.**

The degree of gingival inflammation on the labial aspect of 66 anterior veneer crowns, with subgingival margins in varying positions, was compared with that on the labial aspect of the 66 uncrowned contralateral teeth. The inflammation score was correlated with the location of the crown margin in the gingival crevice. **The nearer a subgingival crown margin approaches the base of the gingival crevice, the more likely it is that severe gingival inflammation will occur.** The least inflammation is observed when subgingival crown margins are placed at the gingival crest or just into the gingival crevice.

11. Parkinson CF: Excessive crown contours facilitate endemic plaque niches.
J Prosthet Dent **35:424-429, 1976.**

Twenty-five complete cast metal crowns and 25 porcelain-fused-to-metal crowns were compared to 50 contralateral teeth which served as controls in: 1) facial-lingual width at the height of contour, 2) plaque index. Facial and lingual surfaces of teeth restored with complete metal and porcelain-fused-to-metal crowns exhibited greater mean plaque accumulation than did the contralateral teeth. The multifactorial phenomenon influencing plaque accumulation contributed to the findings. In this study, greater facial-lingual width and plaque indices were seen in the restored teeth. However, the creation of artificial crown contours that are greater than natural tooth convexities can be another parameter promoting endemic plaque niches.

12. Leon AR: The periodontium and restorative procedures. A critical review. *J Oral Rehab* **4: 105-117, 1977.**

A review article. The literature associated with the effect on the periodontal tissues of 1) the carious lesion, 2) operative procedures, 3) restorative materials, 4) defective restorations, and 5) the cervical margin of the restoration was reviewed. The bottom line is: opinions have changed from the assumption that only poor restorative dental treatment led to periodontal disease to that **even clinical sound restorations, if positioned subgingivally, may be important etiologic factors in the initiation of periodontal disease.**

13. Blank LW, Caffesse RG, Charbenear GT: The gingival response to well-finished composite resin restorations. *J Prosthet Dent* **42:626-632, 1979.**

Carious lesions occurring at or below the free gingival margin were chosen in this study. Twenty-seven composite resin restorations were placed. The control was the nearest contralateral tooth which was neither carious nor restored. The conclusions are: 1) Well-finished and contoured composite resin restorations do not adversely affect the health of the gingiva. 2) The gingiva exhibits less inflammatory response to a well-finished and contoured composite resin restoration than to an open carious lesion. 3) The gingival inflammatory changes which do occur are independent of the presence of well-finished and contoured composite resin restorations. 4) Observation over an extended period of time is necessary to determine if composite resin restorations ultimately become gingival irritants.

14. Wilson RD, Maynard G: Intracrevicular restorative dentistry. *Int J Periodont Rest Dent* **1:34-49, 1981.**

The first part is "Toward reconciling the esthetic potential of ceramo-metal restorations with established criteria for soft tissue management". Dr. Weiss settled a very simple solution to resolve the esthetic problem of conventional porcelain margin, which is substituting a premier nickel-chromium alloy for gold to reduce the width of the collar to 0.1 mm. The deviation from the standard technique is that two steps are done with the aid of magnification. Insertions of these margins 0.25 mm into the sulcus produces a very lifelike result. The second part is "Periodontal postulates for the prosthodontist". Five postulates are described, which are: 1) Certain clinical procedures are based on concepts and provide empirical therapy. 2) When controversy exists, the periodontal tissues are the yardstick whereby concepts are evaluated. 3) Unless the patient is susceptible to periodontal disease, absence of reaction of the periodontal tissues to a given procedure has no significance. 4) Only patients of proven susceptibility to periodontal disease can provide clinical evidence for evaluating a treatment modality. 5) When the periodontal tissues are actively breaking down under one treatment modality and the break-down is reversed by substitution of another, then systemic factors may be deemed to be of secondary importance and the substitute treatment beneficial.

15. Abbate MF, Tjan AH, Fox WM: Comparison of the marginal fit of various ceramic crown systems. *J Prosthet Dent* **61:527-531, 1989.**

This study evaluated the marginal fit of four ceramic crown systems, 1) metal ceramic crowns with a metal margin, 2) metal ceramic crowns with a porcelain facial margin, 3) Cerestore crowns, and 4) Dicor crowns. Forty tooth-preparation analogs were divided into experimental groups of 10. Measurements of the marginal adaptation were recorded from the facial and lingual margins by using a video-enhanced microscope with digital micrometer and image intensification in a high resolution television screen. **Results indicate that all four crown systems yielded comparable and acceptable marginal fit.**

16. Fitzig S, Eli I: Repair of an overcontoured cemented crown. *J Prosthet Dent* **58:558-559, 1987.**

A method for retracting gingival tissue to allow recontouring of crown surfaces and removal of overhanging margins was presented. Two retraction cords which are conventional retraction cord without epinephrine and soft orthodontic metal cord are placed in gingival sulcus. Good retraction of sulcular wall from irritating restoration is achieved and the existing overhang or overcontour on the crown can be removed with rotary instruments.

17. Carnevale G, di Febo G, Fuzzi M: A retrospective analysis of the perio-prosthetic aspect of teeth re-prepared during periodontal surgery. *J Clin Periodontol* 17:313-316, 1990.

The study describes a retrospective study in which the gingival and periodontal status was assessed of crowned and natural teeth. 510 crowned teeth and 510 natural teeth in 109 subjects were examined. 90% of the patients were on a recall schedule that required prophylaxis once every 3 months; 8% returned every 6 months and 2% once a month. Plaque index and gingival index were assessed at 4 sites per tooth and pocket depth at 6 sites per tooth, the highest reading per tooth being used for the statistical analysis. The results indicated that there was no difference in plaque and gingival indices between crowned and natural teeth. In addition, **the gingival status of the crowned teeth was good, irrespective of the position of the crown margin (subgingival, at the gingival margin or supragingival).**

18. van Dijken JW, Sjostrom S: The effect of glass ionomer cement and composite resin fillings on marginal gingiva. *J Clin Periodontol* 18:200-203, 1991.

Glass ionomer cement and composite resin are the most popular restorative materials in operative dentistry today. Earlier studies have shown more crevicular exudate around different types of composite resins than around intact enamel surfaces. The aim of this study was 1) to investigate plaque, retention on and the condition of the gingiva around, 1-year-old, subgingivally located, glass ionomer cement and composite resin fillings, and 2) to compare the initiation of gingival inflammation around these materials with that around enamel during a 14-day period of experimental gingivitis. Plaque index, gingival index, bleeding on probing and crevicular fluid were recorded and compared intra-individually. The amount of plaque and the degree of gingivitis adjacent to the composite fillings were not significantly higher than those for the glass ionomer cement and enamel surfaces in both the cross sectional and the experimental gingivitis study. Composite resin surfaces showed significantly higher crevicular fluid levels than did enamel at all days in the experimental gingivitis study. Glass ionomer cement showed significantly higher values at day-0 and day-7.

IV. Temporary Restoration

19. Donaldson D: Gingival recession associated with temporary crowns. *J Periodontol* 44:691-696, 1973.

Recession of the free gingival margin from the temporary crown was investigated by direct and indirect methods at subsequent procedures (preparation, temporary crown in place, fitting the temporary crown, and fitting the permanent crown). The results suggested that gingival recession should be expected **when a temporary crown is fitted to a tooth and the sooner the permanent crown is fitted, the less will be the overall recession.** In this study, 10% of the patients showed larger than 1mm recession, therefore, **the margin of the preparation is recommended to be placed at least 1mm into the sulcus as a precaution against subsequent recession.**

***20. Yuodelis RA, Faucher R: Provisional restorations: an integrated approach to periodontics and restorative dentistry. *Dent Clin North Am* 24:285-303, 1980.**

The main objectives of the provisional restoration are to reduce mobility, stabilize the position of the prepared teeth, and to protect the pulp following tooth preparation. It also affords the opportunity to determine the correct esthetic, phonetic, and functional occlusal qualities necessary for each individual patient. The major phases of provisional restoration therapy are presented step by step. Two types of provisional restorations were discussed, all-acrylic resin restoration and gold band and acrylic resin restoration. Tooth movement procedures with provisional restoration and surgical procedures after provisional restoration were also presented. Criteria for success of provisional restoration are 1) mobility decrease, 2) soft tissue appears healthy, 3) supporting bone is free of pathology, 4) mucogingival environment is normal, 5) radiographically normal PDL and well-defined lamina dura, 6) endodontically treated teeth show signs of healing, 7) no discomfort of patient, 8) esthetic, phonetic, and functional qualities are satisfactory to the patient and dentist, and 9) no symptoms of TMJ dysfunction.

21. Tarnow D, Stahl SS , Magner A, Zamzok J: Human gingival attachment responses to subgingival crown placement. Marginal remodeling.** ***J Clin Periodontol **13:563-569, 1986.**

13 teeth in block were extracted from 2 patients. Their facial periodontal condition was essentially within normal clinical limits. Temporary crowns covering the bevel were placed below the base of the crevice 1 to 8 weeks prior to extraction. At time of extraction, all blocks were decalcified, the temporary crown dissolved, and the blocks prepared for histologic examinations using buccolingual cut, step serial sections. Histologic data revealed reformation of a new supracrestal attachment unit within 1 week following crown placement. The reformation of the gingival unit consisted of marginal recession with apical and lateral migration of the junctional epithelium to the level of remaining cementum inserted fibers. With gingival recession and migration of junctional epithelium, resorption of crestal portions of the facial plate occurred. However, periodontal fibers anchored into cementum opposite the resorbed bone were not lysed. Rather, the attached fibrillar ends appeared to interdigitate with fibers from the corium of the facial gingiva at this site, thereby forming a more apically located crestal attachment. **This response may be one mechanism of reformation of the gingival attachment unit taking place following mechanical and/or surgical injury to this site and is completed often, within 2 weeks after injury.**

22. Shavell HM: Mastering the art of tissue management during provisionalization and biologic final impressions. ***Int J Perio Restorative Dent*** **8:24-43, 1988.**

The key to successful, atraumatic, bloodless final impression is the soft tissue. The integrity of the periodontium during tooth preparation and final impressions must remain inviolate. The author presented cases with certain procedures("dry" or "wet" gingival retraction techniques), materials(Gingibraid, Gingigel), and instruments(retracting/deflecting instrument- Retracto-Grad, Big-Bite diamond burs). He also **emphasized preparing the soft tissue before the hard tissue and not taking an impression at the same appointment of preparation.**

23. Creugers NH, Snoek PA, Vogels AL: Overcontouring in resin-bonded prostheses: plaque accumulation and gingival health. ***J Prost Dent*** **59:17-21, 1988.**

Five factors have been mentioned to be responsible for plaque accumulation and gingival reaction associated with resin-bonded partial dentures. These are 1) overcontouring of the lingual surface of abutment teeth, 2) a cervical niche apical to overcontoured retention wings, 3) contour of the connector between the retention wing and pontic, 4) contour of pontics, and 5) surface characteristics of materials used in fabrication. The former 3 factors were evaluated and the results showed **1) preparation of abutment teeth for resin-bonded prostheses to avoid cervical overcontouring by the retention wings may not be necessary to control gingival health and 2) oral hygiene procedures including the use of dental floss is necessary to limit the amount of plaque accumulation at the site of the overcontoured connector.**

24. Lowe RA: Esthetic restoration of the maxillary anterior region: a case report. ***Int J Periodontics Restorative Dent*** **9:354-363, 1989.**

A case has been presented that illustrates **the importance of the proper gingival levels, the use of provisional restorations to develop proper contour and characterization, and how these parameters interact to enhance the esthetic result obtained** when restoring the maxillary anterior segment of the dentition.

