Radiographs in Clinical Periodontal Trials*

by

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DENTAL RADIOGRAPHS are used extensively in detection and assessment of severity of periodontal disease. Various radiographic techniques have been developed for recording of bone levels before and after periodontal treatment with the implication that results of periodontal therapy can be evaluated from radiographs.

However, statistical comparison of clinical and radiographic measurements obtained before and during controlled experimental conditions in longitudinal studies are not available.

The purpose of the present investigation was to test the applicability of the long cone, paralleling radiographic technique in clinical trials of periodontal treatment.

MATERIAL AND METHOD

A total of 58 patients were selected from an ongoing study of periodontal therapy at The University of Michigan.[1] All patients with long cone radiographs for their initial and all of the following examinations and with one to four years of follow-up from the initiation of the treatment were included. The examination, scoring, and treatment of these patients have been as outlined in our previous publication.[1] Since this experimental design operates with half-mouths as experimental units for the treatment method, roentgenographic scorings of half-mouths also had to be used for statistical comparison of the clinical and roentgenographic values. Data from 58 patients (1416 teeth) were analyzed.

Each set of radiographs consisted of 18 individual periapical films. They all had been exposed by a trained x-ray technician using routine paralleling long cone technique. Millimeter scores of attachment levels and pocket depth for all teeth, scores of gingivitis, plaque, calculus, mobility, attrition, and open contacts, all according to the periodontal disease index (PDI) system[2, 3] had previously been transferred to computer cards which were available for the present study.

The periapical radiographs were scored according to the method of Björn et al.[4] The individual radiographs were mounted in slide holder no. 10-147 for projectors.† A 35 mm slide projector was mounted on a projection table by means of a vertical stand (Fig. 1). The projector

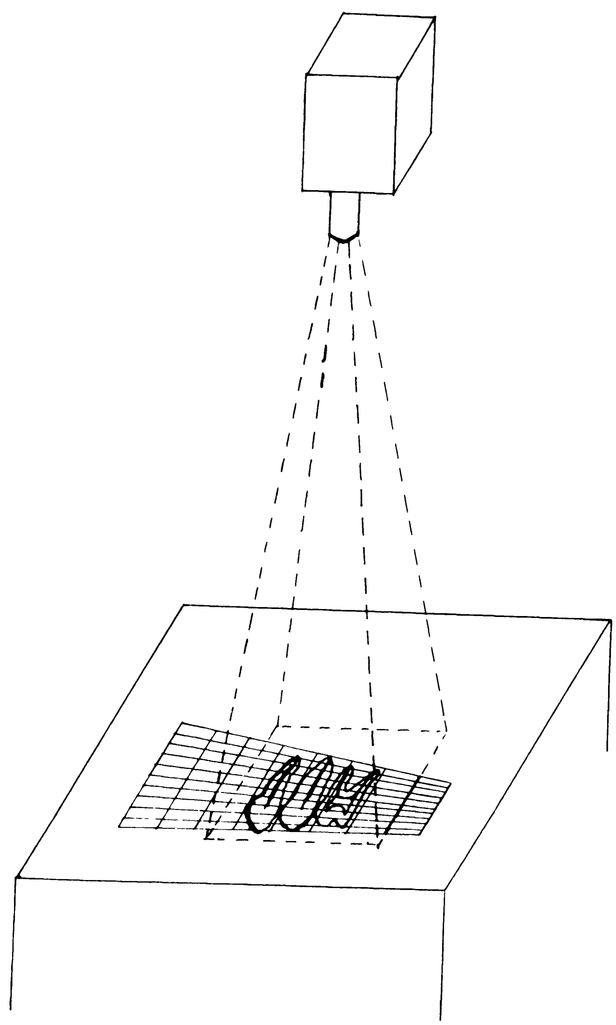

FIGURE 1. *Vertical mounting of slide projector to produce a linear magnification of × 5 normal at level of measuring scale.*

was fixed in position with the optical axis at right angles on the projection table surface at a height that provided a linear magnification of × 5.

