THE EFFECT OF OCCLUSAL BITE SPLINT THERAPY AND OCCLUSAL ADJUSTMENT THERAPY UPON PANTOGRAPHIC REPRODUCIBILITY

by

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DEDICATION

To my wonderful wife, Vicky, for her constant unselfish support in my academic career and my beautiful children, Chad and Kristy, for the many smiles they provided when needed most.

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INTRODUCTION

Diagnosis of pain dysfunction syndrome and poor neuromuscular coordination resulting from occlusal problems has been done almost exclusively by subjective symptoms and examination. Success of therapy once started again is judged by clinical signs and symptoms. Researchers can use an electromyograph but few practicing dentists would have easy access to such an expensive piece of equipment and quantitation is impossible.

For many patients relief of symptoms would provide a desirable and successful end result. For the patient that is in need of extensive restorative dentistry, relief of symptoms may not be enough. This latter example places new demands on therapy. Complete operator confidence in locating mandibular positions and complete operator control and knowledge of all mandibular movements are essential if a major restorative effort is to be contemplated.

It has been shown that some people can produce reproducible pantographic tracings while others cannot. It has been assumed that the lack of ability to produce reproducible pantographic tracings may be related to poor neuromuscular coordination resulting from faulty occlusion. Treatment of occlusal problems should lead to the ability to produce reproducible pantographic tracings. Also, it has been shown that many patients devoid of any clinical symptoms cannot produce reproducible

pantographic tracings. The restorative dentist needs a means by which such problems can be diagnosed and treatment monitored.

It is the purpose of this study to show the relationship between occlusal splint and occlusal adjustment therapy to pantographic reproducibility on non-reproducible subjects. If pantographic reproducibility can be shown to directly be related to occlusal therapy, a means by which the monitoring of such therapy will be provided and a positive relationship between that which is being altered in treatment and that causing altered pantographic reproducibility established.

REVIEW OF THE LITERATURE

I. Interrelation of Masticatory Components in Function and the Use of Occlusal Bite Splints and Occlusal Adjustments

In 1959 Jarabak[1] did an electromyographic study to examine the following: to determine whether or not occlusal interferences cause functional imbalances in the temporal muscles, to see if these imbalances are a contributing factor to clicking, trismus and pain in the temporomandibular joint, and to find out if it is possible to eliminate abnormal muscular activity by reestablishing a correct functional occlusion. Three groups were studied of which the first group of four had good occlusion, free of temporomandibular joint symptoms, and any occlusal discrepancies were adjusted. The second group of seven were orthodontic patients who had or developed joint clicking. The third group of eleven were patients with functionally broken down, lost and maligned teeth accompanied by clicking, pain, and trismus in the temporomandibular joint. In the third group occlusal adjustments were impossible, so occlusal splints were constructed to reestablish lost vertical dimension and secondly to remove occlusal interferences. Full palatal coverage splints, using an indirect method to construct anterior guidance and a poster direct method to establish a stable, interference-free occlusion were used. Electromyographic analysis was done on the right temporal muscle for various exercises and in group three analysis was done prior to splint insertion, during and five minutes after splint removal.

It was found that in short-term occlusal interferences as with

orthodontic treatment, temporal hyperactivity was less severe and of shorter duration than those associated with long-term occlusal problems and joint symptoms. Correct function of the temporomandibular joint appeared to be dependent upon the relationship of the occlusion, the temporomandibular joint and finally muscle balance according to Jarabak.[1] Muscle spasms disappeared when occlusal interferences were removed with the splint and reoccurred when the splint was removed.

In 1957 Perry[2] reported his findings from electromyographic studies of 126 patients. Patients unable to attain an EMG resting inactivity had their occlusion checked and adjusted. Reevaluation within seven days after adjustment showed an electromyographic resting inactivity. None of these patients complained of dysfunctional symptoms or pain. Electromyographic studies of the functioning dentition in patients suffering from occlusal and temporomandibular joint disturbances showed poorly coordinated and overworked muscles of mastication. Proprioceptive receptors in the periodontal space lead to the thalamus and consciousness or to the brain stem and the mesencephalic nucleus. All proprioceptive nerve endings around the teeth sent sensory impulses to this nucleus. Connections are made to the motor nucleus of the trigeminal nerve and efferent motor impulses to the masticatory muscles may be initiated. This mechanism directs muscle guidance to avoid areas of noxious, premature contacts. The position of least occlusal interference is found and maintained at the expense of normal muscle function. The use of occlusal splinting or occlusal equilibration in which interferences were removed resulted in mandibular movement unhindered by

protective impulses. Perry[2] believes that not all but many patients can be cured of temporomandibular joint dysfunction by equilibration and splinting.

Ware and Taylor[3] in 1958 advocated the use of occlusal splints in diagnosing the relationship between malocclusion and patient symptoms because of its reversibility, affording protection to both patient and clinician.

Shore[4] in 1959 stated that if treatment of the temporomandibular joint and muscles are to be lasting, the basic cause must be removed. Symptoms are caused by occlusal disharmony and its resultant pathologic occlusion. Many times it is impossible to treat the dentition until a major portion of the joint and muscle symptoms are alleviated. Cases of pathologic occlusion often present with deeply imbedded mandibular convenience relation habit patterns. The utilization of acrylic bite-plates are used to remove noxious occlusal stimulus which upset the pathologic pattern in a short period of time and allows for equilibration to centric relation. The flat occlusal plane will unlock pathologic occlusion and allows for freedom of mandibular movement and permits the temporomandibular joint time for rest and repair.

Franks[5] in 1965 stated his belief in reviewing the literature that temporomandibular pain-dysfunction disorders are basically a complaint of muscles with a background complex of disordered function and emotional factors. He did a controlled study in which three conservative treatments were done on three groups having dysfunction of the temporo-

mandibular joint. Group A was given reassurance and advice on diet. Group B had occlusion restored with removable appliances and advice as in group A. Group C was given an occlusal night guard and advice as in group A. If treatment improved or cured the symptoms it was called a success. Success in group A was 41%, in group B it was 70%, and in group C it was 84%. The night plate, by not allowing posterior tooth contacts, eliminated heavy proprioceptive stimulus from the periodontal membranes by temporarily relieving occlusal interferences which can lead to muscle hyperactivity. He believed that his study strongly supports the opinion that the basic complaint of temporomandibular joint dysfunction is localized in the masticatory muscles and should be treated as such.

Ramfjord and Ash[6] in 1966 stated that bite planes eliminate the disturbing input upon the neuromuscular mechanism from occlusal interferences in centric and balancing excursions. They facilitate muscle relaxation, decrease dysfunctional muscle forces, and eliminate the misguiding influence upon jaw movements from occlusal interferences. Thus the condyles are no longer forced into a traumatic position during closure and lateral excursions. Splints decrease muscle tonus and the magnitude of forces. Combined with the elimination of faulty guidance from occlusion and the traumatized temporomandibular joints, it allows the mandible to seek a normal position with a proper balance between muscles and temporomandibular joint.

In 1967 a study[7] was done to demonstrate the interrelationship

between tooth contacts and muscular activity of the chewing muscles by using intraoral radio transmitters together with the electromyograph. This study used transmitters to study contacts in unaltered occlusion by placing transmitters in artificially inserted balancing interferences. Results showed that only during empty tapping movements did the EMG activity of all muscles outlast the onset of intercuspal tooth contacts, while during mastication, EMG activity ceases on the muscles of the chewing side prior to or at the moment of intercuspal tooth contact. The reflex mechanisms determining mastication seem to be primarily influenced by the fact that tooth contacts occur and not where and in what maxillomandibular relationship it occurs provided a proprioceptive response can be elicited. This study demonstrated that the mandible is guided by light irregular contacts into centric occlusion. What appears as cuspal guidance may be nothing more than involuntary neuromuscular coordination in closing. Interference contacts elicited a high percentage of inhibitory EMG response in the form of a pause. Thus the neuromuscular mechanisms can avoid possible damaging effects of deflective occlusal contacts through their highly sensitive, self-protecting muscular response. This was not to say that damaging effects due to bruxism and parafunction might not occur. It was shown therefore, that tooth contacts are a part of the reflex mechanisms controlling mandibular movements and muscle contraction.

Bell[8,9] stated that in temporomandibular joint pain-dysfunction patients, muscle tonicity and pain will usually decrease within a few

weeks of occlusal splint therapy. Splint adjustment must be continued as myospasm is controlled and occlusion changes. After splint therapy the occlusion should be evaluated and adjusted if felt contributary to the problems.

In 1969 Loiselle[10] in a study of 2,000 veterans stated that occlusal problems are not the sole source of temporomandibular joint dysfunction. He did show that treatment with bite splints allowed symptoms to subside and that occlusal adjustments were not done because many of the non-symptomatic patients also had occlusal discrepancies. Thus if symptoms subside why adjust their occlusion?

In a 30 to 36 month study by Zarb and Thompson,[11] 39 patients with temporomandibular joint syndrome were treated with temporary splint or bite plane therapy followed by occlusal adjustment and/or prosthetic restorative treatment. Patients were seen frequently at first as noxious proprioceptive stimuli decreased and alterations in occlusal relationships lead to the necessity of splint adjustments. The majority of the patients responded to treatment within the first two weeks. Patients who responded first demonstrated conspicuous occlusal discrepancies. In the $2\frac{1}{2}$ to 3 year follow-up, several patients had discrepancies in occlusion without awareness of a slide or accompanying symptoms. Obviously, the occlusion had been brought within the adaptive tolerance of the patient. These clinical results indicated that functional occlusal therapy led to elimination of temporomandibular joint dysfunction.

Baumhammers,[12] in 1971, claimed that a night guard eliminates

the occlusal interferences and reduced lateral stress on teeth. Reduced input on the neuromuscular mechanism resulted in muscle relaxation and reduced muscle forces in dysfunction.

Crum and Loiselle[14] in 1972 stated that the physiologic function of the masticatory system is primarily dependent upon the integration of sensory feedback and neuron response. Proprioception and perception are the sensory processes that act to program and monitor the motor response. The function of the masticatory system is very dependent upon the input of the neural system by proprioception and perception. Perception results from sensory input from the periodontal membrane, epithelial surfaces, the muscles of the tongue and mastication and the temporomandibular joints. A defect or nonintegration of the proprioceptive or perceptive input may result in poor function or pathologic changes to parts of the system. The success of the prosthodontic restoration was dependent upon the integrations of proper proprioceptive feedback and motor responses. Any nonintegration or pathosis of one of the components (such as malocclusion, interceptive occlusal contacts, periodontitis, inflammation, muscle dysfunction or joint disorders) may yield proprioceptive inputs which are out of synchrony. This caused asynchronous sensory inputs which may lead to disharmony in the function of the masticatory system.

Greene and Laskin[15] in 1972 reported a study of 71 patients with myofacial pain-dysfunction syndrome. These patients had masticatory pain, limitation, deviation, or tenderness but if clicking or crepitus in

the temporomandibular joint was unaccompanied by pain or dysfunction they were not included. Three types of splint designs were used in this study. A nonoccluding palatal coverage placebo or control splint (splint # 1). Those not cured with this appliance were modified to have an anterior platform (splint #2) and the ones not cured or symptom-free with this appliance received a modified full occlusal coverage appliance (splint # 3). The results showed that 40% of 71 with splint #1 yielded positive responses, 50% of 60 with splint #2 yielded positive responses, and 80% of 44 with splint #3 yielded positive responses. This study showed that success is attainable with various methods and the findings tend to favor the latter as the most successful.

II. Border Positions and Movements and the Utilization of the Pantograph

Cohen[16] in 1956 did a study to find out if the paths of condylar movement are constant when anterior guidance and the degree of vertical opening were changed. Using the McCollum Gnathoscope and Gnathograph, clutches were made to fit a fully dentulous patient so that the maxillary clutch had interchangeable bearing surfaces (concave, flat, convex) allowing vertical and anterior guidance changes. After locating the hinge axis, border tracings to the right and left lateral and protrusive were made and compared by superimposition and setting of the gnathoscope. Observations showed that the various bearing surfaces did not alter the gnathoscope settings, the three posterior sagittal right sides superimposed as did the left, the three posterior horizontal right sides superimposed as did the left, and the anterior tracings moved forward with

increased vertical. It was concluded that within the range of variation used, no change in the paths of the condylar movements occurred. In another bench study Cohen[16] showed that the condylar guidance was constant and unaltered by anterior guidance. Misinterpretation of tracings done under different conditions has caused confusion as to the consistency of condylar guidance. This study according to Cohen has shown that such a consistency does exist.

Stuart[17] in 1959 stated that the importance of recording border positions and movements are that they are constant enough in position, direction, and path characteristics to be dependable. Habitual positions vary according to postures, health, muscular and nervous states. Although muscles have some memories they are not as accurate as border movements which can be recorded repeatedly. These border positions and movements are the boundaries of function to which oral prosthesis must have freedom.

Posselt[18] in 1960 claimed that in border movements the neuromuscular mechanisms play a small part compared to functional movement guidance. He also discredited the "Wustro Effect" showing that hard foods and even gutta percha did not displace the condyle as Wustro reported a glass ball did when unilaterally occluded upon.

Posselt[19] in 1952 reported a study of posterior border movements on three patients before and during the use of general anesthesia with curare. He found no change in the position of these movements and concluded that ligaments were responsible for limiting posterior border

movements because they are unaffected by the anesthesia or curare.

Boucher and Jacoby[20] in 1961 did needle point gothic arch tracings of posterior border movements on 12 subjects before and during general anesthesia with succinylcholine chloride. Findings showed that tracings on conscious and premedicated subjects were not different. Eleven of the 12 subjects showed a more posterior mandibular border movement when under general anesthesia as moved by the clinician. They concluded that muscles are responsible for limiting posterior border movements of the condyles in the articular fossa of the temporomandibular joint.

McMillen[21] in 1972 did a study to reconcile the conflict between Posselt[19] and Boucher and Jacoby.[20] McMillen used ten students with no signs or symptoms of traumatic occlusion and an extraoral pantograph. He did border movement recordings in the horizontal and vertical planes on subjects in a conscious state and while under general anesthesia with succinylcholine chloride. He also used occlusal splints prior to the experimental recordings to disorient the subjects' proprioceptive awareness of the centric occlusion position and to facilitate retruding the mandible to the centric relation position. Results from the horizontal graphic tracings showed small posterior displacements averaging 0.28 mm while vertical changes were more marked due to the inability to prevent vertical displacement or drop while under general anesthesia. Lateral movements recorded on the horizontal graphs showed an increase of 0.65 mm average for immediate side shift and 0.77 mm average wider

progressive side shift as recorded five mm from centric relation position. Several operators attempted to attain greater posterior displacement but were unsuccessful in attaining anything near the two mm displacement reported by Boucher and Jacoby. This study did not support the theory of muscles limiting posterior horizontal movement nor did it prove that centric relation is limited by ligaments. Also the fact that wider lateral border movements were recorded might indicate border movements recorded on the conscious patient may not be total border movements according to McMillen.

Grasso and Sharry[22] in 1968 did consecutive intraoral unguided arrow point or gothic arch tracings on 15 patients over a period of 29 days. Their purpose was to determine the reproducibility of "centric relation position." They found that an average of 0.44 mm mediolateral variability of the apex occurred versus an average of 0.28 mm anteroposterior variability of the tracing apex. These variations appeared to vary with time and the same apex could not be duplicated over a 29-day period. Thus a freedom in centric was concluded. They also concluded that their data suggests a muscular, not ligamentous, control of border movements.

Celenza[23] in 1973 reported the findings of a clinical study similar to Grasso and Sharry.[22] In this study he compared the accuracy of guided and unguided gothic arch tracings versus guided and unguided biting point reproducibility. His findings showed it was easier to read points and that the greatest reproducibility of "centric relation position"

was achieved with the guided biting point technique. The study was done using an intraoral device on 15 patients over a 21-day period. The results of this part using the most accurate method showed an average anterio-posterior displacement of 0.16 mm and an average mediolateral displacement of 0.15 mm for "centric relation position." Thus a dispersion pattern was noted but it was much smaller than that noted by Grasso and Sharry.[22] Celenza states that myotatic or stretch reflexes and muscle splinting are protective mechanisms. One must think of the whole system as a coordination of protective mechanisms and back-up systems. The neuromuscular complex protects the ligaments while the ligaments protect the joint.

Ingervall, Helkimo and Carlsson[24] in 1971 reported a study using different retruding forces in locating centric relation. They used forces of 0.5 kg, 1.5 kg, and 2.5 kg and used an intraoral recording device. They concluded that increased protrusive force caused the recordings to shift posteriorly. Thus in locating the "retruded position" use strong external pressure and guidance is necessary for accuracy.

Huffman, Regenos and Taylor[25] state that the pantograph is a written record of mandibular movements and is a method of recording mandibular border movements. It is desirable that these recordings represent the full extent of the border movement; therefore, the operator must guide the movements rather than letting the patient alone guide movements.

In 1969 Guichet[26] claimed that no matter what occlusal scheme

was used in reconstruction, the dentist must concern himself with mandibular movements to prevent adverse "occlusal programming" which may precipitate bruxism. Many patients cannot obtain true peripheral recordings with the pantograph because of long standing neuromuscular accommodation to malocclusion. Only true peripheral recordings are desirable and the pantograph has the advantage of double check capabilities. The reproducibility of border tracings are used as a measure of whether or not true border movements have been accurately recorded.

In a study by Kotowicz, Clayton, and Smith,[27] seven dentulous patients were pantographed six times, each at different times, and an articular set from these recordings. Three of these used the same clutches and three non-control clutches were used. An arbitrary figure of 0.3 mm variation at the cusps was considered clinically significant. Findings showed that 98.5% of the clinical errors were smaller than the clinically significant figure. It was concluded that pantographic-recording reproducibility is a practical quality of border movements (as pertaining to articulation). Variation in bearing surfaces also produced no clinically significant errors.

In a study reported by Clayton, Kotowicz, and Myers[28] in 1971, a pantograph was attached to a patient so it did not interfere with occlusion. Guided and unguided lateral excursions were compared and it was observed that the unguided tracings were not border tracings. In tracing chewing movements, the functional movements did not extend to the

border positions but appeared to be guided around centric occlusion. Upon elimination of occlusal interferences, function did extend to the border positions. It was stated that tooth interferences, and muscles conditioned to these interferences, direct unguided movements away from the guided border movements.

In 1971 Clayton, Kotowicz, and Zahler[29] reported a chewing study in which the pantograph was used to record functional movements in relation to border movements. Clutches were used which did not interfere with tooth contacts during function. Four subjects were used and all had various occlusal interferences and a slide from centric relation to centric occlusion which were not adjusted. Unguided lateral tracings from centric occlusion and guided lateral tracings from centric relation were made before the chewing of various test foods. Results showed that two of the subjects contacted border tracings from centric relation frequently. In the other two subjects, chewing was confined to the centric occlusion tracing. One of these subjects functioned nearer to the centric relation tracing following the elimination of some of the occlusal interferences. Movement never extended beyond the border tracings. It was stated that mandibular movements can be influenced by tooth guidance or deflective occlusal contacts. Teeth with occlusal interferences can proprioceptively guide mandibular movements around the deflective occlusal contacts. Muscles may become conditioned to this continual feedback. Occlusion should be designed to allow function to the border positions, to minimize tooth guided adaption, and allow the

muscles and temporomandibular joint to function independently of the teeth. The pantograph is an instrument that records border movements. It was concluded that patients can function to the border tracing if deflective occlusal contacts are absent.

Clayton[30] reported in 1971 that border positions of the mandible are limited by anatomic features of the joints and are stable, reproducible positions. Border positions are the limits of functional movements without influence from the muscles and teeth. Tooth contacts or muscle and joint disorders may restrict movements to the border positions. A pantograph is the most accurate means of recording mandibular border positions available. The pantograph graphically reflects the influence of the temporomandibular joint on mandibular movements without muscle or tooth influence. Tooth interferences can cause muscle or joint disorders which can deflect movements away from border positions. Thus occlusal splints and occlusal adjustments should be used to permit normal muscle and joint function prior to pantographic surveys.