V. Gingival Reaction to Crown Margins

25. Loe H: Reactions to marginal periodontal tissues to restorative procedures. ***Int Dent J*** **18:759-778, 1968.**

This paper described the influence of restorative procedures on the marginal periodontium. It stated that the use of rotating instruments during subgingival preparations and the placement of retraction material traumatized the crevicular epithelium and adjacent connective tissue. **However, the trauma produced by these procedures is reversible, and provided the lesion can heal against a clean tooth surface, no permanent damage is done.** Also, the author stated that at that time (1968) there was substantial evidence that restorations extended subgingivally can cause damage to the periodontium by bacterial retention and that the GV Black concept of extention of preps subgingivally for prevention of caries should be abandoned.

***26. Renggli HH, Gegolati B: Gingival inflammation and plaque accumulation by well-adapted supragingival and subgingival proximal restorations.** *Helv Odontol Acta* **16:99-101, 1972.**

The aim of this investigation was to determine whether the location of filling margins supragingivally or subgingivally had an influence on inflammation of the interdental gingiva, or on plaque accumulation. Paticipants included 29 subjects with either a sound tooth surface or a well adapted amalgam filling with a sub or supra gingival margin on the mesial aspect of four selected teeth. Gingival inflammation and plaque accumulation on these surfaces were scored. Results showed that **gingivitis was more pronouned with subgingival margins** than with supragingival margins or sound tooth surface. Also, **plaque accumulation was greater on fillings (irrespective whether sub or supra gingival) than on sound tooth surfaces.**

27. Newcomb GM: The relationship between the location of subgingival crown margins and gingival inflammation. *J. Periodontol* **45:151-154, 1974.**

The degree of gingival inflammation on the labial aspect of 66 anterior veneer crowns, with subgingival margins of varying positions from the base of the crevice (0.25, 0.5, 0.75, 1.0 mm) were compared with uncrowned contralateral controls within the same patient. An inflammation score (Loe and Silness' GI) was then correlated with the location of the crown margin in the crevice. Results **showed that the nearer a subgingival crown margin approaches the base of the gingival crevice, the more likely it is that severe gingival inflammation will occur.**

28. Valderhaug J, Birkeland JM: Periodontal conditions in patients 5 years following insertion of fixed prosthesis. *J Oral Rehab* **3:237-243, 1976.**

389 fixed prostheses in 114 patients were evaluated yearly for 5 years. The margins of the prostheses were located sub-gingivally, at the gingiva, and supra-gingivally. Evaluation was based on oral hygiene, gingival condition, pocket depth, and loss of attachment. Initially 65% of the crown margins were sub-gingival compared to 41% 5 years later. Results showed that **when the crown margins were located sub-gingivally there was an increase in Gingival Index scores, in pocket depth, and in loss of attachment compared to a supra-gingival placement.** Most of the alterations were small , (eg. average LOA was 1.2mm for sub-gingival margins, 0.8 at the gingiva, and 0.6 for supra-gingiva margins.)

29. Dragoo MR, Williams GB: Periodontal tissue reactions to restorative procedures. *Int J Periodont Rest Dent* **1:8-23, 1981.**

This investigation was designed to examine the response of the human periodontium to crown preparations and related restorative procedures. Ten teeth, which had been scheduled for extraction, in four human subjects were prepared on the labial surface. The preps were performed with and without retraction methods The teeth were in different stages of passive eruption as well. The teeth were removed with their associated alveolar and gingival processes and submitted for histo evaluation. **Results:** 1) Preps cut without retraction cord resulted in extensive damage to sulcular epith and the conn. tissue. **2) Placement of retraction cord *prior* to tooth reduction results in minimal damage to the gingival complex (supposedly the cord shields the soft tissues from the cutting instrument).** 3) Excessive damage to the gingival complex occurred when a cord was placed *after* the prep (more pressure usually needed to place the cord afterwards to keep it in place, thus causing separation of both JE and CT attachments) 4) A margin to be placed subgingivally will eventually become exposed with passive eruption. It is recommended to plan on replacing the restoration later at a subgingival level, if needed for esthetics, rather than to try to predict the future by placing the margin excessively subgingval and possibly violating biological width.

30. Tarnow D, Stahl SS, Magner A, et al: Human gingival attachment responses to subgingival crown placement. Marginal remodelling. ***J Clin Periodontol*** **13:563-569, 1986.**

The purpose of this study was to sequentially monitor the gingival margin responses to temporary crowns when margins were placed within the gingival attachment unit (midway between ging. margin and bone) over an eight week period. A total of 13 teeth, previously planned for extraction, in two patients were prepared for crowns and temporized 1 to 8 weeks prior to in block removal. The facial perio condition was essentially within normal limits prior to crown placement. Results revealed that 1-2 wks post-treatment, gingival recession (ave.- 0.9mm) had taken place and the gingival marginal attachment had shifted. Histo observations of this time interval showed that **reorganization of the supracrestal fiber unit had already been established** and that significant resorption of the labial plate had occurred. Gingival inflamation was mild. In the 3-8 week post-treatment group, gingival recession averaged 1.2mm. Histo revealed a functionally oriented supracrestal unit and limited remodeling at the crest. Mild to moderate inflammation was present. **Thus, from the material presented here, it appears that a rapid gingival repair mechanism is activated by the placement of subgingival crown margins, especially in the form of recession and limited gingival inflammation.**

31. Chen JT, Burch JG, Beck FM, Horton JE: Periodontal attachment loss associated with proximal tooth restorations. ***J Prosthet Dent*** **57:416-420, 1987.**

Sixty extracted teeth (31 premolars, 29 molars) with discernible levels of previous periodontal attachment and containing an amalgam restoration on only one proximal surface, were selected to determine if there is a correlation between prox. restorations and perio attachment loss. The supra CEJ restorations were categorized as *"good"* : smooth tooth/restoration junction; or *"poor"* : rough or deficient tooth/restoration junction. Results showed that there was no significant difference in mean attachment between "good restored proximal surfaces" and "poor restored surfaces", however, there was a significant difference between unrestored and poor restored proximal surfaces (0.34mm ± 0.09). **The overall difference in attachment level between restored and nonrestored surfaces was 0.20mm, concluding in this study, that there *is* greater attachment loss adjacent to restored surfaces than nonrestored.**

****32. Flores-de-Jacoby L, Zafiropoulos GG, Ciancio S: Effect of crown margin location on plaque and periodontal health.** ***Int J Perio Rest Dent*** **197-205, 1989.**

They compared the periodontal parameters (gingival index, plaque index, probing depth, and sulcus fluid flow rate) among three groups of patients who had undergone perio treatment prior to placement of 3 kinds of fixed restorations: surfaces ending at the gingival margin, surfaces ending supragingivally, and surfaces endings subgingivally. They looked at the results after 8 weeks and after 1 year. When comparing the subgingival margin to both gingival and supragingival margins, the subgingival had significantly higher disease for all the clinical parameters except for the plaque index which showed no difference between the sub and supra gingival margins. They concluded that crown **margins ending at the end of gingival margin or above resulted in better healthy periodontal structures.**

33. Tal H, et al: Periodontal response to long-term abuse of the gingival attachment by supracrestal amalgam restoration. ***J Clin Perio*** **16: 634-659, 1989.**

This study was done on 3 beagle dogs. Full thickness flaps were elevated. The roots of experimental teeth were planned and class V cavities were prepared and restored with amalgam. The apical border of each cavity was located at the alveolar bone crest. In the control sites, a notch was prepared at the CEJ. The dogs were sacrificed after 57 weeks, and histologic sections were taken. The results showed that control sites had healed uneventfully. Gingival recession averaged only 0.5 mm; bone loss was minimal and averaged 0.15 mm. The combined length of the supracrestal connective tissue and epithelial attachment (biologic width) measured 4.47 mm. In experimental sites, the gingiva receded 3.16 mm. Moderate bone loss was noted. After bone loss, root surfaces which were previously attached to alveolar bone by periodontal ligament were mainly (0.90 mm) attached to connective tissue. They **concluded that continuous abuse of the gingival attachment results in a certain loss of the periodontal attachment apparatus. The biological width is partially restored by a more apical location of a, reduced-in-size, supracrestal connective tissue attachment.**

34. **Wang HL, Burgett FG: Relationship between restoration and furcation involvement on molar teeth. *J Periodontol* **64:302-305, 1993.**

The purpose was to examine the correlation between the presence of a crown (CR) or a proximal restoration (RE) and furcation involvement (FI) on molar teeth. Data was collected from 134 patients. First and second molars with and without restorations were examined clinically using the following criteria: CR, RE, FI, mobility (MO), and probing periodontal attachment level (AL). The results indicated that molars with CR or RE had a significantly higher percentage of FI but no greater mobility when compared to molars without restorations. Mean probing periodontal attachment loss was greater for restored than non-restored molars. This study provides evidence that molars with **crowns or restorations involving the proximal tooth surfaces had a higher prevalence of FI and greater Al than molars without restorations.**

VI. Overhangs

35. **Gilmore N, Sheiham A: Overhanging dental restorations and periodontal disease. *J Periodontol* **42:8-12, 1971.**

Clinical and radiographic examinations on a sample of a New Mexican population aged 18 to 44 years. Criteria for overhanging proximal restorations was a distinct ledge of radiographic filling material. Results showed that 32% of this population had one or more overhanging posterior restorations. Gingivitis existed in 257 subjects; 136 in the predicted direction of the O.P.R. score being higher than the homologue. Destructive periodontal disease existed in 182 subjects out of 456 with O.P.R. According to this study **the severity of periodontal disease was related to posterior restorations with definite overhangs.** Persons with one or more O.P.R had an average 0.22 mm bone loss.