A scale was drawn on white cardboard with India ink. The bottom (coronal) baseline measured 34 cm, and the sides measured 18 and 9 cm (Fig. 2). The scale consisted of 20 equal divisions from the coronal to the apical baselines. Vertical lines were drawn parallel to the sides of the scale at 2-cm intervals so that the long axis of the tooth could be easily oriented perpendicular to the coronal baseline.

The individual radiographs were projected onto the

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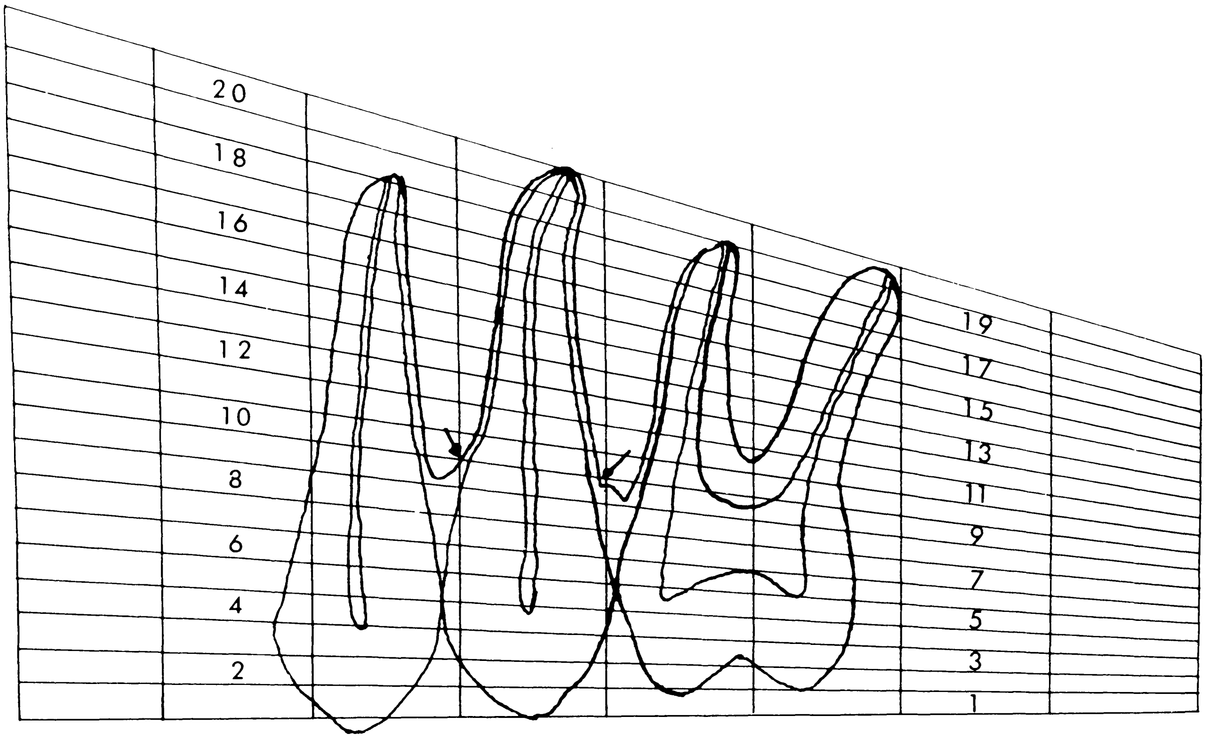

FIGURE 2. *Image of mandibular left second bicuspid positioned on measuring scale. Arrows indicate bone levels at which measurements were determined. Mesial 9.0. Distal 8.5.*

scale. The scale was moved on the projection table until the coronal baseline coincided with the image of the tip of the crown of the tooth to be measured and the apical baseline with the tip of the apex. The scale was also rotated until the vertical lines were parallel to the long axis of the tooth (Fig. 2). The unit measurements of the alveolar crest level related to the mesial and distal aspects of the root surfaces were recorded, except in the case of molars where only the mesial surface of the mesial root and the distal surface of the distal root were measured. Each molar root was measured separately, and only the buccal roots of the maxillary molars were measured. Measurements were made of each tooth only once on each set of radiographs. Each tooth was measured on the radiograph taken specifically for the measured tooth (cuspids on cuspid exposures, molars on molar exposures, etc). In cases where the radiograph taken for a specific tooth was inadequate for measurement, the tooth was measured on an adjacent radiograph when possible. Nonmeasurable bone levels were recorded as missing data. The interproximal surfaces of every tooth from which measurements could be obtained were included with the exception of the third molars which were not consistently well recorded in the available radiographs.