In a pilot study reported in 1973 by Roura,[31] five patients, unable to produce reproducible pantographic border tracings at the onset of testing, were put on occlusal splint therapy for one month. One of the five improved to the point of producing a reproducible border tracing. Inconclusive results yielded no solid conclusions and it was suggested that possible shortcomings were due to time, lack of occlusal adjustment in combination with occlusal splint therapy and sample size.

Review of the literature has shown a correlation between occlusion

and masticatory control and symptoms. Occlusal bite splints and occlusal adjustments can reverse adverse masticatory symptoms and appear to de-program neuromuscular conditioning. Conflict as to true border movements and positions exists; yet the pantograph has been shown capable of graphically recording mandibular movements. Some patients have been shown to record retractable or reproducible "border movement" recordings while others are unable to. It has been hypothesized that neuromuscular conditioning or temporomandibular joint pathosis due to occlusal discrepancies may be the etiology of non-reproducible mandibular "border movements" as recorded by the pantograph.

It is the purpose of this study to see if patients unable to produce reproducible border movements as recorded by the pantograph, can record reproducible border tracings, after occlusal bite splint and occlusal adjustment therapy.

MATERIALS AND METHODS

Introduction

In the following study, the effect of occlusal bite splint and occlusal adjustment therapy upon the reproducibility of mandibular border movements was analyzed. Twenty-six subjects, nine males and seventeen females, ranging in ages from 21 to 50, were divided into three groups according to their abilities to reproduce mandibular border movements as recorded by a pantograph. Each group received a sequence of four recall pantographic recording sessions while the experimental group only received occlusal bite splint and occlusal adjustment therapy in addition to the pantographic recordings.

The pantograph was used to graphically record each patient's abilities to reproduce lateral posterior mandibular border movements over a minimum of 120 days. By comparing the tracings of the control groups receiving no occlusal therapy with the experimental group receiving occlusal therapy, the effect of occlusal bite splint and occlusal adjustment therapy upon the reproducibility of mandibular border movements was studied.

Perfection of Techniques

Preliminary experience and the perfection of procedures are essential in the use of any equipment to be used in research. Error due to inexperience must be minimized. In this study the operator had only minimal exposure in the use of a pantograph and a period of practice and

perfection of technique was essential. This phase of preparation was done prior to any collection of data and the results obtained were used only to test the consistency of the operator.

Multiple pantographic tracings were taken on several patients over a three month period. These tracings were scored and used to test for operator consistency. This procedure also proved very essential in the perfection of pantographic techniques and reliability. The pantograph and pantographic techniques used were modified as a result of this preliminary experience and these modifications will be discussed.

The ability of the operator to determine artifact due to the equipment and/or operator from pantographic data was essential for accurate collection of data about the subjects' mandibular movements. With experience the operator was able to interpret from the pantographic recordings that which was operator or equipment artifact and these recordings were discarded. Only the very best pantographic representation of the subjects' condition was recorded and used. Thus, the preliminary phase of the study proved to be invaluable in technique and instrument perfection and added to the accuracy of the data collected.

Equipment Alterations

The Denar Pantograph* was used as the recording instrument in this study. As has been stated, preliminary studies revealed the need for minor structural alterations to achieve the accuracy desired (Fig. 1).

*Denar Corporation, 220 Howell Avenue, Anaheim, California 92806.

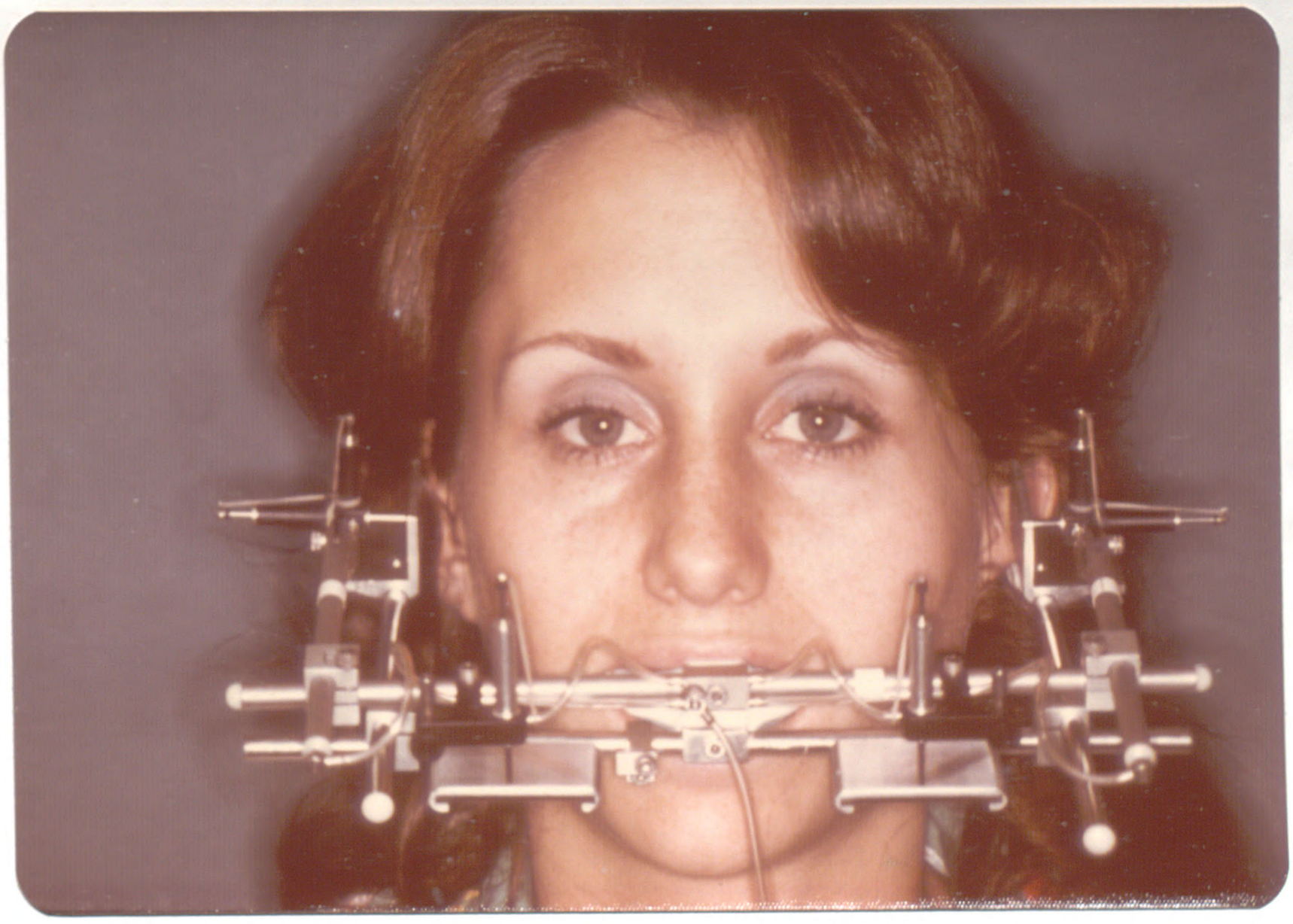

Figure 1.- Pantograph on Subject

Variability of movement patterns from patient to patient showed the size of the standard pantographic recording tables to be inadequate. Graphic and not pantographic interpretations of the recordings were used;[30] thus the entire lateral posterior border tracing was desired and larger tracing tables were required. The supplied anterior tables were enlarged to 22 mm x 37 mm. An aluminum overlay plate, which slipped over the original anterior tables, was fabricated to supply the additional size requirement (Figs. 2 and 3).

The posterior tables were completely remade with 18 mm x 39 mm vertical tables and 17 mm x 39 mm horizontal tables. These new posterior tables were entirely fabricated out of aluminum and attached to existing side arms as the originals. A small hole was placed in the distal of the vertical table for orientation over the arbitrary hinge axis point

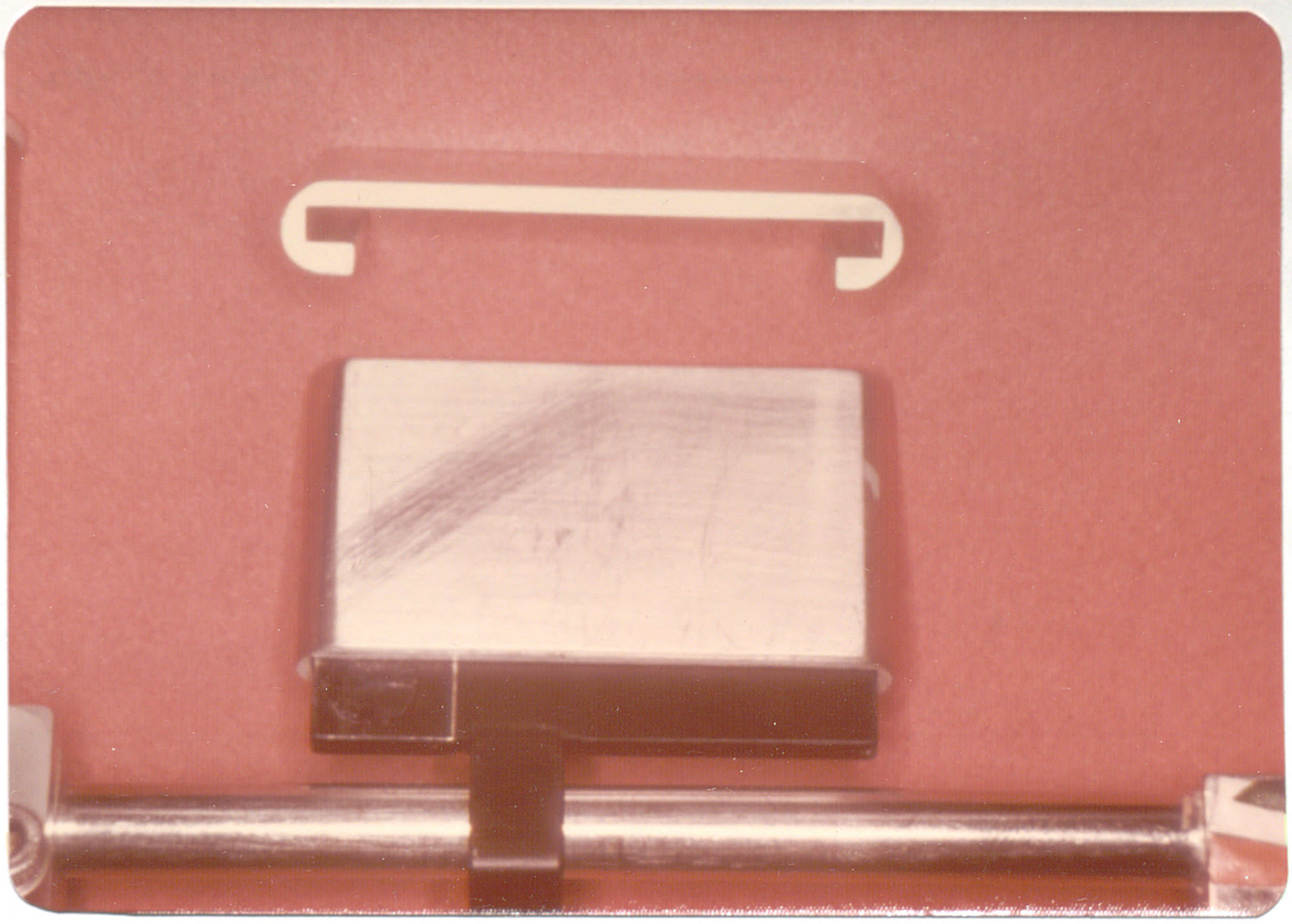

Figure 2.- Anterior Overlay Plate

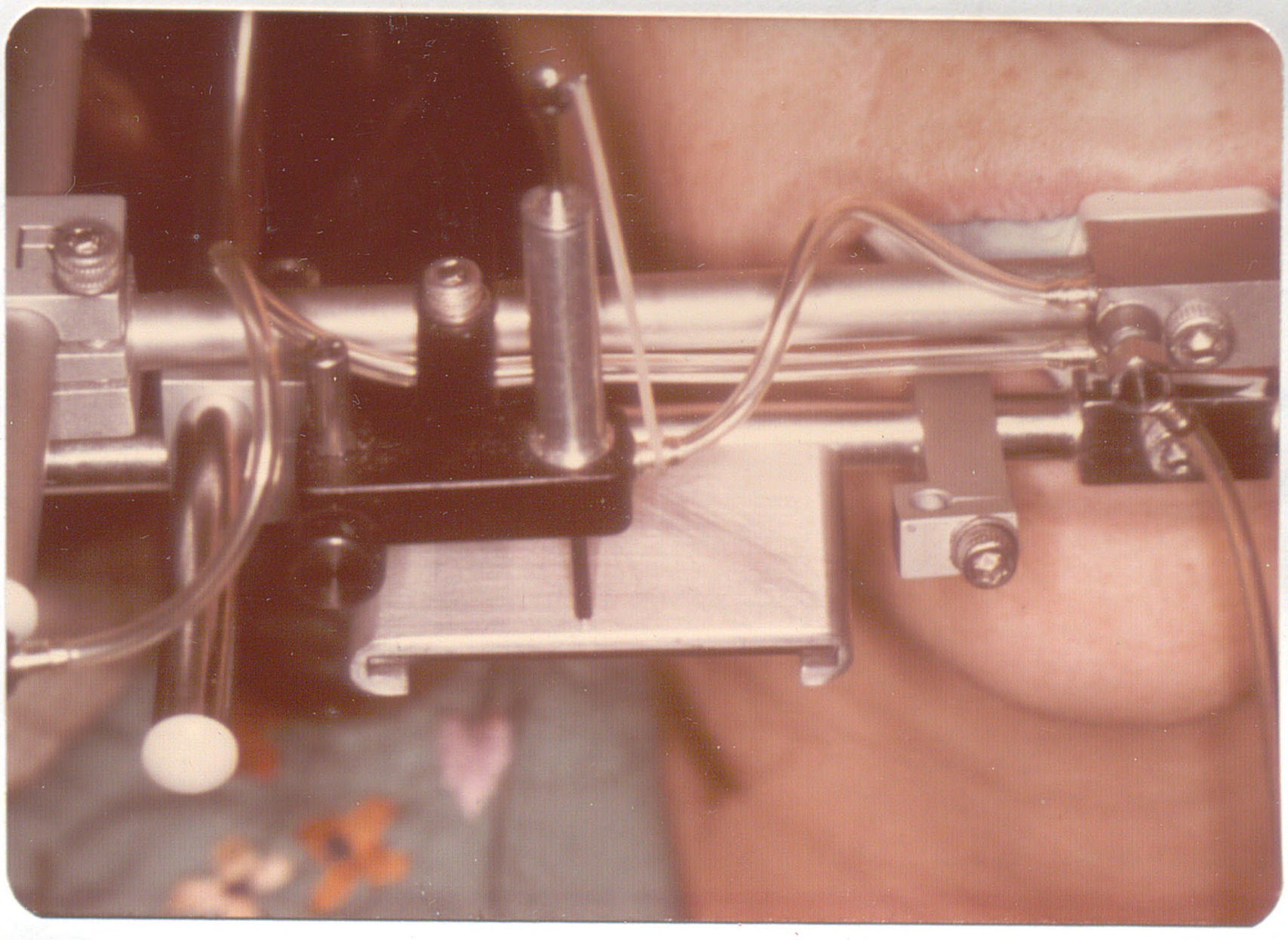

Figure 3.- Anterior Table on Subject

(Fig. 4). The increased dimensions of these tables provided adequate area to contain the entire posterior border tracings of all patients tested.

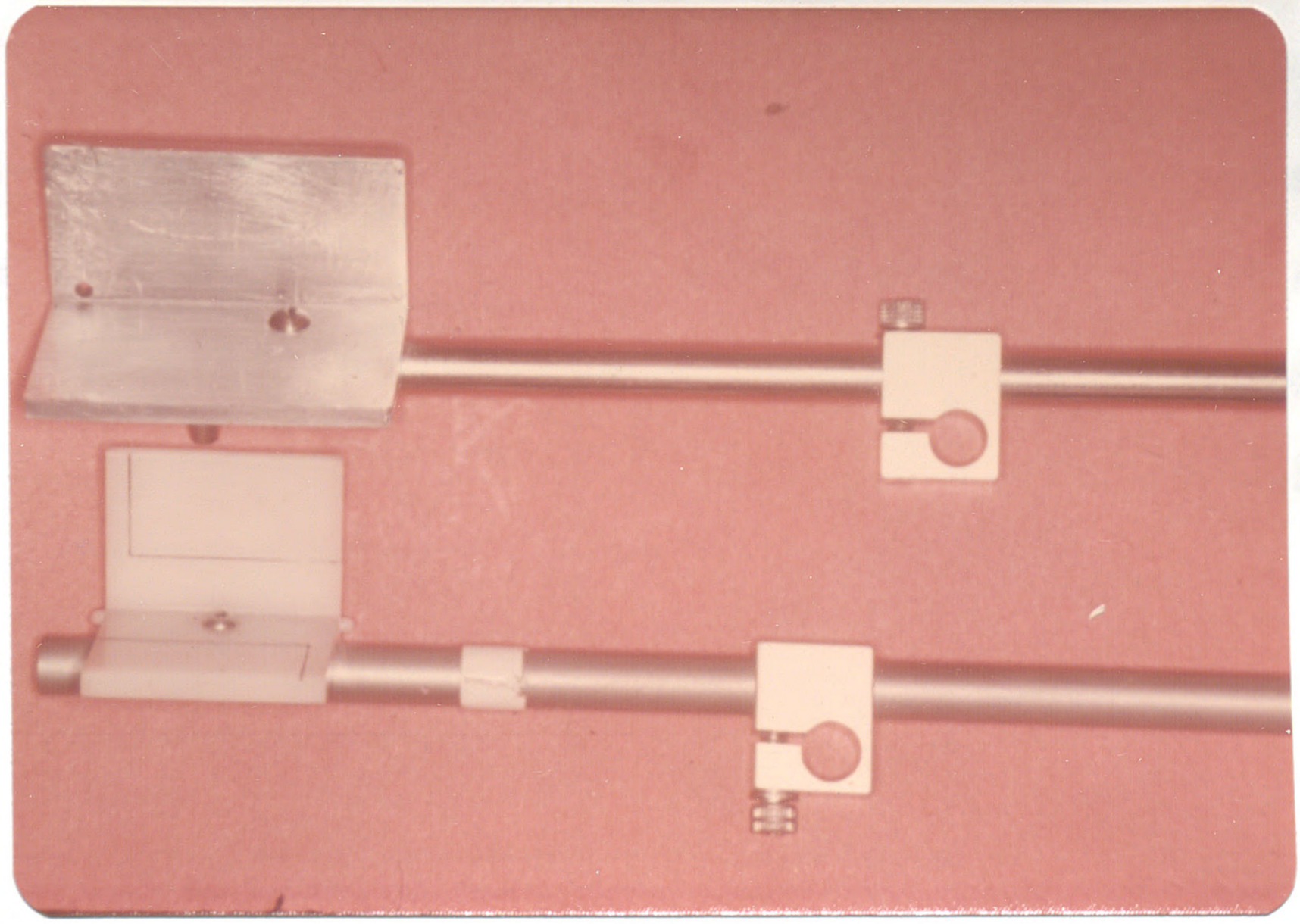

Figure 4.- Comparison of Original and New Posterior Tables

Tracing papers supplied with the pantographic equipment were found to be inadequate because they could only record lines that were too wide. The recording of very fine lines in close proximity was desired; thus the supplied waxed papers were replaced with a thinner pressure sensitive paper.* These were cut to size and backed with two-sided tape.** In order to enhance the reading of these tracings and eliminate the problem of fading with time, the denar overlays were not used. Instead the

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*Sanborn Perma Paper #65140 (e.c.g.-) blank rolls, no lines, Graphic Controls Corporation, Recording Chart Division, 29226 Orchard Lake Road, Farmington, Michigan 48024.