36. **Highfield JE, Powell RN: Effects of removal of posterior overhanging metallic margins of restorations upon periodontal tissues. *J Clin Periodontol* **5:169-181, 1978.**

80 periodontal diseased patients with overhanging restorations were divided into 4 groups:
-Group I, as a control group, overhangs were left.
-Group II, overhangs were removed and habitual oral hygiene methods practiced.
-Group III, overhangs were left, but professional plaque control was carried out at 2-week intervals.
-Group IV, overhangs were removed and professional plaque control program followed.
The periodontal clinical parameters were obtained at the commencement of the study and 3 months later. Reproducible intra oral radiographs were also obtained at the same times. The results showed that regular plaque **removal resulted in disappearance of gingival inflammation and in increased alveolar bone support, and is more effective when overhanging margins are removed.**

*37. **Jeffcoat M, Howell T: Alveolar bone destruction due to overhanging amalgam in periodontal disease.** *J Periodontol* **51:599-602, 1980.**

They reviewed the records of 4600 patients. Interproximal bone loss around 100 teeth with overhanging amalgam restorations was measured and compared to interproximal bone loss around 100 contralateral teeth without overhanging amalgams. The latter served as controls. Overall, **bone loss was found greater around teeth with overhangs, and the more severe the periodontal disease the greater the role of the overhang appeared.** They also found that small overhangs, unlike medium and large overhangs, did not result in increased alveolar bone loss around the affected tooth.

38. **Hakkarainen K, Ainamo J: Influence of overhanging dental reiterations on alveolar bone height in adults.** *J Clin Periodontol* **7:114-120, 1980.**

They compared the approximal bone height adjacent to class II amalgam restorations with and without overhangs to the bone height adjacent to homologue intact tooth surfaces, and they also determined the possible effect of age and sex on the relative amount of such bone resorption. They examined the x-rays of 43 persons aged 27-45 years and 42 persons aged 46-64 years. Their results showed that **the average amount of bone loss increased with age and was 0.34 mm greater in men than in women, and was also increased in the posterior teeth where the overhanging restorations were found.** They also demonstrated that the effect of overhanging restorations seemed to be accentuated with age.

****39. Brunsvold MA, Lane JJ: The prevalence of overhanging dental restorations and their relationship to periodontal disease.** *J Clin Periodontol* **17:67-72, 1990.**

This literature review summarizes research concerning the prevalence, significance and removal of overhanging dental restorations (ODR) and their relationship to periodontal disease. ODR are a major dental health problem. It is defined as an extension of restorative material beyond the confines of a cavity preparation. The prevalence of ODR is very high; at least 25% of restored tooth surfaces and 33% of adult patients have ODR. They have been strongly implicated as an etiologic factor in the progression of periodontal disease and are alarmingly prevalent. Overhangs not only promote an increase in plaque accumulation, but also increase the specific periodontal pathogens in the plaque. In addition, they may cause damage by impinging on the interproximal embrasure space and the biologic width. **Significantly more bone loss, attachment loss, deeper pockets, and inflammation occur adjacent to ODR compared to control teeth without ODR.** Removal of ODR enhances the effectiveness of the hygienic phase of periodontal therapy. Many ODR, however, are not detected on radiographs and are evident only by use of an explorer directed subgingivally. For this reason and others, many ODR cannot be removed.

40. Pack AR, Coxhead LJ, McDonald BW: The prevalence of overhanging margins in posterior amalgam restorations and periodontal consequences. *J Clin Periodontol* **17:145-52, 1990.**

The purpose of this study was to determine the prevalence of overhanging margins and associated periodontal status in 100 patients who had received completed treatment by final year dental students. The results showed that 54% of posterior restorations (62% of all approximal restorations, 35% of buccal, and 40% of lingual) had overhanging margins. **Periodontal disease was more severe when overhangs were present.** However, when approximal overhanging margins were adjacent to an edentulous space, the periodontal effects were lessened. When adjacent to neighbouring teeth, overhanging margins also significantly affected the periodontal status of those teeth. **Periodontal status related to overhanging margins was worse lingually than buccally in this study, from which it is concluded that possibly plaque stagnation occurring lingually rather than buccally had a stronger influence on periodontal status than did the restorative state of those tooth surfaces.**

VII. Interproximal/Pontics Considerations

41. Larato D: Relationship of food impaction to interproximal intrabony lesions.
J Periodontol **42:237-238, 1971.**

This study was designed to gain further knowledge of the relationship between food impaction and interproximal intrabony lesions. The experimental sample consisted of 121 dry adult human skulls, varying from 17-60 or more years in age. The observations revealed the incidence of interproximal intrabony lesions increases with an increase in age of the skull. The majority (66%) of interproximal intrabony lesions occur in the molar areas of the maxilla and mandible. **And of 206 interproximal intrabony lesions, only 38 (18%) were associated with factors able to cause food impaction.**

42. Ohm E, Silness J: The convergence angle in teeth prepared for artificial crowns.
J Oral Rehab **5:371, 1978.**

This paper was to report the results of measuring clinically applied convergence angles from stone dies, prepared from 93 vital teeth and 97 rootfilled teeth. The result of the measurements showed that for vital teeth the mean size of the convergence angles varied between approximately 19 and 27 degrees. For root filled teeth the mean values varied between about 12 and 37 degrees. **The values both for vital and rootfilled teeth are considerably larger than those usually recommended for the preparation of teeth for artificial crowns.**

****43. Hancock EB, Mayo CV, Schwab RR, Wirthlin MR: Influence of interdental contacts on periodontal status. *J Periodontol* 51:445-449, 1980.**

The purpose of this study was to compare the integrity of the contact with the periodontal status and with the occurrence of plaque, calculus, carious lesions, and food impaction. A group of 40 healthy, young adult male naval recruits were examined and scored for gingival inflammation, plaque, food impaction, pocket depth, carious lesions, calculus, restorations and overhangs. The findings of this study support those previously reported in naval recruits, i.e. gingival inflammation is widespread involving almost every area examined. Naval recruits do not adequately remove deposits of interdental plaque, and at least one pocket with a depth of 4 mm or greater is present in three out of every four recruits. Additionally, it was found that the level of gingival inflammation was considered moderate or severe in more than 80% of the areas examined. **Analysis revealed no significant relationship between contact type and Gingival Index or pocket depth. However, the significant relationship observed between food impaction and contact type, and between food impaction and pocket depth, reinforced clinical observations that food impaction contributes to periodontal pathosis.** A high number of restorations had mechanical retentive areas for bacterial plaque accumulations. Thus, in addition to establishing adequate levels of interproximal surface plaque removal by the patient, the clinician should take great care in finishing the gingival margins of restorations and should eliminate those factors associated with food impaction early in treatment.

****44. Koral SM, Howell TH, Jeffcoat MK: Alveolar bone loss due to open interproximal contacts in periodontal disease. *J Periodontol* 52:447-450, 1981.**

90 patient records were examined in order to determine radiographically whether an association between open interproximal contacts and increased alveolar bone loss exists and to present evidence that the influence of open contacts on alveolar bone destruction may be small and may be dependent on the periodontal disease status of the patient. The amount of alveolar bone in the open contact site was compared to the amount of alveolar bone in the contralateral closed contact site. Open interproximal contacts were not found to be associated with increased alveolar bone destruction in Class, I, III and IV periodontal disease groups. In a group of 53 Class II cases, open contacts were found to be associated with an average of 2.4% less relative bone height than contralateral closed contacts. This difference was significant at the 0.01 to 0.02 level. **Therefore, this study indicated a statistically significant association between open contacts and increased bone loss in Type II periodontal cases.**

45. Nevins M: Interproximal periodontal disease - The embrasure as an etiologic factor. *Int J Periodont Rest Dent* 2:8-27, 1982.

There are many dental procedures that must be performed even in the face of damaging the soft tissue papilla. It is therefore necessary to program the value of interproximal accessability into all such restorations. It is possible that the original tooth preparation and crown margin extended significantly subgingivally and that a new restoration that will not cause further damage can only be constructed after periodontal surgery. The papilla may be detached and there may not be enough sound tooth structure available above the gingiva to capture in an impression. If this error is compounded by a provisional restoration with inadequate attention to embrasure space, the result may viewed as a red, ulcerated interproximal papilla. The most frequent lesion noted occurs where there is damage to the bone under the contact point, but without bone damage at the line angles of the teeth; that is, the shallow interproximal bone crater. Operative dentistry must be performed to allow the patient the capability of properly cleansing the interproximal space. It is important to recognize that a limited anterior embrasure may be more tolerable to a patient than a limited posterior embrasure. All embrasures that are bordered by roots with concavities are particularly dangerous. Proximal lesions on such teeth are commonplace and required carefully planned dentistry. The proximal concavity makes the construction of a cleansable restoration difficult. Therefore, it may be necessary to alter a narrow embrasure before introducing a restoration.

46. Kay HB: Esthetic consideration in the definitive periodontal prosthetic management of the maxillary anterior segment. ***Int J Perio Rest Dent*** **2:44-59, 1982.**

An extremely difficult aspect of periodontal-prosthetic therapy is the definitive, esthetic management of the maxillary anterior region of those patients exhibiting advanced periodontal disease. The esthetic management of the maxillary anterior region also required that the periodontist be aware of the need for the establishment of a certain definitive anatomic form to the facial osseous crest of the abutment teeth. Incisors have a basic triangular shape to the facial surface of the anatomic crown. In its most esthetic form, the apex of the triangle is slightly distal to the midline of the tooth. Furthermore, it should coincide with the apex of the curved arc form of the free gingival collar, which also should be slightly distal to the midline.The periodontist should be aware of this form while performing osseous resective procedures, so that the crest of this arc was properly placed. Hence, the optimal esthetic result is initiated with proper periodontal contouring of the osseous crest.

47. Keszthelyi G. and Szabo I: Influence of Class II amalgam fillings on attachment loss. ***J Clin Periodontol*** **11:81-86, 1984.**

176 extracted teeth restored with Class II amalgam fillings, having identical distribution regarding tooth type, jaw and proximal surface localization, were investigated. The loss of attachment was measured on stained teeth under a stereomicroscope fitted with an ocular micrometer. The cervical margins of restorations were examined with a probe. Defective cervical margins were found in 85.8% of the 176 restorations. **The mean loss of attachment on the restored surfaces (1.4 mm) was significantly (*P*<0.001) than on the sound unrestored surfaces of the same teeth (0.9 mm).** Little difference was found between mesial and distal surfaces. The restored surfaces of the lower molars showed less loss of attachment, when compared to similar surfaces of upper molars and lower premolars (*P*<0.05).

48. Heins PJ., Tomas RG. and Newton JW: The relationship of interradicular width and alveolar bone loss. ***J Periodontol*** **59:73-79, 1988.**

This study examined the relationship between interradicular width and the extent of bone loss. Radiographs of 114 adult patients with evidence of bone loss consistent with periodontitis were used. Measurements of interradicular width and the location of the bone margin from the cementoenamel junction were made at 811 interproximal sites using an optical digitizer at 3x magnification. **The results indicate that as the interradicular width increases, the interproximal bone margin tends to be in a more apical location.** No findings supported the contention that bone in a narrow interradicular space is at greater risk in patients who have had periodontitis.