The most coronal level of the alveolar bone without radiolucency and with intact lamina dura was considered as the "bone margin." In cases of angular or "V-shaped" bone defects, the base of the defect at which point the lamina dura appeared normal was considered as the "bone level." The most coronal level in which the periodontal space retained its normal width was also considered in assessing the alveolar bone level.

The measurements were made by two examiners (R.J.C. and G.P.K.). They practiced the use of the Björn et al. index[4] until scoring became automatic and determinations could be made without hesitation. The error of the method was then determined by randomly selecting seven sets of radiographs which were scored by each examiner on three occasions, separated by approximately one week. A two-way analysis of variance was then applied to these data to generate a within group mean square as an estimation of intraexaminer error and a between group mean square as an estimator of interexaminer error. Intraexaminer error was computed as 0.44 for mesial, 0.39 for distal, and 0.68 for mesial plus distal scores. Interexaminer error was 1.22 for mesial, 1.93 for distal, and 3.14 for mesial plus distal scores. In terms of this study with an N of 1416 the intraexaminer error affect on the mean scores would be 0.01 for mesial, 0.01 for distal, and 0.02 for mesial plus distal; the interexaminer error would be 0.03 for mesial, 0.05 for distal, and 0.08 for mesial plus distal.

Statistical Analysis

The measurements of pocket depth, attachment level and radiographic bone height were analyzed by:

(1) individual tooth scores

(2) patient scores: sum of tooth scores (per patient)/ number of scored teeth (per patient).

(3) treatment scores: sum of tooth scores (½ mouth)/ number of scored teeth (½ mouth).

Correlation coefficients were generated for pocket depth, attachment level, and radiographic bone height, for mesial, distal, and mesial plus distal measurements.

Corresponding correlation coefficients were also determined for the various tooth types (maxillary molars, maxillary premolars, maxillary anterior teeth, mandibular molars, mandibular premolars, mandibular anterior teeth). Correlations were computed for initial measurements and for changes in measurements from initial to one, two, three, and four years post-treatment.

Results

A correlation matrix was generated for pocket depth, attachment level, and radiographic bone height of pretreatment periodontal disease using pooled tooth data and arranged by tooth type. The results are given in Table 1. All of these correlations are positive with $P < 0.001$. The clinical measurements of pocket depth and attachment level correlated better than either of these clinical measurements and radiographic bone height. However, attachment level correlates with radiographic bone height generally better than pocket depth correlated with radiographic bone height.

The individual tooth data were analyzed with all four years of post-treatment changes grouped together but with individual tooth types separated out (Table 2). Only attachment level and radiographic bone height were considered here since treatment change in pocket depth was not considered a comparable statistic. When the small values represented by changes after treatment are correlated the values are quite low, having a range of r = 0.03 to 0.26.

When the tooth data were transformed to patient scores the level of correlation of changes in attachment level to changes in radiographic bone height increases dramatically (Table 3). The correlations of patient values are statistically significant ($P < 0.001$) and are very consistent for the two interproximal surfaces.

The correlation of changes in attachment level to radiographic changes in bone height are listed by treat-

TABLE 1. *Correlation Coefficients* of Pretreatment Pocket Depths, Attachment Levels, and Radiographic Bone Heights*

