SYMMETRY, FORM AND DIMENSION OF THE DENTAL ARCHES OF ORTHODONTICALLY TREATED PATIENTS

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Symmetry, form and dimension of the dental arches of orthodontically treated patients

by

Frank Jonathan Hechter

ABSTRACT

Many hypotheses have been proposed concerning the maintenance and stability of tooth position following orthodontic treatment. That pretreatment dental arch asymmetry tends to return in the postretention period has been observed and commented upon by many orthodontic clinicians. This phenomena, however, has not been well quantified.

This investigation of model analysis attempted to identify, quantify and analyze symmetry of the dental arches, compare untreated "acceptable" occlusion case records against preorthodontic treatment records, and compare pretreatment records against those obtained immediately postretention and a minimum of two years postretention. In addition, other orthodontic variables including arch form, intertooth widths, overbite, overjet, curve of Spee, cuspid and molar relationship, were analyzed for the changes affected by orthodontic treatment and subsequent stability of these parameters in the postretention period.

The sample consisted of twenty-seven cases with "acceptable" occlusion, selected from the 1972 study of Banack, Cleall and Yip, and a malocclusion group of sixty-seven orthodontically treated cases of all Angle malocclusion classifications.

The orthodontic models were photographed utilizing a standardized photographic setup and the analyses of the models were performed utilizing a coordinate analysis computer program. Three indices were developed to assess the symmetry of the dental arches. Comparison of measurements of the various orthodontic variables computed pretreatment, at the end of the treatment period, and a minimum of two years post-retention were evaluated statistically by the use of a multi-variate factorial analysis. The statistical and subjective evaluation of the results suggested the following conclusions:

1) Three symmetry indices were devised to quantitatively describe dental arch asymmetries.
2) Dental arch asymmetry is independent from and randomly distributed amongst Angle's malocclusion classifications.
3) The dental arches of the untreated "acceptable" occlusion sample were not perfectly symmetrical and differed statistically from the preorthodontic treatment case values.
4) Pretreatment dental arch asymmetries tend to return in the post-retention period after the retaining devices have been removed. The extraction or nonextraction of teeth as an adjunct to orthodontic therapy, seemed to have no consistent effect on post-treatment dental arch symmetry stability.
5) Regardless of the orthodontic variable under investigation, the values tended to return toward their pretreatment values during the postretention period. Some of the orthodontic variables, however, tended to be significantly more stable in the postretention period than others.

6) Intertooth width changes, particularly expansion, were more consistently maintained in the maxillary than in the mandibular dental arch. In the mandibular arch, intertooth width increases were least tolerated in the cuspid region.

7) Intermolar width, regardless of arch, decreased more significantly in the extraction cases than in the nonextraction cases from pre-treatment to postretention. Much of the treatment intermolar width expansion was maintained in the nonextraction group. In the extraction group, the intermolar width was decreased during treatment and continued to decrease during the postretention period.

8) The analysis of arch form based on mathematical geometric configurations suggested that the parabola had a very high "goodness of fit" to the dental arch form of both the maxillary and mandibular dental arches for both curves investigated.

9) The configuration of the curve of Spee of the "acceptable" occlusion sample differed significantly from the malocclusion groups. The curve of Spee of the "acceptable" occlusion sample appeared to be a composite of two curves, the first from the incisal edge of the central incisor to the cuspid and then a second gentle curve between the cusp tip of the cuspid and the disto-buccal cusp of the first permanent molar.

10) Overjet, cuspid relationship and both Class I and Class II molar relationships as well as a flattened curve of Spee, were found to be relatively stable variables in the postorthodontic treatment period.

11) Cases treated without the extraction of teeth, resulted in the arch length being increased during treatment, while those treated with the extraction of teeth, resulted in a decrease of arch length during treatment. However, arch length decreased in the post-retention period regardless of whether the cases were treated with or without the extraction of teeth.

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INTRODUCTION

CHAPTER I

INTRODUCTION

Many hypotheses and philosophies have been proposed concerning the maintenance and stability of tooth alignment attained during orthodontic treatment after it was realized that teeth may change in their locations following treatment. For instance, E. H. Angle (1907) stressed that in order for teeth to remain stable in their new positions, an occlusion must be established which will enable the inclined planes of the cusps to act ultimately in perfect harmony from mutual support. This belief was based on the notion that properly positioned teeth would allow the functional forces of normal occlusion to stimulate new bone growth in the apical base.

Subsequently, Lundstrom (1925) introduced the concept of the apical base. This is based on the postulate that occlusal function cannot control the form and amount of apical base but conversely the apical base is to a high degree capable of affecting the occlusion. The treatment objective of placing teeth over basal or skeletal bone for stability subsequently evolved from this line of reasoning. Later, Tweed (1944) based much of his treatment philosophy on Lundstrom's apical base theory. He stressed the importance of locating mandibular incisors in a normal relation to their basal bone. Being so positioned, this worker considered that they were in mechanical balance and so best able to resist the forces of occlusion.

The concept of functional muscle balance formulated by Rogers (1922) represented an alternative line of reasoning. This centres around the necessity of establishing proper muscle action in retaining orthodontic cases. Modification of this thinking was the basis of the "equilibrium theory of tooth position". This relationship of the musculature, denture and stability was further elaborated upon by Strang (1949). He stated that malocclusions represented dentures which were under the influence of balanced muscular forces, and considered that these forces were unique in each individual and could not be permanently altered through treatment. In order to increase the likelihood of permanent stability, therefore, attempts should be made to preserve the inherent muscular balance rather than alter it. In an effort to achieve stability of the denture following treatment, certain specific clinical rules and techniques have evolved from the preceeding philosophies.

McCauley (1944) stressed the opinion that two mandibular dimensions, intermolar width and intercanine width, are uncompromising dimensions and should not be changed by treatment. Strang (1952) concluded that the intercanine width of the mandibular denture is an infallable guide to the muscle balance inherent to the individual dictating the limit of the denture expansion in this area. In only one instance did Strang believe that the intercanine width could be expanded without violating the influence of muscle balance, i.e. when canines were moved distally into the spaces created by the extraction of first premolars. Howes (1960) agreed with Strang that increases in intercanine width were stable only if the canines were moved distally into the wider part of the mandibular arch. Reidel (1960, 1969) stated as one of his nine theorems of retention that "arch form, particularly the mandibular arch, cannot be permanently altered by appliance therapy". Nance (1947) suggested that to obtain a stable permanent orthodontic result,

(1) mandibular teeth must be well related to basal bone; (2) that only a limited amount of arch length may be gained permanently and (3) that only in selected cases can a small amount of buccal expansion be maintained.

Although the study of dental arch asymmetry has been extensively investigated, in only a few of the studies did the investigators quantify the entire dental arch but rather utilized various measuring devices to assess values for asymmetry at specific isolated sites.

The purposes of the present investigation were to: (1) identify, quantify and analyse asymmetry of the dental arches, (2) to compare untreated "acceptable" occlusion case records against those obtained before orthodontic treatment, (3) compare the pretreatment orthodontic records against those obtained immediately postretention and a minimum of two years postretention, (4) to provide the clinical orthodontist with an indication of the prevelance and magnitude of changes occurring in the posttreatment period as well as an evaluation of the relative stability of several orthodontic variables including intertooth width, overjet, overbite, curve of Spee and cuspid and molar relationship.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Dental Arch Asymmetry

The study of dental arch asymmetry has been investigated extensively, and it has been suggested that some asymmetry exists in all dental arches.

Korbitz (1909) was the first to suggest that both sides of the maxillary dental arch should be compared, i.e. that dental arch asymmetry occurs. He based this proposal on the midpalatal raphe as an axis of symmetry, and described a simple device called "thread-cross" in order to facilitate the comparison. In 1911, Grunberg, devised the first symmetroscope whereby asymmetries in the positions of teeth could be detected in the sagittal and transverse planes. The Grunberg method of orienting or positioning the casts in the symmetroscope has been criticized by Adler on the basis that the casts were positioned by means of three landmarks upon the occlusal surface of the cast rather than the more popular method of relying on the midpalatal raphe as an axis of symmetry.

In an anthropometric study based upon dried skulls, Keith (1924) measured the area of the palate by charting an accurate drawing of the dental arch on millimeter graph paper. By joining the posterior molar line, Keith found that teeth on the two sides of the palate were never symmetrical in their arrangement.

Korkhaus (1934) introduced the three-dimensional analysis approach to the maxillary arch. He believed this principle of analysis was generally recognized as important but there was considerable divergence of opinion regarding the methods of positioning or orienting the cast upon its base. He devised several instruments to simplify three-dimensional study of the palate, eg. a pair of calipers (1928), a symmetrograph (1930), and a symmetroscope (1937). All these instruments were based upon the midpalatal raphe as the sagittal axis of symmetry and Korkhaus's symmetrograph had the advantage over Grunberg's symmetroscope in that it recorded the symmetric lines directly from the dental cast.

Haberle (1937) devised a unique method for comparing right and left sides of the dental arches with the use of polygon line graphs and illustrated the various malocclusions by providing a visual demonstration of the various asymmetries.

Sedwick and Brawley (1938) reintroduced the importance of measuring the maxillary dental arch in three dimensions using a modified caliper type instrument, the palatometer, which permitted all three dimensions of the palate to be measured directly in the mouth.

Bloomer (1943) introduced the palatopograph which recorded lines on paper, similar to the reading of a geographic topographical map. He pointed out that all previous methods, calculated linear dimensions in the shape of the palate by using instruments for computing height, width and length at certain points. In addition he felt that they did not provide a true representation of the general configuration of the palate. He also concluded that the configuration of the palate was similar to that of a finger print with a high degree of individuality. Steinvorth (1953) utilized Grunberg's symmetroscope as an initial aid to determine the dental arch asymmetry, utilizing the midpalatal raphe as a sagittal axis of symmetry. Once the cast was oriented in the symmetroscope it was radiographed by a method that had earlier been described by W. B. Downs in 1944. Hunter (1953) measured tracings of the maxillary arch of 93 boys and determined the lateral asymmetries at right angles to the median raphe at the first molars and first bicuspids. He found no systematic difference between right and left sides.

Barr and Gron (1960) stressed the fact that the palate is surrounded by teeth positioned in the dental arch which is conspicuously inconsistent in form. They empasized that the only stable anatomic feature lending itself to determination with reasonable reliability was the midline of the palate. They selected the midline as the base line for their measurements in the horizontal plane. Their measurements were made in three dimensions on enlarged photographs of 150 dental casts.

In 1961, Lundstrom studied 28 patients with ideal occlusion for the purpose of investigating the reliability of the midpalatal raphe line as an axis of symmetry and showed only a small difference between the centre of the arch and the raphe line. In the cases in which there was an obvious deviation, it was difficult to say whether it was the raphe line or the dental arch that was asymmetrical. Lundstrom pointed out that bilateral symmetry is but a "theoretical concept". It is a principle in biology which is "applicable to large numbers but seldom, if ever, to the individual organism". He stated that in order to examine the positional asymmetry of the teeth in the arches, one would require a coordinated system of axis of symmetry for each dental arch. He utilized a modified version of the stereograph which had earlier been described by Schwartz in 1931. In Lundstrom's method, the midpalatal raphe line of the dental arch was projected by means of a stereograph on a sheet of paper. He summarized his work by stressing that the biologic principle of bilateral symmetry is never manifested with mathematical precision. Even in fully homologous organs, there are almost invariably small differences.

Staab (1961) studied the form of the palate in cases exhibiting Angle Class I and Angle Class II dental malocclusions. He measured the maxillary dental arch in all three dimensions by means of a modified sliding caliper. He believed, however, that determining areas of the palate by multiplying linear measurements provided a useful metrical definition of palatal shape.

Lebret (1962) utilized the symmetrograph designed by Korkhaus, accepting the midpalatal raphe as the axis of symmetry. He studied growth of the palate on dental casts by tracing the median, sagittal and transverse contours at various developmental stages. Lebret found slight asymmetries present in relation to palatal height and palatal breadth measurements.

Shapiro, Redman and Gorlin (1963) utilizing their modified caliper instrument for measuring normal and malformed palatal vaults in order to demonstrate the proportion which one measurement of the palate bears to another. The proportion was known as the "palatal index".

Lavelle and Plant (1969) undertook a study of arch form comparing the symmetry of the right and left sides of the permanent dentition.

Although the dimensions of the teeth in actual arch lengths of the right were consistently greater than those of the left, such differences were statistically insignificant.

In 1968, Lear utilized a cast metal clasp adapted to the buccal surfaces of the teeth on an investment dental model. He sought to ascertain differences in arch symmetry and shape due to functional forces. Superimposition of the palatal contours in the premolar and molar regions using the midpalatal raphe as a midline registration, showed a close left-right correspondence in shape although the right side of the palate was broader in one of the two subjects. The relationships of each side to the midline raphe revealed slight asymmetry in one of his subjects while marked asymmetry in the second subject. Superimposition revealed that the dental midline represented as the contact point of the central incisors, did not correspond with the midpalatal raphe. His findings indicated that the maxillary dentition was displaced to the right of the raphe line.

Vincent (1965), in an investigation to determine the asymmetry of the palate in 36 subjects with posterior dental crossbite, sectioned the maxillary casts constructed prior to orthodontic treatment in the transverse plane at specific dental landmarks. The outlines of the sections of teeth, both crossbite and noncrossbite, exhibited some asymmetry. Seventeen of the thirty-six maxillary dental arches studied, showed less asymmetry of sections with teeth not in crossbite than sections with teeth in crossbite.

Wahlig (1970), in a study of the maxillary dental arch symmetry in twins, utilized a constructed midline to divide the arch into left and right arcs. When he compared duplication and mirror differences on one side of the maxillary arch against the other side, he found no evidence of asymmetry. The dental arch, therefore, he concluded is generally a symmetrical structure.

Jensen (1972), in a study of dento-alveolar morphology in Down's Syndrome, stated that with regard to lateral arch asymmetries, the left side was significantly larger in both his normal and mongoloid groups at all ages.

Biggerstaff (1974), utilizing a method of arch form curves fitted by the quadratic equation, concluded that asymmetric arch forms appear to be the rule rather than the exception.

Pepe (1975), in a further study utilizing 2nd, 3rd, ... 8th degree polynominal equations to describe the "lines of occlusion" of seven children with "normal" occlusion, demonstrated asymmetries of both the anterior and posterior arch segments.

It is apparent from the literature cited that, although the subject of dental arch asymmetry has been extensively investigated, none of the methods have quantified the asymmetry of the entire dental arch and, thus, little attention has been paid to the effects of orthodontic treatment and subsequent changes occurring in the posttreatment period on the symmetry of the dental arches.

Intertooth Arch Widths

Two basic philosophies are prevalent in orthodontics. One is that the width of the mandibular dental arch cannot be expanded or widened in the intercanine or interfirst molar areas and remain stable. The other maintains that the width of the denture in these two areas can be expanded and held and that the teeth will remain in their new positions after the removal of retention.

McCauley (1944) stressed the opinion that two mandibular dimensions, intercanine width and intermolar width, are uncompromising dimensions and should be maintained as originally presented.

Strang (1949) reported that the mandibular canine and molar teeth are key units in determining the limits of width in correcting the malocclusion. He stated that mandibular intercanine width is an accurate index of the muscular balance inherent to the individual. Furthermore the maintenance of this width during orthodontic treatment comprises the most important objective if stability after treatment is to be achieved. He explained, however, that the intercanine width could be altered in certain instances and a stable result could be obtained, eg. when the crown of the canine was tipped from an incorrect axial inclination to the correct vertical axial inclination. In 1952, Strang reported success in treating cases in his practice where shaped arch wires were used to preserve the width across the mandibular canine and molar teeth. He found that none of the treated cases required any retention in the mandibular denture. Thus, he showed clinically that his earlier thoughts on preserving a muscular balance throughout treatment would help to gain stability in the finished result. Webster (1948) agreed with Strang in stating that to gain a stable result, one must not expand the intercanine width.

In a cephalometric and model study by Litowitz (1948) of 20 non-extraction cases which had no retaining devices for a period of one to five years, there was a tendency for both the maxillary and mandibular first molars to return to their original position and an even stronger tendency for these teeth to move mesially after retention. The mandibular incisors also tended to return to their original position. Both the increase in arch length and gain in arch width produced by treatment, tended to decrease following treatment. Expansion between the mandibular first bicuspids demonstrated the least relapse tendency and usually showed a net width gain.

Cole (1948) studied the results of extraction in 21 orthodontically treated cases out of retention at least one year. The following observations were made:

(1) that closure of spaces was produced by anterior movement of molars and posterior movement of incisors

(2) a strong tendency was present for the mandibular incisors to assume their original axial inclinations after retention and there was an indication that this tendency was accompanied by a forward positioning of the mandibular first molar

(3) that extraction therapy tended to increase the overbite more than was present in the original malocclusion.

Nance (1947) concluded that if a stable permanent result is to be obtained in orthodontic treatment of the mandibular teeth, they must be positioned properly in relation to basal bone. He further stated that the only situations in which buccal expansion may be utilized, are those in which basal supporting bone has adequate width and the contraction is confined to the alveolar bone. He also suggested that attempts to alter arch form in the human dentition, generally meet with failure.

From a study of 22 cases out of retention from two to six years, Dona (1952) concluded that the intermolar and intercanine widths have a tendency to remain the same or to return to their original dimension if increased during treatment. A tendency of overbite to return and for arch length to decrease following retention, were also noted.

Peak (1956), in a study of 43 patients out of retention six months or more, concluded that mandibular canine expansion in successful orthodontic treatment is limited. For instance, most of the cases in his investigation exhibited a decrease in intercuspid width following active orthodontic treatment.

Steadman (1961), in a study of 31 cases out of retention one or more years, indicated that the ultimate intermolar width of the maxillary and mandibular first molars and the intercanine width of the maxillary and mandibular canines, is not produced by orthodontic treatment. It was observed that premolar extraction resulted in a reduction of maxillary and mandibular intermolar width but produced no discernable differences in maxillary and mandibular intercuspid widths. Steadman concluded that orthodontic movement and retention produces permanent changes only in those patients whose forces acting upon the teeth have changed in such a manner during treatment and retention as to support the repositioned teeth in their newly acquired position.

From comparing intercanine widths on cases with recurrent lower incisor crowding with those with no recurrent crowding, Miller (1958) concluded that the significant difference was the maintenance of intercanine width in the noncrowded group while a decrease was observed in every case where crowding occurred. Kelly (1959), in a sample consisting of 21 marked growers and 7 nongrowers out of retention from one to five years, indicated that in the majority of subjects, the relapse that did occur could be attributed to other factors. He found that if intercanine width was increased during treatment, it tended to return to its original dimension during the postretention period resulting in crowding of the lower anterior teeth.

Martin (1962) found in a study of 32 treated orthodontic cases, at least one year out of retention, that the linear distance between the permanent mandibular canines decreased in very case.

Walter (1953), in a study of cuspid expansion in 102 nonextraction cases, found that the mandibular intercanine widths were increased by a mean of 3.4 mm during active treatment and showed a mean decrease of 0.05 mm following active treatment. He concluded from his investigation that the statement indicating that the dental arch cannot be permanently widened or lengthened, is incorrect. In 1962, Walters stated that in a study of 50 extraction and 50 nonextraction cases out of retention an average of two years and nine months, 62 percent of the extraction cases maintained an average of 1.4 mm increase of intercanine width. His study also showed that 70 percent of the extraction cases demonstrated an average decrease in intermolar width of 2.9 mm but in non-extraction cases, 72 percent maintained an average increase of 1.8 mm in intermolar width. This concurred with the conclusions drawn from his previous study of 1953.

Amott (1962) studied 55 non-extraction cases at least four years subsequent to the removal of all retainers. The cases were divided according to Angle's classification of malocclusion and the following conclusions were made:

(1) the intercanine width demonstrated the strongest tendency to return toward its pretreatment dimension

(2) although 46 percent of the mandibular intercanine widths retained a part of their expansion, this was negligible except in the case of Class II, Division 2 cases which showed a mean permanent increase of 0.5 mm

(3) the intermolar widths tended to return to their pretreatment dimension which showed the largest permanent increase

(4) the overbite and overjet were decreased during treatment but continued to decrease in the post retention period and

(5) when buccal segments were expanded, the overall effect was a shortening of perpendicular arch length which further decreased as the expansion

was lost during the postretention period indicating some mesial migration of the buccal segments into an ever decreasing segment of the arch.

Arnold (1963) studied 30 extraction cases and 20 nonextraction cases, a minimum of 5 years after all retaining devices had been removed and concluded that:

(1) the intercanine width showed a remarkable tendency to return to or approach its original dimension and this tendency was not affected by the amount of treatment increase

(2) premolar extraction had no significant effect on the resultant intercanine width but did have a significant effect on increasing the frequency of intermolar width decrease

(3) the postretention resultant intercanine width had no significant relationship to the frequency of the resultant intermolar widths and

(4) a minimum of five years must elapse before an apparent maintenance of increased intercanine width can be accepted.

This opinion has been restated by Gianelly and Goldman (1971).

Using a sample of 34 extraction cases out of retention at least five years, Welsh (1965) carried out a cephalometric and model analysis of dimensional changes in the mandibular dental arch. From his study, he concluded the following:

(1) intercanine width showed an exceptionally strong tendency to return toward its pre-treatment dimension

(2) there was no significant relationship between the maintenance of intercanine width expansion five years postretention and the distal retraction of the cuspids into pre-molar extraction space during treatment

(3) the postretention intermolar width tends to be less than its pretreatment value regardless of whether or not this dimension was increased or decreased during treatment and

(4) the mandibular first molar tended to migrate mesially following treatment and retention.