** 1" 3-m #465 Double Adhesive Tape, St. Paul, Minnesota 55101.

completed tracing papers were protected by sticking them to black construction paper with a non-adhesive plastic overlay covering the entire sheet.*

One new problem was created with the new paper. The styli had the tendency to tear the paper. This was especially true on the posterior recordings while tearing was infrequent on the anterior tables as supplied. Trial and error with different elastics on the posterior styli lead to the discontinued use of the standard posterior elastics and the use of 5/8" elastics.** These elastics were too long when attached in the standard method through the anchor loop. To shorten them they were wrapped around the entire perpendicular styli cylinder and through the loop (Fig. 5). This combination gave good fine lines with minimum to no tearing of the modified papers.

During practice sessions it was observed that in lateral excursions, contact of the central bearing stud on the concave bearing surface would sometimes leave the groove or the stud moved over the ridges of the concave surfaces. This factor had only minor significance in the tracing consistency but was considered a possible source of guidance error. Also the grooves themselves might be considered guidance, so the entire concave bearing surface on the maxillary clutch was recontoured to eliminate any grooves and ridges. The gradual distal incline was maintained (Fig. 6).

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*Sheet Protectors, heavy weight with black mounting sheets. 11" x $8\frac{1}{2}$", Ful-Vu Cood's Incorporated, Chicago, Illinois.

** 7 B (5/8") Ormco 2-pak Elastics Ormco Corp., 500 N. Mich. Ave., Suite 344, Chicago, Ill. 60611.

These were the only alterations of the pantographic equipment necessary. All other pantographic equipment was used as supplied from the manufacturer.

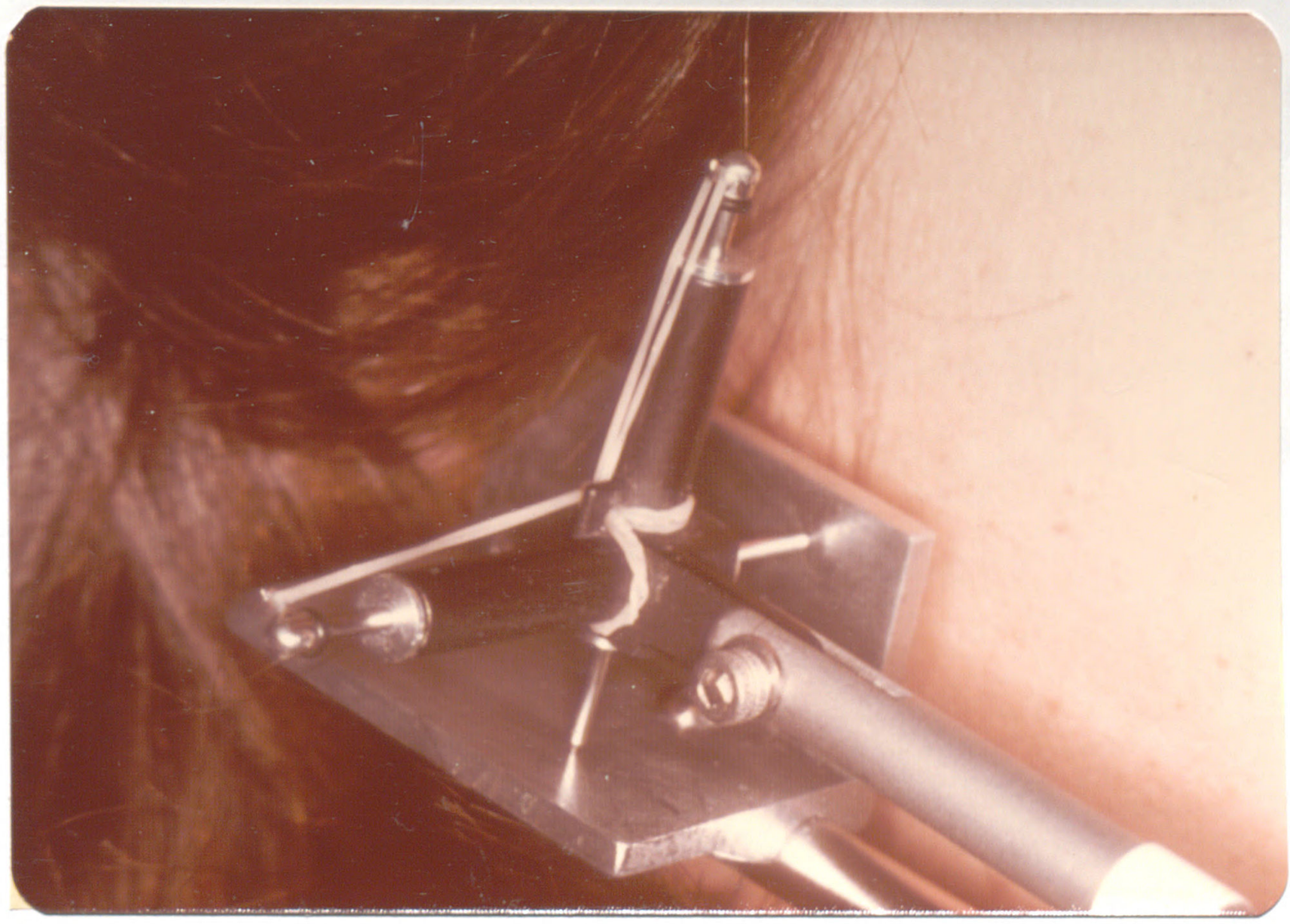

Figure 5.- Posterior Elastic Alteration

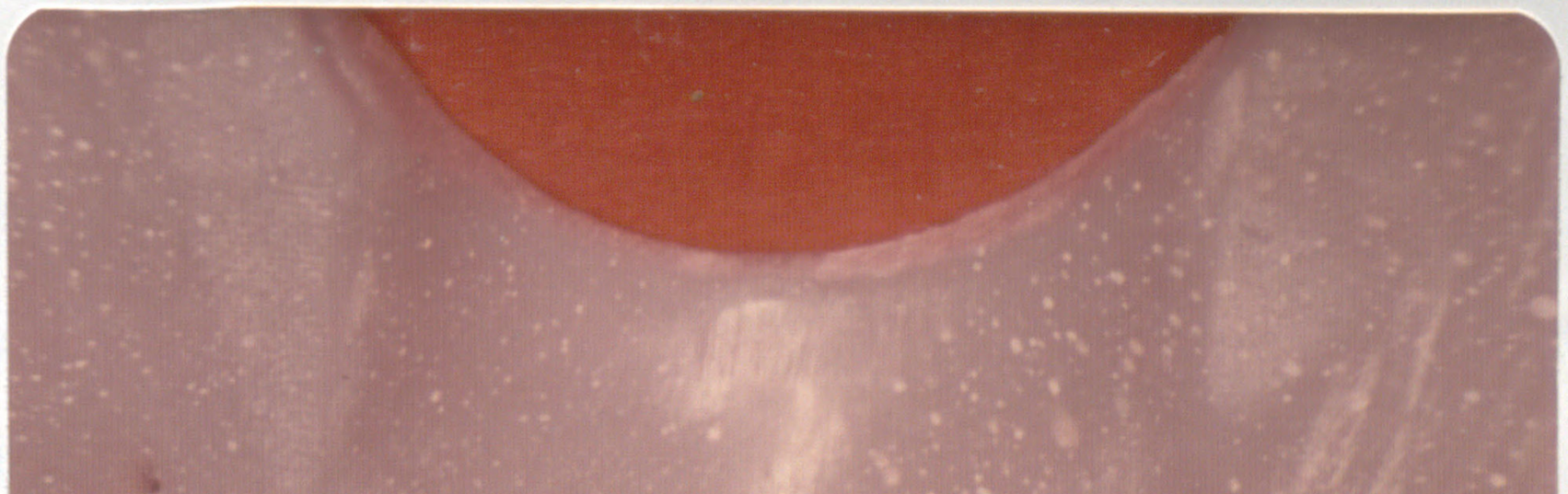

Figure 6.- Modification of Clutches Bearing Surface

Preliminary Procedures

Initial subjects' selection was on a basis of availability and the desire for occlusal treatment. Prior to categorization and experimentation, all subjects were handled as follows:

1. Registration: At The University of Michigan Dental School as patients.
2. Health Questionnaire: (Refer to Appendix).
3. Consent form: Descriptive in nature (Refer to Appendix).
4. Full mouth x-ray series: Consisted of four posterior bite wings and eighteen periapical films.
5. Temporomandibular joint x-rays: The technique used was an averaging technique where the central ray was started $2\frac{1}{2}$ inches superior and 1 inch distal to the distal tragus of the ear and directed at a 25^{o} angle inferior. From this starting point the central ray was aligned with a piece of string to the palpated location of the condyle on the opposite side. A collimated cone gave an exposure of approximately two inches in diameter at this distance. Views of the condyle in the centric occlusion position and wide-open position were recorded in two exposures on the same film.
6. Occlusal examination and questionnaire: (Refer to Appendix).
7. Fabrication and modification of clutches: Basic technique as recommended by Denar Teaching Atlas[26] using auto cure acrylic.*
8. Pantographic recordings: A pantograph is an instrument designed to record mandibular border movements of subjects. A recording of

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* Bosworth Fastray, 531 S. Plymouth Court, Chicago, Illinois.

these movements is called a pantographic recording. Some subjects can make reproducible recordings, while others cannot. Reproducibility can be defined as the exact superimposition of lateral border tracings when done while the pantograph has been left in a constant orientation to the subject. Those subjects that cannot make reproducible recordings may have muscle and/or temporomandibular joint dysfunction. Therefore, the reproducibility of a pantographic recording may be used in diagnosing possible muscle and joint abnormalities.

Reproducibility is determined from tracings that the subjects made. Each subject was required to trace three lateral movements to each side. The characteristics of these lines were used to determine if a subject's movements were reproducible or non-reproducible. The tracings were scored with a pantographic index for mandibular border movements (Refer to scoring section). A score of 0-144 was given to characteristic tracings. Scores from 0-15 were considered reproducible. Scores above 15 were considered non-reproducible. The non-reproducible category was divided into three groups according to scores with 16-30 being slight, 31-60 moderate and 60+ being classified as severe. This designation indicates slight, moderate or severe dysfunctional involvement.[33]

A pantographic recording has been designated as three tracings in each lateral movement plus one protrusive movement on each tracing paper. The initial recordings were taken with a minimum

of one morning and one afternoon session. Each session consisted of two pantographic recordings on all six tables. Thus, a minimum of four sets of recordings were used to categorize each patient. In cases where patient learning potential or artifact lead to inconsistencies, additional sets of recordings were taken to substantiate categorization of candidates. In cases where inconsistency was continuous, trends were at least established by additional sets of recordings.

9. Categorization: From the pantographic recordings, numerical scores were established and the patient placed in the appropriate category. Scoring was not done by the operator and except for the purpose of categorization this information was not given back to the operator on subsequent recall recordings.

Scoring Pantographic Recordings

Scoring of pantographic recordings was done for the purpose of assessing a numerical score that would correspond to the subject's abilities or inabilities to reproduce lateral posterior border movements. Evaluation of these numerical scores allowed for easy interpretation of each subject's progress throughout the study. In order to keep the scoring process impartial, the operator was not informed of the method used in scoring recordings and except for the initial classification was given no feedback about patient progress. The completed set of tracing papers are arranged on construction paper so that a scorer can score them. Each tracing on each table is scored in working and balancing movement to the right and then the left lateral movements. The scores are

recorded on a standard form (Refer to Appendix). Each lateral tracing on each table is divided into the beginning one-half and the ending one-half. A score of 0, 1, 2, and 6 is given for the line patterns on each $\frac{1}{2}$ of each lateral movement. The 0 score is given if the three traced lines are superimposed. The 1 score is given if two lines touch, a score of 2 if two separate lines appear and a score of 6 if three separate lines are present. The 0 - 6 score is given for each beginning $\frac{1}{2}$ and each ending $\frac{1}{2}$ of the movement. A single lateral movement recorded on any one table can have 12 points. There are six tracing tables and each table has right and left movement. Therefore, the total score for a set of tracings is 144 points.

The lower the score, the more reproducible the movement. A score of 0 - 15 is considered reproducible, scores higher than 15 are non-reproducible and they are divided into 16 - 30 is slight, 31 - 60 is moderate and 61+ is severe muscle involvement.

Scoring was done exclusively by one committee member (J.A.C.) and he was not informed as to which subjects were experimental or control. All recordings were kept by the scorer to eliminate the operator from rechecking previous recordings. The scoring method itself was devised by the scorer and through preliminary studies the amount of scoring error was tabulated. During the preliminary practice phase of the study the scorer took 15 sets of tracings consisting of all six tables and scored each 15 times. The standard deviation of error was calculated to be 2.11 points. Again it should be emphasized that all scoring

was done by one person (J.A.C.) and that results were handled in a blind manner. Results and scoring methods were kept from the operator until all data was collected.

Categorization

Test subjects' pantographic recordings were either classified as reproducible or non-reproducible. The purpose of the study was to determine the effects of occlusal bite splint and occlusal adjustment therapy upon the reproducibility of posterior mandibular border movements as recorded by the pantograph. Due to operator limitations, therapy was directed exclusively at the non-reproducible subjects and the following categories were formed: the non-reproducible experimental group which was used to test the study's purpose, the non-reproducible control group which controlled the results of the experimental group, and the reproducible control group which along with the other control group tested the validity of the classification system over time. In other words do these scores change over a period of time?

Thus the three categories into which subjects might be placed were reproducible control, non-reproducible control and non-reproducible experimental. From the preliminary pantographic recording sessions, each subject was scored and put into a reproducible or a non-reproducible group. The reproducible subjects were all put in the reproducible control category. The non-reproducible group was divided into slight, moderate, and severe subcategories and distributed among the non-reproducible control category and non-reproducible experimental category. It should

be noted that if any one of the four pantographic recordings was above 15 points, the subject was put in a non-reproducible category. Patients in both control categories were subject only to periodic pantographic recalls. The non-reproducible experimental group had periodic pantographic recalls plus being treated with occlusal splint therapy and occlusal adjustment therapy.

Once the initial scoring was done and the reproducible and non-reproducible groups established, the operator received no further feedback from the scorer. Likewise each subject's name and the category into which he was placed was kept from the scorer. By keeping the feedback between the scorer and operator somewhat blind, the operator was unaware of the exact progress of the patients and the scorer was not influenced by the knowledge of which patients were experimental or control.

Utilizing the above three categories, several factors should be evident. First of all the control groups should show a subject's response to pantographic recordings over time. These groups received no therapy and the results should reflect only factors other than those resulting from splint and occlusal adjustment therapy. The experimental group would reflect the effects of the control group as well as the effects caused by splint and occlusal adjustment therapy. Comparing results of control and experimental categories should show the difference that splint and occlusal adjustment therapy can have on pantographic recordings and thus mandibular movement over time.

The final categories were set up with 11 non-reproducible experimental subjects, 10 non-reproducible control subjects and 5 reproducible control subjects. Slight, moderate, and severe classifications were used exclusively to ensure a comparable range of patients in each non-reproducible group.

Appointment Sequences

Control patients all went through the preliminary stages up to categorization. Recall appointments only were done on these patients. Each recall as often as possible consisted of one morning appointment for two pantographic recordings and one afternoon appointment for two pantographic recordings. Thus each recall consisted of four pantographic recordings on each patient. Time and scheduling did not always permit morning and afternoon appointments. Four recall appointments were done on each patient with the first being no less than 30 days after categorizing and each subsequent recall no less than 30 days from the one succeeding it. Time factors forced the shortening of this period for the last four patients' last recalls. Thus a minimum of twenty pantographic recordings was taken over a minimum of 120 days. Due to scheduling difficulties longer time between recalls was more frequent than shorter time.

Control subjects were subjected to the same basic recall schedule as the experimental subjects, except that splint and occlusal adjustment therapy was done within the time schedule on the latter group. Preliminary records and categorization was completed for all subjects and the

experimental patient had an occlusal splint fabricated and delivered. The first thirty-day recall period did not start for experimental patients until the splint was in the mouth. For the first two recall periods this group was instructed to wear the splint as much as possible. Following the second recall recordings, the occlusal adjustment work-up was started and the occlusal adjustment was started and perfected. The third recall period for this group did not begin until after the first adjustment appointment. It should be noted that for the experimental patients, the occlusal splint was still in continuous use while the adjustment was being done and to the end of the third recall was worn all the time. Following the third recall recordings, no further occlusal adjustment was done and the subject was weaned off the splint (Refer to Appendix). By the end of the fourth recall period the patient had been off the splint completely for at least one or two weeks. Following these fourth recall recordings the study was completed.

Schedule Summary

(A) Control patients -- reproducible and non-reproducible

1. Preliminary records and categorization from pantographic recordings.
2. First recall: 30 days + after No. 1, a.m. and p.m. pantographic recordings.
3. Second recall: 60 days + after No. 1, a.m. and p.m. pantographic recordings.
4. Third recall: 90 days + after No. 1, a.m. and p.m. pantographic recordings.
5. Fourth recall: 120 days + after No. 1, a.m. and p.m. pantographic recordings.

(B) Experimental patients -- non-reproducible only

1. Preliminary records, categorization of subjects into groups from pantographic records, and splint delivered and adjusted.
2. First recall: 30 days + after splint delivered -- a.m. and p.m. pantographic recordings.
3. Second recall: 60 days + after splint delivery -- a.m. and p.m. pantographic recordings -- occlusal adjustment was now started and perfected with continued splint use.
4. Third recall: 90 days + after the splint delivery and 30 days after the first adjustment appointment -- a.m. and p.m. pantographic recordings. Begin weaning off the splint.
5. Fourth recall: 120 days + after the splint delivery and 60 days + after the adjustment was started -- a.m. and p.m. pantographic recordings. Note that the patients have been off the splint for at least one or two weeks prior to this recall series.

The control group received only periodic pantographic recall recordings while the experimental group went over 90 days on the splint of which the last 30 - 40 were in combination with an adjusted occlusion. For only that last one or two weeks did the experimental group discontinue splint use.

The reason for such a time division on the experimental group was to thoroughly check the effects of splint therapy, followed by the combination of splint therapy and adjusted occlusion and finally that of adjusted occlusion only. Longer splint therapy was necessary to allow for adequate neuromuscular reprogramming prior to occlusal adjustment therapy.

Pantographic Recording Technique

The recording appointment began with the subject being seated with the feet slightly elevated and the head well supported by the head rest in a position parallel to the back. The back was placed at approximately a 45^{o} angle to the floor. Arbitrary hinge axis points were marked 13 mm

anterior to the most posterior part of the tragus on a plane to the outer canthus of the eye. True hinge axis location was not necessary because scoring was done on tracings recorded without changing or removing the pantograph. Comparison was strictly graphic and not pantographic as with setting an articulator. Therefore, variability of hinge axis orientation would not alter the graphic data sought in this study.

Next the modified clutches were washed with a layer of bite registration paste* and seated in the subject's mouth with the subject lightly holding the contacting surfaces together in the retruded position. This procedure had a dual purpose. First of all the same individual clutches were used throughout the study. Rewashing before each recording session compensated for clutch inaccuracy and instability over time due to dimensional distortion of the acrylic resin or minor tooth movement. Secondly, the cementing effect of the clutches into the mouth with the bite registration paste eliminated pantographic movement due to rocking clutches while recording. This minimized any artifactual recording error due to mechanical problems.

The lower member of the pantograph was now attached to the mandibular clutch. The posterior tables were oriented so a hole in the vertical table was over the hinge axis mark. This was done by extending a small metal rod through the hole approximately 15 mm. The rod was aligned with the mark. The vertical tables were oriented perpendicular to the floor. The anterior tables were set parallel to the side arms.

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* Bite Registration Paste, Kerr Sybron Corporation, Romulus, Mich. 48174.

The upper member of the pantographic apparatus was now attached to the maxillary clutch. All six styli were set approximately perpendicular to the tracing tables and in such a position that extreme lateral movements would not cause the styli to run off the table.