Correlated variables	Total teeth	Maxillary molars	Maxillary premolars	Maxillary incisors and cuspids	Mandibular molars	Mandibular premolars	Mandibular incisors and cuspids
M† pocket depth M att level	0.69 (1389)‡	0.76 (166)	0.74 (205)	0.68 (325)	0.75 (165)	0.73 (209)	0.65 (319)
M pocket depth M rad bone ht	0.47 (1289)	0.54 (140)	0.48 (192)	0.49 (310)	0.54 (158)	0.52 (181)	0.29 (308)
M att level M rad bone ht	0.64 (1289)	0.61 (140)	0.56 (192)	0.71 (310)	0.63 (158)	0.56 (181)	0.66 (308)
D† pocket depth D att level	0.75 (1389)	0.70 (166)	0.74 (205)	0.73 (325)	0.80 (165)	0.75 (209)	0.75 (319)
D pocket depth D rad bone ht	0.50 (1179)	0.35 (125)	0.47 (190)	0.48 (224)	0.45 (149)	0.58 (190)	0.52 (310)
D att level D rad bone ht	0.69 (1179)	0.53 (125)	0.67 (190)	0.70 (224)	0.56 (149)	0.70 (190)	0.75 (310)
M + D pocket depth M + D att level	0.68 (1389)	0.69 (166)	0.66 (205)	0.67 (325)	0.72 (165)	0.70 (209)	0.64 (319)
M + D pocket depth M + D rad bone ht	0.51 (1191)	0.50 (116)	0.43 (186)	0.53 (222)	0.55 (147)	0.61 (177)	0.40 (293)
M + D att level M + D rad bone ht	0.71 (1141)	0.62 (116)	0.61 (186)	0.80 (222)	0.63 (147)	0.68 (177)	0.74 (299)

* All significant, $P < 0.001$.
† M, mesial; D, distal.
‡ Sample size in parentheses.

TABLE 2. *Correlation Coefficients of Post-Treatment Changes in Attachment Level and Radiographic Bone Height*

Correlated variables	Total teeth	Maxillary molars	Maxillary premolars	Maxillary incisors and cuspids	Mandibular molars	Mandibular premolars	Mandibular incisors and cuspids
M* att level M rad bone ht	0.11† (3689)‡	0.12 (357)	0.08 (547)	0.16† (898)	0.07 (463)	0.06 (511)	0.17† (913)
D* att level D rad bone ht	0.12† (3342)	0.09 (332)	0.22† (543)	0.12* (615)	0.10 (429)	0.05 (539)	0.10 (884)
M + D att level M + D rad bone ht	0.15* (3201)	0.16 (297)	0.13 (526)	0.26† (608)	0.16 (422)	0.03 (496)	0.17† (853)

* M, mesial; D, distal.
† $P < 0.001$.
‡ Sample size in parentheses.
§ $P < 0.01$.

ment procedure and based on mean half-mouth scores (Table 4). The values are quite consistent between treatment procedures with a tendency for better correla-ion for the modified Widman procedure. When the post-treatment values for attachment levels and bone heights for individual teeth at each of the four years of follow-up were correlated (Table 5), a consistently high correlation was found between these two parameters for each time interval.

Discussion

Previous reports which have included pre- and postoperative radiographs and reentry of the previously operated area have claimed that radiographs have the capability of assessing fairly accurately the outcome of periodontal therapy.[5-9] Suomi et al.[10] conducted a comparative study of radiographs obtained by the long cone technique and clinical probing in determining bone levels. They found no significant difference between these two methods in their ability to reveal the extent of alveolar bone height.

The effectiveness of a number of techniques in reproducing alveolar crest relationships to the teeth has been tested.[11] The long cone technique was found to be as effective as more cumbersome methods in reproducing measurements of apex to crown, distal cementoenamel junction to crown tip, width of the crown on anterior teeth, and apex to crown tip. Almost all of the tested methods (including the long cone) also were equally accurate for measurements of tooth length and mesial cementoenamel junction distance to crown tip. It does appear that comparable accuracy in measurement may be obtained using the long cone technique compared to various positioning devices.[11]

Various methods utilizing the cementoenamel junction as a reference point[12] have been used extensively. However, the difficulty of accurate interpretation of the cementoenamel junction due to restorations, angulation, and overlapping of teeth and difficulties in scoring bone heights meant that no measurements were possible in 25% of the bone septa in one study.[12] Another study[13] reported that the distance between the cementoenamel junction and the alveolar crest varied with alteration in

TABLE 3. *Correlation Coefficients of Post-Treatment Changes in Attachment Level and Radiographic Bone Height Comparing Tooth Value with Patient Values*

Correlated variables	Individual tooth values	Patient values
M* att level M rad bone ht	0.11† (3689)‡	0.43† (157)
D* att level D rad bone ht	0.12† (3342)	0.43† (156)
M + D att level M + D rad bone ht	0.15† (3201)	0.43† (161)

* M, mesial; D, distal.
† $P < 0.001$.
‡ Sample size in parentheses.