Rose (1969), in a study of 54 cases of Angle Class I and Class II malocclusions, with a posttreatment time averaging 38 months, concluded that the three most stable measurements during posttreatment were the maxillary intercanine and intermolar width and the mandibular intermolar width. He concluded that the Class II cases did not tend to relapse more than Class I cases and that the maxillary arch was able to tolerate expansion of intercanine and intermolar widths during treatment better than the mandibular arch. The most unstable measurement found was the mandibular intercanine width. His study also suggested that overbite and overjet showed high tendencies to return toward their original malocclusion dimensions and that 44 percent of his treated cases had some degree of midline discrepancy averaging 0.54 mm.

Harris (1970), in a study of 41 extraction cases and 19 non-extraction cases, out of retention for at least six months, came to the following conclusions on measurements which were recorded for the mandibular arch only: (1) In nonextraction cases, intercanine width, which was increased during treatment, returned towards its original dimension after retention and (2) intermolar width, which was increased, continued to expand after the completion of treatment and retention. (3) In the extraction cases, the intercanine width was expanded during treatment and then relapsed towards its original positions similar to that of the nonextraction group. The intermolar width showed a decrease during orthodontic treatment but a slight increase after retention, also exhibiting a relapse towards the original position.

Davis (1971), in a study of 66 completed cases in which he evaluated the linear behaviour of intercanine and intermolar widths, concluded that (1) there was a strong tendency for the intercanine width to approach the original pretreatment dimensions once retainers were removed but only a very small percentage actually returned to the original width, (2) the tendency to return toward the original intercanine width was not affected by the amount of increase during treatment and (3) post-retention resultant intercanine width had no demonstratable significant relationship to the intermolar width behaviour. He concluded that expansion in intercanine width can be achieved, however, some degree of recovery should be expected when the retainers are removed.

Renger (1973), in a study of 25 nonextraction cases in which mandibular intercanine width and lower incisor crowding were measured directly on plaster models in cases at least one year after retention, concluded that mandibular intercanine width will contract during the postretention period in most cases. In addition, he reported no significant relationship between the maintenance of mandibular intercanine dimension and postretention stability of the lower anterior segment in orthodontically treated nonextraction cases. He cautioned, however, that the results should not be construed to mean that gross expansion of the intercanine width will not adversely affect the stability of the lower incisors. He also suggested that perhaps there is a limit to the amount of canine expansion that can be tolerated and once the theoretical limit is surpassed, a high correlation may exist between changes in intercanine width and recurrent lower incisor crowding.

From a study of mandibular intermolar width measured directly on plaster casts of treated cases, King (1973) concluded that in orthodontically treated nonextraction cases there was a trend toward expansion of the lower denture and this expansion showed a tendency to be maintained in the majority of the cases. There was minimal or no discrepancy in this dimension one year out of retention. In the extraction cases, there was a tendency toward contraction of the intermolar width of the lower denture. This contraction was observed to be stable in the majority of the cases and the postretention discrepancy was none or minimal in all of the cases. He suggested that it was possible to expand or contract intermolar width within controlled limits without affecting the stability of the denture.

Shapiro (1974), in a sample consisting of 80 ten-year post-retention nonextraction and extraction cases, concluded that (1) intercanine width demonstrated a strong tendency to return toward its pretreatment dimension but that the Class II, Division 2 group of subjects demonstrated a significantly greater ability to maintain its treatment intercanine width expansion than the Class I and Class II Division 1 groups. (2) That intermolar width decreased significantly more in the extraction cases than in the nonextraction cases from pretreatment to postretention but that much of the treatment intermolar width expansion was maintained in the nonextraction group although the trend was to return toward the pretreatment dimension. In the extraction group, intermolar width was decreased during treatment and continued to decrease during the postretention period.

Although all investigators recognize individual variation, there is general agreement on the typical changes occurring in this variable in the postretention period: intercanine and intermolar widths tend to decrease, especially if expanded during treatment.

Arch Form

Several geometric curvilinear configurations have been suggested for the description of human dental arch form. Among these, the ellipse, parabola, catenary and some modifications of the first two, in addition to a miscellaneous category, have been suggested to describe the dental arch.

Bonwill (1885) described a curve which most closely represented that of a parabola based on an observation that the lower jaw had a tripod shape composed of an equilateral triangle, the base of which extended from one condyle to the other and the sides extending from the respective condyle to the median line at the central incisors. He suggested that the six anterior teeth resided on the arc of the circle determined by this equilateral triangle, while the bicuspids and molars were extended on a straight line from the cuspids to the condylar processes.

Broomell (1902) suggested that the jaws were arranged in the form of two parabolic curves, the superior one being somewhat larger than the inferior one.

In 1904, Hawley modified Bonwill's method by constructing a circle the radius of which equalled the combined widths of the anterior teeth. He cautioned against the strict use of this method in determining arch form, suggesting it rather as a guide.

Angle (1907) considered his normal occlusion to be of a form which he considered to be that of a parabolic curve. Chuck (1934) modified the Bonwill-Hawley method by the addition of bicuspid offsets in an effort to prevent the cuspid from being too prominently positioned to the labial.

Sved (1952) suggested his theory of "spherical occlusion" in which he suggested that the dental arches are comprised of sections of spheres with different radii.

Remsen (1964), in a comparison of the Bonwill-Hawley, Sved, parabolic and 45 degree ellipse, concluded that the parabola best represented the anterior curvature of the dental arch. However, he cautioned that he found no method to be ideal and considered them to be only guides and rough approximations of dental arch form.

Mills and Hamilton (1965), by substituting width and length measurements of the maxillary arch by means of mathematical calculations, computed the arch circumference of the dental arch by substituting these values into the formula of the parabola.

Currier (1966) felt that the parabola had a better "goodness of fit" to a curve which connected the central fossae of the molars and the cinguli of the canines and incisors in the upper and lower arch.

Another general group of descriptions of arch form was based on curves, shapes and sizes which were determined by tooth size or other mathematically describeable structures. In this group, Pont (1909), on the basis of the sum of the mesio-distal width of the maxillary central and lateral incisors, calculated in table form the optimum interfirst premolar and interfirst molar width for that particular arch.

Williams, in 1917, advocated positioning the maxillary anterior teeth on an arc of a circle situated with its centre midway between the buccal grooves of the first molars.

Stanton (1922), studying "normal occlusions" in three dimensions with the construction of orthognathic maps, concluded (1) that the outer cusps and incisal edges lie on a smooth curve and (2) that arch forms are open and closed curves as in a parabola or an ellipse. He advised, however, that any plan of arch determination must be flexible enough to produce arches varying in form including the 'ellipse, parabola, cubic parabola, parallel sides and "horseshoe" '.

Gilpatrick (1923) constructed a set of templates representing "normal arches" which were later used as a standard for comparing malformed arches. They were based on fitting artificial teeth on arches which correspond anatomically to averages obtained from arches able to contain and support the definite number of teeth and a definite amount of tooth structure.

The form of the arches being described as an ellipse was first proposed by Black (1902), who suggested that the upper teeth were arranged in a semi-ellipse with the long axis passing between the central incisors. He felt the lower incisors were similarly arranged on a smaller curve.

Izard (1927) described a method of arch determination based on facial measurements which he concluded from the observation of a constant ratio of dental arch width to facial depth. He observed that an ellipse represented variations of normal arches, in the majority of cases, 75 percent, while the parabola, 20 percent, and rarely a "u" or square-shaped arch, 5 percent. Meredith and Higley (1951), studying arch widths in relation to widths of the face and head, found no association between those dimensions or the ratios thereof. Their study, therefore, did not support the work of Izard.

Wheeler (1958) described the occlusal aspects of the dental arches as conforming to a curve similar to that of an ellipse. He cautioned, however, that "nothing anatomic may be reduced to the mathematical exactitude of geometric terms".

In 1960, Sicher suggested that the shape of the dental arches varied considerably but that in the normal individual, the upper arch could best be described as an ellipse while the lower arch that of a parabola.

Currier (1967) described the ellipse as having a better "goodness of fit", that is, a smaller variance to the facial periphery of the teeth in the upper and lower arches than that of a parabola.

Neilans (1968) concluded that the ellipse demonstrated a better "goodness of fit" to the outer curve, that is, the facial periphery of the maxillary teeth than the parabola or the catenary.

In 1949, MacConaill and Scher first described the dental arch form in terms of the catenary curve. The catenary curve is assumed by a fine chain of many links suspended by its ends but otherwise allowed to hang freely. The catenary curve is always symmetrical but its curvature is not constant. The catenary curve resembles a parabola, but its arms do not tend to approximate straight lines, they are always curved, however slightly. MacConaill and Scher found that the catenary curve fitted exactly the arches of the Columbia Dentoform and the Densco Dentoform which is based on G. V. Black's arch form.

Scott (1957) observed that in fetal life the dental lamina, enamel organs, primordial jaw cartilages, and the teeth-bearing bones, develop in a series of similarly curved catenary-like arches.

Burdi and Lillie, in 1966 using a catenometer refined Scott's inference that the dental lamina of the embryonic skeleton conformed to a catenary curve. They found that the human deciduous maxillary dental arch changes shape during embryonic development gradually elongating from a semi-circle to resemble a catenary curve by nine-and-a-half to twelve weeks in utero. Burdi (1968) demonstrated that the mandibular arch first conforms to a catenary curve at approximately eight-and-a-half weeks of embryonic life. He felt that the catenary curve serves as a convenient quantitative expression of dental arch shape.

Neilans (1968) concluded that the catenary curve demonstrated a better "goodness of fit" to the outer curve of the mandibular arch than the ellipse or the parabola.

Musich and Ackerman (1973) described a method of estimating dental arch perimeter by the use of a "catenometer" which was devised by modifying a Boley gauge and attaching the ends of a 90 mm long gold chain to the jaws of the gauge. They suggest, however, that since they are dealing with a relatively small segment of the dental arch, from the mesial aspect of the first molar to the mesial aspect of the contralateral first molar, it probably is not important whether a catenary, ellipse, parabola, or trifocal ellipse is chosen as the "mean curve".

Other various mathematical formulas have been suggested to best represent the human dental arch form. Hayashi (1956), who elaborated earlier works by Numato and Kato, suggested a curve of the form $y = ax^n \pm e^{(x-\alpha)}$ as a function which would define the arch form.

Lou (1966) discussed the chief drawback of Hayashi's method in that it assumed that the arch was symmetrical and made no effort to measure its asymmetry. In an effort to evaluate the form, symmetry and asymmetry of the dental arch, Lou described the use of a fourth degree orthogonal polynominal which he used to represent the dental arch. The quadratic and quartic terms he felt measured taperedness and the squaredness of the arch form. The linear measurement indicated the lopsidedness and the cubic term measured the tiltedness of the asymmetry. He described the orthogonal fourth degree polynominal as being a procedure which may be used in classifying the dental arches in terms of dental arch isomorphism.

Biggerstaff (1972) suggested a general quadratic equation of the form $AX^2 + BY^2 + CXY + EY - F = 0$. Utilizing the coefficients, the equations were solved for Y in terms of X. If the coefficients A and B have the same sign then the resulting smooth curve is an ellipse. If the signs are different, the smooth curve is hyperbolic. And finally, if either coefficient A or B is 0, the curve is parabolic. He felt that this method permitted a quantitative definition of dental arch types in a population such that the frequency of hyperbolic, parabolic and ellipsoidal arch form can be assayed to determine within and between population differences.

Pepe (1975) suggested that the coefficients of the sixth degree polynominal equation "appear to have potential as clinical indicators of arch form and, perhaps, malocclusion".

There have been very few reports concerning the actual form of the arches particularly as it changes with treatment.

Speck (1950) found that arch form changed slightly from the deciduous dentition until the eruption of the permanent bicuspids. The anterior segment he described as becoming flatter and the posterior segments expanded. In several cases, no change was noted in the arch form. Moorees, in his longitudinal study (1959), found that most mandibular arch forms are parabolic and tend to change little during development.

Riedel (1960 and 1969) suggested as one of his theorems of retention that "arch form, particularly in the mandibular arch, cannot be permanently altered by appliance therapy". He was particularly referring though to linear dimensions such as intercanine and intermolar widths.

Lindquist (1963), in a study of mandibular dental arch form at the end of treatment in 33 Class II patients treated only with headgear and maxillary bite plates, utilized a method in which acetate tracing paper was placed over photographs of the dental casts and continuous lines were drawn around the buccal surfaces and incisal edges of the teeth terminating at the first molars. The first molar terminal ends were then connected. A bisecting midline was then constructed on each of the tracings and the pretreatment and posttreatment arch form tracings were then superimposed upon this line utilizing the mid-point between the mid-incisal edges of the central incisors as the registration point. Although changes in arch form were observed, no statistical methods were utilized to describe these changes and as a consequence, no conclusions were drawn about the changes that had occurred in the arch form.

Lear (1968) utilized a cast metal clasp fabricated to the buccal surface of the teeth on an investment dental model. He then radiographed the casting on a Broadbent-Bolton cephalometer and used the resulting sillouettes to produce positive transparencies. No mathematical or statistical methods, however, were utilized to describe the observed changes in arch form.

Shapiro (1973), in a 10-year postretention study of 80 cases of Angle's Class I and Class II malocclusions, in an attempt to validate Reidel's theorem of retention, based on arch form, suggested with some reservation that permanent alteration of the mandibular arch forms of his sample had been observed. He cautioned, however, that although the catenary curve may have a considerable value in determining changes in arch form, it needs further study. Some of the problems encountered in fitting the arch form to a catenary curve include (1) that the catenary parameter "a" demonstrated a large standard deviation around the mean of almost every group of his sample, indicating to him that there was much variability of this value and that the mean is not representative of many individual cases in the sample; (2) probably more important, that it could not be determined how much influence blocked out teeth had in determining the "goodness of fit" to the catenary curve. Shapiro added that when these blocked out teeth were moved into the arch "this gross movement may have masked some of the finer arch form changes that had taken place during treatment".

Several curvilinear configurations have been suggested in the literature, however few of the investigations have analyzed the data statistically. In addition, differences in dental arch form may exist between and within various populations.

Overbite

There has been considerable discussion in the literature concerning overbite.

Strang (1950) defined overbite as being the "vertical overlapping of the upper and lower incisor teeth". Rowlett (1923), however, described the incisors of primitive man occluding end-to-end while the molars were in a normal occlusion, while Begg (1965) reported that the permanent incisors of Stoneage man erupted into a position of vertical overbite but that mastication of coarse, fibrous foods caused Stoneage man's permanent incisors to move incisively at first at an oblique angle and, ultimately, establishing an edge-to-edge relationship of the upper and lower incisors as the plane of attrition went from oblique to horizontal.

The normal range of incisal overbites are not in complete agreement with regard to various observers. Moyers (1960) suggested that overbite may vary with the individual's age and facial type. Strange (1934) described the "average" overbite equal to 1/3 of the length of the maxillary incisor crown. Steadman (1940) reported that the mean overbite of the anterior teeth on plaster casts of 47 subjects with acceptable occlusions was 3.1 mm with a standard deviation 1.9 mm, indicating a great deal of individual variation.

Neff (1949) measured the mesio-distal diameter of the six upper and lower anterior teeth and made use of this anterior coefficient to determine the correct amount of overbite. He placed his ideal overbite at 20 percent coverage of the lower incisor by the maxillary incisor.

Bolton (1952), using the same technique as Neff, examined 52 cases of excellent occlusion and found that the mean overbite was 31.3 percent but there appeared to be a great deal of individual variation.

The causative factors of overbite are not readily agreed upon. There are those, Goldstein and Stanton (1936), Litowitz (1948), Bonn (1951), Fleming (1961), and Saltzman (1965), who believe that the amount of overbite is related to the growth of the mandible. An insufficient growth rate of the mandible they suggest, will result with an occlusion possessing a deep anterior overbite.

Another group of investigators, who suggest that the position of the anterior teeth relative to their respective basal bone is of importance with regard to overbite and who feel that overbite is caused by supraeruption of the maxillary and mandibular teeth, include Prakash and Margolis (1952) and Jacobson (1973). They both add, however, that the vertical height of the maxillary and mandibular arches also play an equally important role in influencing the amount of overbite.

Yet another group of investigators has placed emphasis upon the proper inclination and angulation of the anterior teeth during the finishing stages of orthodontic treatment. Backlund (1958) stressed the need for proper consideration of the maxillary incisor inclination to avoid relapse after orthodontic treatment in his study of Class II, Division 2 cases. Other investigators with this view include Popovich (1955), Riedel (1960), McGill (1960), Schudy (1963) and Ludwig (1966).

Backlund (1958), in a study of 225 patients with both normal occlusions and malocclusions, emphasized the importance of the lingual anatomy of the maxillary incisors and the contact relationship with the mandibular incisors. He found this to be more highly correlated to the stability of postretention overbite than the axial inclination of the upper and lower incisors.

Bjork (1953), re-examining 243 men at 20 years of age that he originally examined at 12 years of age, found that the changes of overbite with age showed pronounced individual differences with regard to both deviation and amount. He found generally, though, that the overbite showed a certain relationship with the primary type of bites. Deep overbite exhibited a greater tendency to open than normal overbite.

Baum (1953) and Moorees (1959) showed a slight average decrease in overbite in normal longitudinal growth studies in the permanent dentition of subjects between the age ranges of 8 to 10 and 18 to 20.

Fleming (1961), in a longitudinal study of 48 normal occlusions from ages 9 to 16, utilizing cephalometric radiographs and study models, demonstrated that overbite increased from age 9 to 12 and then tended to decrease to age 17. He interpreted the reduction in overbite after age 12 as being due to mandibular ramus growth.

Some postretention studies have examined changes in overbite. Cole (1948), who examined 21 orthodontically treated patients out of retention at least one year all of whom required premolar extraction, observed that with the extraction therapy the postretention overbite was deeper than in the original malocclusion.

Dona (1952), studying 22 cases both extraction and nonextraction, out of retention between 2 and 6 years, concluded that there was a tendency for the incisal overbite to return toward its pretreatment relationship following orthodontic treatment. This opinion was restated by Hasstedt (1956), who examined 28 orthodontically treated patients out of retention at least one year and Stackler (1958), who examined 20 Class II Division 1 cases. Rose (1967), in his study of dental casts and records of 54 cases of Class I and Class II extraction and non-extraction treated cases out of retention an average of 38 months, reported that overbite showed a 64 percent return to its original measurement. Walter (1953), reporting on 34 nonextraction cases out of retention for an average of 2 1/2 years indicated an overall mean decrease of overbite of 2.01 mm.

McGill (1960), in a study including both extraction and non-extraction cases of 29 Class I malocclusions and 34 Class II malocclusions found the typical treatment decrease, posttreatment increase and an overall net reduction in the amount of overbite.

Hernandez (1969), in a study of 25 extraction cases and 58 nonextraction Class II, Division 1 treated cases out of retention at least six months concluded that there was a greater increase in overbite relapse in extraction cases than in nonextraction cases.

Amott (1962), in a study of 55 nonextraction orthodontic cases out of retention at least 4 years, found that overjet and overbite were decreased during treatment but that they continued to decrease during the postretention period.

Payne (1964) studied the effects of growth on 41 orthodontically treated children who had been out of retention five to twelve years. He found that the mandibular plane tended to close in the postretention period due to ramus growth, which resulted in increased posterior face height and forward positioning of the symphysis.

Ludwig (1967), in a study of 94 treated nonextraction cases measured from cephalometric radiographs relative the facial plane, concluded that (1) the percentage of relapse was greater in cases showing minimum overbite than in cases which show large overbites; (2) that all incisal relapses take place within a year or two post-retention and (3) the percentage relapse of Class II cases as compared to Class I cases was found to be similar.

Simons and Joondeph (1973), in a sample of 70 orthodontically treated patients 10 years or more out of retention, studied by means of cephalometric radiographs, concluded that patients who had a deep overbite prior to treatment also had the deepest overbite 10 years postretention. They reported, however, that these patients also retained the greatest amount of correction or overall net decrease in overbite. They also suggested that if upper and lower incisors were too upright after treatment, the overbite will most likely return. In addition, they felt that overbite was not related to whether or not permanent teeth were extracted during orthodontic treatment.

Reidel (1960) and Schudy (1963) suggested that the degree of initial overbite was related to the relative angulation of the maxillary and mandibular incisors. A deep overbite was associated with a high interincisal angle and a slight overbite was associated with a small interincisal angle.

Smith (1969), in a study to determine whether there was a significant relationship of deep overbite relapse with other cephalometric measurements, examined 34 Angle Class II, Division 1 malocclusions, all of whom had extraction of bicuspid teeth as an adjunct to orthodontic treatment, and concluded that the incisal angulation is very important in treatment objectives. In support of the earlier observation of Reidel (1960 and 1969), he suggested that deep bites should be overtreated, especially in patients with horizontal growth patterns.

In a 1974 study of 25 orthodontically treated cases, Dempsey found that the interincisal angle was significantly correlated to overbite change at the 1 percent level. However, in a study of 36 cases arbitrarily selected, Levin (1972) concluded that there was a tendency for an unpredictable varying amount of overbite to reoccur after treatment. He could not, however, find any significant correlations between overbite and interincisal angle nor between overbite and the occlusal plane angle as suggested by Schudy.