Having the pantograph assembled and adjusted, the air supply was connected, the styli were activated and the elastics were attached to the styli. The lower member of the pantograph was removed from the mandibular clutch and the recording papers were placed on the tables. The lower member was reattached to the mandibular clutch and the recording procedure started. It should be noted that while pantographic orientation was not the same from appointment to appointment, orientation of position and like vertical dimensions were very close.

The pantographic recordings were all operator guided and patient directed, but forced guidance was avoided. The subjects verified that only a minimum operator guidance pressure was used, thus allowing for maximum patient direction. The tip of the subject's chin was held with the operator's thumb just above the tip of the chin and his forefingers just below the tip of the chin, extending slightly along the lower border of the mandible on each side. A similar grip was used for all recordings. The only time any heavier guidance was intended was in the retrusion movement to get the mandible in position to begin lateral movements.

Prior to any recordings, a session was held where the procedure was practiced. Frequently, recordings were taken to allow the subject to hear the styli work and to make sure that tracings to be used in the

experiment contained a minimum of learning artifact or faulty tracings due to inexperience only. During the practice period the subject was informed about what was being recorded. The lower jaw should be held in the retruded position while moving laterally and a positive clutch contact would aid in this retrusive movement. Once it was felt that the subject was ready, pantographic recordings were taken.

The actual recording sequence was as follows:

(1) Forward back, forward back, mark centric dot.

(2) Forward back, forward back, mark and confirm centric dot. (In subjects where the centric dot was reproduced, the centric dot was used as a starting point for all recordings.) A practice right lateral movement was then taken.

(3) Forward back, forward back, record right movement.

(4) Repeat #3.

(5) Repeat #4.

If it was apparent that a subject could not reproduce the centric dot, tracings were taken using the best approximation of centric.

(6) Forward back, forward back, left practice movement.

(7) Forward back, forward back, record left movement.

(8) Repeat #7.

(9) Repeat #8.

(10) Forward back, forward back, record protrusive movement.

The lower member of the pantograph was next removed from the mandibular clutch, the recording papers removed and mounted for scoring

and new tracing papers affixed to the tables. The above recording sequence was repeated until two acceptable sets of recordings had been attained. An acceptable set was one that represented only the subject's optimum abilities for reproducibility and not operator or instrumentation error as judged by the operator. Upon completion of the recording session the clutches were removed and cleaned in an ultrasonic cleaner to prepare for the next session.

During each recording session the subject was asked if he was comfortable and any external distractions were minimized as much as possible. Complete concentration by both the subject and the operator was desirable and once a recording sequence was started, it was not stopped. Smooth soft voice control with almost rhythmic motions appeared adjunctive for optimum results. The velocity of recording movements varied for each individual and the one yielding optimum results was used. Some patients had better control with faster movements while others did better with slow movements.

Occlusal Splint Therapy

Procedures involved in the fabrication and usage of occlusal splints, on the experimental group, were started immediately following classification of the subjects into a group.

Two maxillary and one mandibular alginate impression were made. These were poured in model stone and used for both splint fabrication and the occlusal adjustment procedures. Two maxillary models were necessary because one would be destroyed when the splints were

processed. A facebow registration and a centric relation registration were then taken, using extra hard base-plate wax.* The maxillary model was next mounted on a Whip-mix Articular ** and the mandibular model mounted using the wax interocclusal registration. The occlusal splint was then waxed.

Heat-cured occlusal splints were used in this experiment. The splint was waxed on the models, processed in acrylic resin and delivered to the subject. The design of the occlusal splint was that of full maxillary occlusal coverage to prevent hypereruption of the teeth. In cases where the third molars were present, only partial coverage was used over this tooth to minimize anterior vertical dimension increases. Palatal extension of the splint covered approximately 10 - 15 mm of the palate lingual to the teeth. The splint extended about 2 - 4 mm over the buccal cusps or incisal edges to give adequate retention. The occlusal thickness was kept as thin as possible. Thickness was dictated by the amount of anterior opening attained when about $\frac{1}{2}$ the thickness of base-plate wax was used in the molar region. As a guide to waxing, the incisal pin was first opened 3 mm and altered as each case demanded. The occlusion was waxed so that all mandibular buccal cusp tips and incisal edges contacted in retruded closure. In all excursions the anterior teeth provided immediate disocclusion of the posterior teeth. Guidance was placed on as many anterior teeth as possible but the cuspids and sometimes the laterals

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* Swiss Denture Wax-Swissdent Corporation, P.O. Box 60054, Terminal Annex, Los Angeles, California 90054.

** Whip-mix Corporation, P.O. Box 17183, Louisville, Kentucky 40217.

did the most lateral guidance and the centrals and others gave protrusive guidance. Guidance angles were kept minimal and just enough to provide posterior disocclusion. The occlusal surface of the splints were not intentionally made flat but contained shallow buccolingual concavities. This allowed for a minimal increase in vertical dimension.

Once waxed, the splints were processed in clear heat-cured acrylic resin,* the acrylic flash was removed, and the splint was readied for delivery. Splints were not remounted on the articulator but were totally adjusted in the mouth.

Splint delivery was started by removing acrylic undercuts until the appliance seated completely and was stable. If processing error lead to inaccuracy, the inside of the splint was washed with clear autopolymerizing acrylic** until adequate stability and retention were achieved. Next, the occlusion was adjusted so that small pinpoint contacts were present on all mandibular buccal cusps and incisal edges. The occlusion was first adjusted by grinding and then refined by painting a thin layer of autopolymerizing acrylic in areas where contact was light. The final occlusion was adjusted so that only pinpoint centric relation contacts were present in the posterior region with immediate posterior excentric disocclusion. Excentric guidance was on the anteriors exclusively as recorded by thin blue articulating paper.*** Finally, positive

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* F. P. Polymer, Type I, Super fine. Sschem, Co Division Sartomer Inc., P.O. Box 56, Essington, Penn 19029.

** Perm-Type II Class I, Rebase Acrylic, The Hygienic Dental Manufacturing Company, Akron, Ohio 44310

*** Mynol Chemical Company, Broonall, Pennsylvania 19008.

occlusal contacts were verified with .0005 inch shim stock.*

The last step in adjustment involved the trimming of any excess acrylic and the splint was polished. The buccal overlap was thinned to a minimal thickness and adjusted to follow the buccal contours of the teeth and embrasures in a scalloped fashion when viewed from the occlusal. In cases where retention and stability were good, the labial overlap was removed anterior to the incisal edges enhancing esthetics and phonetics. The acrylic in the anterior palatal region was also thinned as much as possible to enhance phonetics. Thinness in this region did not lead to weakness or breakage.

Following adjustment, all rough or sharp edges were smoothed and rounded off. A pumice finish was placed on all exposed surfaces except where occlusal stops existed. Verbal and written instructions were given to the patients that 24-hour usage was desired (Refer to Appendix).

Post-delivery adjustments consisted of a minimum of two within the first two-week period followed by adjustment at subsequent recall appointments. Splints were adjusted when posterior occlusal contacts were more than pinpoint or when undesirable excursion contacts existed. In cases where a protrusive slide existed from the most retrudable position to maximum intercuspation, splints were adjusted or relined so that retruded contact and maximum interocclusal contact coincided.

The splints in all cases were made as thin, as esthetic, and as phonetically acceptable as possible with the assumption that compatibility

* Artus Corporation, 201 S. Dean St., Englewood, N.J. 07631.

leads to maximum use. Vanity minimizes splint usage by many active people and if a splint can be made minimally noticeable, the amount of use was increased.

Occlusal Adjustment Technique

The occlusal adjustment technique used in this study was generally the procedure taught and used in The University of Michigan Dental School.

Following the second recall recordings, interocclusal registrations of the most retruded mandibular position were taken with extra hard baseplate wax. The second maxillary model, previously taken, was mounted on the Whip-mix Articulator against the mandibular model used in the occlusal splint fabrication. These mounted models were painted with die spacer*, a surface paint to provide a contrast in color of the adjusted areas. The trial occlusal adjustment was completed when the paint had dried. The mounted models were then used as a guide to the actual adjustment in the mouth (Fig. 7).

The adjustment in the mouth was started next. A high-speed handpiece and small flame diamonds were used to get rid of the gross interferences. Perfection of the adjustment was completed with stones and a slow-speed handpiece followed by rubber wheels to give the smooth final surface to all ground areas. Thin blue articulating paper, occlusal indicator wax strips,** and .0005 shim stock were used in locating and marking areas to be adjusted. Patient feedback was also invaluable in

* 735 Ocean Avenue, Brooklyn, New York, 11226

** Kerr Sybron Corporation, Romulus, Michigan 48174.

Figure 7. Adjusted Models Coated with Die-Spacer

locating areas of contact that needed adjustment.

The basic rules used for the occlusal adjustment of various occlusal discrepancies were those recommended by Ramfjord and Ash.[6] The occlusal adjustment was started by the stabilization of the most retruded position. This requisite was satisfied when no vertical, lateral, or anterior slide was detectable when the mandible was positioned in its most retruded position and the patient was instructed to squeeze. Elimination of any "slide in centric" was the initial step in all adjustments and was the major part of the adjustment sequence. In cases where the stabilized retruded position and centric occlusion still did not coincide, a smooth unrestricted "long centric" was established.

The next phase of the occlusal adjustment was to eliminate eccentric interference. Balancing interferences were eliminated first,

laterally from retruded position and centric occlusion. In every instance, balancing interferences were eliminated to allow the working side teeth to contact in lateral excursions. Next, any deflective working side contacts were removed. In cases where anterior guidance existed and isolated posterior working contacts, the posterior contacts were removed. Where working guidance was distributed throughout the anterior and posterior regions or the posteriors alone, guidance was refined to eliminate any deflective contacts there by establishing an evenly distributed working guidance. Smooth unrestricted guidance devoid of any deflective or tripping contacts was the prime goal in the adjustment of all eccentric contacts. The final adjustment was that of protrusion and all posterior protrusive interferences were eliminated. Rubber wheels were used to smooth all ground surfaces and any rough contacts.

During the phase between the second and third recalls, the patient's adjustments were checked and refined one or two weeks after the initial adjustment appointment. A final check was done by another operator from The University of Michigan faculty. This step provided a double check on the acceptability of the occlusal adjustment. The occlusal adjustment was completed prior to the third recall.

Summary of Data Handling

The data was kept by the scorer (J.A.C.) until all recall recordings were taken. Upon completion of the clinical phase of the study, analysis of the data was started (Refer to Table 1). Analysis was divided into two phases: statistical analysis utilizing a computer program, and analysis by observation on an individual level.

The statistical analysis involved dividing the population into the three groups. Each of these groups had a sequence of five pantographic recording sessions consisting of four scored recordings. The total population of 26 yielded 516 scored pantographic recordings. The main goal of the statistical analysis was to show that occlusal splint and/or occlusal adjustment therapy would produce lower pantographic scores, indicating a greater reproducibility of mandibular movements following treatment. Using the MIDAS computer program at The University of Michigan, mean scores were calculated for each of the three groups for each pantographic series of four recordings. Analysis of covariance was used to compare the two non-reproducible groups, followed by comparison of the two control groups. This analysis showed whether or not there was any significant amount of score change from recall to recall when comparing the above two group combinations. Comparing the experimental non-reproducible with the control non-reproducible groups showed the effects of therapy upon the non-reproducible population. By comparing the control groups, significance was gained as to how pantographic scores change over time with no therapy. Analysis of covariance was used as a way to adjust for the fact that the mean actual categorization or starting score for each group was different. Adjustments were thus necessary in comparing change scores. Expansion on the statistical analysis and results obtained will be covered in the results section.

The second phase of data analysis was an interpretation of why certain things occurred as they did in the data. This phase correlated unusual pantographic recording scores with clinical observations. By

doing this, insight was gained about certain modifying factors involved indirectly and not quantified under the study's guidelines. Analysis of these modifying factors was necessary to fully understand the data received. Statistical analysis of the modifiers was impossible due to the lack of controls and the small sample size; yet significant information, that was necessary in fully understanding the controlled numerical results was provided. This information will be expanded in the discussion section.

RESULTS

A. Raw Data

The total raw data consisted of 516 pantographic scores from 26 subjects. Group 1 contained the non-reproducible experimental subjects, group 2 contained the non-reproducible control subjects, and group 3 contained the reproducible control subjects. Sample size for each group numbered 11, 10, and 5 respectively. The five series of four pantographic scores were taken during categorization (C) and four subsequent recall appointment series (1st, 2nd, 3rd, 4th)(Refer to Table 1).

B. Mean Scores (Actual)

The actual mean scores were computed for each group as a unit. Five actual mean scores which corresponded to the five series of pantographic recordings were computed for each of the three groups. These scores are listed on Tables 2, 3 and 4. It should be noted that analysis of variation was not calculated directly from the actual mean scores. Variation in starting means made it necessary to use an analysis of covariance and adjusted means for the final statistical analysis. The actual means are useful in visualizing the raw data and changes that have taken place. Utilizing these scores will be helpful in visualizing and understanding the adjusted scores.

Graph 1 shows the relationship of the actual mean scores between groups from recall to recall.

It is important to note not only the magnitude of change but the direction of change over time. Group 1 (experimental non-reproducible)

TABLE 1.- Total Pantographic Index Scores*

Subject Number	Group	Categorized Scores				1st Recall Scores				2nd Recall Scores				3rd Recall Scores				4th Recall Scores			
1	2	12	16	13	9	18	30	26	27	11	18	17	33	8	12	14	14	17	8	13	10
2	1	80	95	75	92	53	50	39	55	35	25	51	35	68	71	43	42	39	21	36	39
3	1	34	31	44	44	24	31	37	51	32	18	22	23	28	19	14	18	28	28	14	16
4	1	50	59	37	19	26	14	20	23	15	15	17	23	17	09	17	6	24	10	11	8
5	1	83	67	62	63	40	46	31	31	21	31	25	15	13	10	41	10	4	3	17	5
6	3	10	11	6	4	11	25	51	26	11	18	18	19	29	15	26	23	17	22	42	14
7	2	16	34	36	13	31	15	25	28	9	18	22	13	11	11	21	59	12	7	7	5
8	3	9	14	12	3	7	13	12	11	12	19	7	9	8	4	7	4	9	5	7	4
9	1	42	8	26	18	19	20	19	23	10	6	5	11	8	11	6	6	6	6	10	5
10	2	18	20	7	4	7	8	8	10	9	13	10	17	4	4	5	3	7	7	5	4
11	2	20	18	78	53	43	74	32	37	20	10	26	28	71	51	39	54	48	27	55	21
12	1	22	46	22	27	7	5	15	11	11	7	13	10	7	10	12	7	10	7	9	9
14	2	7	25	22	37	22	34	23	8	13	7	9	15	9	12	4	10	9	3	7	7
15	2	38	46	34	20	40	31	38	41	32	38	40	24	42	57	35	34	42	48	15	61
16	2	44	42	81	62	51	65	94	68	70	42	26	27	34	25	27	57	37	53	27	47
17	1	21	45	48	27	11	12	10	15	22	25	15	10	14	19	13	14	13	10	11	16
18	2	16	20	8	4	9	8	5	12	12	11	10	8	10	7	8	9	6	6	6	4
19	2	10	16	15	22	12	12	7	19	13	10	18	11	10	9	8	10	4	8	13	5
20	2	12	9	21	10	15	38	34	24	17	12	17	21	39	41	28	51	23	24	17	42
21	1	16	10	18	12	15	7	7	5	14	7	6	9	14	7	8	7	10	6	7	8
22	1	22	27	19	42	18	12	19	12	25	38	70	80	6	4	7	3	11	9	7	7
23	3	8	8	8	7	8	9	6	5	6	4	5	5	12	8	8	7	7	5	9	5
26	3	10	6	7	6	14	10	8	11	10	11	8	7	5	8	4	5	6	5	5	7
27	1	24	23	12	24	14	8	6	16	9	11	11	8	14	5	15	11	18	12	20	3
28	1	12	24	29	40	16	15	11	4	22	14	18	20	11	13	12	13	5	8	12	6
29	3	8	10	11	6	16	15	11	4	38	35	29	29	27	7	25	17	-	-	-	-

* Each score represents the results of one pantographic tracing consisting of six separate tracing tables.

TABLE 2.- Actual Mean Scores for the Experimental Non-Reproducible Group 1.

Measurement	Mean (Actual)	Std. Dev.
Categorization (C) scores	37.30	21.50
1st Recall (1st)	20.98	13.66
2nd Recall (2nd)	20.68	13.69
3rd Recall (3rd)	16.02	13.97
4th Recall (4th)	13.05	8.22

TABLE 3.- Actual Mean Scores for the Control Non-Reproducible Group 2.

Measurement	Mean (Actual)	Std. Dev.
Categorization (C) scores	24.70	15.45
1st Recall (1st)	28.23	18.92
2nd Recall (2nd)	19.43	10.26
3rd Recall (3rd)	23.93	17.74
4th Recall (4th)	19.175	15.70

TABLE 4.- Actual Mean Scores for the Control Reproducible Group 3.

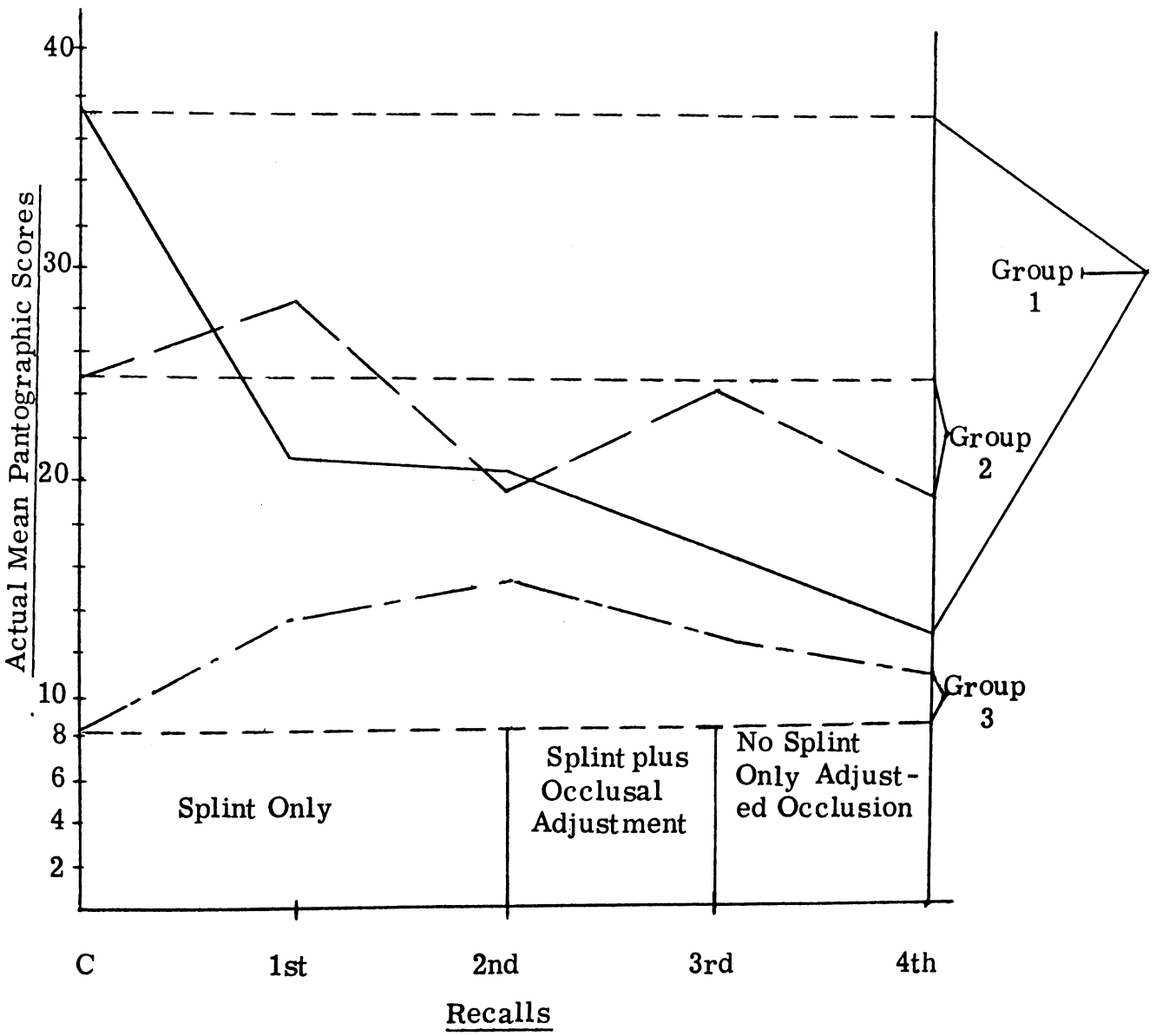
Measurement	Mean (Actual)	Std. Dev.
Categorizing (C) scores	8.20	0.91
1st Recall (1st)	13.65	8.35
2nd Recall (2nd)	15.00	10.77
3rd Recall (3rd)	12.45	8.16
4th Recall (4th)	10.56	8.80

GRAPH 1.- Actual Mean Score

Group 1 -- Experimental Non-Reproducible ————————

Group 2 -- Control Non-Reproducible —— —— —— ——

Group 3 -- Control Reproducible —— – —— – —— –



Note the amount and direction of change in actual mean scores for each group in relationship to categorization (C) levels.

had an initial large drop followed by a continuous gradual decrease. Note that at no time did the actual mean score increase. Group 2 (control non-reproducible) followed a cyclic pattern. An initial increase followed by a decrease, then an increase and finally a decrease in score occurred. This cyclic pattern resulted in a final score lower than that of the initial categorization score. It should be noted that the final score corresponded with a low point in the cycle. Group 3 (control reproducible) followed yet another pattern. Starting at an initial low, it made a gradual increase to the second recall, then a gradual decrease. The final score was slightly above that of the initial score.