VII. Long Term Maintenance

49. Polson A: Periodontal considerations for function utilization of a retained root after function management. ***J Clin Periodontol*** **4:223-230, 1977.**

Case report. The rationale for periodontal treatment in this case was that inflammatory periodontal disease can be arrested by creating a dento-gingival anatomy which is accessible for daily plaque removal techniques and that hypermobility per se does not mandate splinting to adjacent, less mobile teeth. Splinting would be necessary only if the mobility interfered with masticatory function or increased progressively. In the weeks following crown placement, no increase in mobility occurred although the tooth was in full masticatory function. One year later there had been no change in the mobility status. It was concluded that the retained mesio-buccal root which had reduced periodontal support and a degree of hypermobility was capable of independent function. No periodontal breakdown occurred due to this mobility. Furthermore, efficient removal of plaque prevented recurrence of inflammatory periodontal disease and, in the presence of this plaque control, root caries did not develop after placing the crown margins in a supragingival location.

50. Nyman S. and Lindhe J: Considerations on the design of occlusion in prosthetic rehabilitation of patients with advanced periodontal disease. *J Clin Periodontol* **4:1-15, 1977.**

The case presented illustrates how teeth with different degrees of hypermobility and with unfavorable distribution in the dental arch may still be used as abutments for a fixed bridge. The concluding remarks are: 1) In a hypermobile bridge, where distal abutment teeth are lacking, the balance of the total bridge can be obtained by the use of cantilever pontics. 2) In advanced cases, where it is not possible to predict if increasing mobility of a planned bridge will develop, a provisional acrylic bridge should first be inserted. 3) The occlusal patterns of the acrylic bridge should then be reproduced in the permanent bridge.

****51. Nyman S. and Lindhe J: A longitudinal study of combined periodontal and prosthetic treatment of patients with advanced periodontal disease.** *J Periodontol* **50:163-169, 1979.**

The purpose of the present investigation was to present the results of periodontal and prosthetic treatment of patients with advanced breakdown of the periodontal tissues. The material consisted of 299 individuals. In 48 of the patients (Group I), a well-functioning dentition could be established with periodontal treatment only, whereas in the remaining 251 patients prosthetic therapy was required subsequent to the treatment of the periodontal tissues. Out of these 251 individuals, every fifth patient (50 patients in all) was selected from Group II in the present study. Following the active phase of treatment, all patients were placed in a maintenance care program which included recall appointments every 3 to 6 months. At these periodic recalls, scaling, professional tooth cleaning and repeated oral hygiene instructions were given to each individual. The patients of Group I have been followed up for 8 years and those of Group II for 5 to 8 years (mean 6.2 years). **The results showed that following periodontal treatment, periodontal health can be maintained in patients enrolled in controlled oral hygiene program.** The type of maintenance care exercised in the present study was equally effective in patients for whom fixed bridgework was part of the initial treatment. Severe reduction of periodontal support around the abutment teeth and differences in design of the bridgework did not influence the periodontal status during the observation period. Failures of a technical nature occurred in 26 out of the 332 bridges. These failures appeared as 1) loss of retention of retainer crowns from abutment teeth, 2) fracture of bridgework, and 3) fracture of abutment teeth.

IX. Partial Dentures

52. Bissada NF., Ibrahim SI. and Barsoum WM: Gingival response to various types of removable partial dentures. *J Periodontol* **45:651-659, 1974.**

The partial denture should cover the gingival margin, with or without relief. Others advocate leaving the marginal gingiva completely uncovered in order to preserve and maintain the healthy status of the gingiva. The present investigation was conducted to seek a solution to such a prosthetic-periodontal problem. 68 clinically healthy individuals were selected on the basis of having two or more missing teeth in the maxillary arch. 28 clinically healthy individuals were selected on the basis of having two or more missing teeth in the maxillary arch. 28 metallic (cobalt-chromium) and 40 nonmetallic (methylmethacrylate) removable partial dentures were constructed to restore the missing teeth. The conclusions are: 1) **Gingival health was adversely affected by removable partial dentures.** The degreé of gingival changes varied according to the denture-gingiva relationship. The most severe pathologic changes areas covered with no relief. Gingival areas not covered by the denture base were the least affected. 2) Metallic removable partial denture bases elicited less gingival inflammatory changes than the nonmetallic bases. 3) No roentgenographic changes could be detected during the one-year study period.

53. Brill N., Tryde G. and Stoltze K: Ecologic changes in the oral cavity caused by removable partial dentures. *J Prosothet Dent* **38:138-148, 1977.**

15 partially edentulous patients were studied. The experimental base line for gingival health was considered to have been established when the gingival and plaque indices approached zero and the bacteriologic criteria had been met. The conclusion of this study is the following: 1) **The introduction of a removable partial denture into the oral cavity adversely affects the prevailing ecologic situation in terms of plaque formation.** 2) The rehabilitative effect of a removable partial denture may be safeguarded by controlling plaque formation by strict personal hygienic measures on the part of the patient. In particular, proximal surfaces adjacent to denture bases should be pointed out to patients as surfaces to which they must give special attention. 3) Simplification of the design of removable partial dentures can reduce their damaging potentialities. 4) Further prophylactic measures, such as topical application of fluoride and perhaps other chemicals, should also be taken.

54. Bergman, Bo (The Department of Prosthetics, University of Umea Sweden): Periodontal reactions related to removable partial dentures: A literature review. ***J Prosthet Dent*** **58:454-458, 1977.**

Causes of periodontal breakdown related to RPDs - Categories: 1) Plaque and OH. 2) Coverage of marginal tissues by the RPD. 3) Occlusasl forces transmitted to remaining teeth via the prosthesis.
Conclusions: **OHI can be maintained with an RPD. If plaque control is established and the prosthesis checked and adjusted regularly the forces transmitted to abutment teeth do not seem to induce perio breakdown. Good studies are scanty.**
1) Bissada, Hobkirk & Strahan,: Marginal gingiva shows greatest inflammation when covered by a prosthesis without relief. Therefore, **if FGM must be covered, provide relief and monitor its adequacy.**
2) Carlsson **4 year study,** Bergman **10 year study:** Distal extension RPDs: Frequent supportative perio therapy is important as this decreases Gingivitis, PD, and mobility increase. Inflammation increased if RPD's worn at night. **If good alveolar bone support for abutments, plaque control, & prosthetic maintenance are acheived, then forces generated by the RPD do not induce perio breakdown.**
3)Rudd & O'Leary: 12 patients with severe bone loss studied over 2 years: **good fitting RPD's with guide planes are effective in stablizing mobile teeth.**

55. Isidor, F. Jorgensen, E.B (Department of Prosthetic Dentistry and Sromatognathic Phisology, Royal Dental College, Aarhus, Denmark): Periodontal conditions following treatment with distally extending cantilever bridges or removable partial dentures in elderly patients. A 5-year study. ***J Periodontol*** **61:21-26, 1990.**

All participants had a CD/ and moderate-advanced bone loss on mandibular remaining teeth. All pts recieved periodontal therapy. 27 received distal extension cantilever bridges and 25 received distal extension RPDs. Prophylaxis was provided q 6 months for 2 years and annually for 3 years. **RPD group showed higher GI and PI scores. No significant changes demonstrated with removable partial denture or radiographic alveolar bone height.** Critique: LOA was not used as a parameter. X-ray reproducibility was poor although an attempt to standardize was made, only 59% showed < .2 mm difference between 2 consecutive radiographs the 41% remaining demonstrated a difference from .3 - 1.1 mm.
Radiogrphic bone loss did not exceed .27 mm in any of the groups. However, frequency of surfaces with a bone loss exceeding the variations of reproducibility in bone level assessments was questionable.

X. Marginal Contacts

56. Larato, DC: Relationship of food impaction to interproximal intrabony lesions. ***J Periodontol*** **42:237-238, 1971.**

121 dry adult human skulls were examined to determine the relationship between interproximal intrabony (IB) lesions and food impaction. Conclusions:
1) incidence of IB-defects increases with age
2) 66% of IB-defects are in max/mand molar area.
3) **only 18% of IB-defects were assoc with factors able to cause food impaction including:** Plunger cusps, Deficient contacts, marginal ridge relationships, tooth alignment, & position.
Hirchfeld **- defined food impaction as "forceful wedging of food through occlusal pressure into interproximal spaces"**
Prichard **- primary extrinsic factor in the pathogenesis of vertical interproximal bone loss is food impaction.** Based on 77% of 106 subjects demonstrating IB-defect assoc with food impaction.

57. **Kepic TJ and O'Leary TJ: Role of marginal ridge relationships as an etiologic factor in periodntal disease.** *J Periodontaol* **49:570-575, 1978.**

Hirschfeld, Glickman: **interproximal wedging of food is normally prevented by proper contour of marginal ridges and developmental grooves.**
Prichard: **plunger cusps should be reduced to prevent food impaction.**
Paunio: **cofactors act as aggravating agents which alter periodontal tissue and lower its resistance, but are not capable of causing Periodontitis.**
Based on the examination of 100 subjects the results show that **uneven marginal ridges of contiguous posterior teeth are not as important as the presence of plaque and calculus w/r periodontal health.**
Parameters: O'Leary's Periodontal Index, Oral Hygiene Index, (Green & Vermillion.) PD & LOA based on Ramfjord technique.

58. **Hancock, EB, Mayo, CV, Schwab, RR, Wirthlin, MR** (Naval Dental Research Institute, Great Lakes, Il): **Influence of interdental contacts on periodontal status.** *J Periodontol* **51:445-449,** 1980.

A group of 40 healthy, young adult male naval recruits were examined and scored for gingival inflammation, plaque, food impaction, pocket depth, carious lesions, calculus, restorations and overhangs. The findings of this study support those previously reported in naval recruits, i.e. gingival inflammation is widespread involving almost every area examined. Naval recruits do not adequately remove deposits of interdental plaque, and at least one pocket with a depth of 4 mm or greater is present in three out of every four recruits. Additionally, it was found that the level of gingival inflammation was considered moderate or severe in more than 80% of the areas examined. Analysis revealed no significant relationship between contact type and Gingival Index or pocket depth. However, the significant relationship observed between food impaction and contact type, and between food impaction and pocket depth, reinforced clinical observations that **food impaction contributes to periodontal pathosis.** A high number of restorations had mechanical retentive areas for bacterial plaque accumulations. Thus, in addition to establishing adequate levels of interproximal surface plaque removal by the patient, the clinician should take great care in finishing the gingival margins of restorations and should eliminate those factors associated with food impaction early in treatment.