There exists general agreement amongst the investigators that overbite tends to return toward its pretreatment value in the post-retention period, however, the magnitude of the relapse tendency as well as the causative factors are still controversial.

Curve of Spee

The curve of Spee was first mentioned by Ferdinand Von Spee in an article in 1890. He defined this anatomical feature as a curve along the buccal cusp tips of the mandibular premolars and molars continuing concentric with the articular emminence in the glenoid fossa. Subsequently, however, the curve of Spee has been described in two different ways.

Firstly, it is considered to be an anatomical arrangement of the teeth and secondly, it is considered to be a geometric phenomenon of the development of the face, which presupposes that the face develops around an imaginary 8-inch sphere, the centre of which lies behind the naso-frontal suture beneath the anterior cranial vault. Those supporting the curve of Spee as being a geometric phenomenon of the development of the face include Bonwill (1899), Abell (1926) and Monson (1920).

Angle, however, (1899) felt that the line of greatest occlusal contact passed over the buccal cusps of the molars and bicuspids and the cutting edges of the cuspids and incisors of the lower arch. He said this line described a parabolic curve.

Those supporting the view that the curve of Spee is an anatomic arrangement of teeth include Steiner who in 1934, wrote that failure to properly harmonize the teeth with the curve of Spee and failure to correct proper arch form in the horizontal dimension, immediately caused disharmony in the length of the two arches. He felt little attention was given to the axial inclinations and cuspal heights which determine the curve of Spee.

In 1934, Strang correlated overbite with the curve of Spee and felt that a deep curve may be due to infraocclusion of the lower premolars and molars as well as supraocclusion of the maxillary incisors.

In 1938, Drew emphasized the geometric patterns that exist in the natural dentition referring to the curve of Spee and the compensating curve. He pointed out the spherical congruency which exists in the natural dentition and the similarity between both of these curves.

In an article entitled "Three Dimensional Consideration of Occlusion", Strange (1940) stated that the curve of Spee provided ease of action and balance with muscular movement during the various functional movements of the jaws and teeth.

In 1950, Strang provided four objectives of the curve of Spee: (1) establish the correct amount of overbite, (2) provide shearing power to the anterior teeth, (3) determine a more uniform separation between the maxillary and mandibular occlusal planes and (4) permit maintenance of uniform occlusal contact when the mandible is shifted slightly forward. He speculated that deep curves may be due to infraocclusion of lower molars and premolars along with supraocclusion of the maxillary incisors. In 1960, Strang stressed the success of correcting a deep curve of Spee by a combination of incisor depression and premolar elevation.

In an article in 1951, challenging the classic view of the curve of Spee, Zingeser noted that the distance from nasion to the tip of the maxillary incisor and the distance from nasion to the buccal groove to the maxillary first molar, were usually very nearly the same. He noted that an arc constructed from nasion passing through the incisor tip in the maxillary molar groove did not approximate the other teeth in the maxillary denture.

Jaraback (1963) suggested the primary purpose of the curve of Spee was to provide functional occlusal balance of teeth in all aspects of functional movements of the mandible. He believed that the range of anteroposterior movements was controlled in a large measure by the curve of Spee, overbite and overjet and concluded that in normal balanced occlusion, the curve of Spee is shallow.

Sicher (1952) and Brescia (1961) observed that the curve of Spee varied considerably among individuals. Braun and Schmidt (1956), utilizing a cephalometric appraisal of the curve of Spee in Class I and Class II, Division 1 malocclusions, found no significant difference in ramus height, gonial angle, mandibular length, or shape of the curve when comparing the two malocclusion groups. It suggested to them that it was not valid to assume premolar infraeruption or incisor supraeruption to be one of the causes of a Class II malocclusion. Diametrically opposed, however, were the findings of Jaraback and Fizzell (1963), who suggested that the curve of Spee was most pronounced in Class II, Division 1 malocclusions and least pronounced in Class I, Class III and Class II, Dividion 2 malocclusions.

Barnett (1964) reported that the extraction of teeth during orthodontic treatment did not produce deeper curves of Spee following treatment. He usually found a large reduction in the curve of Spee was accompanied by a large reduction in overbite.

Hedges (1963), Mann and Panky (1963) and Schuyler (1963) suggested that the curvature of the occlusion, the incisal guidance and the temporomandibular articulation were all related and that lines drawn from the centre of Monson's theoretical sphere more than any other point or origin, passed through the long axis of each tooth.

Baldridge (1969) determined the increase in mandibular arch length due to levelling of the curve of Spee and found it to increase in direct proportion to the amount by which the curve is levelled.

Postretention investigations of the curve of Spee include Spell (1967), who examined 26 bicuspid extraction cases and five nonextraction cases utilizing a palatometer in which the occlusal plane was defined as a line joining the cusp tip of the lower right cuspid and the mesiobuccal cusp of the mandibular right second molar. He was able to describe significant differences between the means of the first and second bicuspids in the nonextraction cases comparing pretreatment and postretention measurements.

Turner (1973), in a study of overbite and curve of Spee, evaluated the curve of Spee in two ways: (1) from the cuspid through the distal of the second molar and (2) from the cuspid through the distal aspect of the first molar. Ninety-two percent of the treated cases showed a permanent levelling of the type A curve of Spee while 84 percent showed a permanent change in his type B curve. While he described the high correlation between curves of Spee and overbite in untreated cases he found that correlation was not as good in the finished cases. He felt that "the ability to maintain the flattened curve of Spee is influenced little by the position of the second molar. The area between the first molar and cuspid seems to be the determining factor in successful levelling any curve".

Although the curve of Spee has often been discussed in the literature, few studies have quantified and statistically analyzed the effects of treatment and the changes in this variable in the posttreatment period.

Review of Experimental Methods

The majority of the studies on dental casts have been made by direct measurements from the casts using a varied number of instrumentation including the symmetrograph, symmetroscope, palatometer, and others which have been described previously in the review of the literature. In addition to these, instruments such as helios gauges and boley gauges have been utilized for the measurement of intertooth widths.

Within the last decade several highly sophisticated methods have been developed in an effort to reduce the error of measurement which is encountered in measuring directly from dental casts and well described by Richardson, et al. (1963).

Included in these new techniques was a method first described by

Garn (1962) and later implemented by Savara (1969). The method consisted of placing the dental casts on the glass table of a Xerox duplicating and printing machine and making measurements on the reproductions of these casts. The landmarks were marked and shaded dark for better contrast. Instant lettering (letraset) black dots were used to locate buccal cusp tips of the permanent molars and cuspids, as well as other specific selected points. This method was later utilized by Jensen (1972), who utilized the coordinate analysis program of Cleall and Chebib (1971) in which he digitized the selected points.

In 1972, Biggerstaff described a method in which the dental casts were duplicated and then marked utilizing a Staetler-Morris 700 pen with India ink. The cast was then mounted on a surveying table, Williams Dental Surveyor, and the occlusal plane was adjusted so that it was level. The models were then photographed in a 1:1 relationship utilizing a crown graphic 4 x 5 camera. The photographic negatives were then digitized on a Benson-Lehrner Optical Chart Reader and then recorded and punched on Holorith cards. He reported that the between operator differences were 0.083 mm with a standard deviation of 0.075 mm and the within or individual operator error had an average difference of 0.041 mm with a standard deviation of 0.038 mm. He suggested then that this method could be applied objectively to anthropologic and genetic studies of tooth and arch dimensions.

In 1970, Van der Linden, Boersma, Zelers, Peders and Raaben described a method which allows the collection of 3-dimensional data treating the upper and lower casts as one unit. The instrument is called the Opticom which is a microscope mounted over a 2-dimensionally moveable table. The dental cast is attached to a base and is placed on a sliding table in a fixed position. The point to be recorded is aligned with the centre of two crosswires in the microscope. The position of the sliding table is recorded in tenths of a mm by using two measuring rules with photoelectric screening heads mounted on the bottom of the sliding table. The data is then transmitted through a data converter to a teletype machine and then punched on paper tape. They describe the "accuracy of the method is high" and suggest that the method makes it possible to study many aspects of the dentition and to analyze numerous available variables in all types of combinations.

Another digitizer method which has been utilized is known as the Erickson Digitizer. It is described as

> "a device consisting of two moveable platforms following the x and y axis and a pointer, the z axis, whose motion is perpendicular to the x, y plane. Three cutdown vernier calipers are mounted on the device so that the displacement of the cast or the pointer from the starting point may be directly ascertained. In addition, both platforms and the pointer are equipped with potentiometers which divide a voltage applied across them. They were calibrated so that one cm displacement resulted in a one volt change in output. The output of these potentiometers is fed into a digital voltmeter which serves as an analogue digital converter. On command, a scanner directs the digital voltmeter to convert the analogue signals in an x, y, z sequence. The digitized signals are routed to a paper tape perforator which provides "hard" copy of the model dimensions".

This method has been utilized by Shapiro (1973) and Swanson (1973) at the University of Washington, Seattle.

A method described by Thompson and Popovitch (1974), utilizes the Gradicon digitizer, which they describe as being able to handle cephalograms and photographs as well as dental casts. For the dental cast, the digitizing apparatus consists of a dental cast holder and a dental cast digitizing pencil. The holder has upper and lower holding plates and one reference plate. The upper and lower casts are mounted on the respective holding plates by double sided adhesive tape with the occlusal plane parallel to the digitizing table or the reference plate. Both casts are digitized separately relative to a common point on the reference plate. The mandibular cast is digitized first and then the maxillary cast is inverted and digitized. The ability to vary the position of dental cast holder allows for measurements to be taken in height as well as mesio-distal width relative to the origin on the reference plate. A 3-dimensional construction of the dentition can then be made by combining the two sets of two dimension coordinates. They described the resolution and accuracy of their Gradicon digitizer as being comparable to the equipment used by other investigators. They feel its advantage, however, is in its versatility, making it possible to input coordinate data from cephalograms, facial photographs and dental casts.

Thus, with the advent of various sophisticated analytical techniques, it is now possible to obtain a significant reduction in the error of the measurement.

METHODS AND MATERIALS

CHAPTER III

METHODS AND MATERIALS

The sample consisted of 27 cases of "acceptable" occlusion selected from the 1972 study of Banack, Cleall and Yip† and a malocclusion group of 67 cases of all Angle malocclusion classifications which were made available from cases treated in the University of Manitoba Graduate Orthodontic Clinic and from the private practices of staff members. The distribution of the sample according to source is illustrated in Table I.

Criteria for case selection included: 1) availability of complete and accurate records, 2) fixed multi-band edgewise mechanotherapy of both arches, and 3) active treatment performed during periods of growth. No attempt was made to select cases on the basis of treatment results.

Orthodontic plaster model records of the orthodontically treated sample were analyzed at the following three stages of treatment: 1) pre-orthodontic treatment, 2) immediate postretention, i.e. after completion of treatment, and 3) a minimum of two years postretention.

The sample was divided on the basis of the pretreatment records into groups according to Angle's concept of occlusion. The malocclusion group was further subdivided according to whether permanent teeth were or were not extracted as an adjunct to orthodontic treatment. The distribution of the sample according to Angle's concept of occlusion is illustrated in Table II.

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† Banack, A.R., Cleall, J.F. and Yip, A.S.: Epidemiology of malocclusion in 12 year old Winnipeg school children. J. Can. Dent. Assoc., 38: 437-455, 1972.

CLASSIFICATION of SAMPLE by SOURCE

Graduate Orthodontic Clinic University of Manitoba	33
Normal Occlusion* (from the study of Drs. Banack, Cleall, Yip)	27
Dr. J.F. Cleall (private practice)	25
Dr. E. Cohen (private practice)	5
Dr. P.D. Henderson (private practice)	2
Dr. L.C. Melosky (private practice)	2
Total	94

TABLE I

Classification of Sample by Source

*The terms "acceptable" occlusion and normal occlusion will be used interchangably in this manuscript to represent cases selected from the 1972 study of Drs. Banack, Cleall and Yip.

CLASSIFICATION of SAMPLE

(according to Angle's concept of occlusion)

Normal Occlusion			27
Class I	Non-Extraction	9	23
	Extraction	14	
Class II Div 1	Non-Extraction	10	32
	Extraction	22	
Class II Div 2	Non-Extraction	5	9
	Extraction	4	
Class III	Non-Extraction	1	3
	Extraction	2	
		Total	94

TABLE II

Classification of Sample

(according to Angle's concept of occlusion)

All the model records obtained were of an adequately high quality to allow easy recognition of dental landmarks. The model trimming was evaluated only on the basis that the base of the mandibular model was parallel to the mandibular occlusal plane as defined by the mandibular central incisors and the disto-buccal cusp of the mandibular first molars. An adjustable metal plate was constructed for this evaluation purpose and any necessary trimming adjustments were performed accordingly.

Preparation of Dental Models for Analysis

The midpalatal raphe was utilized as a reproducible anatomic midline and was identified by a point on the distal aspect of the incisive papilla and an easily identifiable point on the midpalatal raphe near the fovea centralis. Other selected points were marked on the dental casts using a black Pentel 2H hard leaded pencil. In total, seventy-seven (77) landmarks were identified on both the maxillary and mandibular occlusal views (Figure 1). A detailed description of each landmark may be found in the Glossary.

The two midline points were transferred to the lower model by means of a specially designed mechanical device. The transfer device illustrated in Figure 2 consisted of a horizontal component which precisely fitted a machine vertical groove. A 25 gauge needle, sharpened at both ends, was mounted vertically at the end of the horizontal component. The midline transfer procedure consisted of bringing the maxillary and mandibular models together into full occlusion and positioning the models on the model table so that they were viewed from the posterior aspect, such that the two midline points on the maxillary model could be observed. The horizontal

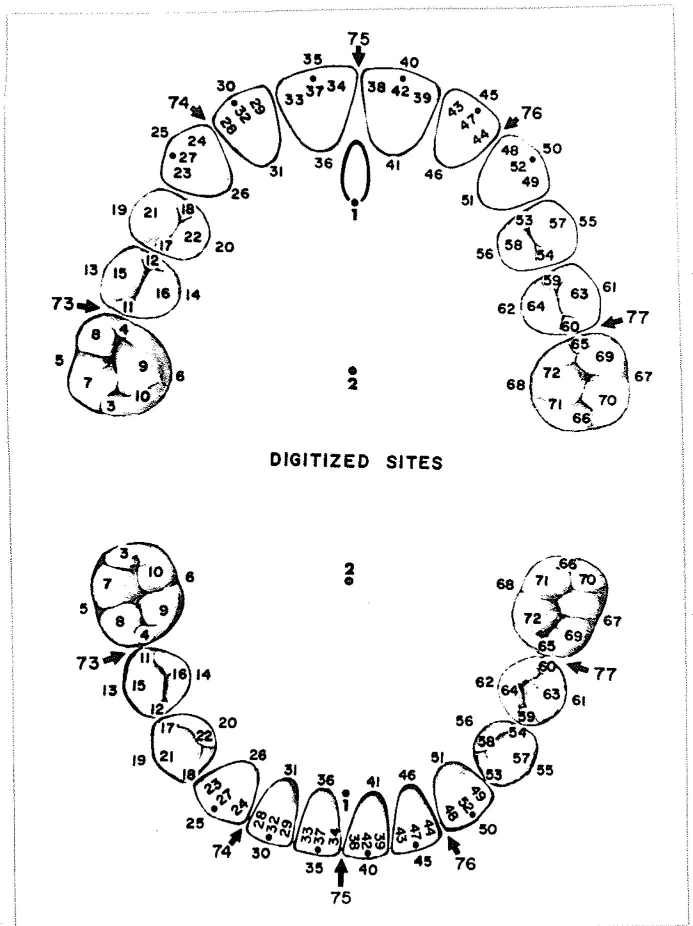

Figure 1. Seventy-seven dental landmarks on both maxillary and mandibular arches.

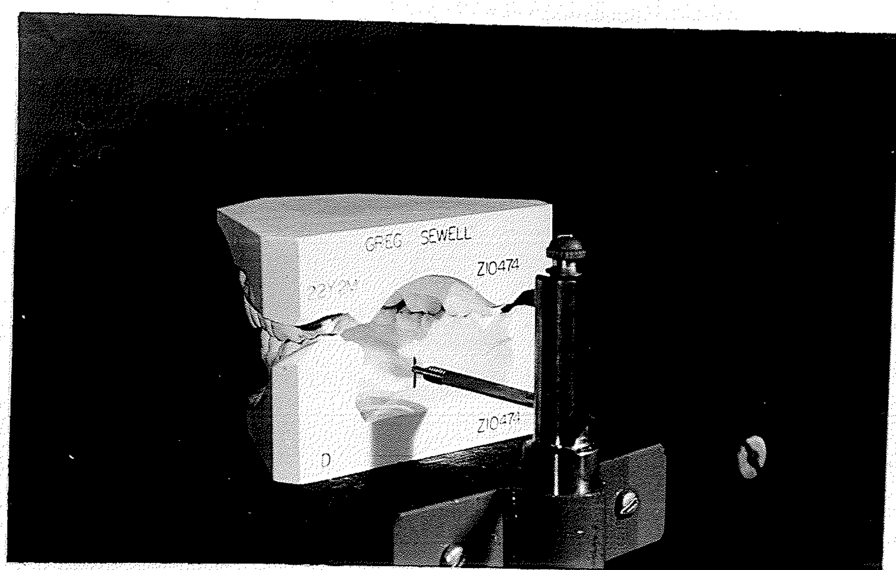

Figure 2. Mechanical transfer device

component of the transfer device was then positioned until the sharpened needle point made contact with one of the midline points. It was then locked in this position so that no further horizontal movement was possible. Subsequently, the entire horizontal component was allowed to descend along the vertical channel until it marked the lower model. The same procedure was followed for the other midline point on the mid-palatal raphe near the fovea centralis.

Two orientation points were marked on the art portion of the buccal segments of the mandibular models which enabled the utilization of a modified cinefluorographic coordinate analysis program. Ten other selected landmarks were identified on both the right and left lateral buccal segments of the models. A detailed description of these points may be found in the Glossary.

On the anterior of the dental casts, two orientation points were marked on the art portion of the model as well as five selected land-marks. A detailed description of these landmarks may be found in the Glossary.

Maintaining the models in full occlusion, they were then viewed from the anterior aspect in order to mark the models for overbite analysis. Another attachment was subsequently mounted on the horizontal component of the transfer device which consisted of a flattened, hard-leaded pencil (Figure 3). The horizontal component was then positioned so that the incisal edge of the maxillary right central incisor rested on the pencil lead and the mandibular right central incisor was marked on its labial surface.

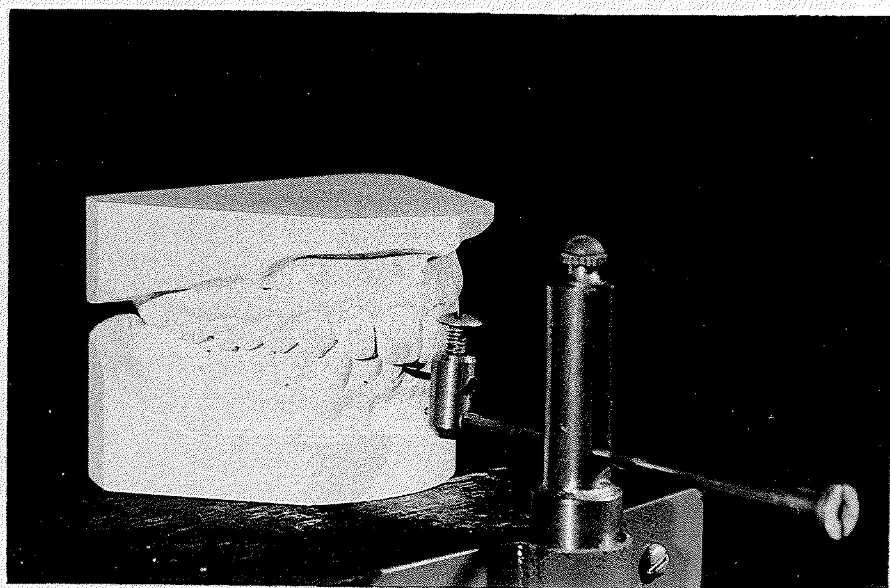

Figure 3. Overbite marking attachment mounted on transfer device.

The models were then individually photographed using a standardized photographic setup (Figure 4) consisting of a 16 mm Bolex movie camera, capable of photographing single-frame views. This was equipped with a 125 mm telephoto lens (Figure 5). Black and white commercially available Kodak 7276 Plus X reversal film was utilized. The target-film distance was 2 meters. The purpose of the telephoto lens in conjunction with the large target-film distance was to minimize the peripheral distortion encountered in the photography procedure.

The models were positioned on an adjustable mount which allowed positioning of the occlusal plane, and/or the midline construction to be either parallel and/or perpendicular to the film. In order to assist the positioning of the model, a coordinated plexiglass system scored at one-quarter inch intervals on the top and on the bottom of the positioning table was utilized. In addition, two metal plates were provided which were mounted one parallel and the other perpendicular to the film to ensure the appropriate positioning of the models for the photographic procedure (Figure 6).