C. Analysis of Actual Mean Change Scores

The statistical analysis of variation between groups from recall to recall used seven variables. These variables were used to show how much and at what time change had taken place. The variables were as follows:

(V-1) Change score from categorizing (C) to 1st recall (1st)

(V-2) Change score from 1st to 2nd recall (2nd)

(V-3) Change score from 2nd to 3rd recall (3rd)

(V-4) Change score from 3rd to 4th recall (4th)

(V-5) Change score from C to 2nd

(V-6) Change score from C to 3rd

(V-7) Change score from C to 4th

Tables 5, 6, and 7 show the actual mean change scores for the above seven variables. A minus sign denotes a reduction in score.

TABLE 5.- Group 1 (Experimental Non-Reproducible)

Variable	Actual Mean Change	Std. Dev.
1st -C	-16.32	11.20
2nd -1st	- 0.30	14.81
3rd -2nd	- 4.66	16.08
4th -3rd	- 2.98	7.68
2nd -C	-16.61	20.00
3rd -C	-21.27	12.11
4th -C	-24.25	17.44

TABLE 6.- Group 2 (Control Non-Reproducible)

Variable	Actual Mean Change	Std. Dev.
1st -C	3.53	7.25
2nd -1st	-8.85	10.86
3rd -2nd	4.50	13.75
4th -3rd	-4.75	7.95
2nd -C	-5.28	9.01
3rd -C	-0.78	13.66
4th -C	-5.53	10.09

TABLE 7.- Group 3 (Control Reproducible)

Variable	Actual Mean Change	Std. Dev.
1st -C	5.45	8.57
2nd -1st	1.35	12.13
3rd -2nd	-2.55	8.13
4th -3rd	-0.25	1.34
2nd -C	6.80	10.45
3rd -C	4.25	8.26
4th -C	2.50	9.04

The actual mean change scores are descriptive of the actual changes that took place but could not be used to test significance levels of group variations. An analysis of covariance, using adjusted means, was used to test for statistical significance levels. The actual levels were presented here for the purpose of showing what actually took place and as an aid in correlating this with the statistical analysis of covariance.

In review it should be noted that Group 2 and Group 3 received no therapy while Group 1 did. The first four variables reflected the effect of therapy on Group 1. Variables #1 and 2 showed actual change scores for the first and second periods of splint therapy. Variable #3 showed the actual change score when splint therapy was continued and an occlusal adjustment done. Variable #4 showed the actual change score when splint therapy was discontinued following the occlusal adjustment. The final three variables showed the total actual change scores in relation to the categorization scores.

D. Analysis of Covariance

Utilizing the MIDAS Computer program at The University of Michigan, an analysis of covariance between Group 1 and Group 2 followed by an analysis of covariance between Group 2 and Group 3 was performed. This analysis compensated for the difference in mean categorization scores between the three groups. It should be noted that the adjusted mean change scores were different for each combination of groups analyzed. This was due to variations in statistical adjustments caused by differences in actual mean starting scores and variation in

slopes of actual mean changes in relation to starting scores.

1. Adjusted Mean Change Scores

Table 8 shows the adjusted mean change scores for the seven variables when doing an analysis of covariance between Group 1 and Group 2.

TABLE 8.- Adjusted Mean Change Scores When Doing an Analysis of Covariance Between Group 1 and Group 2.

Variable	Group 1	Group 2
1 -C	-14.81	1.86
2nd - 1st	2.04	-11.37
3rd - 2nd	-6.23	6.23
4th - 3rd	-1.78	-6.07
2nd -C	-12.77	-9.50
3rd -C	-19.00	-3.28
4th -C	-20.78	-9.34

Table 9 shows the adjusted mean change scores for the seven variables when doing an analysis of covariance between Group 2 and Group 3.

Comparison of the actual with the adjusted mean change scores showed an obvious difference. The direction of change was similar but the magnitude of change was altered.

Graph #2 plots the adjusted mean change scores when Group 1 and Group 2 have a common starting point.

Graph #3 plots the adjusted mean change scores when Group 2 and Group 3 have a common starting point.

TABLE 9.- Adjusted Mean Change Scores When Doing an Analysis of Covariance Between Group 2 and Group 3.

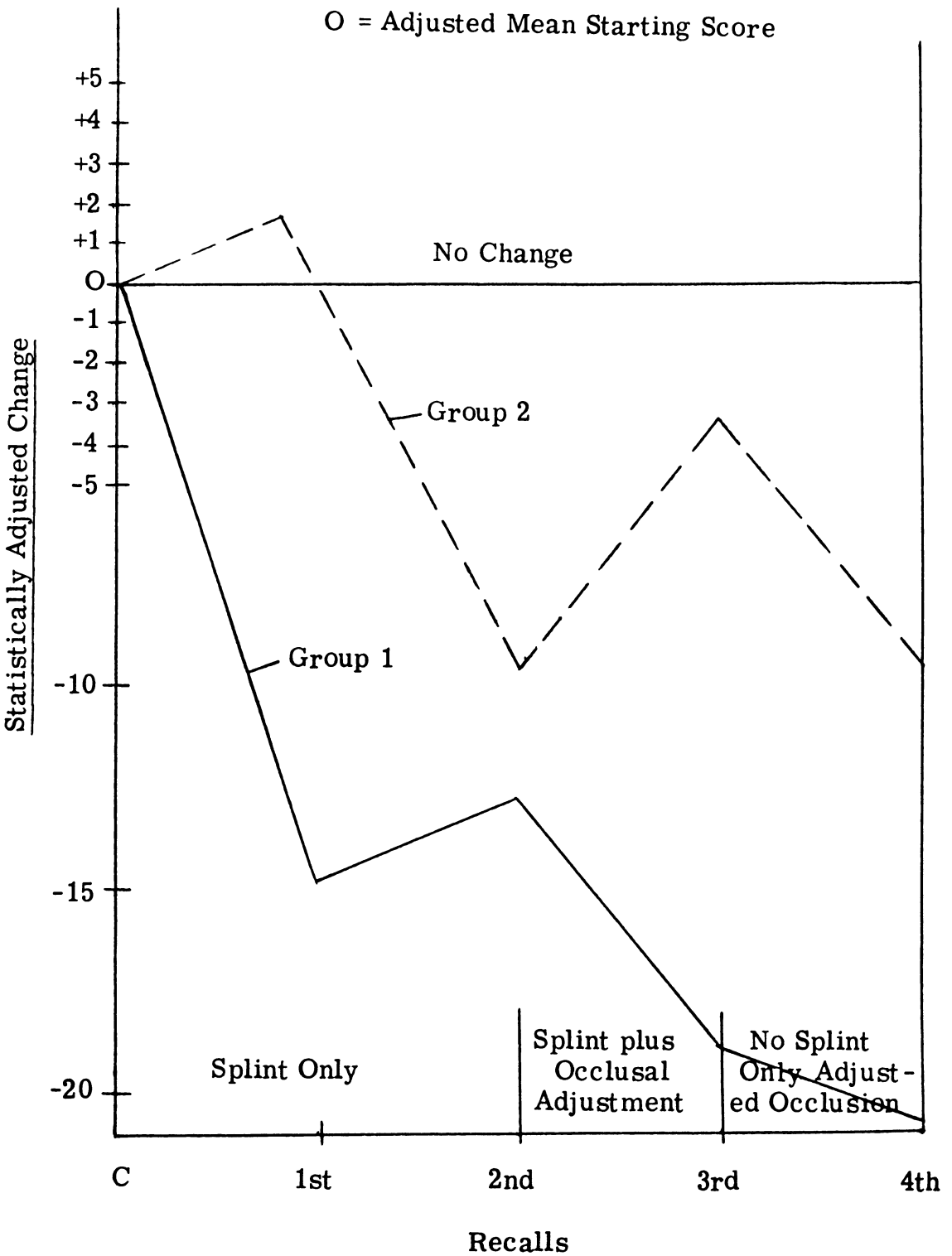
Variable	Group 2	Group 3
1st -C	2.87	7.74
2nd - 1st	-6.02	-10.58
3rd - 2nd	3.49	2.78
4th - 3rd	-4.92	0.17
2nd -C	-3.14	-2.84
3rd -C	0.35	-0.54
4th -C	-4.57	0.11

Analysis of Graph 2 showed that Group 2 followed an erratic course of declines and improvements in scores very similar to the actual mean change scores. Group 1, on the other hand, showed no actual mean declines but when adjusted in relation to Group 2 showed a minor decline at the second recall level. The total adjusted change score for Group 1 was slightly less than the actual change score while the adjusted change score for Group 2 was slightly greater.

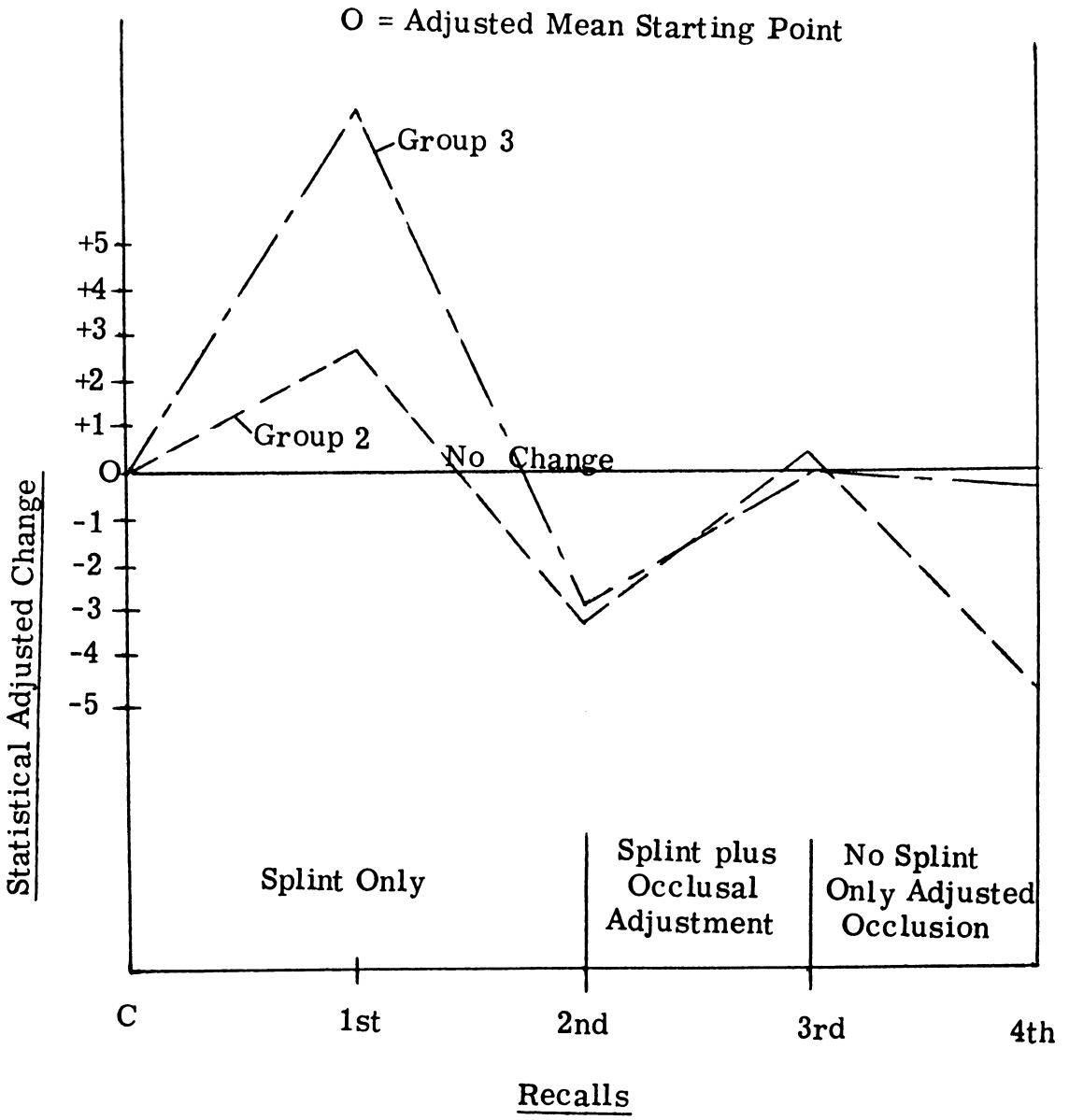
Analysis of Graph 3 showed that Group 2, when compared with Group 3 using analysis of covariance and adjusted mean change scores, repeated its erratic changes but resulted in a final score slightly less than the actual mean change scores. Group 3 scores changed from an initial increase, then gradual decrease in actual means, to a pattern similar to Group 2. Group 3 ended with a slight improvement in score where the actual mean change score was higher than the average starting level.

Expansion upon the adjusted mean scores and their relation to the

GRAPH 2.- Adjusted Mean Change Scores from the Analysis of Covariance Between Group 1 and Group 2.



GRAPH 3.- Adjusted Mean Change Scores from the Analysis of Covariance Between Group 2 and Group 3.



actual mean scores was presented to help explain how analysis of covariance handles the data. When adjusting for a common starting level, the scores change and interpretation becomes more difficult. It was apparent that analysis of covariance is highly dependent upon the make-up of the groups analyzed and change scores are different for each combination of groups used.

One final factor can be interpreted from the comparison of adjusted change scores and the actual change scores. Higher scores showed a tendency for greater improvement. This was shown by the fact that adjusted mean change scores for Group 1 were generally of a lower magnitude of improvement than the actual mean scores, keeping in mind the actual starting mean of Group 1 was higher than Group 2. The adjusted mean change scores for Group 2, on the other hand, were generally of a higher magnitude of improvement than the actual mean change scores when analyzed with Group 1. This was shown again in the Group 2 and Group 3 analysis of covariance which ended with Group 2 at a level of improvement below its actual mean and Group 3 at a higher level. In this case Group 2 had a higher mean than Group 3. Analysis of covariance compensated for both unequal starting means and the fact that degrees of change varied with differences in starting score levels. In other words the potential for change was greater with the higher scores.

2. Statistical Significance of Change Scores

Table 10 presents the data calculated in the analysis of covariance between Group 1 and Group 2 for the seven variables. Note the signifi-

cance levels of the adjusted cell means. A significance at or below 0.05 was considered a clinically significant change.

Table 10 showed that the drop in the adjusted score for the 1st recall period was significant to the .001 level of significance. This indicated that there was a very significant drop in the adjusted mean pantographic scores of Group 1 under occlusal splint therapy when compared to the control Group 2. During the second recall period Group 2 made a large decrease while Group 1 did not and Group 2 showed a drop statistically significant to the .05 level of significance. This fact should be noted for the direction of significance is not indicated on Table 10. This period corresponded to the second interval of occlusal splint therapy. Comparing the 3rd scores with the 2nd and the 4th with the 3rd showed no statistically significant change between Group 1 and Group 2. These periods corresponded to the addition of occlusal adjustment therapy and removal of splint therapy respectively.

The final three variables showed the statistical significance of sum changes. The variation of adjusted mean scores between Group 1 and Group 2 for the sum of the first two recalls was not statistically significant. The sum difference for the first three recalls showed a statistically significant drop in Group 1 scores at the .01 level of significance while the sum of all four periods showed Group 1 with a drop in scores over Group 2 with a statistical significance to the .05 level. It should be obvious that the cyclic changes of Group 2 altered the significance levels somewhat, depending upon what point in the cycle the analysis was done. It has been shown that regardless of Group 2 fluctuations, Group 1

TABLE 10.- Data from the Analysis of Covariance Comparing Group 1 and Group 2.

	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Sq. (MS)	F-Statistic (F)	Sig.
		1st-C (V-1)			
Equality of Adj. cell means (EQM)	1	1296.6	1296.6	17.998	.0005***
Error (E)	18	1296.7	72.039	-	-
Equality of Slopes (ES)	1	482.41	482.41	10.071	.0056
		2nd-1st (V-2)			
EQM	1	838.51	838.51	6.7695	.0180*
E	18	2229.6	123.87	-	-
ES	1	126.02	126.02	1.0184	.3270
		3rd-2nd (V-3)			
EQM	1	724.19	724.19	3.371	.0831
E	18	3871.4	215.08	-	-
		4th-3rd (V-4)			
EQM	1	85.607	85.607	1.731	.2048
E	18	890.18	49.455	-	-
		2nd-C (V-5)			
EQM	1	49.719	49.719	.4594	.5065
E	18	1948.2	108.23	-	-
		3rd-G (V-6)			
EQM	1	1153.4	1153.4	9.5548	.0063**
E	18	2172.9	120.72	-	-
ES	1	68.105	68.105	.5500	.4684
		4th-C (V-7)			
EQM	1	610.56	610.56	6.4948	.0202*
E	18	1692.1	94.007	-	-
ES	1	458.57	458.57	6.3197	.0223

*** $P < .001$
** $P < .01$
* $P < .05$

adjusted mean scores made a statistically significant improvement over Group 2.

One final factor regarding the data presented on Table 10 must be studied. Analysis of covariance goes on the assumption that cell slopes are equal. Variables V-1 and V-7 showed significant differences in the equality of slopes that must be accounted for to make the analysis of covariance valid. When the maximum degree of negative change due to unequal cell slopes was calculated for variables V-1 and V-7 significant adjusted score drops in Group 1 over Group 2 were still calculated even when the starting scores were adjusted back to the mean Group 2 level. This indicated that the variation was still statistically significant and that slight errors in significance levels, although present, are probably not important.

Table 11 presents the data calculated in the analysis of covariance between Group 2 and Group 3 for the seven variables.

Table 11 proved statistically what Graph 3 appeared to show graphically. The amount of variation of the adjusted mean change scores between the two control groups was not statistically significant for any of the seven variables. This factor indicated that both the non-reproducible and the reproducible control group scores remained statistically constant with each other over time.

3. Summary

Analysis of actual data and actual mean change scores followed by statistical analysis of covariance using adjusted mean change score was

TABLE 11.- Data from the Analysis of Covariance Between Group 2 and Group 3.