59. **Jernberg, GR, Bakdash, MB, Keenan, KM** (Department of Periodontology, Schools of Dentistry and Public Health, University of Minnesota, Minneapolis): **Relationship between proximal tooth open contacts and periodontal disease.** *J Periodontol* **54:529-33, 1983.**

Univ of Minnisota: 104 adult subjects (mean age 42.8 years, SD = 16.3 years) with unilateral open contacts were assessed interproximally for periodontal status at both the open and contralateral closed contact. An open contact was defined by unrestricted passage of unwaxed dental floss through the interproximal area. Gingival index, crevicular bleeding, probing depth, attachment level, debris, calculus and tendency for food impaction in each study area were recorded. Less debris was seen at open contacts ($P < 0.001$). However, increased probing depth (0.27 mm, $P = 0.002$) and attachment loss (0.48 mm, $P < 0.001$) were found at the open contacts. Small but statistically significant relationships were observed between side to side differences in food impaction and both probing depth ($P = 0.005$) and attachment level ($P = 0.006$). Differences in calculus index and attachment level were associated similarly ($P = 0.003$).

XI. Crown Lengthening

60. **Ivery DW, et al: Orthodontic extrusion: its use in restorative dentistry.** *J Prosthet Dent* **43:401, 1980.**

Demostration of the concepts involved in orthodontic extrusion. Multiple case reports.

61. Ingber. Forced eruption: Part II. A method of treating nonrestorable teeth-periodontal and restorative consederations. ***J Periodontol*** **1976;47:203-216.**

Purpose : to present the biologic rationale and clinical documentation which demostrates the potential of forced eruption as a useful technic to manage the isolated nonrestorable tooth.
Objectives for restoring a tooth fractured at the alveolar crest:
1. restoration margins on sound tooth 2. maintenance of biologic width (Gargiulo 1960>) 3. access for impression 4. hemorrhage control 5. maintenanced of periodontal health 6. function. 7. esthetics.
Methods: extraction-bridge, crown lengthening, forced eruption.
Reitan: **Eruptive tooth movements result in a stretching of the gingival and PDL which caused a coronal shift of gingiva and bone.**
Edwards: **The attached gingiva including the FGM is pulled along with the tooth as it is rotated** this was demonstrated by placing tattoos in gingival tissues prior to rotational orthodontic movement.
Batenherst: Demonstrated **an increased width of keratinized (attached) gingiva while the MGJ remained stable** in his experiments in monkeys.
Summary: **As a tooth is erupted the gingiva and alveolar crest will follow, and the resultant change in position of the soft tissue is not due to a displacement of the MGJ, but rather to an increase in the zone of attached gingiva.**
Tooth eruption average 4 mm in 6 weeks and then stabilized for an additional 8 weeks.
Problems: 1) As tooth is erupted a smaller diameter root cross section is placed in the same fixed mesial distal space **which requires attention to avoid overcontoured margins** on the final restoration. 2) **Crown Lenthening is usually needed** anyway to create an esthetic FGM and establish biologic width.
Advantages: **Crown/root ratio may be improved.**

62. Carnevale G, Sterrantino SF, DiFebo G: Soft and hard tissue wound healing following tooth preparation to the alveolar crest. ***Int J Periodont Rest Dent*** **3:36-53, 1983.**

This was a short term controlled study undertaken to determine what differences, if any, exist in the wound healing of denuded interproximal areas after root planing to the alveolar crest, rotary instrumentation to the alveolar crest, or no treatment. The investigators used four adjacent teeth per quadrant in three dogs. Following an external bevel gingivectomy one of the experimental treatments was used. The animals were sacrificed at 0, 15, 30, and 90 days. The results indicate that **the surgical exposure of the interproximal alveolar crest and the removal of adjacent root cementum results in a permanent loss of approximately 1 mm of crestal bone.**

63. Schneider Ar, Binder H. Periodontal considerations relevant to treating the fractured tooth. ***J Prosthet Dent*** **51:624-627, 1984.**

This classified tooth fracture with regard to attachment apparatus and other periodontal structures. They also attempted to relate treatment options for the different classifications.

Class I	fx above bone crest	Gingivectomy / APF
Class IIA	fx at / below bone crest adequate zone of attached gingiva	Flap & Ostectomy
Class IIB	fx at / below bone crest inadquate zone of attached gingiva	Flap & Ostectomy also Mucogingival Sx
Class III	fx well below bone crest	Treatability? Ext. Root Amputation

XII. Ridge Augmentation

64. Danielson PA, Nemarick AN: Subcortical bone grafting for ridge augmentation. ***J Oral Surg*** **34:887, 1976.**

This was a short term observational study using 9 stump-tailed monkeys. The authors utilized an autogenous iliac crest graft placed subcortically following a horizontal osteootomy in the anterior mandible. The animals were sacrificed at 27, 31, 45, and 48 weeks. Microscopic study showed that all specimens had undergone bony union.

65. Langer B, Calagna L. The subepithelial connective tissue graft. *J Prosthet Dent* **44:363-367, 1980.**

This was the first article to describe the use of a connective graft to augment the alveolar ridge. This article was the basis for **Langer & Langer '85.** The authors describe harvesting connective tissue from the palate, and using sharp dissection on the alveolar ridge to create a split thickness blind pouch for implantation. The marginal tissues adjacent to the recipient are "left untouched". They state that the augmented ridge becomes dimensionally stable 2 months post treatment.

66. Tabita PV, Vasilakis GJ, Bissada NF: Surgical correction of alveolar ridge form to enhance esthetics of fixed partial dentures. *J Prost Dent* **46:284, 1981.**

This is a one patient case report utilizing a split thickness flap and a scleral implant for ridge augmentation. At one week post surgery, "most of the flap covering the sclera was sloughing." By 8 and 11 weeks, further remodeling of the ridge was evident.

67. Kent JN, et al: Correction of alveolar ridge deficiencies with non-restorable hydroxyapatite. *JADA* **105:993, 1982.**

This article presented the use of HA and "subperiosteal tunneling", as a means to augment Md and Mx atrophic ridges, in preparation for complete denture fabrication. HA is not used on a routine bases.

68. Allen EP, Gainza CS, Farthing GG, Newbold DA: Improved technique for localized ridge augmentation. A report of 21 cases. *J Perio* **56:195-199, 1985.**

This paper presented an "improved" technique for ridge augmentation and presented 21 case reports. The technique is a variation of **Dr. Abrams' ('80)** "Roll Technique" and involves the use of HA in combination with a split / full thickness flap. Of the twelve reported cases using HA, two resulted in failure due to flap perforation and ten were successful. The author notes that shrinkage is diminished with HA and post augmentation stability is maximized.

69. Siebert JS, Cohen DW: Periodontal considerations in preparation for fixed and removable prosthodontics. *Dent Clin North Am* **31:529-555, 1987.**

This article discusses the etiology, classification, and treatment of ridge deformities as well as pontic considerations. Siebert has classified ridge defects into Class I: buccolingual loss of structure; Class II: Apicocoronal loss; Class III: combination of I and II. When restoring edentulous spaces with fixed bridges, the author prefers the ovate or bullet type pontic mainly because of its esthetic as well as hygienic advantages over the ridge lap or modified ridge lap designs. Surgical procedures discussed for ridge augmentation include 1)the de-epithelialized connective tissue pedicle graft or roll procedure, 2)pouch procedures for subepithelial grafts and implants, 3)wedge and inlay-onlay graft procedures, and 4)free graft procedures of masticatory mucosa in preparation for removable prosthesis.

70. Shanaman RH: The use of guided tissue regeneration to facilitate ideal prosthetic placement of implant. *Int J Periodont Rest Dent* **12:257-65, 1992.**

This article presents four case reports where implants were placed with accompanying fenestrations or dehiscences through bone. Decalcified freeze dried bone, freeze dried bone or a combination of both were placed over the exposed implants and covered with a GTAM. Only one case didn't achieve complete coverage of bone like tissue possibly because the cover screw had become exposed prematurely.

71. Allen EP, Miller PD Jr: Coronal positioning of existing gingiva: short term results in the treatment of shallow marginal tissue recession. *J Periodontol* **60:316-9, 1989.**

This article evaluates a surgical technique for the correction of shallow (class I) recessions. The experimental sites had recession that ranged from 2.5 to 4 mm. The procedure consisted of the removal of cementum from the root surface and treatment with citric acid. Vertical incisions are placed on the treated tooth lateral to the recessed area but not including the papilla. These incisions extended well into the alveolar mucosa. A sulcular incision is done and a partial thickness flap is reflected. The vertical incisions are sutured first with the flap in a coronal position in order to cover the area of recession. The interproximals are then sutured and coapted to the graft and luted into place with cyanoacrylate. At six months an average of 97% of root coverage was achieved in the areas of recession.

72. Siebert JS, Nyman S: Localized ridge augmentation in dogs: a pilot study using membranes and hydroxyapatite. *J Periodontol* **61:157-65, 1990.**

This study evaluated the potential for reconstructing ridge defects using occlusive membranes and grafting materials. Defects resembling knife edge bone resorption were surgically created and allowed to heal for 90 days in two beagle dogs. e-PTFE membranes were used to cover the defects in an attempt to reconstruct the lost bone structure. Hydroxyapatite blocks or porous e-PTFE were cut to fit the size of the defect and served as filling materials. Either membranes, filling material, or a combination of both were placed in the defects. A sham operated site served as control. **The use of a membrane alone as well as with a porous hydroxyapatite implant showed complete bone fill into the space provided by the membrane. The use of implants without membranes produced varying proportions of bone and non-mineralized connective tissue.**

73. Scharf DR, Tarnow DP. Modified roll technique for localized alveolar ridge augmentation. *Int J Periodont Rest Dent* **12:415-425, 1992.**

A modification of the Abram's roll technique for ridge augmentation is described in this article. Two full thickness vertical releasing incisions are made from the crest of the ridge towards the palate. A split thickness flap at least 0.6 mm thick to ensure complete removal of epithelium is reflected toward the palate. The underlying connective tissue and periosteum is reflected to form a pedicle and rolled into a buccal pouch created using a blade separating periosteum from bone. A suture is placed at the base of the pedicle to hold it in place. The flaps are then sutured in place and tissues allowed to heal.

74. Buser D, Dula K, Belser U, et al: Localized ridge augmentation using guided bone regeneration. 1. Surgical procedure in the maxilla. *Int J Periodontol Rest Dent* **13:29-45, 1993.**

Two case reports are presented in which screws are placed in the bone over which a e-PTFE membrane is placed. The screws have a tenting effect to prevent the membrane from collapsing. The space between the membrane and the bone may be filledwith small pieces of collagen fleece or bone grafts. The screws and membrane are removed at 9 months after surgery at which time new bone is apparent.