TABLE 4. *Correlation Coefficients of Post-Treatment Changes in Attachment Level and Radiographic Bone Height for Each Treatment Method*

Correlated variables	Pocket elimination	Subgingival curettage	Modified Widman
M* att level M rad bone ht	0.26‡ (129)‡	0.38† (96)	0.46† (104)
D* att level D rad bone ht	0.38† (127)	0.31† (93)	0.38 (103)
M + D att level M + D rad bone ht	0.33† (126)	0.36† (96)	0.48† (107)

* M, mesial; D, distal.
† $P < 0.001$.
‡ Sample size in parentheses.

TABLE 5. *Correlation Coefficients* of Post-Treatment Values for Attachment Levels and Radiographic Bone Height at Each of the Four-Year Periods*

Correlated variable	1 year	2 years	3 years	4 years
M† att level M rad bone ht	0.62 (1085)‡	0.62 (1047)	0.64 (1077)	0.66 (778)
D† att level D rad bone ht	0.66 (997)	0.63 (965)	0.65 (984)	0.68 (723)
M + D att level M + D rad bone ht	0.68 (969)	0.66 (944)	0.68 (964)	0.71 (708)

* All significant, $P < 0.001$.
† M, mesial; D, distal.
‡ Sample size in parentheses.

the direction of the central x-ray beam, the film position, and the long axis of the tooth, and therefore, questioned the validity of this method of scoring bone loss. The method of Björn and co-workers[4, 14, 15] apparently has solved many of these problems. The nonmeasurability was reduced to an average of 4% for intraoral radiographs, and there was no significant intra- and/or interexaminer variation for the intraoral radiographs. The influence of variations in angulation of the bone score values has been found to be nonsignificant with this method and did not seriously affect the reliability of the determination of the average bone levels for an individual or group of individuals. Radiographic assessment of bone levels provides only interproximal measurements of the relationship between the alveolar crest and reference points on the tooth, so radiographic findings can be compared only with the interproximal clinical measurements of pocket depth and attachment levels.[16]

Björn and co-workers[4, 14, 15] determined the "bone margin" from the point where the periodontal space retained its normal width. The most coronal level where the periodontal space retained its normal width was also used to determine the "alveolar bone level" in the present study. However, when the periodontal space was indistinct, or widened, the level with an intact lamina dura was considered "the alveolar bone level." This modification was adopted because of recent evidence indicating that the radiographic image of the marginal aspect of the periodontal membrane varies markedly with changes in the horizontal angle of the x-ray beam.[17]

Radiographic data analyzed from an earlier phase of the Michigan longitudinal study failed to demonstrate any statistically significant correlation between post-treatment changes in attachment levels and changes in radiographic bone heights.[18] However, in the present study statistically significant correlations were found between these two parameters. In the earlier study[18] radiographic bone height was determined using the method of Schei et al.[12] The method of Björn et al.[4] used in the present study may be more precise and sensitive due partially to the magnification factor. Also, the total tooth length used by Björn et al.[4] as a reference may be determined more accurately than the cementoenamel junction to apex length used in the Schei *et al.*[12] study. The radiographs measured in the earlier study[18] all were obtained by the bisecting angle technique. This technique is inferior to the paralleling, long cone technique used in the present study for anatomical accuracy, standardization, and reproducibility.[19-21] Also, the sample size in the earlier report was not as large as in this study. These variations in methods and sample size could explain the differences in findings between the previous and the present study.

Clinical assessment of periodontal status in past studies has utilized pocket depth measurements, attachment level measurements, and radiographic bone level measurements. When these three parameters were correlated utilizing the individual tooth data from untreated teeth quite high correlations were found (Table 1). The attachment level and pocket depth, both of which are probing measurements, correlated with the same magnitude as the attachment level and radiographic bone height, which are both measures of periodontal support. However, pocket depth and radiographic bone height are not as highly correlated. These latter two parameters exist together in chronic destructive periodontal disease, but they differ in what they measure as well as in the technique of measurement. The degree of uniformity of the correlation coefficient among the tooth types is of interest considering the problems which are inherent in both probing and assessing radiographs in the molar areas compared to the anterior areas.