The following views were then photographed of each set of records, maintaining the occlusal plane and midline construction either parallel and/or perpendicular to the film: (1) the occlusal view of the maxillary model (Figure 7), (2) the occlusal view of the mandibular model (Figure 8), (3) the right lateral view, unoccluded and occluded (Figure 9), (4) the left lateral view, unoccluded and occluded (Figure 10) and (5) the anterior view, unoccluded and occluded (Figure 11).

The film was then processed by a local commercial firm[1]. The

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1 Ken Davey Productions, Winnipeg, Manitoba, Canada

Figure 4. Overview of standardized photographic setup.

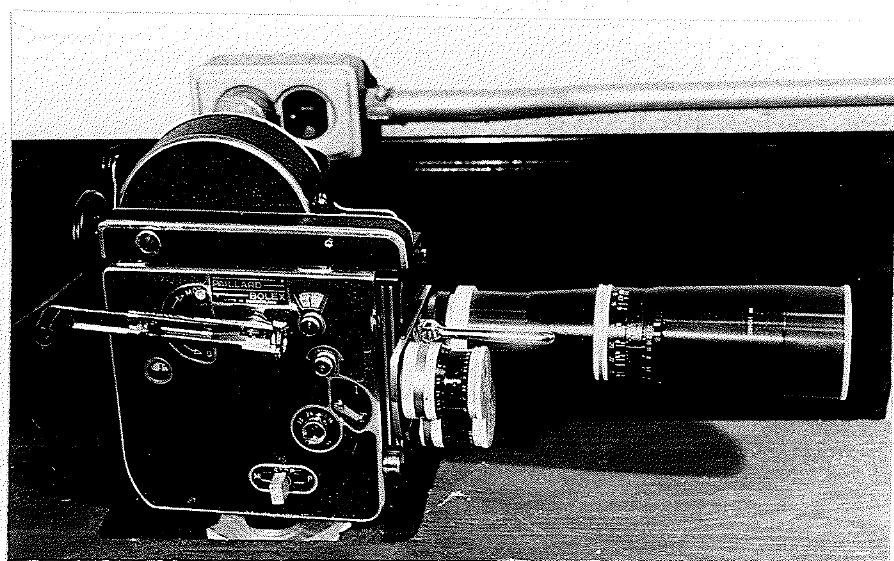

Figure 5. 16 mm Bolex movie camera with 125 mm telescopic lens.

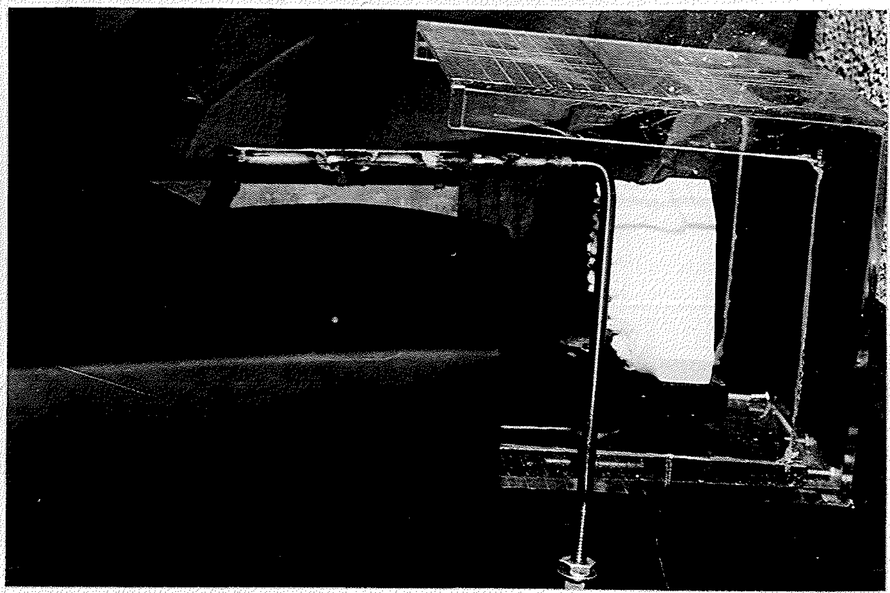

Figure 6. View of adjustable model positioning platform with coordinated plexiglass system.

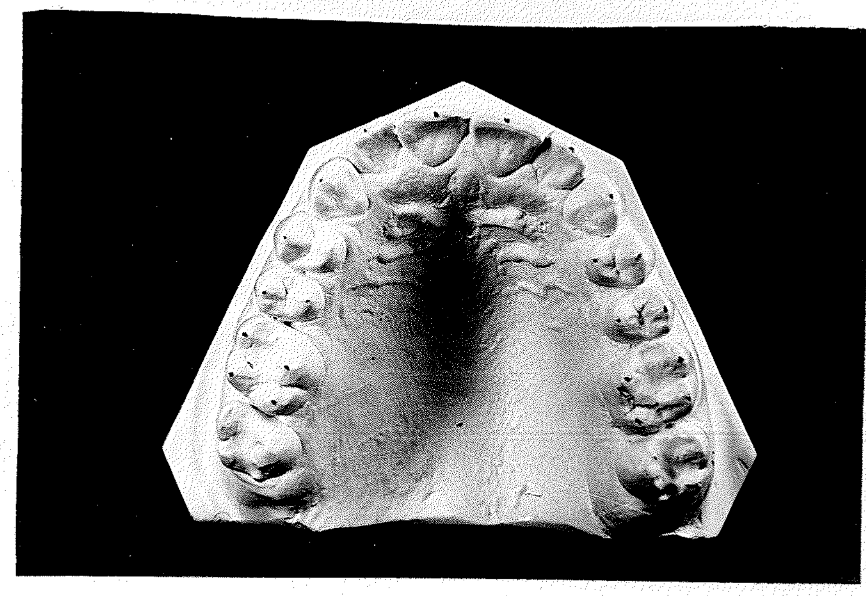

Figure 7. Occlusal view of maxillary dental arch.

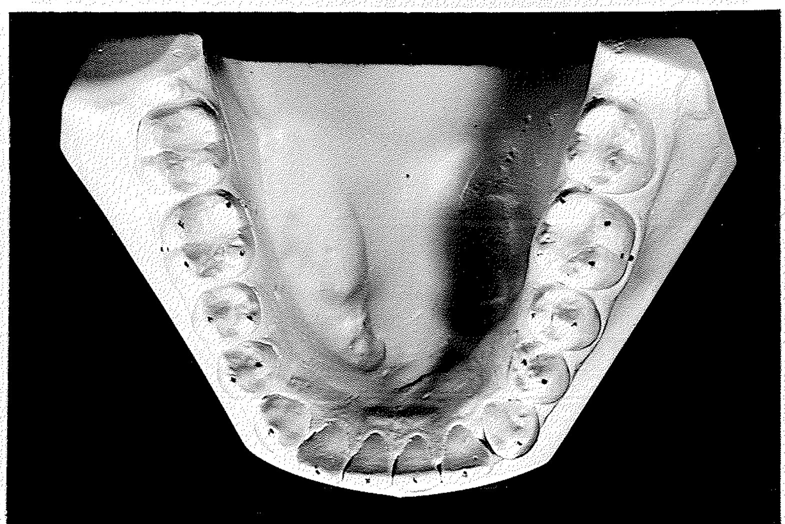

Figure 8. Occlusal view of mandibular dental arch.

Figure 9. Right lateral view (a) unoccluded.

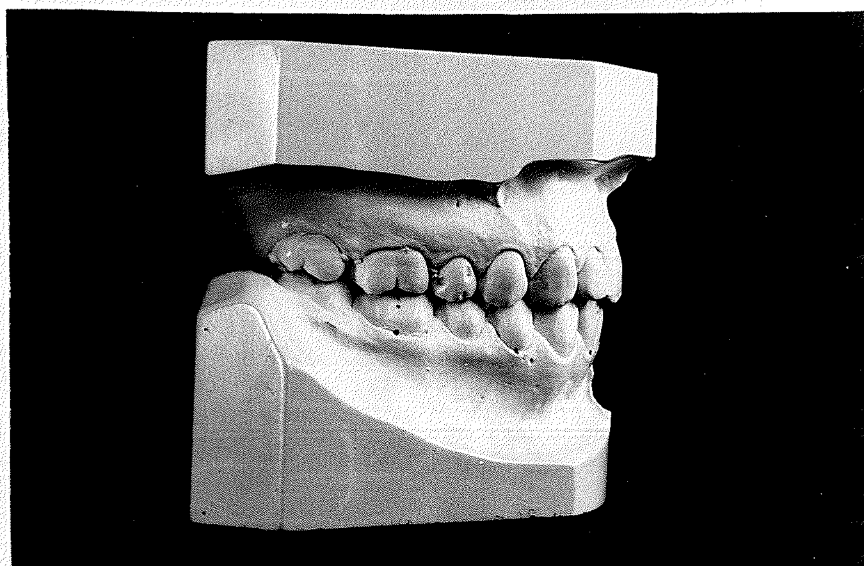

Figure 9. Right lateral view (b) occluded.

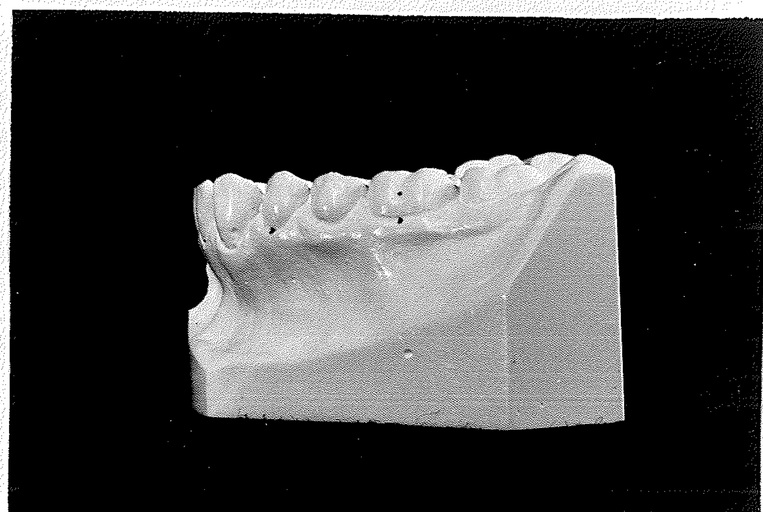

Figure 10. Left lateral view (a) unoccluded

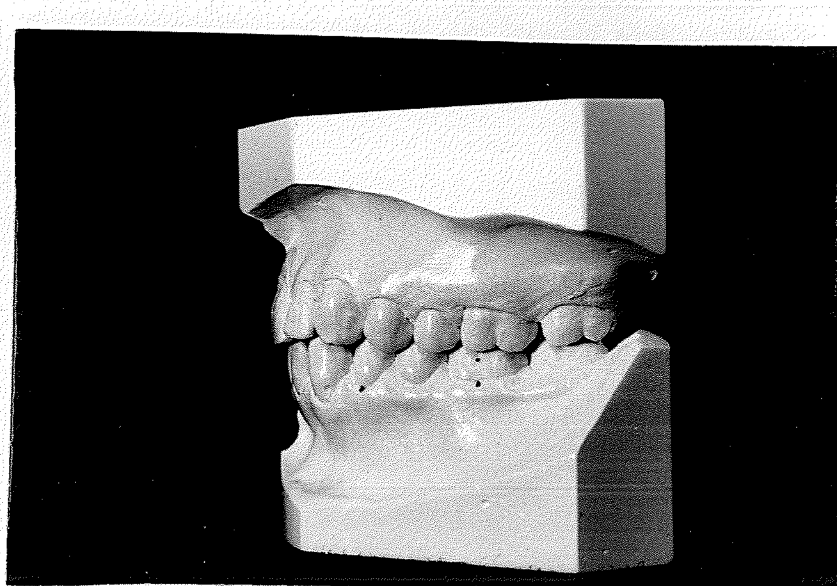

Figure 10. Left lateral view (b) occluded.

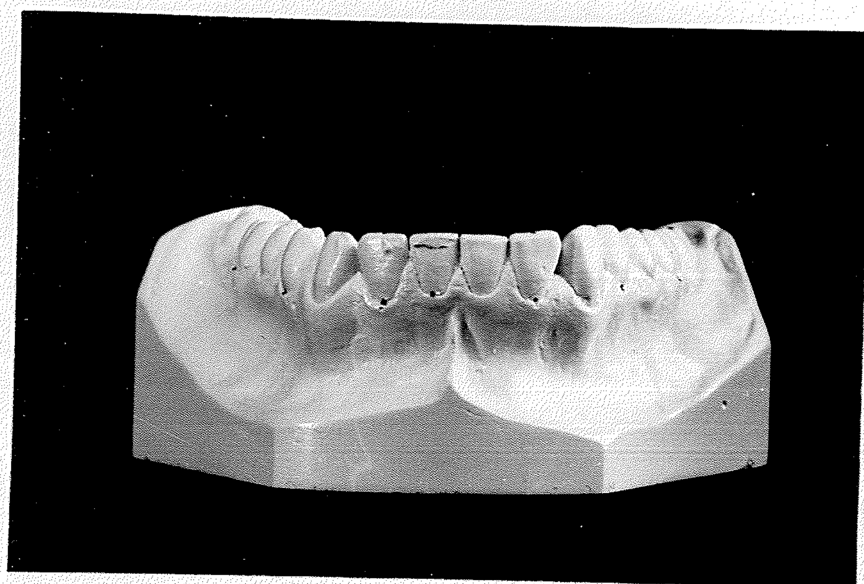

Figure 11. Anterior view (a) unoccluded.

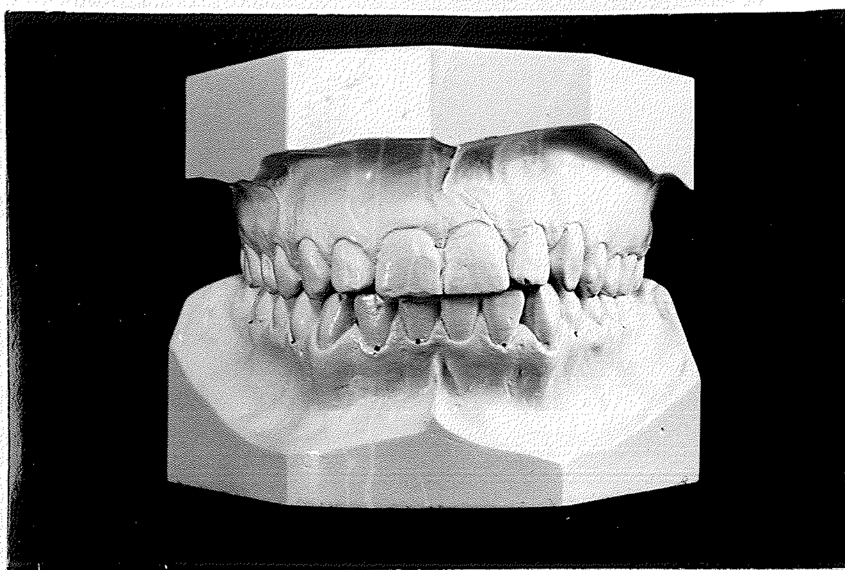

Figure 11. Anterior view (b) occluded.

advantage of the one step processing Reversal type film eliminated any processing enlargement encountered with the conventional two step processing methods.

The processed film was then projected using a Tagarno 16 film editor* and digitized, frame by frame. The selected points were digitized using Ruscom** logistics strip chart digitizer and the X and Y coordinates of the landmarks were punched directly on cards using an IBM*** Keypunch machine (Figure 12).

The cartesian data for the maxillary and mandibular occlusal views was then subjected to a coordinate analysis program (Cleall and Chebib, 1971) which standardized the coordinates for each point and calculated selected distances and angles between points as well as listed these distances for each subject plus their means and standard deviations.

For the right and left lateral views and the anterior views a modified cinefluorographic coordinate analysis program was utilized to allow the computer to mathematically superimpose the maxillary dental model over the mandibular model. This program was also capable of standardizing the coordinates for each point and calculating selected distances and angles between the points.

Symmetry

In order to quantify the degree of asymmetry of the dental arches of both the "acceptable" occlusion and the three stages of treatment of

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* Phillips Electronic Equipment Ltd., Winnipeg, Manitoba, Canada

** Ruscom Logics Limited, Rexdale, Ontario, Canada

*** IBM, Don Mills, Ontario, Canada

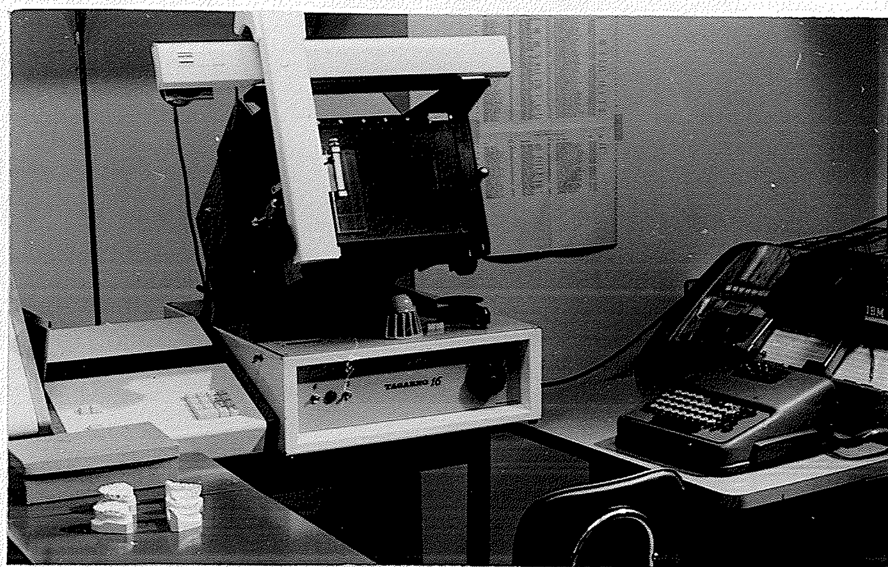


Figure 12. Ruscom logistics strip chart digitizer and IBM keypunch machine.

the malocclusion groups, three indices were developed to assess symmetry utilizing the following seven dental landmarks: (1) the mid-incisal edge of the central incisor, (2) the mid-incisal edge of the lateral incisor, (3) the cusp tip of the cuspids, (4) the buccal cusp tip of the first premolar, (5) the buccal cusp tip of the second premolar, (6) the mesio-buccal cusp tip of the first molars, and (7) the disto-buccal cusp tip of the first molars. The maxillary and mandibular dental arches were examined independently.

Symmetry Index 1: Consisted of the summation $(\text{right minus left})^2$ of the perpendicular distance from the tooth sites to the constructed midlines (Figure 13).

Symmetry Index 2: Consisted of the summation $(\text{right minus left})^2$ of the linear distances from the tooth sites to the distal aspect of the incisive papilla or its corresponding point on the mandibular arch (Figure 14).

Symmetry Index 3: Consisted of the summation $(\text{right minus left})^2$ of the angular dimension from the tooth sites to the midline construction utilizing the distal aspect of the incisive papilla or its corresponding point on the mandibular model as the vertex of the angle (Figure 15).

The values were computed for both the maxillary and mandibular arch for the "acceptable" occlusion group and the sets of records obtained at the three stages of treatment for the malocclusion groups.

To quantify the degree of asymmetry the values were computed by a specially designed computer program developed by this author in conjunction with Dr. F. S. Chebib, Biostatistician, Department of Preventive Dental Science, Faculty of Dentistry, University of Manitoba.

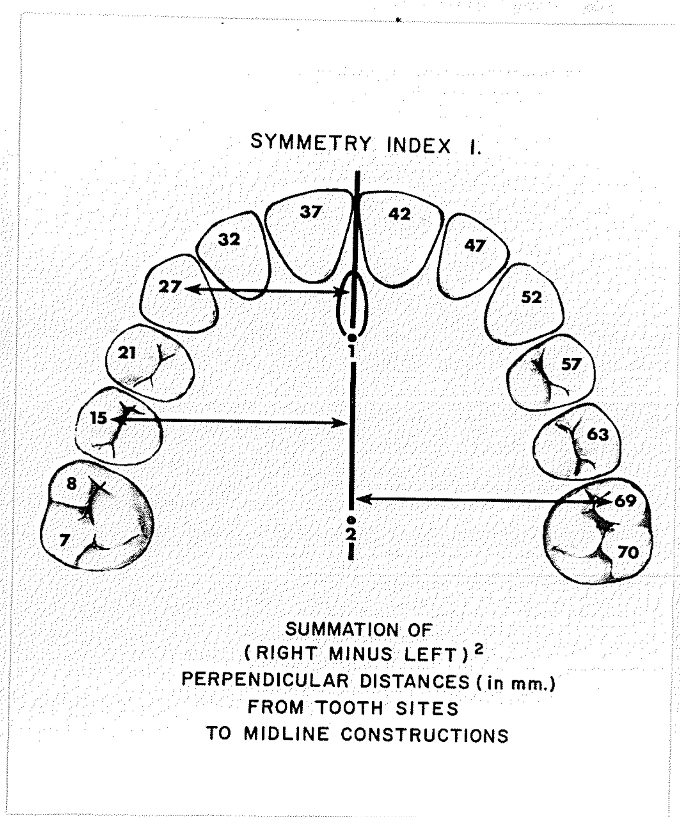


Figure 13. Symmetry Index 1: (a) Maxillary dental arch.