75. Callan DP: Guided tissue regeneration without stage 2 surgical procedure. *Int J Periodontol Rest Dent* **13:173-179, 1993.**

This article presents an alternative way to fill osseous defects using demineralized freeze-dried bone and freeze-dried facial lata. The surgical technique consists of reflecting a mucoperiosteal flap with incisions on keratinized gingiva. The osseous defect is degranulated and demineralized freeze-dried bone is placed overfilling the defect. Freeze-dried facial lata is used to cover the bone graft and prevents epithelial migration into the grafted site. Flaps are then sutured in place and a periodontal dressing may be placed. Post op medications include antibiotics, analgesics, and a Decadron dose pack. The sutures are removed 14 days after surgery. **The main advantage of this procedure is that the use of freeze dried facial lata eliminates the need for a second surgery.**

updated 9/23/93

Examination, Diagnopsis, And Treatment Of TMD

Dr. Christian S. Stohler

Fifth Annual Comprehensive Review in Prosthodontics
September 29 - October 1, 1994
The University of Michigan

Title: **Examination, Diagnosis and Treatment of TMD**

Lecturer: Christian S. Stohler, University of Michigan
(313) 747-4242

Objectives: This lecture will provide a guide for the individual study of both basic and applied topics related to the subject of TMDs. It will focus on the reasons why the prosthodontist needs to become familiar with the current knowledge base and will give some thoughts to the selection of a text. Finally, earlier views are integrated into the current understanding of TMDs.

Suggested Literature:

1. TMD - Temporomandibular Disorders.
National Institutes of Health, National Institute of Dental Research
Bethesda, Maryland 20892, 1994
NIH Publication No. 94-3487

2. To be released in October, 1994:
Temporomandibular Joint and Masticatory Muscle Disorders.
Zarb, G., Carlsson, G., Sessle, B. and Mohl, N. (Eds.)
Munksgaard, Copenhagen, 1994

3. To be released early 1995:
Progress in Pain Research and Management: Temporomandibular Disorders and Related Pain Conditions.
Edited by NIH/NIDR staff
Elsevier, Amsterdam, 1995

Section Four - Ceramic Restorations

Section Four contains information related to the interdisciplinary relationship between prosthodontics and dental technology. The use of ceramics in the restoration of single and multiple units has grown in significance during the past several decades. The metal/ceramic restorations has been the main restorative unit in both the esthetic zones and for posterior tooth rehabilitations. All ceramic restorations in the anterior regions of the dental arches has been used with excellent esthetic success. The all-ceramic posterior restoration has become popular only in recent years with improvements in the strength of these materials. The ceramic laminate has also been a very important reconstructive unit where minimal tooth preparation is in demand and esthetics is a major factor. The authors and the titles of their presentations related with ceramic restorations follow:

Dr. Kenneth A. Malament

"The Interdisciplinary Relationship Between Prosthodontics And Dental Technology"

Dr. Kenneth A. Malament

"Ceramic And Metal/Ceramic Restorations

Dr. Jack Preston

"A Literature Review On Metal Ceramics"

Dr. Robert E. Lorey

"Porcelain Laminates

Dr. William J. O'Brien

"The Science Of Color In Prosthodontics"

The Interdisciplinary Relationship Between Prosthodontics And Dental Technology

Dr. Kenneth A. Malament

The Interdisciplinary Relationship Between

Prosthodontics and Dental Technology

Kenneth A. Malament D.D.S., M.Sc.D.*

INTRODUCTION

Over the last decade dental technology, dental science and dental practice have advanced dramatically, greatly expanding and improving the choices of materials and techniques. The most important issue in dentistry today is not debate about which material, color or technique is best. The most significant issue is the problems that exist within relationships. Despite the potential for a unique collaboration between the prosthodontist and the dental technician, problems results from breakdowns in interdisciplinary communication and education.

Cooperative goals must be established and better ways found to share knowledge. When prosthodontists and technicians each understand the many variables and problems the other faces, they can work as a team, helping each other to identify significant facts and potential difficulties posed by specific dental materials, techniques, or stages of the work in progress. In that way, both disciplines can share responsibility for a treatment plan based on a mutual understanding of the factors involved. An appreciation of each discipline's objective and responsibilities can ultimately help individuals to advance their personal professional goals.

RESPONSIBILITIES OF TECHNICIANS AND PROSTHODONTISTS

The mandate and responsibility of prosthodontists is to restore and improve oral function so as to improve the health, comfort, and appearance of their patients. The specialty contributes to the general practice of dentistry by providing expertise in diagnosis and in treatment planning and sequencing. The American Dental Association's Standards for Advanced Specialty Education Programs in Prosthodontics call for an in-depth knowledge and clinical competency in fixed, removable, implant and maxillofacial prosthodontics.

Laboratory procedures that must be mastered by the technician (and understood by the prosthodontist) are diagnostic waxing, provisional restoration, master dies, frame or core fabrication, veneer fabrication and occlusion.

The dental technician supports the prosthodontist's effort in many ways. Indeed, dental technicians have made major contributions to dental material science. A standard for excellence in dental ceramics has been established by *Dicor* glass-ceramic (researched and developed by Peter Adair and Dr. David Grossman at Corning Glass Works), Empress glass-ceramic (Arnold Wohlwend at the University of Zurich and the Ivoclar Co.), Creation iridescent feldspathic porcelain (Willi Geller), Vintage/Opal feldspathic ceramic (Makoto Yamamoto and the 3M Co.), and Omega and Alpha opalescent feldspathic ceramic (Claude Sieber and the Vita Co.). The Alpha ceramic greatly improved the color properties of Inceram glass-ceramic, which a dentist, Dr. Michael Sadoun, developed. These ceramic materials, equipment, and new forming techniques have improved the marginal fit and color properties of prosthetic teeth and have significantly affected dental practice.

COOPERATIVE MAKING OF A DENTAL PROSTHESIS

The esthetic resolution in fixed prosthodontics is limited by anatomic deficiencies. In describing the esthetic factors related to teeth, Miller[1] noted that visually teeth have both three-dimensional (form) and two-dimensional (silhouette) properties. The nature of the gingival framing or dark spaces around teeth affects their symmetry. Although Stein[2] and Preston[3] have established requirements and discussed factors involved with tooth color, Stein[4] has also described the esthetic appearance of teeth as controlled more by form and the emergence profile than by color.

There are many steps in building a successful prosthesis, and the temptation to combine or omit steps should be resisted.

Diagnostic waxing. An accurately mounted diagnostic cast is prepared to resemble the planned tooth preparations. The diagnostic wax-up, made on this cast, reestablishes proper arch form, occlusal plane and form, tooth contours, and esthetics. It can be used as a blueprint for both the provisional and final restoration.[5] Computer imaging is helpful in initially directing thought regarding the patient's esthetic needs and in planning the wax-up. The waxing procedure, however, demonstrates three-dimensional problems that both the prosthodontist and technician will face and need to resolve. Furthermore, the diagnostic wax-up can be helpful as a teaching model. The patient can understand problems better by seeing them and discussing them with the prosthodontist. This information can be shared with the technician, and alterations, if necessary, can be made easily.

Provisional restorations. Ideally a provisional acrylic resin restoration should be flasked and heat cured. The diagnostic wax-up can provide the form for the resin teeth. A technician can make the provisional restoration in all-acrylic resin or can make a metal subframe and process acrylic resin over it. All-acrylic restorations can be more convenient for the prosthodontist, especially if he or she is replacing an existing prosthesis and does not know the true tooth preparation form underneath it. If the prosthodontist finds that he needs to create more space in the provisional restoration, his task will be more difficult and frustrating if a metal subframe must be cut back along with the acrylic. When the prosthodontist makes the initial tooth preparation, he or she usually prefers an all-acrylic resin prosthesis.

A long-term provisional restoration is ideal in patients who have long edentulous spans or who will be treated with extensive periodontal surgery and need a long healing time.[6] An impression of the tooth preparations is made, and the casts are accurately mounted on an articulator. A metal subframe is cast to fit the triple-spaced dies, leaving the margin areas short. Acrylic resin teeth can be set (or wax teeth made) with accurately finished margins on this metal and stone cast. The stone cast, metal subframe, and wax or resin are embedded in stone and flasked for acrylic resin processing. This type of provisional prosthesis is significantly more resistant to breaking forces.

Master dies. The new generation of polyvinyl siloxane or polyether impression materials produces highly accurate, stable dental impressions, which can be poured many times producing accurate stone casts. It is helpful that the prosthodontist uses these newer, more stable impression materials, which do not have to be poured immediately and therefore do not force the technician to interrupt often sensitive procedures or disturb his or her concentration.

Previous die systems used plaster bases and were more likely to distort because of the unpredictable expansion properties of setting plaster. Newer master die systems, such as the Zeiser[7] and Kiefer Systems, utilize indexed plastic resin bases that have improved die positional accuracy and stability. When a die is sectioned off a master cast, its accuracy to the original cast is not as compromised. The demand for these types of systems is increasing as more dentists attempt to complete restorations without try-in procedures. These systems are also popular with dentists who use all-glass ceramic materials for fixed partial dentures; such prostheses have to be made in one piece since they cannot be soldered. Unfortunately many variables, including the expansion properties of impression material or setting stone, still have the potential to distort the positional accuracy of a sectioned master cast. Try-in procedures should not be omitted until further improvements are made in pin and individual die stability.

Tooth preparation. A strong, well-fitting and esthetically pleasing dental restoration absolutely requires proper tooth preparation. Black[8] established length, width, taper, resistance form, and margin design as the physical factors crucial to a long-lasting prosthesis. Even with the recent improvements in dentin bonding materials and luting agents, proper attention to tooth preparation cannot be ignored. Many authors have described the merits of different margin designs. Shoulder or chamfer preparations have been advocated for use with all-ceramic materials[9]. Goodacre and Friedlander[10-13] have shown that the shoulder preparation (Fig. 1), with its buttressing qualities, produces strong all-ceramic margins that resist fracture forces better than chamfer margins do. Stein[2], McLean[14], Preston[15] and Miller[16] have advocated proper tooth reduction for dental ceramics.

All authors have suggested minimal reduction of 1.4 mm for any type of dental ceramic. With this amount of reduction, the ceramic restoration is strong, and color can be developed by layering or stratification methods. Miller[16] has demonstrated that at least 0.7 mm of ceramic veneer is needed for development of correct tooth color.

When preparing teeth, the prosthodontist may have to deal with poor visibility, poor preparation anatomy, or awkward hand piece control. These problems can affect tooth preparation form and margin definition. A lip preparation[17], a compromised margin form made by the prosthodontist, is a source of frustration for dental technicians. It is difficult to make an accurate impression of a lip on a margin area, and the resulting casts are often distorted. The technician has trouble defining or scribing this margin area. Waxing procedures are difficult, and the pattern is often distorted during removal from the die. Once the core is cast or formed, it is not easy to fit this casting accurately without harming the die. These difficulties can ultimately result in a completed restoration with a loose fit or with a fit so tight that pressures created during luting break a ceramic margin.

Even when the greatest care is taken, some problem usually compromises ideal margin form. Hand instruments or tissue-safe end-cutting shoulder burs are helpful in flattening the tooth preparation and reducing the lip.

Intraoral records. These records, made by the prosthodontist, can consist of centric relation, facebow (arbitrary or kinematic) or pantographic tracings. The technician can collaborate by making centric relation jigs (Fig. 2-4) at an arbitrary vertical dimension and rims that can be positioned on teeth or implants with central bearing point plates to assist these procedures.[18] Both of these laboratory devices help the prosthodontist to make accurate centric relation records at a desired vertical dimension. If desired, a pantographic record is used to record excursive mandibular movements.[19] If electronic instrumentation is unavailable, the dental technician can mount the record clutches and pantograph on a fully adjustable articulator. Working together, the prosthodontist and technician can set the articulator using the pantographic tracings. Casts can be mounted on the articulator with the facebow and centric relation records.