	DF	SS	MS	F	Sig.
		C-1st (V-1)			
EQM	1	49.397	49.397	.75723	.4028
E	11	717.57	65.234	-	-
		2nd-1st (V-2)			
EQM	1	43.430	43.430	1.1419	.3081
E	11	418.38	38.034	-	-
		3rd-2nd (V-3)			
EQM	1	1.0341	1.0341	.64566-2	.9374
E	11	1761.7	160.15	-	-
		4th-3rd (V-4)			
EQM	1	54.202	54.202	1.0430	.3291
E	11	571.64	51.967	-	-
		2nd-C (V-5)			
EQM	1	.19199	.19199	.57969-2	.9407
E	11	364.32	33.120	-	-
		3rd- (V-6)			
EQM	1	.33491	.33491	.20604-2	.9646
E	11	1788.0	162.54	-	-
		4th- (V-7)			
EQM	1	46.016	46.016	.47076	.5068
E	11	1075.2	97.747	-	-

performed. The following information was demonstrated:

A. Actual mean starting scores for Group 1 and Group 2 were not equal, thus adjustment was necessary utilizing analysis of covariance.

B. Actual total mean score decline for Group 1 exceeded that of Group 2 by 19.72 points. Starting 12.60 points higher, the actual mean score of Group 1 ended 6.13 points lower than Group 2.

C. Actual mean scores for Group 1 showed a constant decline while both control groups demonstrated random increases and decreases of their actual mean scores.

D. Analysis of adjusted mean scores showed similar trends of change in comparison to the actual mean scores but the magnitude of change varied.

E. Analysis of covariance between Group 1 and Group 2 showed:

(1) During the first recall period a significant decrease in the adjusted mean scores occurred in Group 1 to the .001 level of significance.

(2) The second recall period yielded a significant decrease in the adjusted mean scores for Group 2 to the .01 level of significance.

(3) Third and fourth recall periods did not yield any significant change between Group 1 and Group 2 for these isolated periods.

(4) Sum changes to the third recall period yielded a significant decrease in Group 1 adjusted mean scores to the .01 level of significance.

(5) Sum changes in the entire study yielded a significant decrease in the Group 1 adjusted mean scores over Group 2 scores to the .05 level of significance.

F. Analysis of covariance between Group 2 and Group 3 showed no significant difference for any of the seven variables.

G. The final Group 1 actual mean ended at 13.05 which is in the reproducible range.

H. The final Group 2 actual mean ended at 19.18 which was still in the non-reproducible range.

I. The final Group 3 actual mean ended at 10.56 which was still in the reproducible range.

J. Group 1 was the only group that changed from its categorization classification.

DISCUSSION

Analysis of Individual Subjects

Statistical analysis provided the solid unbiased data interpretation that was essential for arriving at valid conclusions. Analysis of individual idiosyncrasies and interpretation of unusual score changes provided greater understanding of the results. Possible explanations for unusual individual score changes provided a greater understanding of certain modifying factors not analyzed in the study.

This section will discuss certain individual recall score changes that were unusual and that did not follow the mean trends. A possible explanation for these changes will be presented but should not be mistaken for actual proven solutions. It is the goal of this section to show how certain individual scores may have caused minor alterations to the final statistical results.

A. Psychological Modifiers

Patients in all three groups showed unusual score changes that could be attributed to stress or emotional factors. It has long been assumed that psychological input was one of the modifying factors that alters an individual's threshold of tolerance to occlusal discrepancies and the whole masticatory neuromuscular complex.[5,6,15,17] This assumption has been supported utilizing pantographic scores as the yardstick for measuring this change. Certain stressful situations were related directly to unusual pantographic score increases. It must be assumed that all subjects were under stress at one time or another and

only certain ones exceeded the threshold for change at the time of the recall appointments. Other subjects may have had neuromuscular thresholds that were less susceptible to psychological input, keeping in mind that this is only a modifying factor of varying degrees of importance among individuals.

Examples: Subject #6 started with a 7-point mean and made a jump to 28 points at the first recall. The mean went down but never back to the Group 3 level. The first recall scores were taken just after an exam and for the remainder of the study this final semester senior dental student was very nervous about finishing his requirements on time. It was also possible that his categorization scores were taken at low peak experiences by many control subjects.

Subject #11 followed an erratic pattern similar to the mean Group 2 subjects but with a greater magnitude of change. This was a 21-year-old, high-strung female in the process of finishing school and moving.

Subject #20 also followed a magnified Group 2 pattern. This subject was also a final semester male dental student.

Subject #22 of Group 1 made an unusual score increase at the second recall period. This was a 23-year-old female that was very anxious and nervous about a trip she was to start the next day. As can be seen, her third and fourth scores were back to more normal levels for her group.

Subject #29, a young female secretary, made score jumps after her first scores. When questioned she complained about being under a lot of temporary pressure at the medical school where she was employed.

These factors were not statistically significant but point out the reliability of pantographic scores in correlating emotional stress and the role it plays in neuromuscular tension.

B. Occlusal Modifiers

Examination of occlusal factors was the main purpose of the entire study. One additional occlusal modifying incident occurred. Patient #27, the wife of a dental student, was progressing normally until after the third recall. Her husband, one week later, delivered a crown with a centric relation prematurity recreating a 1 mm plus slide. Final pantograph scores got worse. Even when repeated several times they could not be brought back into the reproducible range, but remained slightly higher.

The reversibility of splint therapy effects on pantographic scores were not directly analyzed in this study. This incident supports the assumption that pantographic scores can reverse towards starting levels if occlusal discrepancies were returned.

Effectiveness of Therapy

The total occlusal therapy program using occlusal splints and occlusal adjustments was shown to significantly reduce pantographic scores and improve the reproducibility of border movements. Eight of eleven Group 1 subjects averaged in the reproducible range at the fourth recall. One of the three that did not was Subject #27 who was in the reproducible range for the first, second, and third scores but relapsed following an unplanned occlusal change as already mentioned. A second

subject started with the highest total categorization actual mean of 85.5 points and improved to a mean actual score of 35 points at the fourth recall. In this patient's case it was obvious clinically that the pre-determined course of therapy was insufficient to handle cases of such long-standing problems. With continued therapy this patient might be made to reproduce. The final Group 1 subject that did not become reproducible went from a categorization mean of 38 points to a fourth mean score of 23 points. Progress of this subject was very gradual and as above, therapy might not have been long enough to attain the desired reproducible level.

In Group 2, 6 of 10 ended with a fourth mean score in the reproducible range. Of these 6 subjects, 4 of them also had a mean categorization score in the reproducible range. This factor existed because mean scores were not used to categorize but the fact that any non-reproducible score automatically put them in a non-reproducible group. Group #1 only had one subject with a mean categorization score in the reproducible range. Even on an individual basis, it was obvious that occlusal therapy significantly reduced pantographic scores. As for which of the phases of therapy was most effective has not been fully analyzed.

A. Occlusal Bite Splint Therapy

Statistically and actually the splint therapy phase of treatment produced significant reductions in pantographic scores. The initial phase of splint usage produced the most dramatic results. This first recall period averaged 45 days for the Group 1 subjects. The second

recall period produced further improvement but not at the significance level of the initial period. This second recall period averaged 39 days for Group 1. It would appear that the most rapid changes resulting from occlusal splint therapy occurred initially and that long-term splint usage appeared to continue improvement but at a slower rate. Continued splint therapy in long-standing problem cases may eventually lead to the desired results. One final factor brought out by the analysis of covariance was that higher scores improve faster than lower scores. Lower starting scores after the first recall might explain why continued splint therapy appeared less effective.

It has been shown many times that occlusal bite splints improve T.M.J. pain dysfunction symptoms.[4,5,6,8,9,11] It has also been stated that occlusal splints deprogram neuromuscular mechanisms that were created by occlusal discrepancies,[6,8,9,11] the end result being a mandible that was much easier to manipulate and locate occlusal discrepancies due to decreased muscle tonus. It follows very logically that this decreased muscle tonus or a drop in protective neuromuscular reflexes may be reflected by a decrease in pantographic scores. If defective muscular reflexes decline, the possibility of temporomandibular joint symptoms drops and the factors that prevent recording reproducible pantographic tracings should decline. Pantographic tracings as done in this study were little more than a measure of a subject's neuromuscular control. Splint therapy decreases nervous inputs that might prevent or alter this complete neuromuscular control. Thus splint therapy has been proven to cause a significant drop in pantographic scores and these scores

appear to measure the efficacy of therapy.

B. Occlusal Adjustment Therapy

The statistical analysis of covariance between Group 1 and Group 2 did not show any significant change as a result of occlusal adjustment therapy in this study. Did this mean that occlusal adjustment therapy was not effective in reprogramming neuromuscular circuits that prevent reproducible pantographic recordings or did it only show that no further statistically significant variations occurred? Several factors must be kept in mind before making any conclusions about occlusal adjustment therapy.

The first factor of significance was that pantographic scores by the end of the second recall when the occlusal adjustment was started were already significantly lowered. The analysis of covariance showed that lower starting scores improve at a slower rate. Thus the expected change would be lower. Occlusal splint therapy was continued throughout the third period of the study in conjunction with the occlusal adjustment and was not stopped until after the third recall recordings. Thus, third recall scores reflected the results of both therapies while only the fourth recall scores were preceded by the adjusted occlusion alone.

One of the shortcomings of splint therapy was that it lacked permanence and could be removed by the patient if so desired. For this reason it was felt that one of the reasons for the lack of effectiveness of occlusal bite splints in many cases was that patients did not wear them as directed.[31] Thus, in this study the occlusal splint therapy was followed by occlusal adjustment therapy to correct occlusal discrepancies

while the splint was not in use and to perpetuate the occlusal goals once splint therapy was discontinued. By doing this, maximum total therapy was done with the end result of reproducible pantographic tracings being desired.

The Group 1 population comprised a group of individuals that were in frequent contact with the investigator of this study and consequently were very consistent in using the occlusal splints as directed. Maximum results were thus obtained during the initial recall periods and the effects of occlusal adjustment therapy were not obvious. Two subjects that only used the occlusal splint at night were numbers 4 and 22. Following the addition of an occlusal adjustment to Subject #4, her scores immediately jumped into a mean reproducible range. Even more dramatic was Subject #22 who following her occlusal adjustment scored nothing higher than one 11-point tracing and averaged 5 points and 8 points respectively for her last two recall actual mean scores. Had the total population been less conscientious about wearing their occlusal splints it is very likely that the addition of an occlusal adjustment might have produced more impressive declines.

Occlusal adjustment therapy did produce one significant factor. Following the elimination of the occlusal splint, fourth recall mean scores still improved by three points. This factor, although not statistically significant was very important when considering what might have happened. The occlusal adjustment therapy permanently perpetuated a similar occlusal scheme and neuromuscular coordination established artificially by the occlusal splint. Had an occlusion devoid of occlusal

interferences not been established following splint removal, there would have been a very good chance for the reprogramming of unwanted neuromuscular reflexes to avoid such interferences. The result may very well have been as that evidenced by Subject #27 or a relapse or increase in mean pantographic scores. The fact that this did not occur and a further improvement of mean Group 1 scores was noted might be interpreted as very significant evidence in the favor of occlusal adjustment therapy. Pantographic scores correlated with what might have been expected about both the therapies involved and supported the belief that they were an adequate means to gauge said therapies.

C. Reliability of Pantographic Scores in Measuring Clinical Improvement

The actual scoring procedure of the pantographic recordings was already discussed and the calculated error was 2.11 points. This factor did not change the results and could be considered insignificant. Whether or not the subjects' score changes could be directly related to the results of therapy must be qualified.

The primary goal of occlusal splint and occlusal adjustment therapy was to eliminate unwanted occlusal interferences and provide an optimum occlusion and neuromuscular coordination with the characteristics already discussed. In doing this a neuromuscular reprogramming process occurred. Reflexes programmed in by occlusal interferences were eliminated when the occlusal stimulus was removed. Elimination of these reflexes allowed the masticatory muscles to move in a manner that was less controlled by neuromuscular training and more voluntarily

controlled. It follows that neuromuscular reflexes resulting from occlusal interferences that prevent movement to the border positions might prevent the recording of movements to the borders and result in non-reproducible tracings. Consequently, if reflexes are eliminated as a result of occlusal therapy, movement to border positions would be less hindered, resulting in greater ease in recording border positions accurately.

The pantograph as used in this study was a means to measure the subject's voluntary muscular control in recording border movements with repeated accuracy. Involuntary reflexes might prevent recording reproducible tracings. It was shown that occlusal therapy yielded a significant drop in pantographic scores. This may be interpreted as a measure of the drop in reflexes programmed in by occlusal interferences. Learning phenomena were disproved when Group 2 was compared to Group 3 subjects. Thus, a very close correlation has been set up between pantographic scores and the neuromuscular reprogramming resulting from occlusal therapy.

The pantographic recordings graphically produce an accurate picture of each subject's voluntary neuromuscular control. It was this neuromuscular control that was the primary goal of occlusal therapy. Without neuromuscular control the treatment of temporomandibular joint dysfunction and other related problems would be much less effective. Thus the pantographic tracing utilizing an accurate scoring technique as used in this study provided a very accurate and correlated means to measure the progress of occlusal therapy.

In summary the pantographic tracing was correlated with neuromuscular control which was the primary goal of occlusal therapy. Thus the pantographic tracing showed the results of therapy and pantographic scores provided a method to accurately gauge occlusal therapy in relation to the optimum desired results.

D. Control Scores

Control scores from Group 2 and Group 3 subjects were not shown to be statistically different at any phase of the study. Although fluctuations in mean scores occurred, the overall range of scores remained constant. This factor adds further validity to the use of pantographic scores in gauging effects of treatment. In these two groups, where no occlusal changes occurred, no significant change in their pantographic scores occurred either. Periodic fluctuations may have very well been reflections of modifiers not controlled in this study like psychological factors.

One factor that was significant about control scores was that fluctuations, whatever the cause, might lead to false conclusions if using only one score. Multiple tracings over a period of time would better show a person's range for reproducibility or non-reproducibility.

E. Correlation of Symptoms to Pantographic Scores

Although patient symptoms were taken at the onset of the study, periodic followup was not done. Volunteered information was all that was received. Most common changes were a decrease in clicking, absence of periodic headaches and the feeling of occlusal comfort not

known prior to occlusal adjustment. The last factor was mentioned the most. No attempt was made to correlate symptoms with therapy or pantographic scores.

F. Silent Period (Electromyographic)

Subject #28 had an electromyograph study before the onset of splint therapy and just following the first recall. A distinct decrease in the length of the silent period was noted. Analysis of this fact was not pursued and obviously no statistical significance could be placed upon it. It was not done as part of the study and is mentioned here only for the sake of completeness.

G. Pantographic Examples

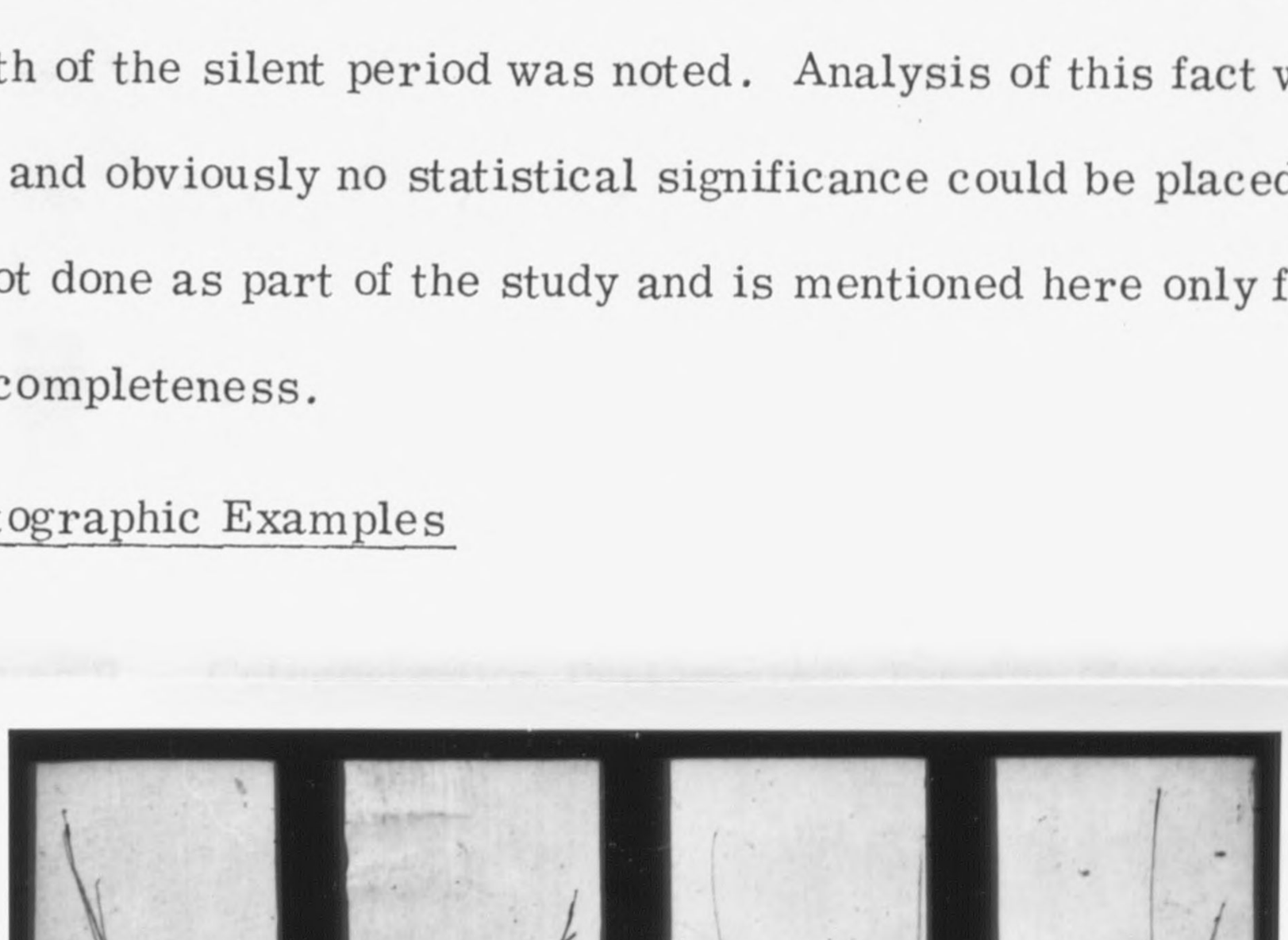


Figure 8.- Patient #2. Example of a severe non-reproducible pantographic tracing (Score = 75 points).

Figures 9 through 13 - Patient #15. Recall sequence for a control non-reproducible subject.