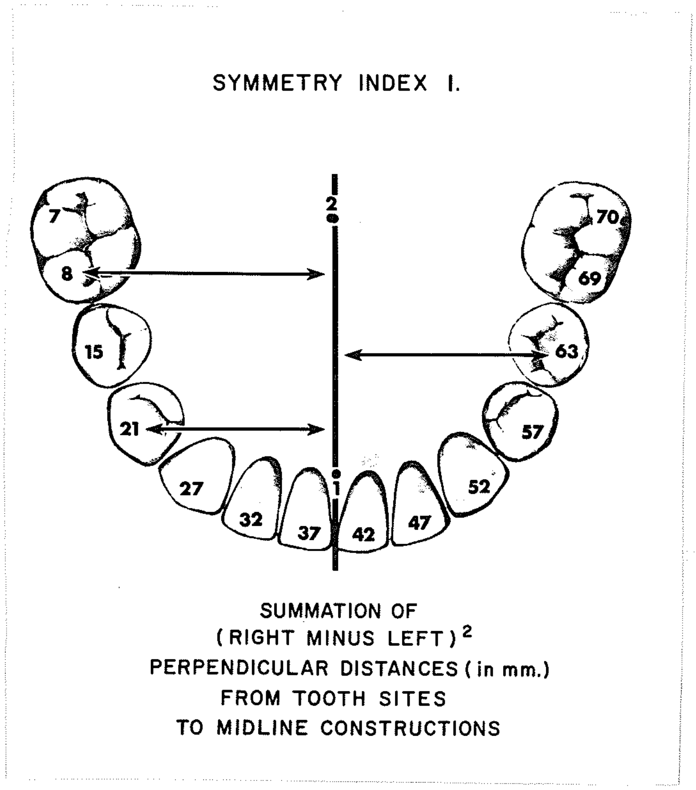


Figure 13. Symmetry Index 1: (b) Mandibular dental arch.

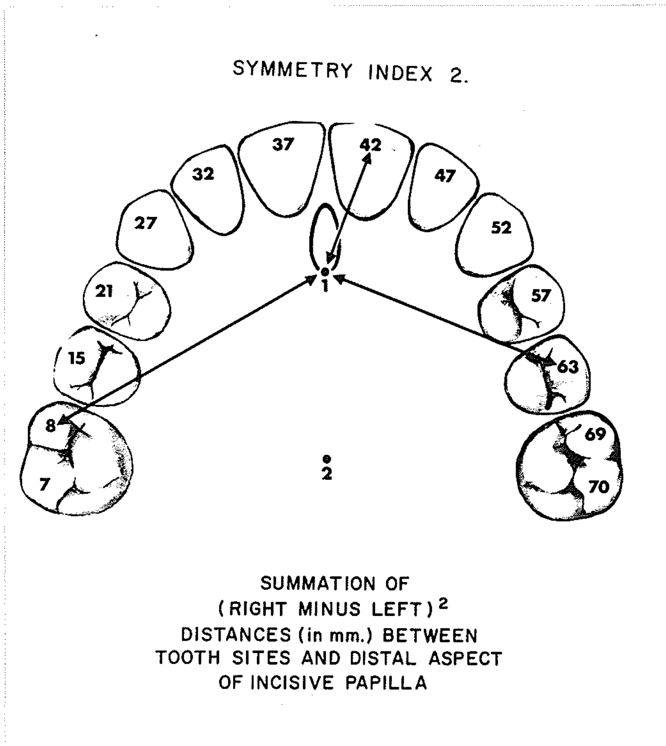


Figure 14. Symmetry Index 2: (a) Maxillary dental arch.

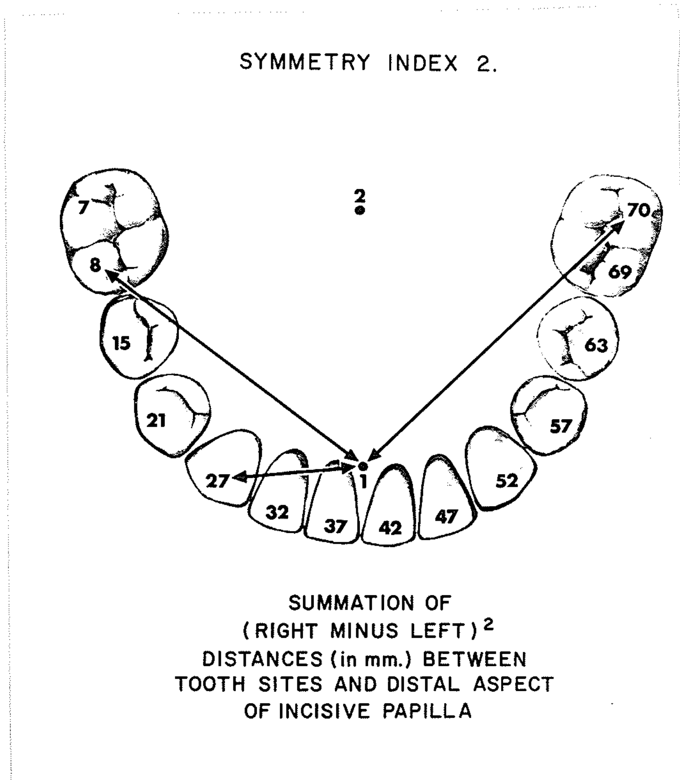


Figure 14. Symmetry Index 2: (b) Mandibular dental arch.

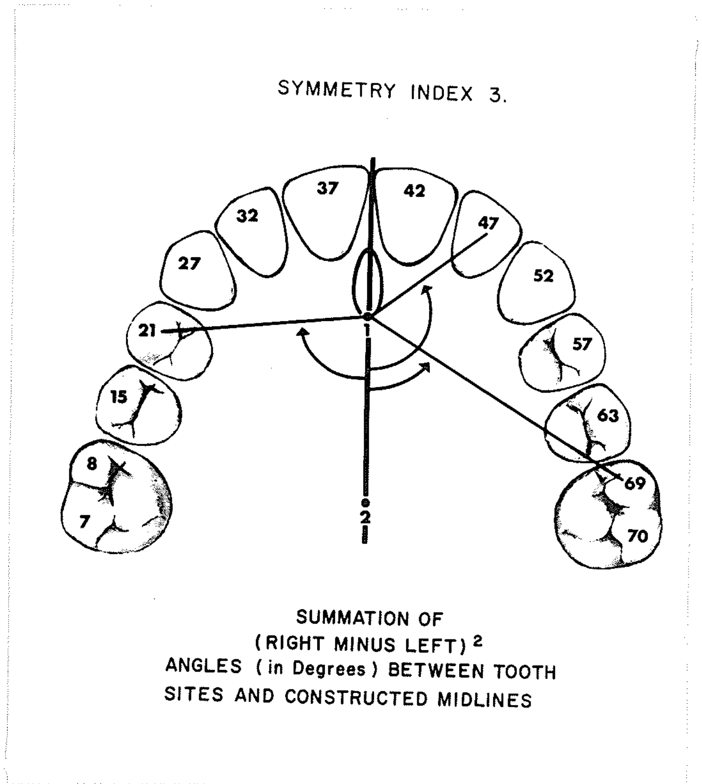


Figure 15. Symmetry Index 3: (a) Maxillary dental arch.

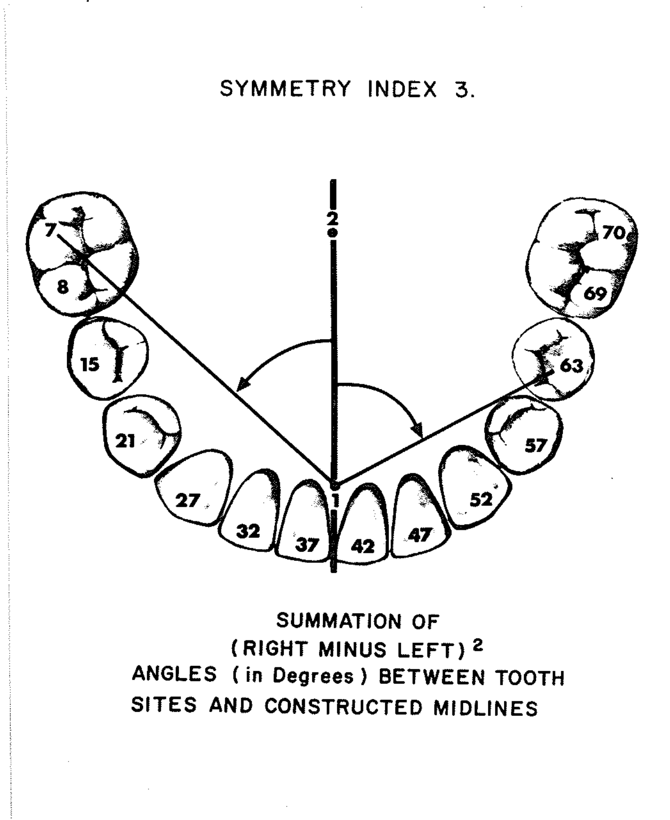


Figure 15. Symmetry Index 3: (b) Mandibular dental arch.

The output of the previously described coordinate analysis program was used. The purpose of squaring the (right minus left) values was twofold: (1) To eliminate any negating sidedness influence at the individual sites, thus recording the total maximum asymmetry value, and (2) to deal with only positive values. Symmetry index values approximating zero indicated near perfect symmetry of the dental arch.

In an effort to assess the sidedness of the dental arch, the three Symmetry Index computations were repeated calculating the summation of (right minus left) for the seven dental landmarks. A positive value indicated an overall right side bias, and a negative symmetry value indicated a left side asymmetry bias.

Each of the seven individual sites for all stages of treatment were then analyzed separately for Symmetry Index 1 and 2 in an effort to identify which site may have been most responsible for the original asymmetry, and which site may have had the greatest tendency to relapse in the postretention period.

Intertooth Arch Widths

To analyze the effect of treatment, and recovery in the postretention period on changes in intertooth arch widths, the intertooth arch widths were computed independently for both the maxillary and mandibular arches at all three stages of treatment. Measurements were computed for each tooth site except for the second molars (Figure 16). Both the mid-incisal edge or cusp tip dental landmarks as well as a palatal point were utilized in an attempt to differentiate between relapse tendencies resultant from tipping as compared to bodily tooth

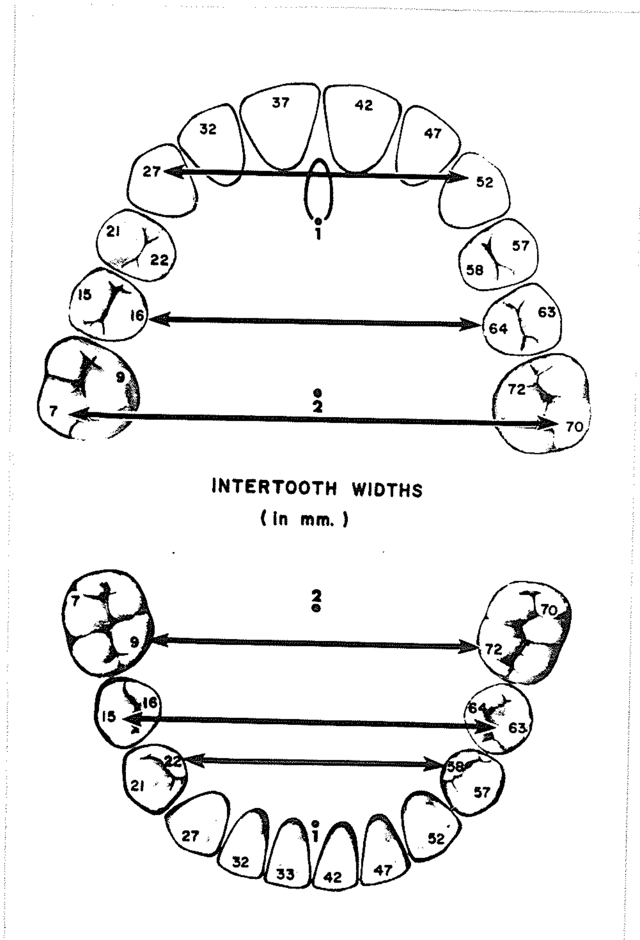


Figure 16. Intertooth widths (in mms).

movement. In the posterior segment, to eliminate the effect of rotation correction, both the buccal cusp tip and the palatal cusp tip intertooth arch widths were compared.

Arch Length

Arch length was represented as the distance between a point tangent to the mesio-labial incisal edges of the central incisors and a line joining the mesial surfaces of the first permanent molars. Values were then computed for the "acceptable" occlusion sample as well as the three stages of records obtained during the treatment of the malocclusion groups (Figure 17).

Curve of Spee

The lateral view projections were used to compute values for the depth of the curve of Spee. The line of occlusion was defined as a line joining the incisal edge of the lower central incisor to the disto-buccal cusp tip of the first permanent molar. Utilizing a modified cinefluorographic coordinate analysis program the depth of the curve of Spee was then calculated as the perpendicular distance to the line of occlusion from the following sites: (1) The cusp tip of the cuspid, (2) the buccal cusp tip of the first premolar, (3) the buccal cusp tip of the second premolar, and (4) the mesio-buccal cusp tip of the first molar. The same procedure was employed on both right and left lateral view projections (Figure 18).

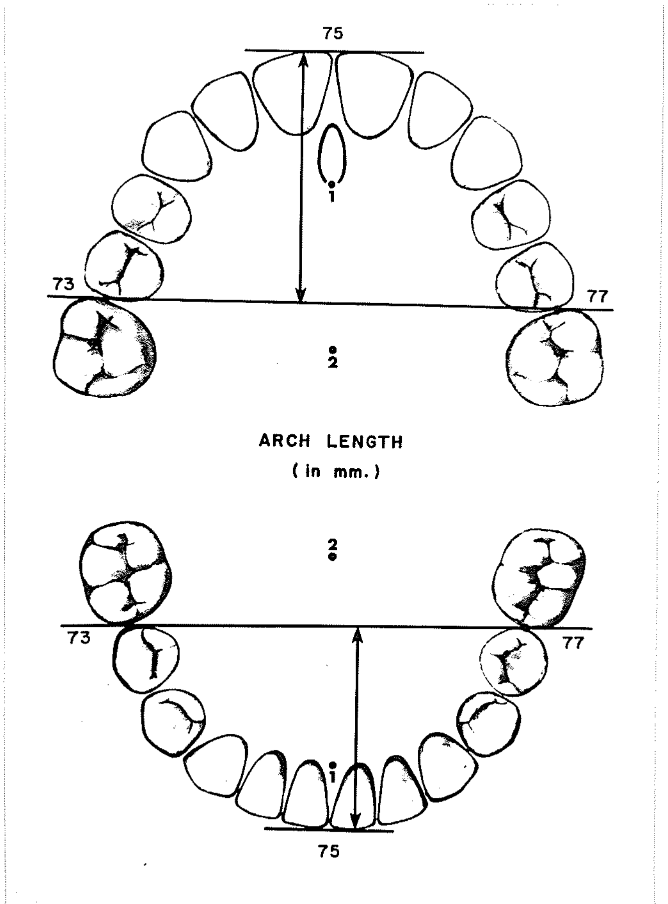


Figure 17. Arch length (in mms).

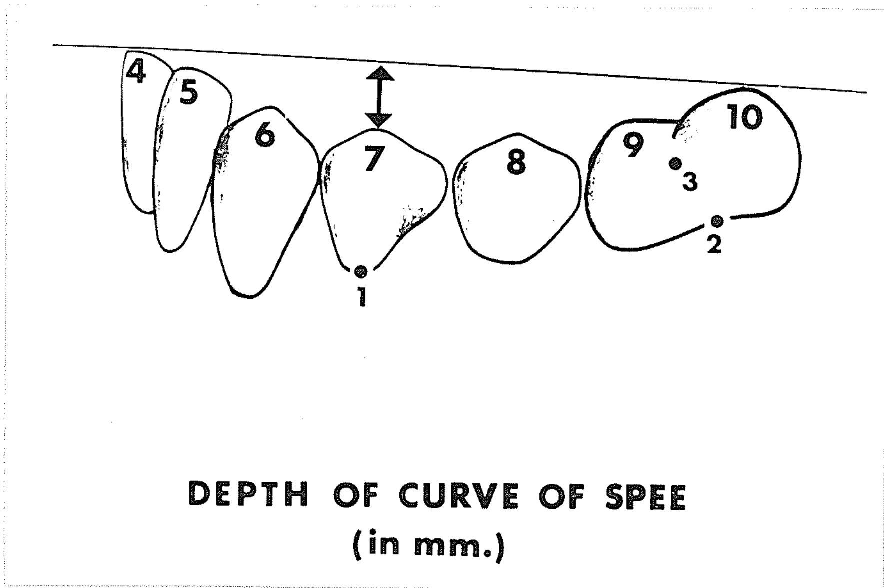


Figure 18. Depth of curve of Spee (in mms).

Cuspid and Molar Relationship

Utilizing the same mathematical computer superimposition technique, the cuspid relationship was computed as the linear horizontal difference in millimeters between the cusp tip of the maxillary cuspid and the cusp tip of the mandibular cuspid along the occlusal plane previously identified.

The molar relationship was computed as the linear horizontal difference in millimeters along the occlusal plane between the mesiobuccal cusp tip of the maxillary first molar and a point representing the buccal groove of the mandibular first molar (Figure 19).

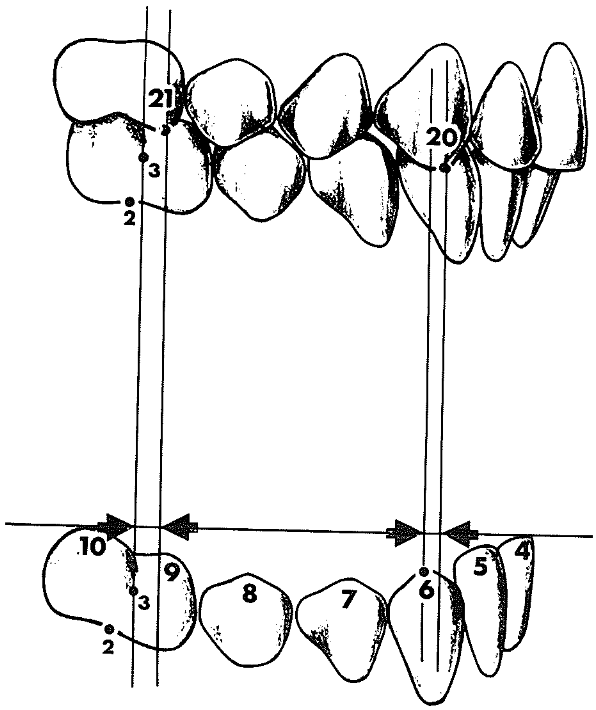
Values were then computed for both the "acceptable" occlusion sample as well as the three stages of treatment records for the malocclusion group.

Overbite

Using the modified cinefluorographic coordinate analysis superimposition technique on the anterior view, overbite was measured as the degree of vertical overlap of the maxillary right central incisor over the mandibular right central incisor. The actual linear distance of overlap was computed in millimeters. Values were computed for both the "acceptable" occlusion sample as well as the three stages of treatment of the malocclusion group (Figure 20).

Denture Midline Discrepancy

The denture midline discrepancy was measured on the anterior



MOLAR and CUSPID RELATIONSHIP
(in mm.)

Figure 19. Cuspid and molar relationship (in mms).

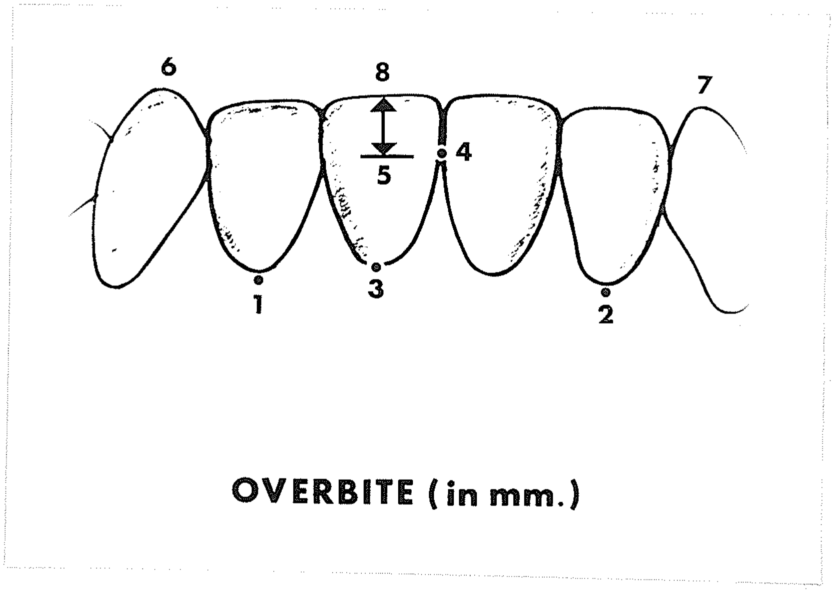


Figure 20. Overbite as measured in millimeters.

view projection. It was identified as the horizontal difference in millimeters between points representing the maxillary and mandibular denture midlines measured along the line representing the occlusal plane which joined the cusp tips of the mandibular cuspids (Figure 21).

Overjet

Overjet was the only manually calculated dimension and was measured by the use of a straight rule calibrated in millimeters. It was measured as the distance between the labial surfaces of the mandibular right central incisor and the incisal edge of the maxillary right central incisor and was measured to the nearest 0.25 mm. A positive sign represented positive overjet and a negative sign represented negative overjet.