Treatment waxing. This simple procedure, while adding extra cost and time, produces considerable benefits because it significantly improves the understanding, communication, and collaboration between the prosthodontist, dental technician, and patient.[5] It is a try-in wax-up, made from tooth or gingival colored wax (Fig. 5, 6), which allows all parties to preview the esthetic result anticipated for the final prosthesis. The wax should be tooth colored[20] because a patient cannot easily relate to blue, red, purple, or green wax teeth. Completed on the master dies, the treatment wax-up can

be tried in the mouth and used to test the contour and shape of the most simple anterior unit or a complicated complete rehabilitation. In edentulous patients being treated with complete implant prosthodontics, artificial teeth can be arranged on a trial denture base (Fig. 7-10). This is developed to meet the patient's individual esthetic and functional needs. The wax treatment denture can then be converted to an accurate implant treatment wax-up. Getting the patient's ideas about the appearance during the treatment waxing stage can be most helpful and can reveal errors in tooth or pontic placement. Although computer imaging is useful for providing alternative working plans quickly, it does not provide as much real patient information as does a treatment wax-up. Often the computer image does not reflect problems that are apparent on the master cast or in the mouth. Without holography, the computer presents a two-dimensional illusion that cannot be touched or seen directly in the patient's mouth. A technician or prosthodontist can directly alter the treatment wax-up to develop optimal form and contour. Even with the diagnostic wax-up and casts of the provisional restorations, large discrepancies may exist between the first treatment wax-up and the esthetic needs of a patient. Alteration of the treatment wax is easily done. A full contour wax-up can be impressioned to make an index; this tested accurate tooth contour guide form allows the technician to build prosthetic cores or frames that support optimal strength, occlusion, and ceramic color properties. The commonly followed procedure, that is, presenting the dentist with bisque ceramic forms, can lead to problems if major alterations are needed. After large alterations, the ceramic may no longer be supported by the metal frame designed and made by the technician. Furthermore, if the dentist grossly alters contours in the bisque ceramic phase, color effects may be permanently lost. Ceramic color is best developed by layering and stratifying different opaque and translucent porcelains, and technicians spend much time developing these subtle but essential effects.[14, 21-23]

Chroma Wax, developed by Wohlwend, and other tooth-colored waxes can be highly accurate and burn out properly. These full-contour wax teeth can be cast into gold, Empress or Dicor.

Selection of dental materials. Materials for fixed prosthodontics continue to improve in strength, margin accuracy and color. Although ceramic materials are the most esthetically pleasing, debate continues as to whether all-ceramic or metal-ceramic materials are the "best" choices for prosthetic teeth.[23-31] The answer lies in treatment planning decisions. At present, all-ceramic materials are useful only as individual restorations, although some have potential as small-span cantilever or three-unit anterior fixed partial dentures.[32-38] Metal-ceramic materials continue to be the state of the art.[21, 23,39,40]They are the most versatile materials and can be used in any situation, as a single-unit restoration or within the most complex complete fixed or implant prosthesis, provided there is enough space to insure that the prosthesis will have the necessary strength to withstand dental forces. The color properties of metal-ceramic restorations can be competitive to all-ceramic restorations (Fig. 4, 9-18). The answers to the esthetic debate regarding all-ceramic vs. metal-ceramic materials are found in the education and talent of the dental technician and the prosthodontist. The issues they need to address for each type of ceramic are color communication, tooth form, opacity, translucency, fit, and biocompatibility. The technique of ceramic stratification[1, 22] has significantly enhanced the building of ceramics. McLean, Kedge, Geller, Wohlwend, and Sieber[41] contributed to this technique, which allows metal-ceramic restorations to be competitive with the color properties of all-ceramic materials. The use of computers and better insulation materials has significantly improved the ovens for dental ceramics; heating is better and more predictable, making cold spots within an oven less significant.[42-48]

Another advance in the metal-ceramic technique is the more stable, accurate and translucent color properties of shoulder (buccal-butt) porcelain.[49-55] Opalescent feldspathic ceramic materials such as *Omega, Creation* or *Vintage* possess an important color quality of natural teeth previously lacking in metal-ceramics.

The interest in all-ceramic materials grew because of the need to eliminate the metal substructure and the need to opaque away negative color properties of metal-ceramics. The aluminous jacket was the first popularly utilized all-ceramic material.[56-59] As the science of dental glass-ceramics improved, materials such as *Cerestore*[60], *Dicor* (Dentsply, York, PA)[61-66] (Fig. 17, 18) *Cerapearl*[67, 68], *In-ceram* (Vident, Baldwin Park, CA)[69-77] (Fig. 14, 15) and *Empress* (Ivoclar North America, Amherst, NY)[78-82] (Fig. 6, 19,20) were developed. These materials are organized, crystalline forms unlike random, non-crystalline feldspathic dental porcelain. Improved Feldspathic porcelain based materials have been used such as *Renaissance* (Williams, Amherst, NY)[83,84], *Captec* (Leach and Dillon, N. Attleboro, MA) or the Magnesia Ceramic.[85-87]

Glass-ceramic materials are significantly stronger than dental feldspathic porcelain, but are not stronger than metal-ceramic articles.[14, 24, 62, 88-96] As the more desirable strength of glass-ceramics improves, so does their inherent opacity. The color properties of all glass-ceramic materials require veneering with feldspathic porcelain layers.[66] (Fig. 21, 22) Color may be easiest to develop over a glass-ceramic core[75], particularly because of the continuing improvements in the quality of the different veneering porcelains and infusion glasses (in *In-ceram*). Wear continues to be a factor with feldspathic porcelain because it is more abrasive than enamal tooth structure.[97-103]

Although pure *Dicor* appears to wear less than enamal most clinical conditions require veneering feldspathic porcelain. With the continued development of dentin bonding, ceramic acid-etching, ceramic silanation, and resin luting, the fracture rates of all-ceramic materials are decreasing significantly.[13, 104-119] Thus, the continuation of research, development and use of these materials is assured.

Ceramic oral mucosa. Gingiva-colored ceramics have been developed sufficiently so that they are now suitable for use in tooth-or implant-supported fixed prosthodontics.[120-122] They are used to recreate normal mucosal contour and are particularly effective in flat, edentulous areas or in areas with residual ridge defects (Fig.2, 4, 10, 25, 26). They also can improve tooth-gingival symmetry or correct gingival defects that cannot be repaired surgically. Finally, they can provide lip support for patients with implants and offer the advantage of being easy to clean. Development and improvements in different gingival-colored porcelains are continuing.

Selection of color. Clark[123], Sproull[124], Preston and Bergen[3] describe tooth color as a function of hue, chroma and value. Factors that influence the absorption and reflection of light (opacity, translucency, opalescence, iridescence, and phosphorescence) are of major importance. An individual's physical ability to perceive and interpret light information is essential to describing color. The different areas of a tooth have different color properties. Opaque and translucent areas in teeth, and even the size, shape and color of the gingival frame, are important factors that must be described before an individual tooth color can be developed.[1-3, 14, 21, 23, 39, 125.]

Tooth shade decisions are difficult[126-128], in the end, the communication between the prosthodontist and the technician is based on guess work modified by countless factors involving training, experience, environment, and acuity of perception. Ideally color should be described before any treatment by the dentist is initiated. Riley[128] has shown that teeth dry out when the mouth is open during dental treatment, and such desiccation significantly changes the color of teeth. The environment also influences shade decisions, since the time of day and variations in artificial light can affect shade recordings. Furthermore, dental shade guides are poorly quality controlled and produce inconsistent, and often inaccurate, color information. They are not even made of regular dental ceramics, but of either acrylic resin or layered high-firing feldspathic porcelain[3, 129] Commercial shade guides are generally 3.5mm. thick in either material. This thickness does not represent the color properties of common veneering procedures.[1, 3.] Miller[1] has stated that present dental shade guides do not represent the range of color in respect to hue, chroma or value found in natural teeth. Given the limitations on the prosthodontist's ability to determine the proper color of teeth, it is helpful to involve the patient directly in decisions on color so as to assure patient satisfaction. It is also essential to involve the technician, who ultimately must make the ceramic article, in tooth shade decisions. Riley[128] has described the use of custom-made shade tabs to facilitate color decisions and development. A metal wax pattern former can be made to cast or form custom shade cores in metal or glass-ceramic (Fig25, 26). Feldspathic porcelain can then be easily built up on the cast core to develop the correct tooth color. The creation of custom color tabs also helps the dentist, technician and patient to understand the problems involved in developing accurate tooth color. This shade tab more correctly represents the required color because the individual core qualities that will be used in the prosthesis are represented. Custom color tabs also should be made so that the dentist, technician and patient can understand the potential difficulties in developing esthetic tooth color.

CONCLUSION

Dental technology and prosthodontics create an esthetic illusion while providing real function and health. Preston noted that it is important to understand which elements of a prosthesis are illusion and which are reality. Nothing is perfect; indeed, an obsession with creating the perfect illusion of a natural tooth can confuse our main responsibility, which is the patient's long-term health. The challenge of prosthodontics is to maintain the highest standard of care for our patients.

A problem, which we can define as the difference between what we have and what we want, can be analyzed and solved in different ways. Systems analysis offers three approaches: First, we may need more information or better methods for analyzing existing information. Unfortunately, the information prosthodontists and technicians rely on is often oversimplified or overstated, since it frequently comes from sources that have a proprietary interest in a particular material or technique.

Second, we may have all the available information, but, because developments in dental science, materials, and techniques continually change the way dentistry is provided, we may need new insight into the nature of the problem. At the same time, we must approach change with caution, since commercial claims often exceed real clinical performance. Dental technicians and prosthodontists should not take risks or reduce practice overhead at the expense of their patients' health. A respectful, conservative approach, based on the scientific method, education and experience, produces the highest standards of treatment. Within this conservative, educated approach there is still much room for artistic expression and advancement of both new technologies and the standard or care. As Einstein said "It's the ideal that animates our best actions."

Third, we may need to look at ourselves and examine whether we are too intellectually comfortable with the convenient, familiar standard of knowledge that we possess. Complacency can block understanding and the ability to work with better solutions.

Collaboration between dental technology and prosthodontics fosters an exchange of information, creates opportunities for new insight into the effects of recent developments, and provides the impetus to improve our standard of knowledge. It results in the continuous refinement of treatments and the development of new definitions for clinical practice. Thus, the scarcity of education and training programs for dental technicians pose a serious problem. If prosthodontics and dentistry are to continue to mature, more attention must be paid to, and opportunities created for, collaboration with dental technology. To truly understand the problems we face, prosthodontists and dental technicians must listen to and work closely with each other.