Correlation coefficients of post-treatment changes when analyzed by tooth type (Table 2) did not demonstrate striking patterns. The maxillary incisor area showed the best correlation which could be explained by the ease of obtaining radiographs of these single rooted teeth. However, this reasoning does not carry through when one considers the lower premolars which gave the lowest correlation level. The values for upper molars, the most difficult area in which to obtain definitive radiographs, showed a correlation of average magnitude for these two parameters of periodontal support.

There is a large drop in level of correlation when we compare changes which occur after treatment (Table 2) with the pretreatment scores (Table 1). This can be understood when it is realized that the changes or differences are so small that the statistical variance of this sample is approximately 10 times the value of the mean, whereas with the original values the statistical variance was approximately the same magnitude as the mean. The discrepancy between mean values and sample variance is reduced when data are pooled to produce patient scores from the individual tooth scores and the level of correlation increases (Table 3). There was the possibility that in the years after treatment a long narrow epithelial attachment would influence the results from probing for the attachment level, thereby resulting in a lower correlation level between radiographic bone height and clinically measured attachment levels. This would also affect the decrease in magnitude of correlation when comparing pretreatment measurements with post-treatment changes (Tables 1 and 2). However, when attachment level and radiographic bone height were correlated for each of the four post-treatment years the correlations were very similar (Table 5).

When the data were analyzed by the split-mouth approach, where the mean values for all the teeth of one side of a dentition which were treated by the same surgical method comprise the statistical unit, the method of treatment does not seem to alter the result (Table 4). There is an apparent spread with the Widman flap surgery showing higher correlation levels. However, the same degree of variation exists in the correlation levels of mesial and distal measurements in the pocket elimination groups which suggest that these differences are artifactual.

One of the main shortcomings of radiographs as a tool in clinical trials of periodontal therapy is the insurmountable difficulty in assessing buccal and lingual bone levels with accuracy. No assessment of buccal and lingual bone levels was attempted in this study.

Summary

Fifty-eight patients were selected from an ongoing study of periodontal therapy at The University of Michigan.[1] Pre- and post-treatment series of full mouth radiographs obtained by conventional paralleling long cone technique were available. Mesial and distal radiographic bone height was scored using the technique developed by Björn et al.[4] A total of 1416 teeth were scored from the initial radiographs, and subsequently at one, two, three, and four years after the treatment. Radiographic bone height scores were compared with level of attachment and pocket depth scores for the same teeth at the same time.

Statistical significance and correlation coefficients were derived using computer analysis of the data. The data were analyzed using three different data groupings: individual teeth, patient means, and half-mouth treatment methods. High positive correlations were found between initial measurements of radiographic bone height and attachment level as well as pocket depth. The correlations between changes in measurements of radiographic bone height and attachment level after treatment were markedly lower but are statistically significant. A highly significant correlation between radiographic bone heights and measurements of attachment level also appeared in follow-up data one to four years after treatment.

The method of data grouping resulted in different correlation coefficients. Highest correlations were found if the data were pooled for patients. Lowest correlations were found if the data for individual teeth were analyzed. When the data were combined to produce patient scores, sample variation is reduced and correlations increase in magnitude.

The generally high correlations between radiographic bone height and attachment level scores before and after treatment tend to confirm the fact that radiographic assessment of alveolar bone height using the method of Björn et al.[4] can provide fairly accurate assessment of interproximal periodontal support.

Conclusions

1. Attachment levels assessed by probing and interproximal bone height determined by the Björn et al. method[4] are correlated with a high degree of statistical significance, both before and following periodontal therapy.
2. Longitudinal interproximal changes in periodontal support as measured by probing and by the Björn et al. radiographic method are related.
3. Roentgenographic evaluation of results from periodontal treatment compared with clinical measurements of interproximal attachment levels is well correlated if mean patient values are used, but is not very useful for comparison of results for individual teeth.

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