Arch Form

A curve fitting procedure was employed on the 27 "acceptable" occlusion samples. Two curves were attempted, the first consisting of the 14 dental landmarks utilized in the Symmetry Index computations and then points representing the facial periphery of the dental units mesial to and including the first molars were selected upon which to apply the curve fitting procedure. The following mathematical curves ranging from the equation for a parabola to polynominal equations to the sixth power were "curve fitted" to the "acceptable" occlusion sample. The curve fitting procedure was done by a computer program designed by this author in conjunction with Mr. K. Carpenter, Biostatistician, Department of

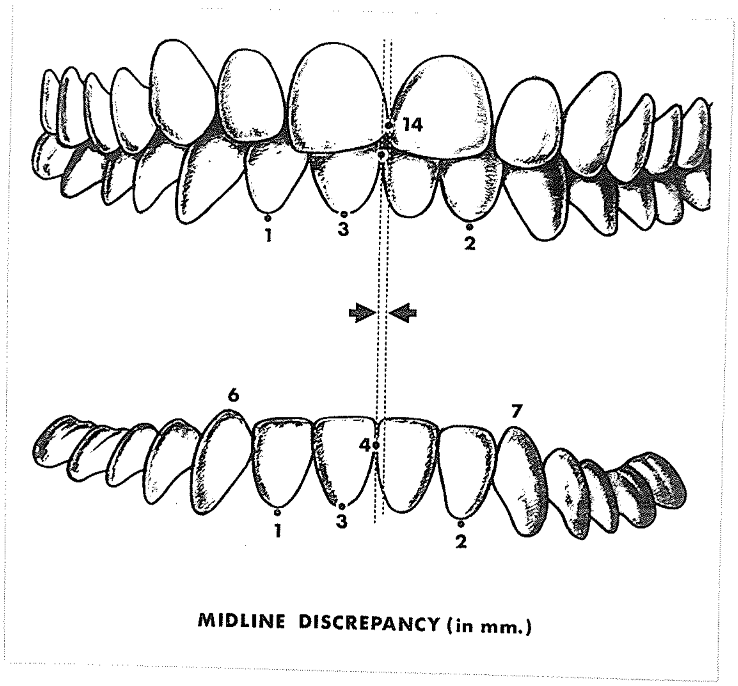


Figure 21. Midline discrepancy (in mms).

Preventive Dental Science, Faculty of Dentistry, University of Manitoba, using a SPSS[1] multiple regression program.

Statistical Treatment of the Data

The data was processed by the IBM 360-65 computer system at the University of Manitoba. The maxillary and mandibular occlusal views were analyzed utilizing the coordinate analysis program of Cleall and Chebib (1971). The right and left lateral view projections as well as the anterior view projection were analyzed applying a modified cinefluorographic analysis program.

The values obtained for the Symmetry Indices and the other orthodontic variables for the "acceptable" occlusion sample as well as the preorthodontic treatment group sample were subjected to an analysis of variance program. This program compared the "acceptable" occlusion sample with the preorthodontic treatment values of the malocclusion groups, and produced "F" values which were evaluated for a statistical significance at the 5 percent, 1 percent and 0.1 percent levels of confidence.

To assess the results of orthodontic treatment and any relapse tendency in the postretention period, the values computed for the three stages of treatment for the malocclusion groups, were subjected to a mixed analysis of variance program. "F" values were produced for the malocclusion groups by stage of treatment interaction. These values were then evaluated for statistical significance at the 5 percent, 1 percent and 0.1 percent levels of confidence. When required, the results were further evaluated

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1 Statistical Package for the Social Sciences, Stanford University, Stanford, California, U.S.A.

by the use of a multiple range test comparing the results for significance at the 5 percent and 1 percent confidence levels.

Error of the Method

The error of the method was evaluated by marking, mounting, photographing and then subsequently digitizing five sets of models on three separate occassions, and comparing selected linear and angular results for accuracy. The linear distances were accurate within plus or minus 0.1 mm and the angular dimensions were accurate within plus or minus 1.5 degrees, with 95 percent certainty.

RESULTS

CHAPTER IV

RESULTS

Dental Arch Asymmetry

Significant differences were noted between the "acceptable" occlusion sample and zero, which represented complete symmetry, when a 't' test was employed, indicating that the "acceptable" occlusion sample demonstrated dental arch asymmetry. This value was found to be statistically significant at the 1 percent confidence level.

Comparison of the values of the three Symmetry Indices for the pretreatment malocclusion group and the "acceptable" occlusion sample is graphically represented in Figures 22 and 23 comparing the mean values for Symmetry Index 1 and Symmetry Index 2, respectively. Table III represents the comparison of the "acceptable" occlusion sample for Symmetry Index 3 with that of the preorthodontic treatment group values. These results indicated that for both maxillary and mandibular arches and for all three Symmetry Indices, the "acceptable" occlusion group differed significantly at the 0.1 percent level from the pretreatment malocclusion group values.

Further statistical analysis, however, utilizing a multiple range test, indicated that the malocclusion groups did not differ significantly from each other because of the high standard deviations. Thus, it may be concluded that dental arch asymmetry is distributed randomly and independent from Angle's malocclusion classifications.

When the stages of treatment of the malocclusion groups were

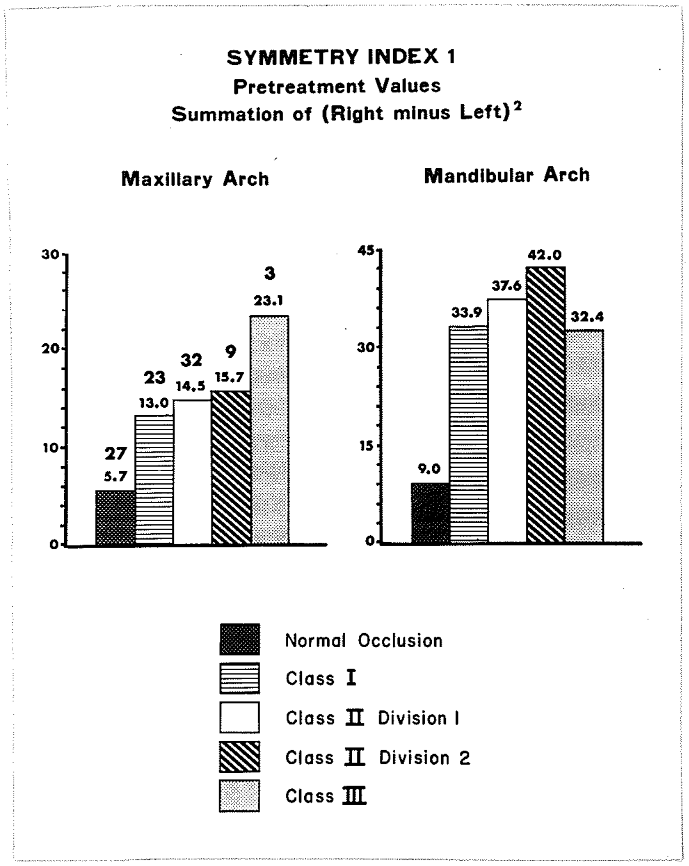

Figure 22. Graphic representation of values for Symmetry Index 1 for both maxillary and mandibular arches comparing the "acceptable" occlusion sample and the preorthodontic treatment sample, divided according to Angle's concept of occlusion.

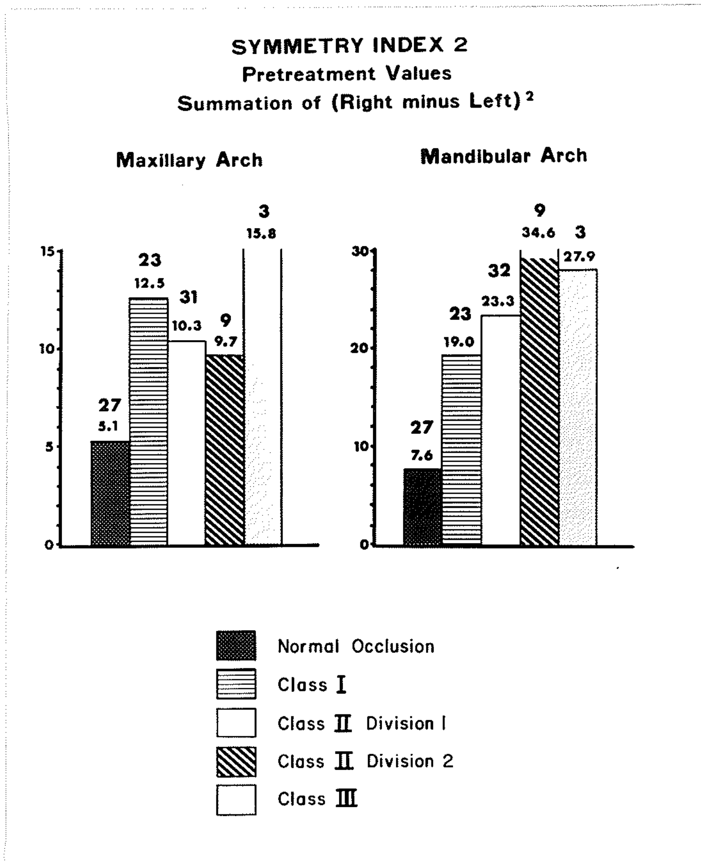

Figure 23. Graphic representation of values for Symmetry Index 2 for both maxillary and mandibular arches comparing the "acceptable" occlusion sample and the preorthodontic treatment sample, divided according to Angle's concept of occlusion.

Symmetry Index 3

$(\text{right} - \text{left})^2$

	Maxillary Arch		Mandibular Arch	
	Mean	Standard Error	Mean	Standard Error
"Acceptable" Occlusion (27)	32.94	3.57	38.09	4.70
Class I (23)	106.63	27.12	514.33	125.23
Class II Division 1 (32)	118.50	29.34	443.57	93.61
Class II Division 2 (9)	152.52	33.74	637.87	218.36
Class III (3)	98.24	85.72	316.75	74.62

TABLE III Symmetry Index 3 values for both maxillary and mandibular arches: means and standard errors between the "acceptable" occlusion sample and the preorthodontic treatment sample as divided according to Angle's concept of occlusion.

analyzed comparing the pretreatment, immediate postretention and the minimum of two years postretention values, the results were also highly statistically significant at the 0.1 percent level. A close appraisal of the data, however, indicated that during active treatment one of two changes were affected in the symmetry of the dental arch. This indicated that either the arches were being made more symmetrical, which occurred in approximately 84 percent of the sample, or were made increasingly asymmetrical during the active treatment period, in approximately 16 percent of the sample. In order that these two groups would not have a negating influence on each other they were examined separately. Thus, the total malocclusion group was then redivided according to the effect of treatment on the symmetry of the dental arches indicated by the Symmetry Index values. The groups were also further subdivided according to whether an extraction or nonextraction therapy procedure had been followed during active treatment.

The trends for the stage of treatment values were consistent for all three Symmetry Indices in that the dental arch asymmetry tended to return toward the pretreatment asymmetry value in the postretention period. Specifically, the Symmetry Index 1 values demonstrated that the pretreatment mean values differed from the immediate postretention values at the 0.1 percent significance level. Also, the immediate postretention values differed from those values obtained from records a minimum of two years postretention at the 1 percent significance levels for both the maxillary and mandibular arches (Figure 24). This trend was also consistent for those cases which during the treatment the dental arch was

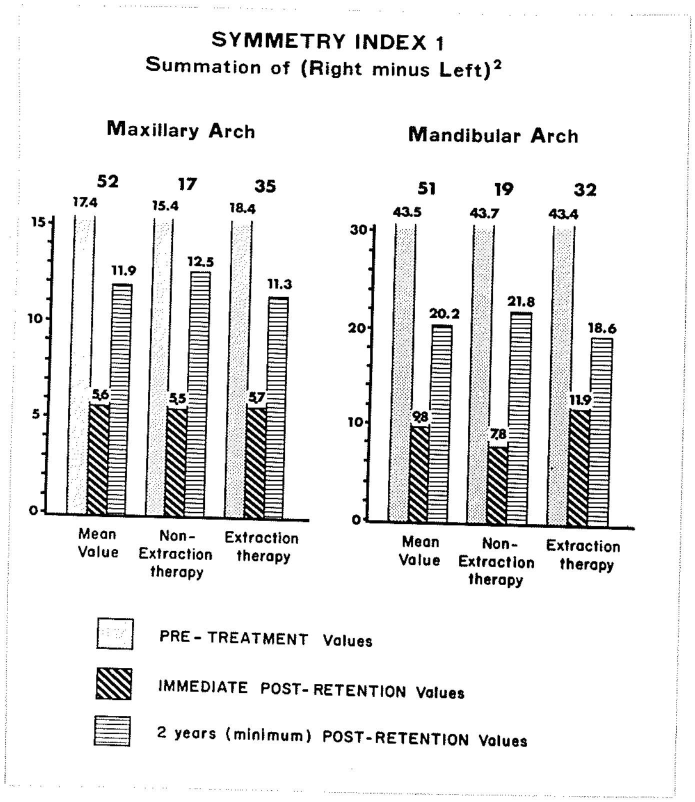

Figure 24. Graphic representation of Symmetry Index 1 values for both maxillary and mandibular arches comparing the three stages of treatment for those cases made more symmetrical during active treatment.

made more asymmetrical. The pretreatment value differed from the immediate postretention value at the 0.1 percent level while the immediate postretention value differed from the two year postretention value at the 1 percent level (Figure 25). The only inconsistency of this finding for Symmetry Index 1 occurred in the mandibular arch in the nonextraction therapy group in which the mean value in the two year postretention group became increasingly asymmetrical during the post-retention period.

The values for both maxillary and mandibular arches, as indicated by Symmetry Index 2, for those cases which were made more symmetrical during treatment, indicated that the pretreatment values differed from the immediate postretention values at the 0.1 percent level, while the immediate postretention values differed from the two year postretention values at the 1 percent level. This finding was consistent for both the maxillary and mandibular arches for both extraction and nonextraction therapy procedures (Figure 26). For those cases which were made more asymmetrical during treatment, the trend was consistent and the pretreatment values differed from the immediate postretention value at the 0.1 percent level. The values computed for the maxillary arch indicated that the immediate postretention values differed from the two year postretention values at the 0.1 percent level. In the mandibular arch, the immediate postretention value differed from the two year postretention value at the 5 percent significance level (Figure 27).

Symmetry Index 3, the computation of angular symmetry dimension, was supportive of the other Symmetry Indices indicating that the pretreatment values differed from the immediate postretention value at the

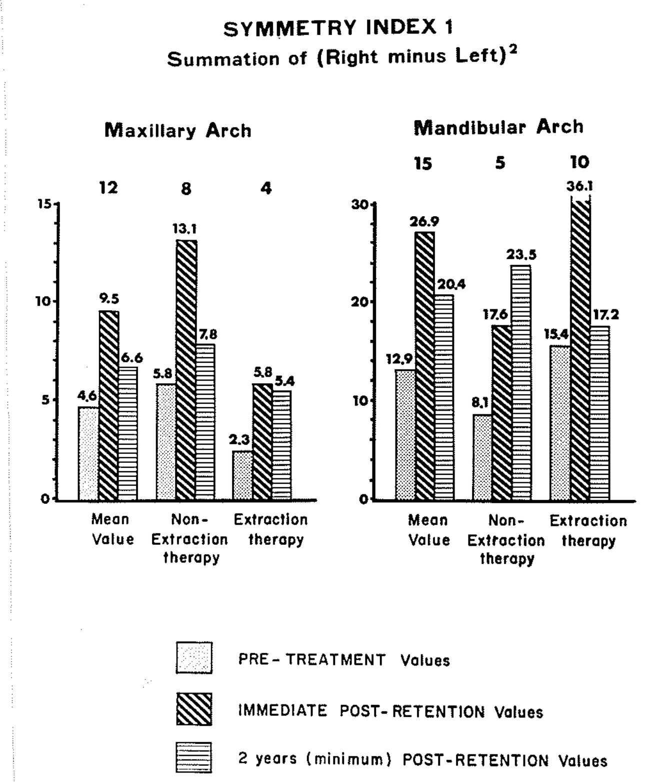

Figure 25. Graphic representation of Symmetry Index 1 values for both maxillary and mandibular arches comparing the three stages of treatment for those cases made more asymmetrical during active treatment.

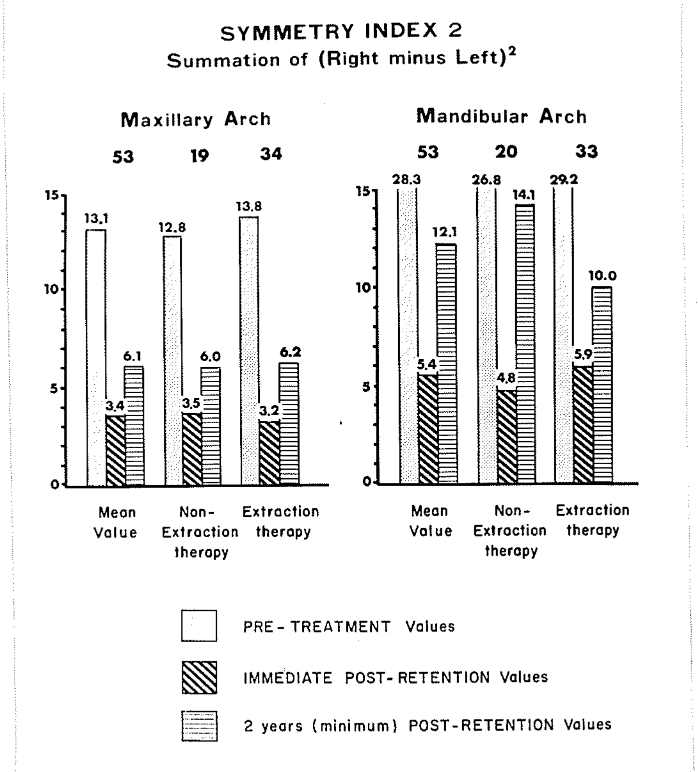

Figure 26. Graphic representation of Symmetry Index 2 values for both maxillary and mandibular arches comparing the three stages of treatment for those cases made more symmetrical during active treatment.

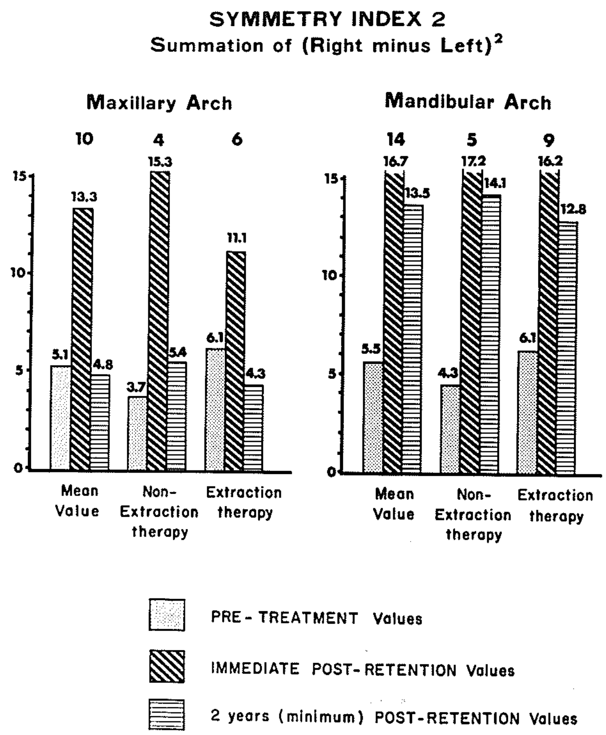

Figure 27. Graphic representation of Symmetry Index 2 values for both maxillary and mandibular arches comparing the three stages of treatment for those cases made more asymmetrical during active treatment.

1 percent confidence level for those cases which were made more symmetrical during the treatment procedure (Table IV).

Those cases in which the dental arch was made more asymmetrical during treatment according to Symmetry Index 3 were also consistent with the trend toward the return to the pretreatment asymmetry value during the postretention period. The pretreatment values differed from the immediate postretention mean values at the 0.1 percent confidence level while the two year postretention value differed from the immediate postretention value at the 5 percent confidence level (Table V).

Regardless of Symmetry Index, the higher order extraction/non-extraction therapy by stage interactions were not statistically significant. This indicated that extraction per se did not affect the degree of posttreatment symmetry stability. Another interesting finding was that the mandibular asymmetry values were consistently higher than the maxillary asymmetry values for all three Symmetry Indices at all three stages of treatment.

The data was evaluated to ascertain the percentage of cases which tended to return toward their pretreatment values in the postretention period. It was found, for both arches, maxillary and mandibular, and for all three Symmetry Indices that more than 70 percent of the cases demonstrated this trend to return toward their pretreatment values in the postretention period (Figure 28).

The mean values representing the sidedness of the dental arches for Symmetry Index 1, 2 and 3 for both the maxillary and mandibular arches are graphically illustrated in Figures 29, 30 and 31. The results indicated that asymmetries were randomly divided according to right and

SYMMETRY INDEX 3

Summation of (Right minus Left)^2

		Pretreatment	Immediate Post-Retention	2 years (minimum) Post-Retention
Maxillary Arch	Mean Value (50)	265.5	83.1	133.3
	Non-Extr'n. (15)	289.3	116.3	148.6
	Extraction (35)	255.4	49.8	118.1
Mandibular Arch	Mean Value (50)	506.1	93.5	135.8
	Non-Extr'n. (20)	575.4	76.8	242.5
	Extraction (30)	626.5	110.5	200.7

TABLE IV Mean Symmetry Index 3 values for both maxillary and mandibular arches for those cases made more symmetrical during active treatment.