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Ceramic And Metal/Ceramic Restorations

Dr. Kenneth A. Malament

Ceramic And Metal/Ceramic Restorations

Dr. Kenneth A. Malament

DESCRIPTIVE OVERVIEW:

Dental ceramics have increased in scope, science and quality clinical applications. It is the most versatile and consistently predictable esthetic dental material. Ceramics can be utilized in partial coverage restorations as well as in the most complicated fixed tooth or implant supported rehabilitations. New ceramic materials such as; In-Ceram, Em-press, Omega or Creation Porcelain and Dicor can create long lasting natural dental restorations.

Whereas the state of the art is within Feldspathic Porcelain systems, this material science is not well understood and can be abused. Feldspathic porcelain and glass-ceramic material science, utilization and advantages will be discussed. Factors such as tooth preparation and luting procedures are significant to long-term ceramic success.

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A Literature Review On Metal Ceramics

Dr. Jack Preston

UNIVERSITY OF SOUTHERN CALIFORNIA ADVANCED PROSTHODONTIC EDUCATION
LITERATURE REVIEW ON METAL CERAMICS

Dr. Jack Preston

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Porcelain Laminates

Dr. Robert E. Lorey

COMPREHENSIVE REVIEW FOR
PROSTHODONTISTS AND PROSTHODONTIC RESIDENTS
UNIVERSITY OF MICHIGAN SCHOOL OF DENTISTRY

Basic Concepts and Principles in Porcelain Laminates

Dr. Robert E. Lorey

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COMPREHENSIVE REVIEW FOR
PROSTHODONTISTS AND PROSTHODONTIC RESIDENTS

UNIVERSITY OF MICHIGAN SCHOOL OF DENTISTRY

Basic Concepts and Principles in Porcelain Laminates
IADR/AADR Abstracts

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The Science Of Color In Prosthodontics

Dr. William J. O'Brien

The Science of Color in Prosthodontics

Dr. W. J. O'Brien

A. Color control in dentistry is problematic. The elements of this old problem are:
   1. Lighting conditions
   2. Individual competence
   3. Shade guides
   4. Product variations
   5. Communication between dentist and laboratory technician

B. Visual color matching system
   1. How colors are transmitted and received
   2. Illumination
      a. Spectra
      b. Color rendering index
      c. Reflected colors and additive color mixing
      d. Chromatic adaptation

C. Individual color matching differences
   1. International color difference units, ΔE
   2. Acceptability differences
   3. Matching shade guide teeth
   4. Clinical matching

D. Shade guides
   1. Color measurements
   2. Color systems – Munsell and CIE L*a*b*
   3. Coverage of tooth colors
   4. Variability
   5. Match with porcelains

E. Product variability
   1. Multiple firings
   2. Batch to batch

F. Recommendations
   1. Control viewing conditions
   2. Use 2 shade guides
   3. Technician take shade
   4. Train in shade matching
   5. Improve communication

G. Related appearance properties
   1. Fluorescence
   2. Gloss
   3. Double layer effects

THE SCIENCE OF COLOR IN PROSTHODONTICS

The big problem in crown and bridge is matching crowns to existing, adjacent teeth. Shade taking is one of the main challenges to esthetic dentistry. Looking at the available literature on this subject, you will find that the following are the main color control problems:

1) Lighting conditions in the operatory and the laboratory.
2) Individual competence of the person taking the shade.
3) Shade guides, which may vary from guide to guide.
4) Product variations, such as variation in color of denture teeth given the same name. In addition, pigmented porcelain compositions may vary from bottle to bottle.
5) Flawed communication between dentist and dental laboratory.

<u>General concept of color</u>. Color is quite complex. It starts as light generated by a source as a white beam or portion of that beam. The generated beam is reflected from surfaces onto other objects. During this process, component wavelengths of the beam are selectively absorbed or reflected by the surface. In dentistry, operatory walls, patient clothing and other sources of color in the environment act as secondary light sources and modify the original source. The modified source in turn may greatly influence the appearance of the patient's teeth.

Color is determined by the wavelength of light present. For example, 400 nm wavelength light is blue, 500 nm light is green and 600 nm is getting into red. Different light sources have different peaks in different ranges. The largest component of incandescent light, for example, is in the red range, while cool white lights have a large amount of blue.

Unit lights often have unknown spectra and can be poor for use in shade taking. In addition, the reflector behind the light has many colors. A defined light source for viewing is very desirable. An accepted standard is the distribution of wavelengths produced by the sun at noontime. The color rendering index is a measure of how well the spectra of commercially available light sources compare to that of noontime sunlight, which is given an index of 100. The following sources are quite different in the amounts of color they contain.

Chroma 50	GE	92
Chroma 75	GE	94
Cool White	GE	65
Hanau Viewing Lamp	Teledyne Hanau	93
Neylite	J.M. Ney	98
Verilux	Verilux, Inc.	93
Vita-Lite	DuroTest	87, 91

For shade taking, a score of at least 90 is desirable. In addition, operatories with a neutral color scheme avoid reflected colors.

Color vision is the synthesis of colors by the brain according to additive mixing to give a perceived color. Synthesis is in contrast to the hearing and smell processes, where individual components are sensed at the same time. Rods and cones in the retina are the sensing part of the eye and pick up sensations of color, but the brain is very active in interpretion. The brain may allow us to think that we are seeing colors that are not there as measured by physical instruments.

Some idiosyncrasies of color perception:

If we are in a room immersed in one kind of light source and the walls have a particular color, we will not notice colors being shifted toward the color being reflected off the walls. This effect is called chromatic adaptation. Perceived colors of objects viewed under a light source other than daylight is altered by the brain toward the remembered daylight color.

Metamerism: Objects that match under one light source do not match under a second light source. The typical example is the situation of matching pants to a jacket in a store. They may look fine in the store, but upon going outside, they do not match anymore. A similar problem is present in attempting to match a shade guide under operatory light, which is likely quite different from daylight.

Is anything being done about these problems in dentistry? Yes. Some laboratories have color matching booths. These booths have gray walls and a daylight light source. The technician does all the final shade matching in that booth.

Cones have receptors for red, blue and green. That is all the eye can sense. The average person has the highest sensitivity to light at 550 nm, which is green. At nighttime, the vision shifts toward the rods, and blue objects appear brighter in low light. The sensitivity toward green has been explained on the basis that primitive man would have an easier time surviving if he could easily find green vegetables. Emergency vehicles, which used to be mainly red, are now more often green.

Visual color systems. All shade guides now have been measured in terms of three color parameters. A popular system is the Munsell Color System, named after Alfred Munsell. Any color can be broken down into three components. The Bioform shade guide supplies the colors on a card with the shade guide in Hue, Value and Chroma. Hue is usually considered to be the colors of the rainbow. Value is the lightness or darkness of the color. The higher the value number, the lighter is the color. Chroma is another term for saturation, or how much pigment is in the color. The Munsell system is widely used in dentistry to describe color, but it is not a uniform color space. It has more of some colors than others. The Munsell colors of teeth have been reported by Sproull, Marui, and Lemire and Burk. They report hues ranging from 3Y to 7YR (yellow to quite yellow-red), and values ranging from 8.5 to 6 (pretty light to pretty dark). Teeth tend to become redder with age. Few shade guides have selections covering this range. Ivoclar has a new shade, 540, which is more yellow-red than are Vita or Bioform.

Another way of describing color is the L*a*b* system. The L*a*b* system is an extension of Munsell. Here, spectrophotometer measurements of two colored objects allow a numerical estimate of color difference called ΔE. The ΔE value can give us an idea of how far off we are in matching. A difference value of greater than 1 can be observed visually. A clinically acceptable difference for a restoration involving shade matching is about 3.5. A difference of 2 is an allowable tolerance between two shade guides. L*a*b* also has the advantage that it is a uniform color space.

Individual color matching differences. Color difference discrimination is interesting. It is well known that people will accept different color differences. A large group of patients find a match to adjacent teeth of 3.0 to be acceptable. A few have excellent discrimination and can see a difference of only 1.0. In most cases, the best we can hope for is a color match of about 2.0 between a crown and the adjacent tooth.

Lou Graham has studied color matching and has shown that experienced color matchers are the best. Choose one individual in the office setting to do all shade matching. Have this person practice matching each day. To choose the most competent individual, all should attempt to match five closely related shade tabs from two identical shade guides. Generally females can see color better than males.

Shade guides. Shade guides have the problem of coverage error. That is, they tend to not cover all of the actual shades of teeth. One way to get around this is a system called Color Link. It is a system of bottles, like nail polish. If you cannot match a shade guide tooth to the patient's tooth, the shade guide tab can be modified by painting over it. The tab is then sent to the laboratory.

A second approach is a shade guide like the Spectratone, which has over 200 colors. The selection process was actually quite fast, but the company has gone out of business.

There has been an attempt to develop a chairside colorimeter. The Chromascan system came out in the 1970's and sole for $1600. It measured the color of the tooth with a fiber optic probe. It failed since it could not measure very sensitively.

Recommendations:

1) Match shades only with normally wet teeth since dried teeth are less translucent and show less of the yellow dentin color. The shade should be taken before work is begun, when the tooth is fully wet.

2) Send the shade guide tab selected to the dental laboratory. Shade guides cost only about $20, so keep a number of them on hand.

3) Send a diagram of the tooth indicating variations in color and translucency to the dental laboratory.

4) The dental technician should not rely on the shade given on the dental material products label, but should match the color of the restoration to the shade tab from the dentist. The lighting under which the dental technician works should be as similar as possible to that used for shade selection.

5) Instruct patients receiving porcelain veneers and restorations to use a toothpaste with a mild abrasive, such as a baking soda cleaner, and only allow the use of non-acidic fluoride gels.

6) Communication with the patient is very important. In terms of esthetics, patients' preferences are often very different.

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The Ten Axioms for Successful Dental Shade Control*

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I. Thou shalt only use Color Corrected lights with a Color Rendering Index (CRI) of at least 90.

II. Take shades in a neutral color environment to avoid reflected colors.

III. The person matching tooth shades in the clinic and dental laboratory shall be tested by matching two shade guides. Shade matching by a tested dental technician is best.

IV. The person matching tooth shades shall practice matching every day.

V. Use more than one brand of shade guide to reduce the coverage error.

VI. Match shades only with normally wet teeth since dried teeth show less of the dentin color.

VII. Send the shade guide tab selected to the dental laboratory.

VIII. The dentist shall send a diagram of the tooth indicating variations in color and translucency along with prescription to the dental laboratory.

IX. The dental technician should not rely on the shade given on the dental material products label, but match the color of the restoration to the shade tab from the dentist.

X. Instruct patients receiving porcelain veneers and restorations to use a toothpaste with a mild abrasive (e.g. baking soda tooth cleaner) and only allow the use of non-acidic fluoride gels (e.g. J & J Normal).

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