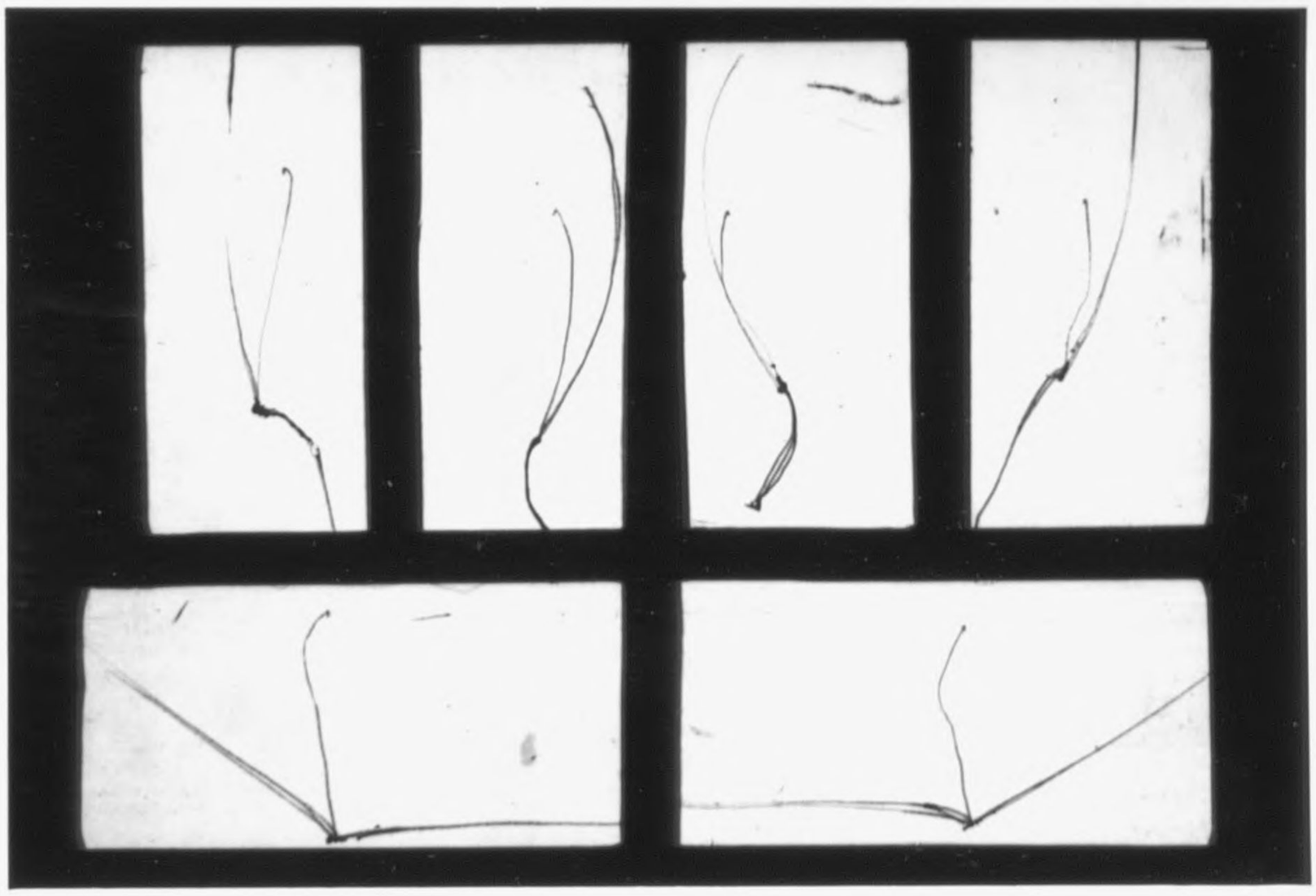


Figure 9.- Categorization Pantographic Tracing (Score - 38 points).

Figure 10.- 1st Recall Pantographic Tracing (Score = 38 points).

Figure 11.- 2nd Recall Pantographic Tracing (Score = 38 points).

Figure 12.- 3rd Recall Pantographic Tracing (Score = 35 points).

Figure 13.- 4th Recall Pantographic Tracing (Score = 42 points).

Figures 14 through 18 - Patient #23. Recall sequence for a control reproducible subject.

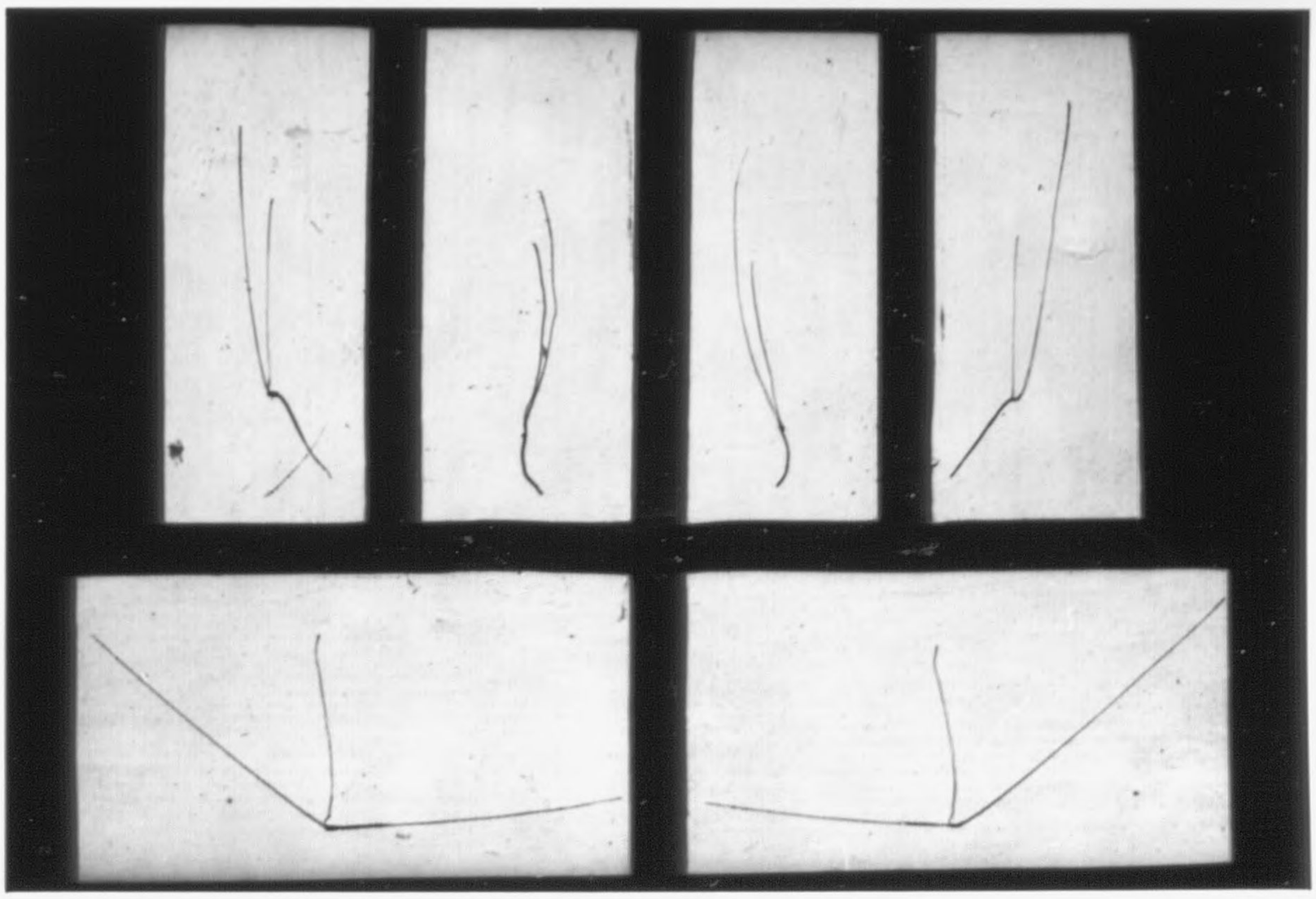


Figure 14.- Categorization Pantographic Tracing (Score = 8 points).

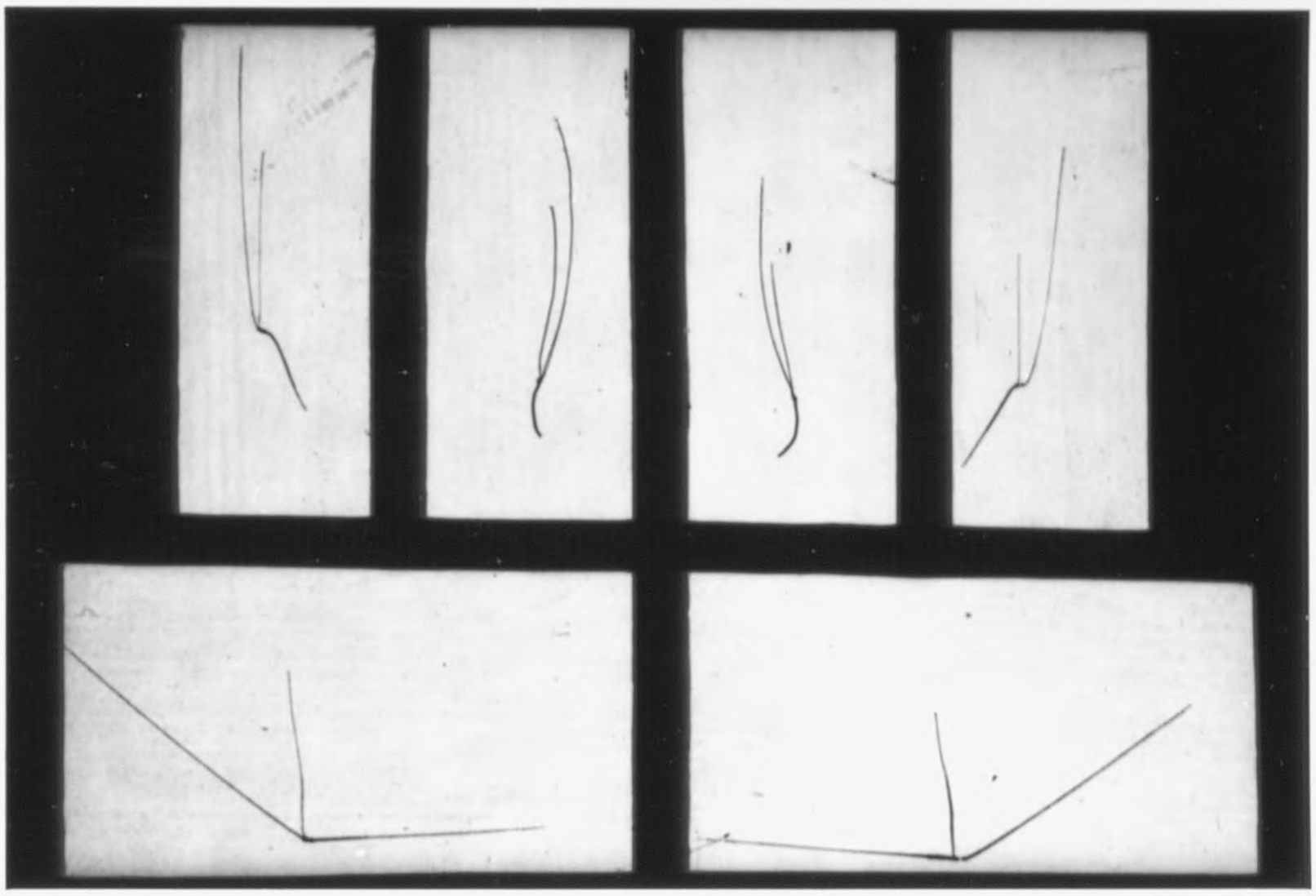


Figure 15.- 1st Recall Pantographic Tracing (Score = 8 points).

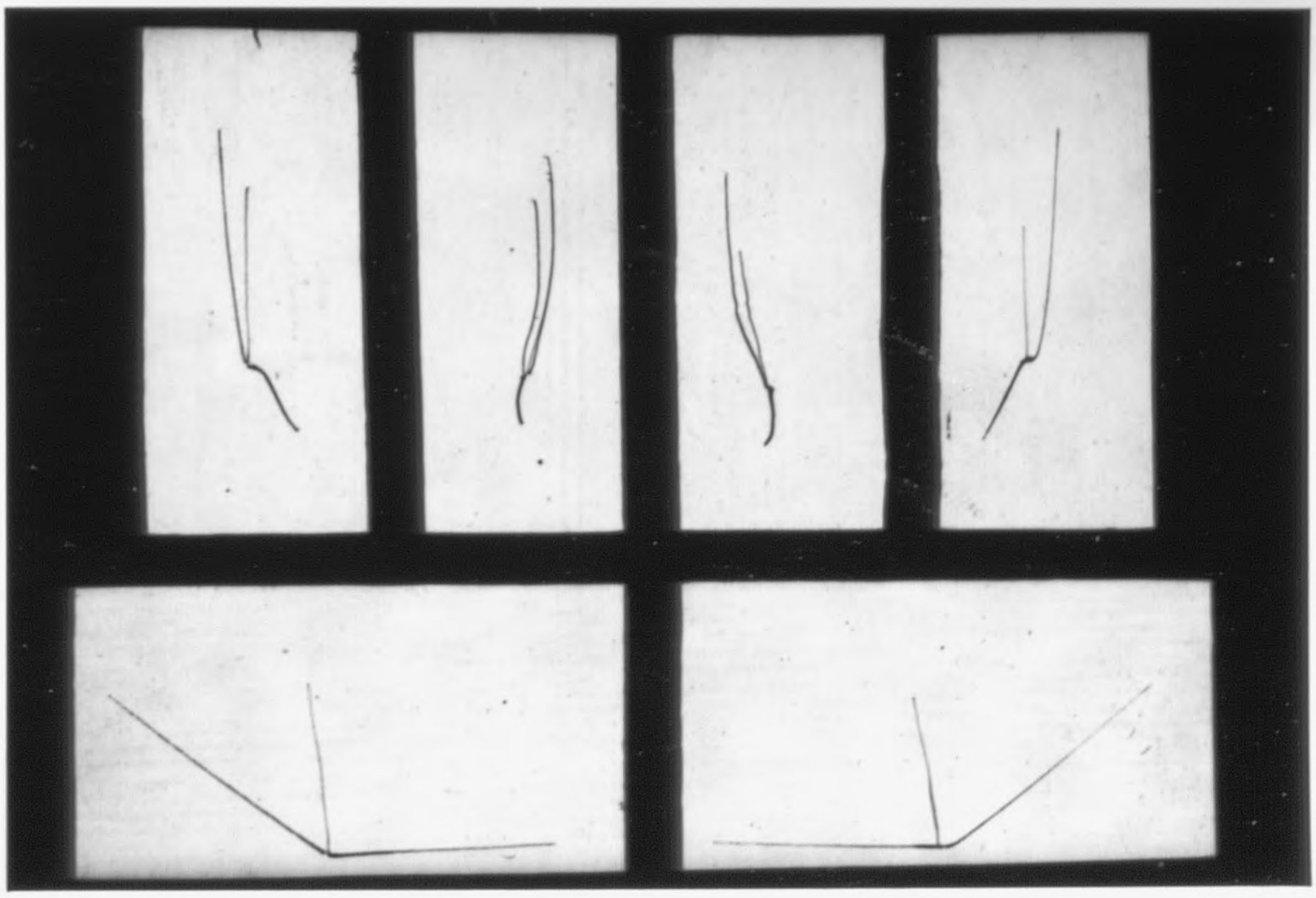


Figure 16.- 2nd Recall Pantographic Tracing (Score = 6 points).

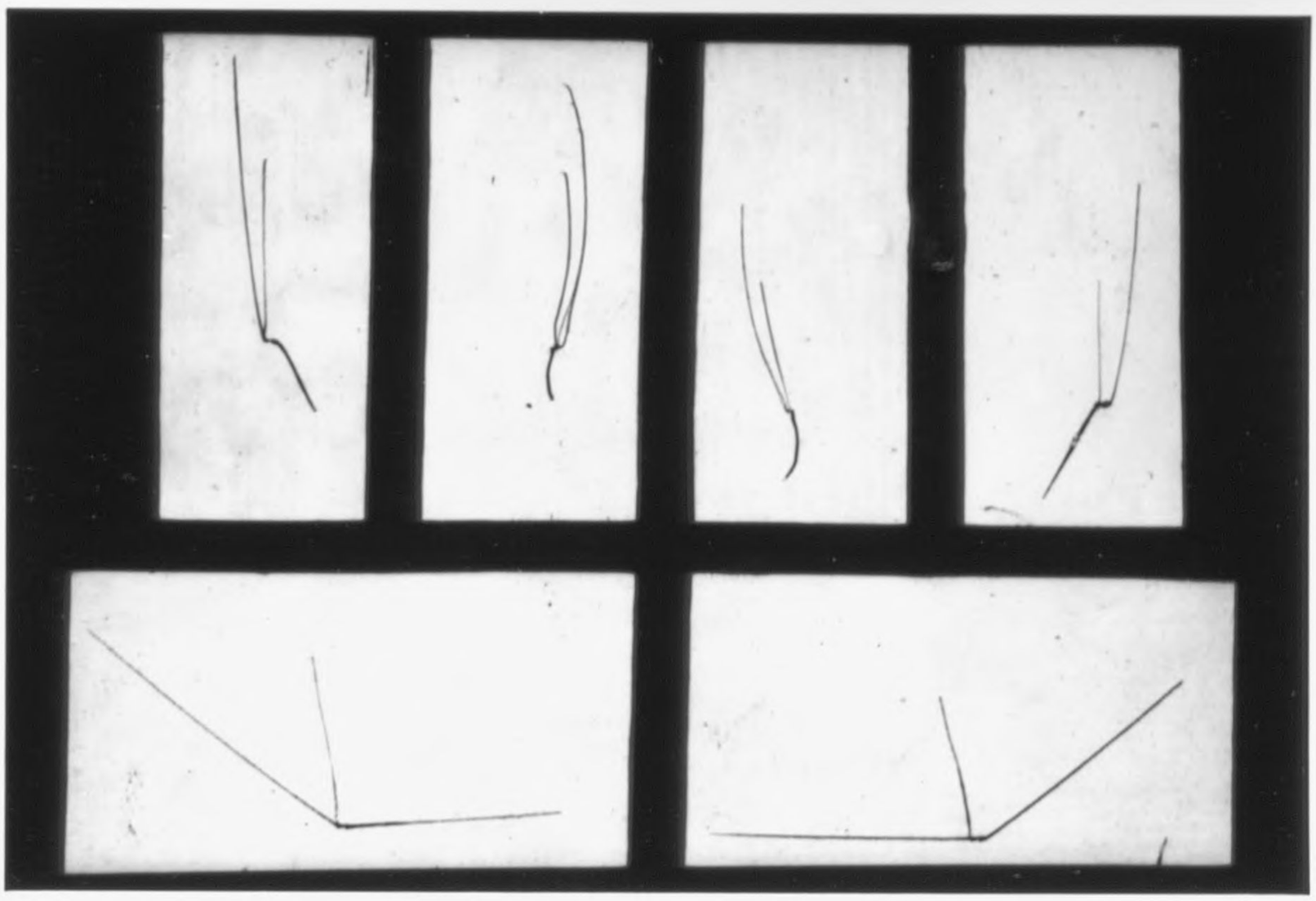


Figure 17.- 3rd Recall Pantographic Tracing (Score = 8 points).