SYMMETRY INDEX 3

Summation of (Right minus Left)^2

		Pretreatment	Immediate Post-Retention	2 years (minimum) Post-Retention
Maxillary Arch	Mean Value (12)	77.6	199.2	131.2
	Non-Extr'n. (9)	67.1	153.3	123.8
	Extraction (3)	109.3	245.1	138.6
Mandibular Arch	Mean Value (16)	123.1	227.8	117.8
	Non-Extr'n. (5)	107.9	201.8	129.1
	Extraction (11)	129.9	253.6	206.5

TABLE V Mean Symmetry Index 3 values for both maxillary and mandibular arches for those cases made more asymmetrical during active treatment.

Trend to Return to Pre-treatment Values (in %)

Summation (Right minus Left)^2

	Maxillary Arch	Mandibular Arch
Symmetry Index 1	76.1	83.3
Symmetry Index 2	78.8	77.6
Symmetry Index 3	74.3	78.8

Figure 28. The number of cases expressed in percent which tended to return toward their pretreatment values in the postretention period for both maxillary and mandibular arches for the three Symmetry Indices.

left side biases.

The values for Symmetry Index 1 for both the maxillary and mandibular arch indicated that the pretreatment values differed from the immediate postretention values at the 0.1 percent confidence levels. Also, the two year postretention values differed from the immediate postretention value at the 1.0 percent confidence level. The exception was the maxillary left side asymmetry bias in which the pretreatment value differed from the immediate postretention value at the 1 percent level while the immediate postretention value did not differ statistically from the immediate postretention value (Figure 29).

The mean values for Symmetry Index 2 (Figure 30) indicated for the maxillary arch right side asymmetry bias that the pretreatment values differed from the immediate postretention values at the 5 percent level. By contrast, the two year postretention value did not differ statistically from the immediate postretention value. For the left side maxillary arch asymmetry bias, the pretreatment values differed from the immediate postretention values at the 0.1 percent confidence level. Furthermore, the two year postretention value differed from the immediate postretention value at the 5 percent confidence level.

The negative immediate postretention mean Symmetry Index 2 value for the right side bias of the mandibular arch indicated that the asymmetry had been overcorrected to a very mild left side asymmetry bias during treatment. The pretreatment mandibular Symmetry Index 2 value differed from the immediate postretention value at the 0.1 percent confidence level, while the two year minimum postretention value differed

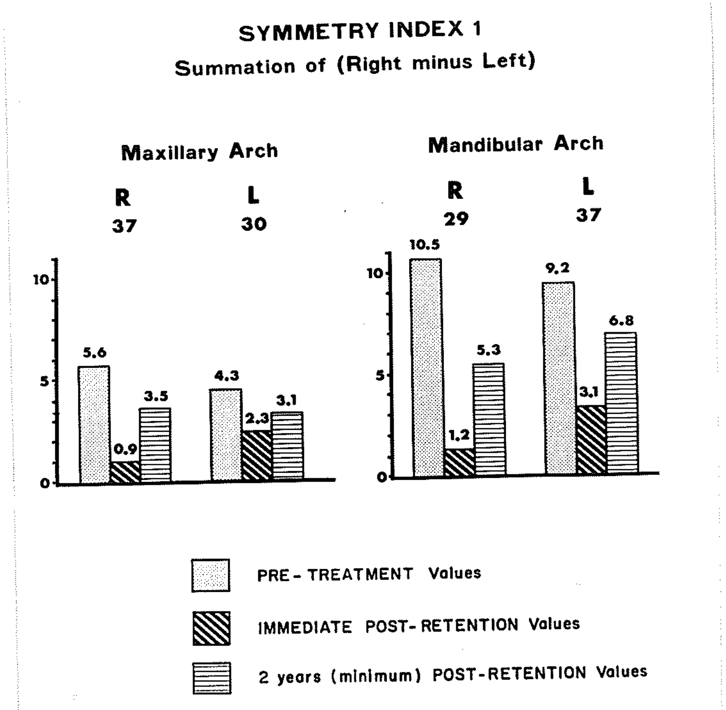

Figure 29. Graphic representation of Symmetry Index 1 values for both maxillary and mandibular arches at the three stages of treatment with the sample divided according to pretreatment right and left side biases.

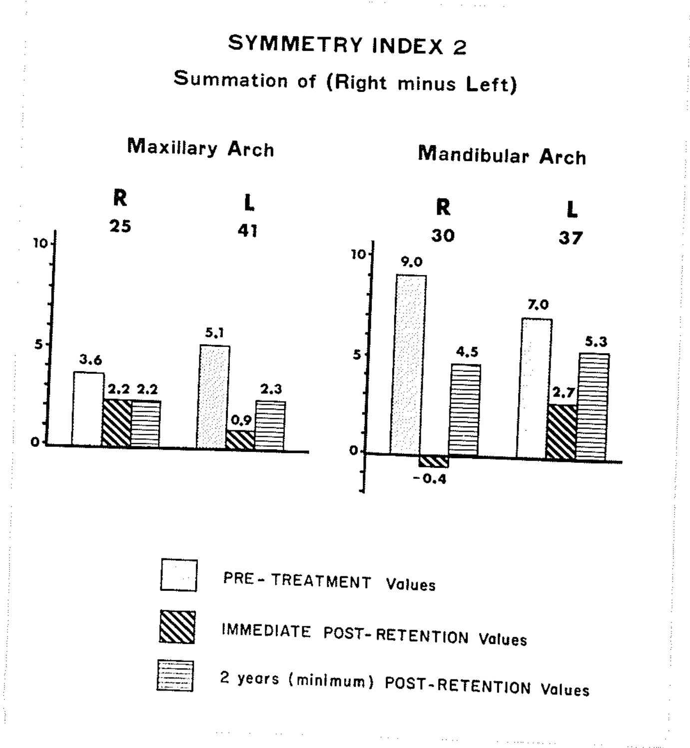

Figure 30. Graphic representation of Symmetry Index 2 values for both maxillary and mandibular arches at the three stages of treatment with the sample divided according to pretreatment right and left side biases.

from the immediate postretention value at the 1 percent confidence level. The Symmetry Index 2 values of the left side asymmetry bias for the mandibular arch demonstrated that the pretreatment values differed from the immediate postretention mean values at the 1 percent confidence level while the two year postretention values differed from the immediate postretention value at the 5 percent confidence levels.

Symmetry Index 3 values are illustrated graphically in Figure 31. The right side maxillary arch asymmetry bias illustrated that the pretreatment value differed from the immediate postretention value at the 1 percent confidence level. By contrast, the immediate postretention value did not statistically differ from the two year postretention value. The left side maxillary arch asymmetry bias indicated that the pretreatment value differed from the immediate postretention value at the 5 percent confidence level; the two year postretention value differed from the immediate postretention value at the 5 percent confidence level.

The mean values for the seven individual sites for both maxillary and mandibular arches for Symmetry Index 1 and Symmetry Index 2 are illustrated in Figures 32, 33, 34, 35, 36, 37, 38 and 39. Significant differences were detected for all seven sites between the three stages of treatment ($P < 0.01$).

Evaluation of the data indicated that for each site the sample should be divided according to whether the symmetry was improved or deteriorated during treatment to avoid the negating influence each group would have on the other in mean value representation.

For each site, the mean values comparing those in which the

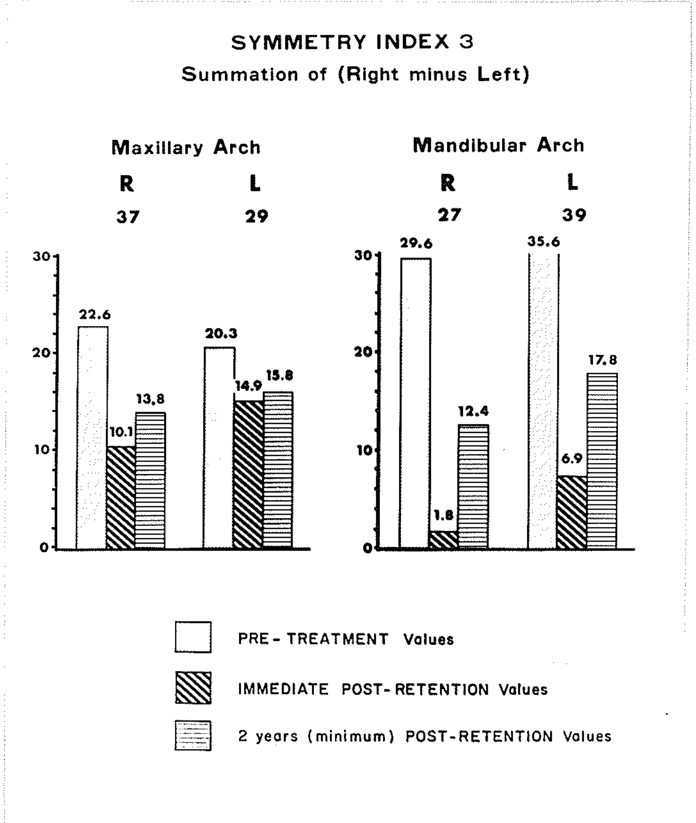

Figure 31. Graphic representation of Symmetry Index 3 values for both maxillary and mandibular arches at the three stages of treatment with the sample divided according to pretreatment right and left side biases.

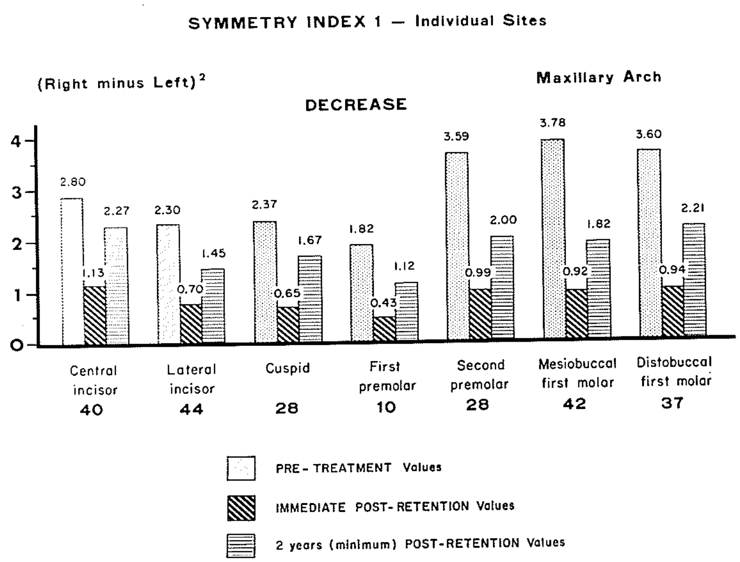

Figure 32. Graphic representation of Symmetry Index 1 values at the individual seven maxillary sites for the three stages of treatment for those cases made more symmetrical during active treatment.

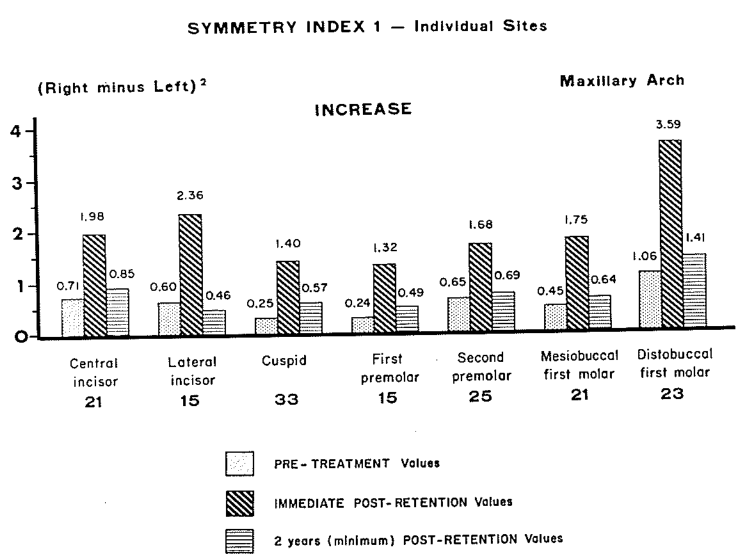

Figure 33. Graphic representation of Symmetry Index 1 values at the individual seven maxillary sites for the three stages of treatment for those cases made more asymmetrical during active treatment.

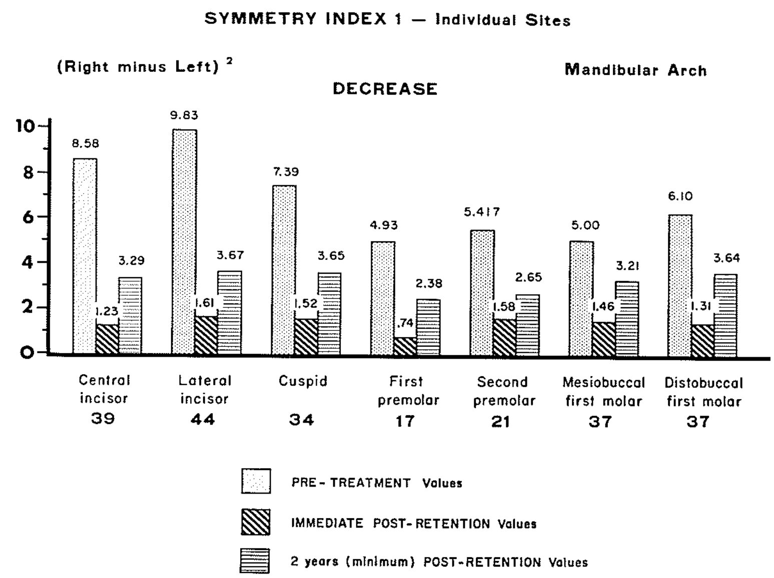

Figure 34. Graphic representation of Symmetry Index 1 values at the individual seven mandibular sites for the three stages of treatment for those cases made more symmetrical during active treatment.

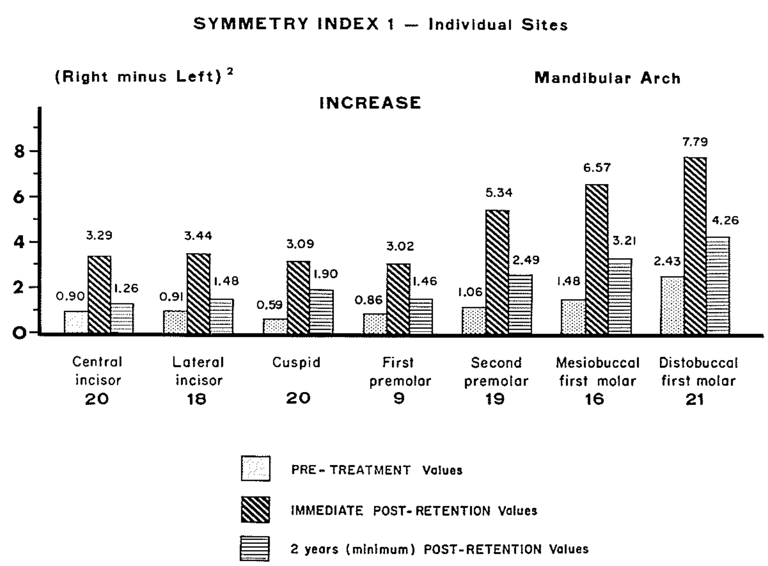

Figure 35. Graphic representation of Symmetry Index 1 values at the individual seven mandibular sites for the three stages of treatment for those cases made more asymmetrical during active treatment.

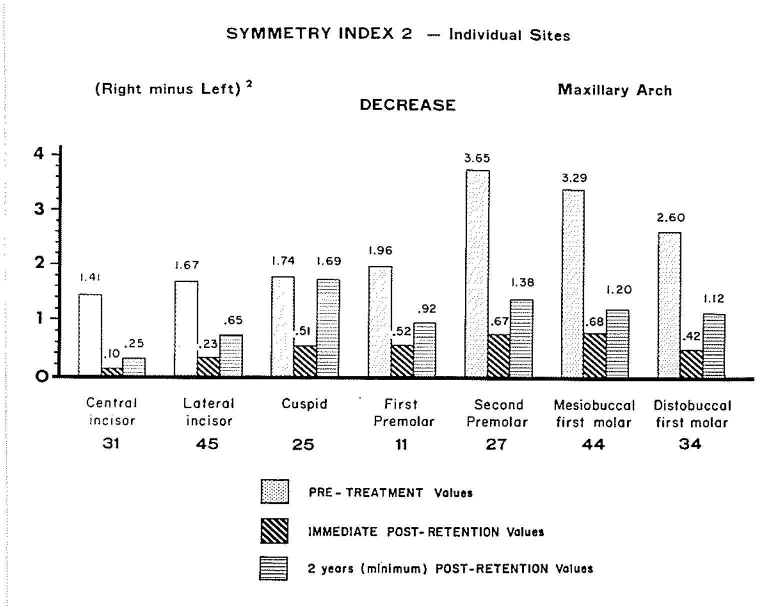

Figure 36. Graphic representation of Symmetry Index 2 values at the individual seven maxillary sites for the three stages of treatment for those cases made more symmetrical during active treatment.

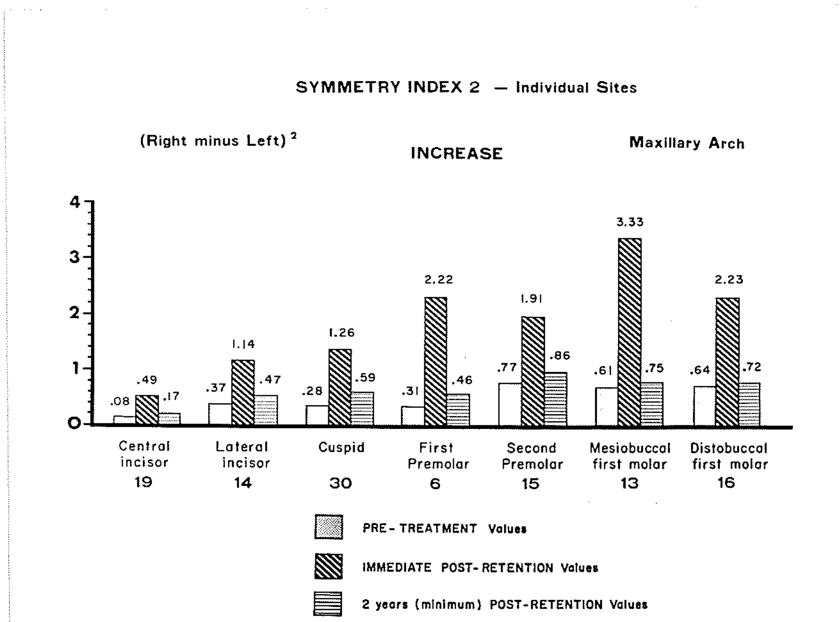

Figure 37. Graphic representation of Symmetry Index 2 values at the individual seven maxillary sites for the three stages of treatment for those cases made more asymmetrical during active treatment.

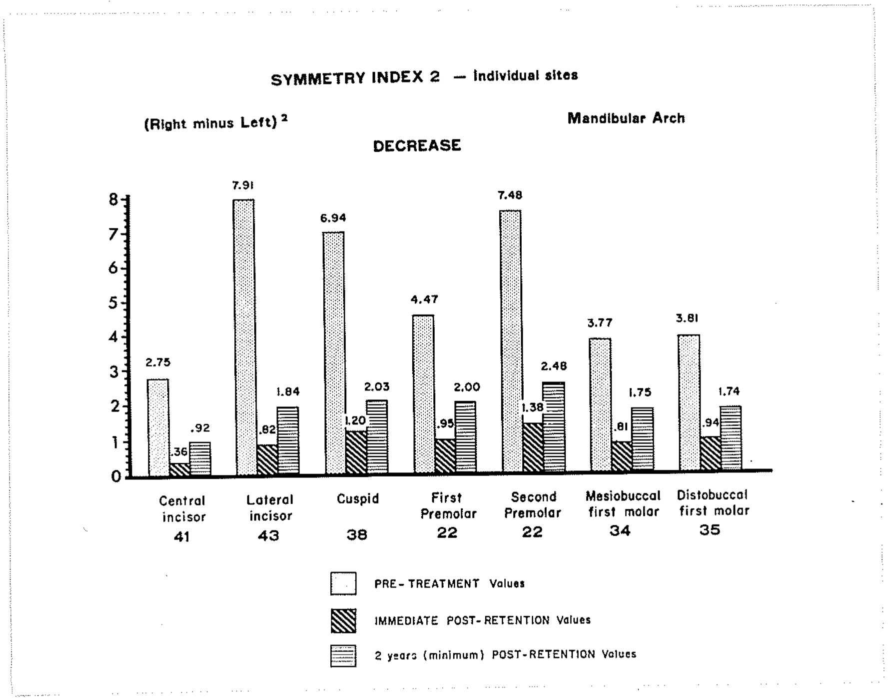

Figure 38. Graphic representation of Symmetry Index 2 values at the individual seven mandibular sites for the three stages of treatment for those cases made more symmetrical during active treatment.