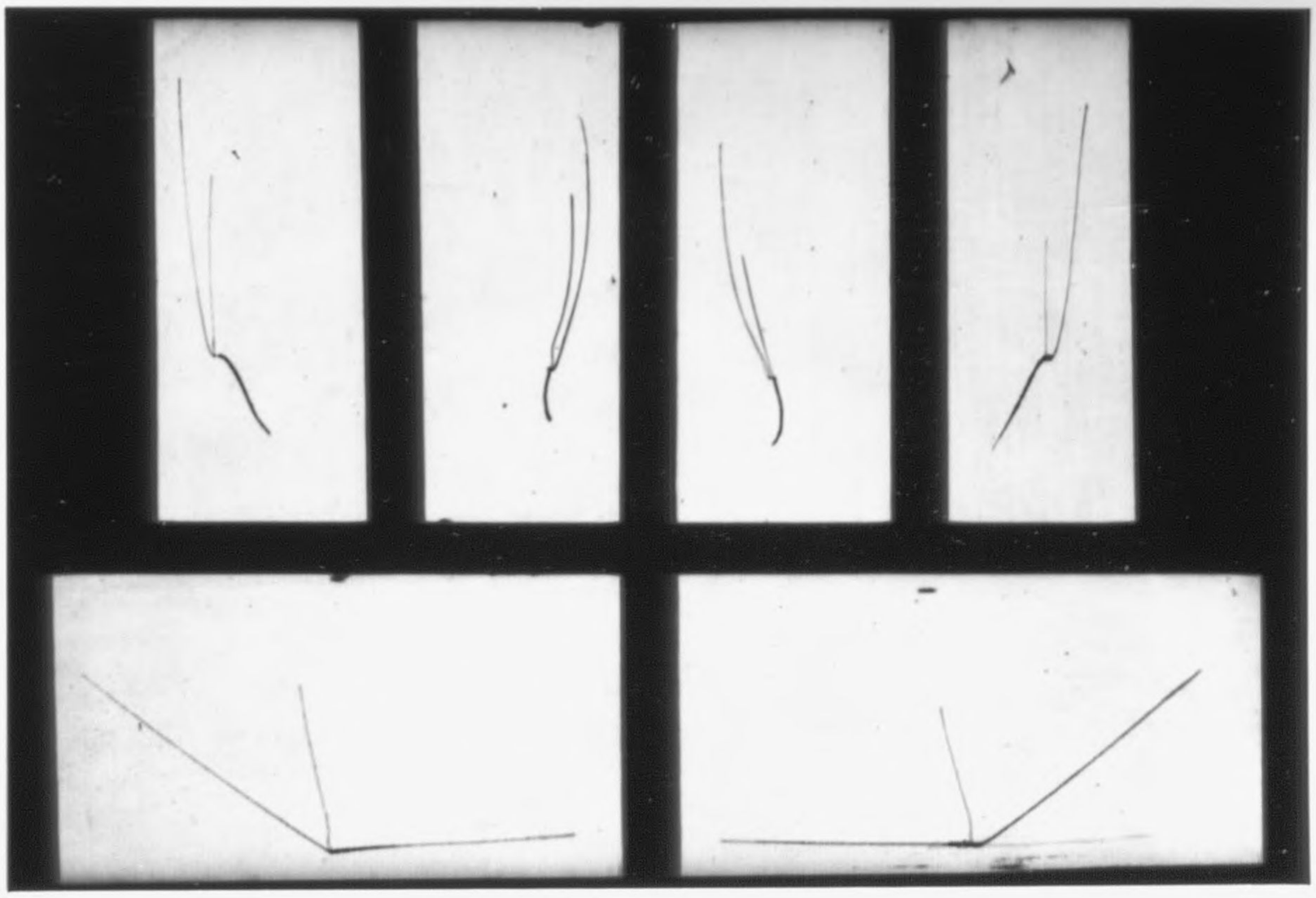


Figure 18.- 4th Recall Pantographic Tracing (Score = 9 points).

Figures 19 through 23 - Patient #5. Recall sequence for an experimental non-reproducible subject.

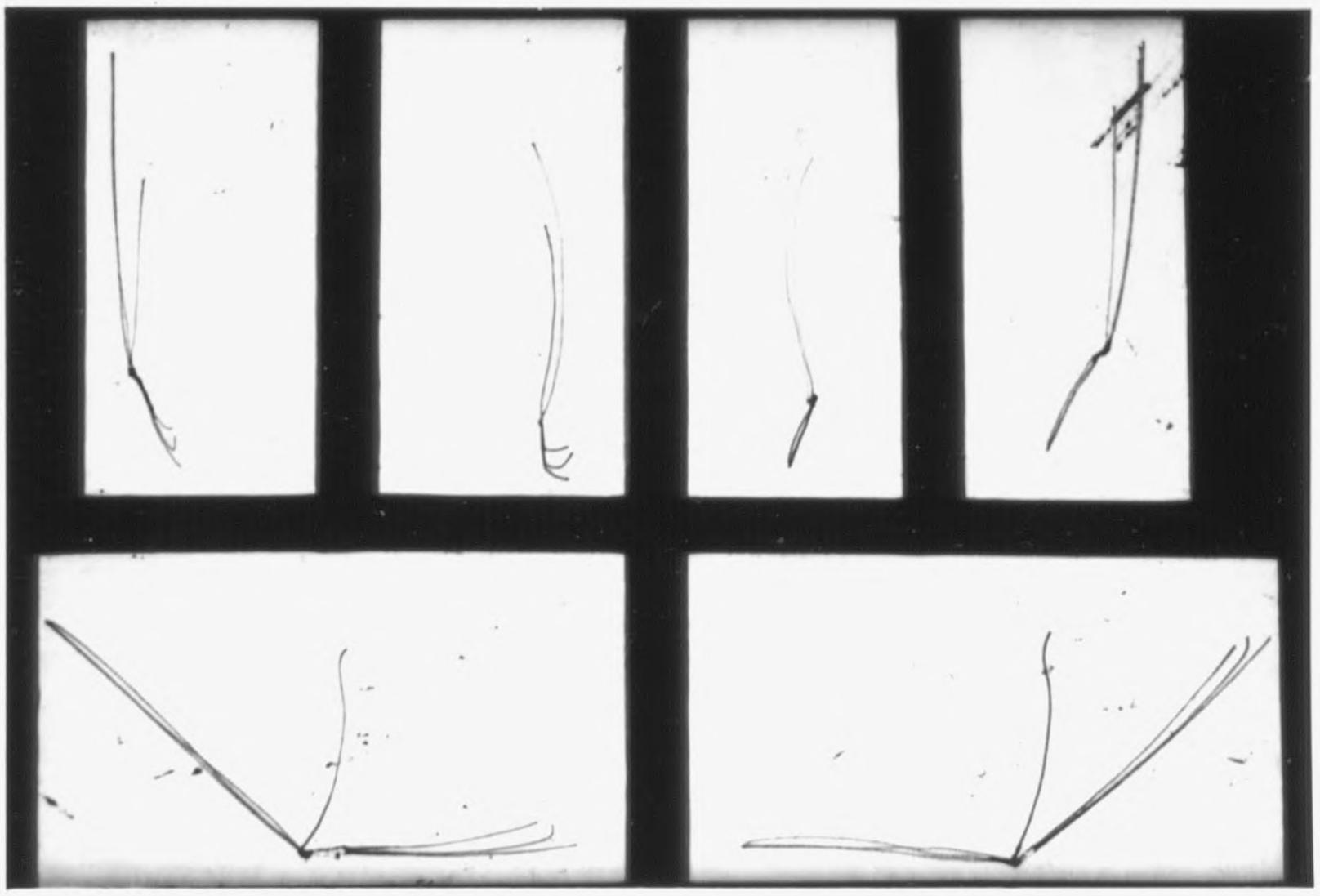


Figure 19.- Categorization Pantographic Tracing (Score = 67 points).

Figure 20.- 1st Recall Pantographic Tracing (Score = 40 points).

Figure 21.- 2nd Recall Pantographic Tracing (Score = 31 points).

Figure 22.- 3rd Recall Pantographic Tracing (Score = 10 points).

Figure 23.- 4th Recall Pantographic Tracing (Score = 3 points).

SUMMARY

A study of 26 subjects was done. Each subject was pantographed a minimum of five times and placed into one of three groups. Group 1 was the non-reproducible experimental group consisting of 11 subjects. Group 2 was the non-reproducible control group consisting of 10 subjects. Group 3 was the reproducible control group consisting of five subjects. Following categorization each subject had four recall pantographic series consisting of four separate pantographic recordings each. These recall recordings were done at 30-day minimal intervals. Coordinated with these recalls, for the experimental group only, occlusal bite splint followed by occlusal adjustment therapy was done. Occlusal splint therapy was used for the first two recall periods. Following the second recall recordings an occlusal adjustment was started and completed. For the third recall period both occlusal splint and occlusal adjustment therapy were used together. Following the third recall recordings splint therapy was gradually discontinued and for the final weeks of the fourth recall period splint therapy was totally discontinued. A total of 516 pantographic tracings was taken on the 26 patients and analyses completed.

Each of the pantographic tracings were scored by an independent scorer (J.A.C.) and assessed a numerical score between 0 and 144 points. Statistical analysis of covariance, comparing the two non-reproducible groups and the two control groups, was performed on the mean recall scores for each group and a statistical significance level

assessed to variations occurring. An analysis of statistical and actual findings provided insight into the effect of therapy on the reproducibility of pantographic tracings and the correlation between pantographic scores and results of therapy.

CONCLUSIONS

1. A statistically significant reduction in pantographic index scores to the .001 level followed the first 30 to 45 days of occlusal splint therapy. This was followed by a slower rate of improvement over the next 30 to 60 days.

2. Occlusal adjustment therapy following occlusal splint therapy caused a slight actual reduction in pantographic index scores and appeared to perpetuate the benefits of splint therapy.

3. No significant overall changes in pantographic index scores occurred in the control groups. Thus learning was not a significant factor in changing pantographic index scores.

4. The mean pantographic index scores of both control groups fluctuated but remained in their original classification category.

5. The experimental non-reproducible group ended with a mean group actual pantographic index score in the reproducible range following occlusal treatment.

6. Pantographic tracings using a pantographic scoring index provided a method by which the progress of occlusal therapy could be monitored.

7. Response to occlusal therapy varies individually and must be adjusted to meet individual needs. Two experimental subjects did not reach the reproducible range following 120 days of occlusal therapy.

8. Subjects with high initial pantographic index scores showed a higher rate of change than did subjects with low initial pantographic index scores.

Experimental Design Shortcoming

The reversibility of splint therapy upon the reproducibility of pantographic index scores was not tested. The removal of splint therapy prior to occlusal adjustment should have been done to test the hypothesis that pantographic index scores would return to the classification level.

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APPENDICES

UNIVERSITY OF MICHIGAN
SCHOOL OF DENTISTRY

FORM #3A

Reg. No. .....

INSTRUCTIONS TO PATIENTS

If your answer is YES to the question asked, put a circle around (Yes).
If your answer is NO to the question asked, put a circle around (No).

Answer all questions. You may comment on answers which require explanation by writing in the space between questions.

Answers to the following questions are for our records only and will be considered confidential.

Do you think that your teeth are affecting your general health in any way? Yes No

Are you dissatisfied with the appearance of your teeth? Yes No

Are you worried about receiving dental treatment? Yes No

Do you have difficulty in chewing your food? Yes No

Are you being treated for any condition by a physician now? Yes No

Have you ever experienced a bad reaction to a dental anesthetic? Yes No

Do you bleed for a long time when you cut yourself? Yes No

Have you ever had any injury to your face or jaws? Yes No

Have you ever had surgery or x-ray treatment for a tumor, growth or other condition in your mouth or on your lips? Yes No

Are you taking any medicines now? Yes No

Have you been examined by your physician within the last year? Yes No

Has there been any change in your general health in the last year? Yes No

13. Have you lost weight without dieting in recent months? Yes No

14. Have you ever been seriously ill? Yes No

15. Have you ever been hospitalized? Yes No

16. Have you ever had a major operation? Yes No

17. Have you had any of the following:

Rheumatic Fever .....Yes No

Inflammatory Rheumatism .....Yes No

Jaundice (yellow skin and eyes) .....Yes No

Diabetes (sugar disease) .....Yes No

High Blood Pressure .....Yes No

Tuberculosis .....Yes No

Venereal Disease .....Yes No

Heart Attack .....Yes No

Stroke .....Yes No

Heart Murmur .....Yes No

18. Have you ever had a blood transfusion? Yes No

19. Do you ever have asthma or hay fever? (Underline which one) .....Yes No

20. Do you ever have hives or skin rash? Yes No

HEALTH QUESTIONNAIRE

FORM #3A

Have you ever experienced a bad reaction to any of the following drugs:

Aspirin ..... Yes No

Penicillin ..... Yes No

Iodine ..... Yes No

Sulfonamides (sulfa) ..... Yes No

Barbiturates (sleeping pills) ..... Yes No

Other medicines ..... Yes No

Do you have frequent, severe headaches? Yes No

Do you have any complaints regarding your eyes? Yes No

Do you have sinus trouble? Yes No

Do you have nosebleeds? Yes No

Are you a mouth breather? Yes No

Do you have any sensitive teeth? Yes No

Have you had a toothache recently? Yes No

Do you have bleeding gums? Yes No

Do you have frequent canker sores or cold sores? Yes No

Have you ever had a severe sore mouth? Yes No

Is it difficult for you to open your mouth as wide as you would like? Yes No

Does your jaw click when you chew? Yes No

Do you have any chest pain on exertion? Yes No

35. Are you ever short of breath on mild exertion? Yes No

36. Do your ankles swell? Yes No

37. Do you have a persistent cough? Yes No

38. Do you ever cough blood? Yes No

39. Are there any foods you cannot eat? Yes No

40. Do you have any difficulty swallowing? Yes No

41. Do you have frequent indigestion Yes No

42. Do you vomit frequently? Yes No

43. Do you urinate more than six times a day? Yes No

44. Are you thirsty much of the time? Yes No

45. Have you ever had painful and swollen joints? Yes No

46. Do you ever have fits or convulsions? Yes No

47. Do you have a tendency to faint? Yes No

48. Do you bruise easily? Yes No

49. Do you have any blood disorder such as anemia (thin blood)? Yes No

50. Are you excessively nervous? Yes No

51. Do you get tired easily? Yes No

52. *Women.* Are you pregnant at the present time? Yes No

e ..... Patient's Signature .....

year month day

iner .....

ked by Dr. .....

C O N S E N T F O R M

Consent form for participation in study of mandibular movements and the relationship to bite splints and occlusal adjustments therapy.

DATE_____Consent Form given by_____

I understand that The University Of Michigan Dental School is studying the effect of bite therapy on movement patterns of the jaw. Such therapy may consist of wearing a plastic removable bite splint, which is like a mouth guard, or occlusal adjustment. Occlusal adjustment means that the biting surfaces of the teeth are minimally ground on so they come together in a less traumatic more beneficial fashion. The study may consist of recording mandibular movements with a pantograph followed by splint and adjustment therapy with subsequent recordings of mandibular movements, or a series of recordings with no bite therapy. I am aware that this study will be over a several month period and will involve five to fifteen appointments spaced over this time depending on the type of treatment done.

Name of Project: Effect of Occlusal Bite Splint and Occlusal Adjustment Therapy on Recorded Mandibular Movements.

Description: Faulty bite or occlusion has been shown to be related to the training of the jaws to move in a restricted, unrelated manner. In theory, if these bite descrepancies are removed, jaw coordination and unrestricted movements should occur if the occlusion is the cause of such problems.

I have been offered the opportunity for further discussion of this procedure with Dr._____.

I understand that the purpose of this procedure is to develop improved treatment techniques but at the present time cannot be guaranteed that participatio will be directly beneficial to_____.

I hereby voluntarily give my permission to be a participant in the above study and understand the possible effects and hazards that might occur and that rare unpredictable side effects may occur.

_____
(Patients Signature)

Date:_____

Witness:_____

Questions:

THE UNIVERSITY OF MICHIGAN

SCHOOL OF DENTISTRY

OCCLUSAL ADJUSTMENT

Patient Information

An occlusal adjustment is a dental procedure for the treatment of certain disturbances of the masticatory system, such as trauma from occlusion and jaw-joint problems. Because of discrepancies in the occlusion, all the teeth may not come into contact simultaneously when the jaws are brought together in certain relations. Such occlusal discrepancies or "occlusal interferences" are often related to functional disturbances.

The occlusal adjustment procedure involves the removal of small amounts of tooth surfaces (occlusal interferences) but does not weaken the teeth or make them more susceptable to dental decay.

After the occlusal adjustment, the "bite" may feel different; but this is not abnormal. After a few days, most individuals no longer notice the change in the "bite", and at the follow-up appointment, the final evaluation and adjustment is made.

Transient occlusal surface sensitivity may occur occasionally and require the application of a desensitizing agent. This is not of frequent occurrence.

If you have any questions regarding the procedure of occlusal adjustment, please ask about them.

THE UNIVERSITY OF MICHIGAN

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USE AND CARE OF OCCLUSAL BITE SPLINT

Patient Information

Your occlusal bite splint serves to relieve muscle tension, decrease painful symptoms, protect the teeth, and maintain the teeth in position. The following information will aid you in its effective use:

The occlusal bite splint should be worn as much as possible, except when eating.

At first you may be aware of a temporary increase in salivation. This is normal.

When positioned each time, the bite splint may feel somewhat tight for a few moments. This is normal.

When the bite splint is removed, your occlusion may feel different and the interferences that are present may temporarily seem greater. This is normal and will disappear in a few minutes. Also, if left out for prolonged periods, symptoms may return.

The occlusal bite splint must be stored in a container of water to preserve shape. When carrying the bite splint, a wrapping of moist plastic is suitable.

The bite splint should be brushed with a toothbrush and toothpaste twice a day to keep it clean.

Initial adjustments of the bite splint are almost always necessary and future adjustments needed will depend on the nature, complexity, and severity of your occlusal and joint problems.

In addition to bite splint therapy, an occlusal adjustment will be necesssary in many instances to provide more effective therapy. It is usually done after the occlusal bite splint has eliminated the symptoms.

The occlusal bite splint should not be worn unless you are under the supervision of a dentist. If you move from your present home or discontinue treatment, do not continue to wear the bite splint without consulting a dentist.

CRISPIN'S THESIS

SEQUENCE FOR STOPPING SPLINT THERAPY.

(1) 1st. Week - wear as normal, don't wear afternoons.

(2) 2nd Week - Wear only at night.

(3) 3rd Week - Wear only when needed for comfort but continue to decrease amount of time in use.

(4) 4th Week - Stop wearing totally.

THESIS: BRUCE J. CRISPIN

E X A M I N A T I O N & E V A L U A T I O N

Patient: _____ Date: _____

Registration No: _____

I. HISTORY

(Complaint in patient's own words.)

I. QUESTIONNAIRE

1. When was your last visit to the dentist? _____

   For what reason? _____

2. Have you been in an accident and received a blow to the face?

   ☐ No ☐ Yes Describe injury _____

3. Have you had orthodontic treatment?

   ☐ No ☐ Yes Year _____

4. Are certain foods difficult to chew?

   ☐ No ☐ Hard, tough ☐ Lettuce ☐ Thick sandwiches

5. Do you prefer to chew on one side?

   ☐ No ☐ Right side ☐ Left side

   If there is a preferred side for chewing, is the reason due to sensitivity in:

   ☐ Tooth or teeth ☐ Right joint ☐ Left joint

   ☐ Right muscles ☐ Left muscles

6. Are you aware of temporomandibular joint sounds?

   ☐ No ☐ During chewing ☐ Right side ☐ Left side

   ☐ During extreme opening ☐ Right side ☐ Left side

7. Are you aware of temporomandibular joint pain?

   ☐ Right side ☐ Left side

8. Do you have headaches?

☐ None ☐ Occasionally ☐ Regularly ☐ Mild ☐ Moderate ☐ Severe ☐ Frontal ☐ Temporal ☐ Occipital ☐ Right side ☐ Left side

9. Are you under pressure for any reason?

☐ No ☐ Questionable ☐ Probable ☐ Definite

. EXAMINATION (Clinical signs)

1. Tenderness of muscles to palpation:

☐ None ☐ Temporal ☐ Masseter ☐ Medial pterygoid ☐ Lateral pterygoid ☐ Right ☐ Left

2. Palpation over joint area at rest:

☐ No pain Tenderness on ☐ Right side ☐ Left side

3. Palpation over joint during movements:

☐ Smooth action Uneven action ☐ Right ☐ Left

4. Deflection of jaw on opening:

☐ None To the ☐ Right ☐ Left

5. Pain on opening:

☐ None ☐ Right ☐ Left

6. TMJ sounds:

☐ None Clicking on the ☐ Right ☐ Left

Crepitation on the ☐ Right ☐ Left

7. Have full mouth T.M.J. x-rays been taken?

8. Are there any gross wear facets?

9. Absent teeth:
☐ None

10. Jaw manipulation: ☐ Easy ☐ Normal ☐ Difficult ☐ Very difficult

11. Slide in centric (incisor area):
☐ None Horizontal component ___mm. Vertical component ___mm.
Lateral component ___mm. to ☐ Right ☐ Left

12. Diagnosis(es):

OPERATOR_____ SUBJECT_____

TRACING#_____ DATE_____ TIME_____

Right Lateral

		Begin	End
Anterior Tables	W		
	B		
Posterior Tables W	V		
	H		
Posterior Tables B	V		
	H		
Subtotal			
Right Total			

Left Lateral

		Begin	End
	W		
	B		
W	V'		
	H		
B	V'		
	H		
Subtotal			
Left Total			

Total Score _____

Standard form for recording of scores. Legend: W=working, B=balancing, V=vertical table, H=horizontal table.