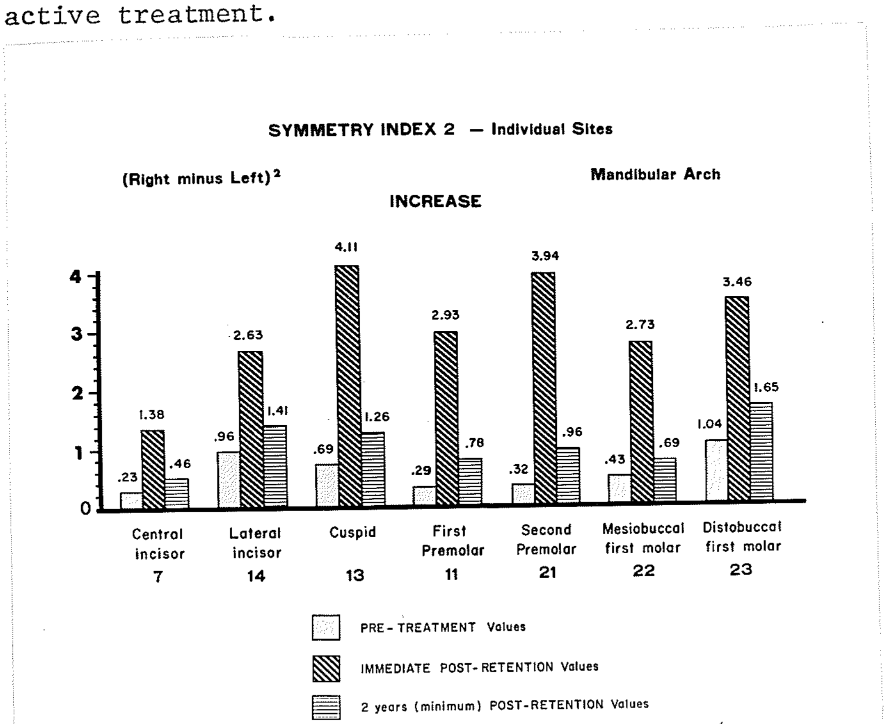

Figure 39. Graphic representation of Symmetry Index 2 values at the individual seven mandibular sites for the three stages of treatment for those cases made more asymmetrical during active treatment.

asymmetry was decreased as compared to those in which the asymmetry was increased during treatment differed at the 0.1 percent confidence levels. The decrease versus increase by stage interaction was significant at the 0.1 percent confidence levels. Further appraisal indicated that for all seven sites the trend for the pretreatment asymmetry to return in the postretention period was consistent for both Symmetry Index 1 in both arches for both those cases in which the individual sites were made more symmetrical and more asymmetrical during treatment. The pretreatment values differed from the immediate postretention values at the 1 percent confidence levels while the immediate postretention values differed from the two year minimum postretention values at either the 1 percent or 5 percent confidence levels.

The higher order interaction of site (decrease versus increase) by stage interaction was not found to be statistically significant.

<u>Overjet</u>

Significant differences were detected between the overjet as measured in millimeters between the pretreatment values for the sample when divided according to Angle's concept of occlusion ($P < 0.01$). The Class II Division 1 group pretreatment mean values were greater than the Class I and Class II Division 2 groups at the 1 percent confidence levels.

The mean overjet values are graphically illustrated in Figure 40. Analysis of values computed for the three stages of treatment indicated that the pretreatment values of all Angle's malocclusion classifications were greater than the immediate postretention values ($P < 0.01$). The only statistically significant change occurring in the postretention period

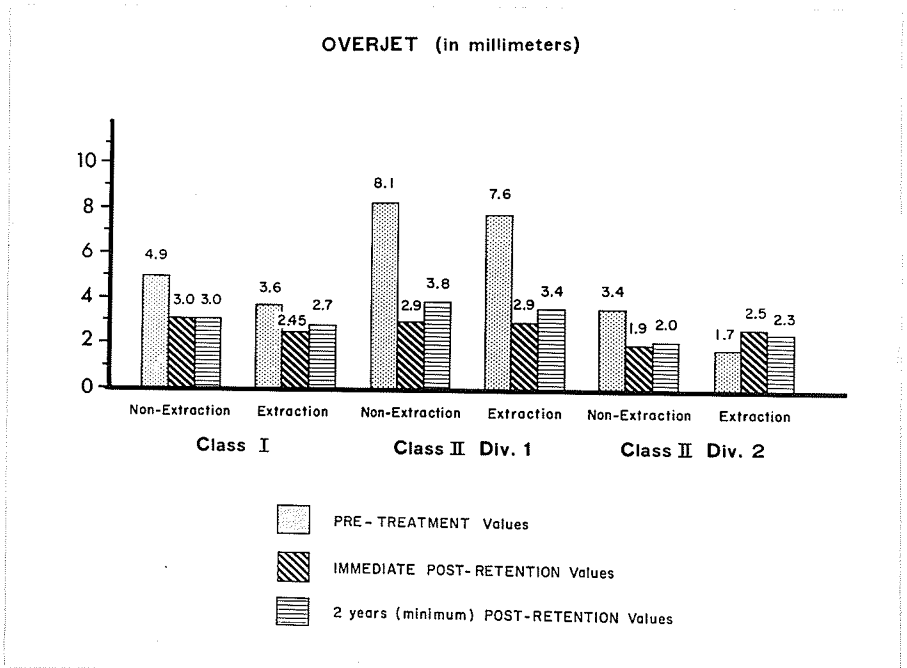

Figure 40. Graphic representation of mean overjet values in millimeters for the three stages of treatment of the malocclusion sample, which was divided according to Angle's concept of occlusion.

was demonstrated in the Class II, Division 1 sample between the two year postretention values and the immediate postretention values ($P < 0.05$). Although only the Class II, Division 1 sample demonstrated a statistically significant increase in the postretention period, the tendency for overjet to return toward its pretreatment value was demonstrated for all Angle's malocclusion classifications as well as extraction/nonextraction therapy groups. Upon examination of the data it was apparent that 58.5 percent of the sample tended to return toward the pretreatment values of this variable in the postretention period. The higher order group extraction by stage of treatment interaction was not statistically significant; nor was the extraction by stage interaction. This indicated that extraction had no discernible effect upon overjet stability.

Overbite

The mean values for overbite for the entire sample (Figure 41) indicated that active orthodontic treatment was effective in reducing overbite as measured in millimeters from the pretreatment value to the immediate postretention value ($P < 0.001$). The change in the postretention period indicated a trend to return toward the pretreatment value ($P < 0.01$). The extraction by stage of treatment interaction was not statistically significant. The pretreatment values of cases treated with both extraction or nonextraction treatment regimen were not statistically significant. However, it was noted that overbite was reduced in active orthodontic treatment to a greater extent in the nonextraction group ($P < 0.01$). The trend to return toward the pretreatment overbite value was noted in the postretention period for both nonextraction/extraction groups at the 5 percent confidence level.

A comparison of the sample when divided according to Angle's malocclusion classification (Figure 42) indicated that the greatest degree of overbite correction was observed in the Class II, Division 2 nonextraction group. It was also noted, however, that this group also demonstrated the greatest amount of relapse. The trend was consistent toward a return toward pretreatment overbite values in the postretention period for all Angle's malocclusion classifications and for both extraction and nonextraction therapy.

The mean pretreatment overbite value was greatest in the Class II, Division 2 malocclusion sample. This is consistent with the criterion for the classic description of Angle Class II, Division 2 classification. Although greater, the pretreatment overbite value of the Class II, Division 2 sample did not differ statistically from the Class II, Division 1 sample. Both Class II group values, however, were greater than the Class I sample at the 1 percent confidence level.

Depth of Curve of Spee

Graphic representations of the mean values of the depth of curve of Spee are illustrated in Figures 43 through 50. This variable was measured as the perpendicular distance in millimeters from the cusp tip of the cuspid, cusp tip of the first and second premolars and the mesio-buccal cusp tip of the first molar to the line of occlusion as defined by a line joining the incisal edge of the lower incisor and the disto-buccal cusp of the first permanent molar. A value of zero indicated that

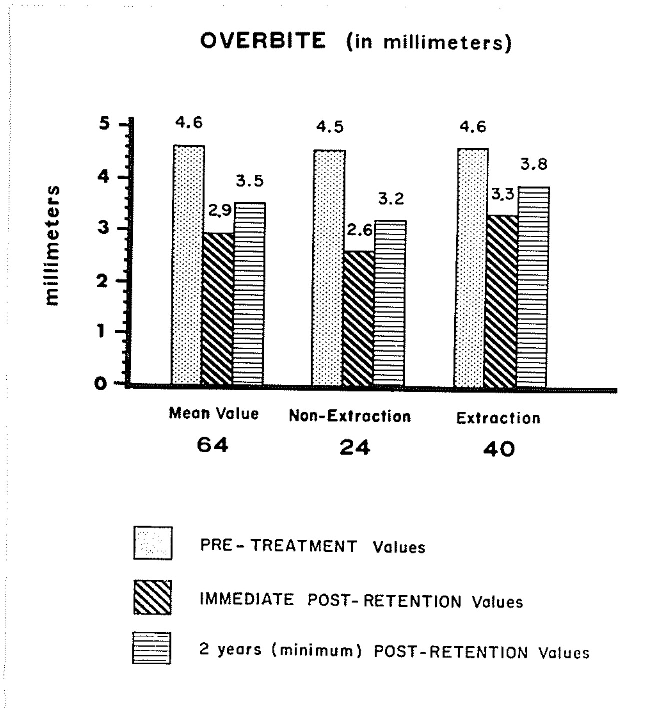

Figure 41. Graphic representation of mean overbite values in millimeters for the three stages of treatment with the malocclusion sample divided on the basis of whether teeth were extracted as an adjunct to orthodontic treatment.

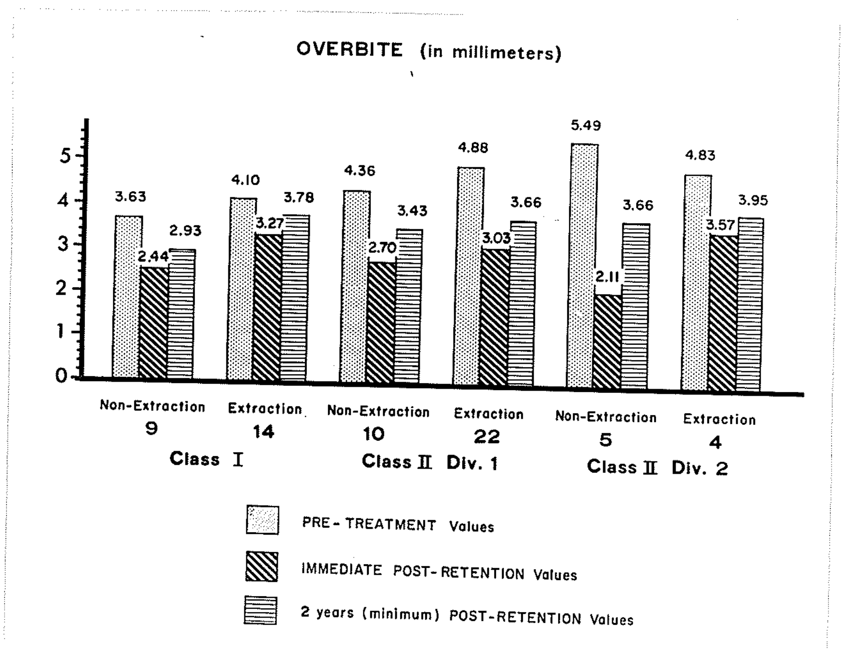

Figure 42. Graphic representation of mean overbite values in millimeters for the three stages of treatment of the malocclusion sample which was divided according to Angle's concept of occlusion.

the cusp tip was found in the same horizontal plane as this line of occlusion. A positive value indicated that the cusp tip was above the occlusal plane and conversely, a negative value indicated that the mean value position of the tooth was below the line of occlusion.

Depth of Curve of Spee as Measured at the Cuspid

Significant differences were detected between the "acceptable" occlusion sample and the malocclusion groups mean values ($P < 0.01$). Upon examination of the mean values it was found that treatment had significant ($P < 0.001$) effects on this variable. The Angle classification by stage of treatment interaction was significant at the 5 percent confidence level. In addition, it was noted that the trend to return toward the pretreatment value of the depth of the curve of Spee was noted for both the right and left lateral views for all Angle malocclusion classifications regardless of extraction/nonextraction therapy treatment (Figures 43 and 44).

Depth of Curve of Spee as Measured at the First Premolar

The pretreatment values of the malocclusion groups differed from the "acceptable" occlusion sample at the 0.1 percent confidence level. In the normal sample, the cusp tip of the first premolar was slightly above the line of occlusion. By contrast, the pretreatment malocclusion group, regardless of Angle's malocclusion classifications, demonstrated that the cusp tip of the first premolar was below the line of occlusion (Figures 45 and 46). Comparison of the stages of treatment indicated that the pretreatment values differed from the immediate postretention

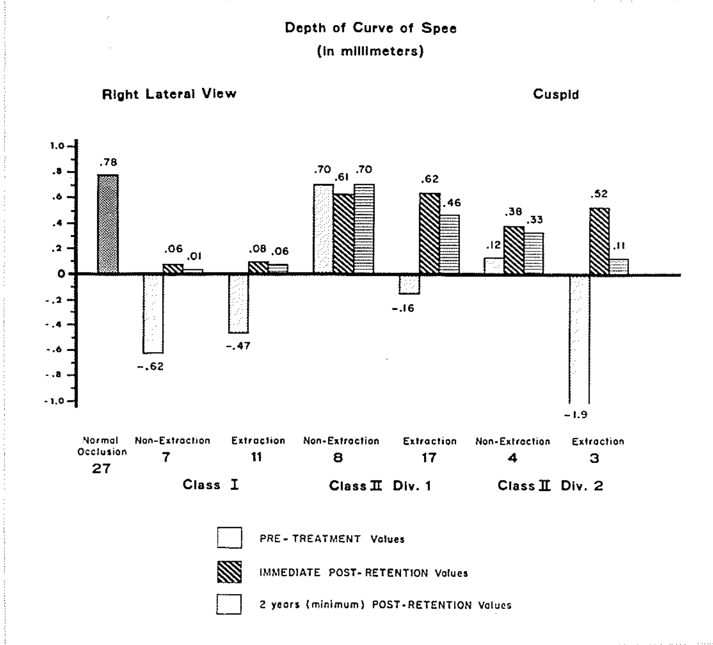

Figure 43. Graphic representation of the depth of the curve of Spee (in millimeters) of the right lateral view measured at the cuspid for the "acceptable" occlusion group and malocclusion group which was divided according to Angle's concept of occlusion.

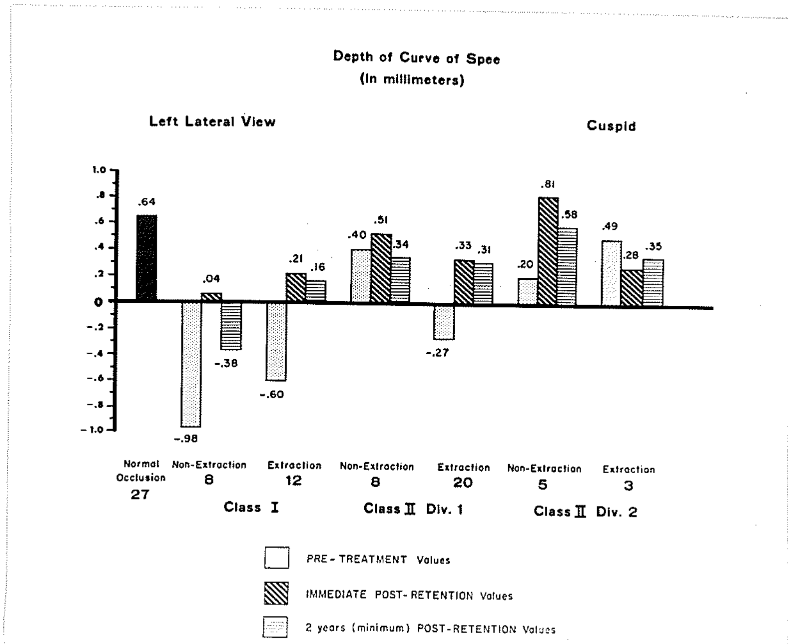

Figure 44. Graphic representation of the depth of the curve of Spee (in millimeters) of the left lateral view measured at the cuspid for the "acceptable" occlusion group and malocclusion group which was divided according to Angle's concept of occlusion.

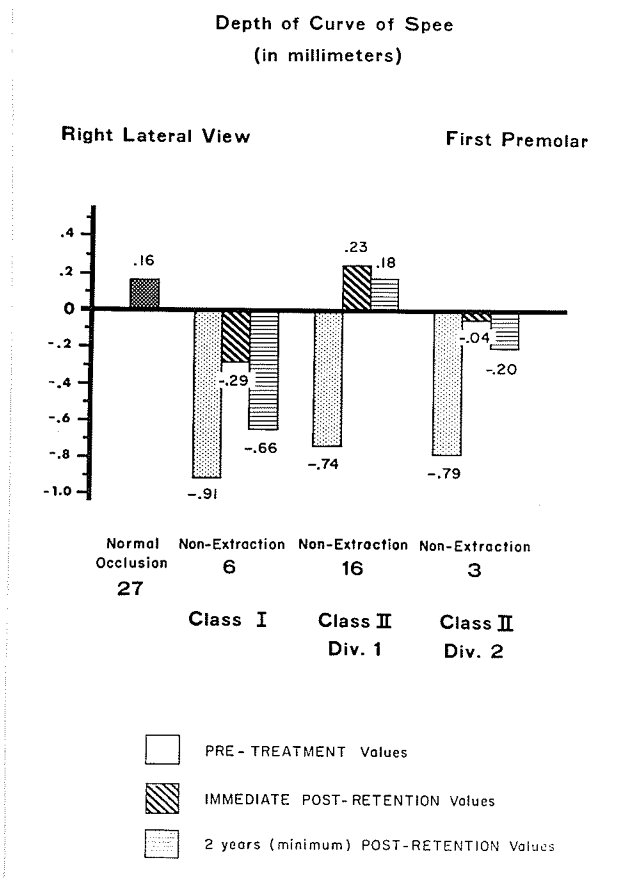

Figure 45. Graphic representation of the depth of the curve of Spee (in millimeters) of the right lateral view measured at the first premolar for the "acceptable" occlusion group and malocclusion group which was divided according to Angle's concept of occlusion.

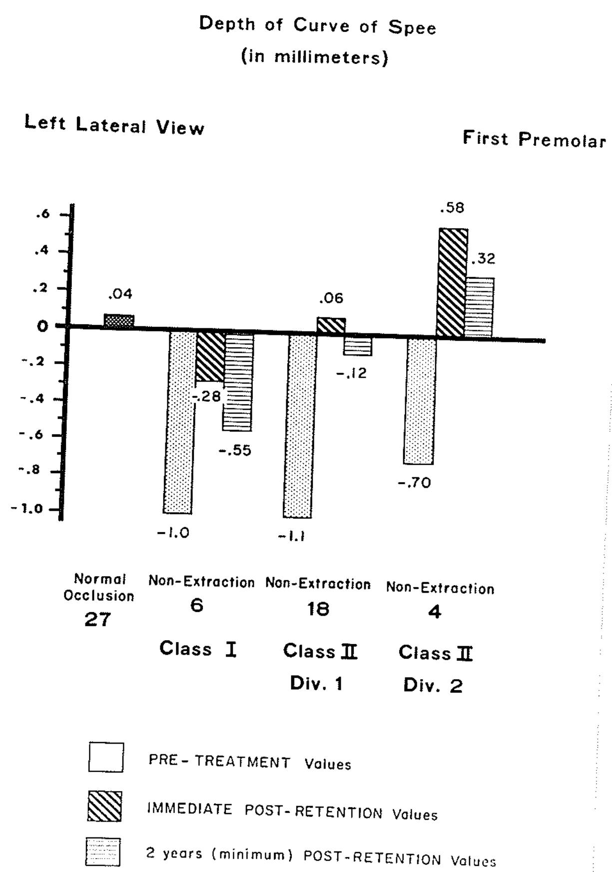

Figure 46. Graphic representation of the depth of the curve of Spee (in millimeters) of the left lateral view measured at the first premolar for the "acceptable" occlusion group and malocclusion group which was divided according to Angle's concept of occlusion.

values at the 1 percent confidence levels. Only in the Class I sample did the two year postretention value significantly differ from the immediate postretention value ($P < 0.05$).

Depth of Curve of Spee as Measured at the Second Premolar

Both the normal occlusion mean value and the pretreatment malocclusion group values for the depth of the curve of Spee as measured at the second premolar, indicated that the cusp tip of the second premolar was below the line of occlusion. However, significant differences were detected between the normal occlusion sample and the malocclusion groups (Figures 47 and 48). For instance, the malocclusion groups demonstrated a higher value for the depth of curve of Spee at this site, significant at the 5 percent confidence level. The effects of treatment on the depth of the curve of Spee were significant at the 0.1 percent confidence level. This indicated that the pretreatment values differed from the immediate postretention values at this level of confidence. No significant statistical differences were demonstrated between the two year postretention values and the immediate postretention values.

Depth of Curve of Spee as Measured at the Mesio-buccal Cusp at the First Molar

No significant differences were detected between the normal occlusion group and the pretreatment malocclusion group values for the depth of curve of Spee as measured at the mesio-buccal cusp of the first

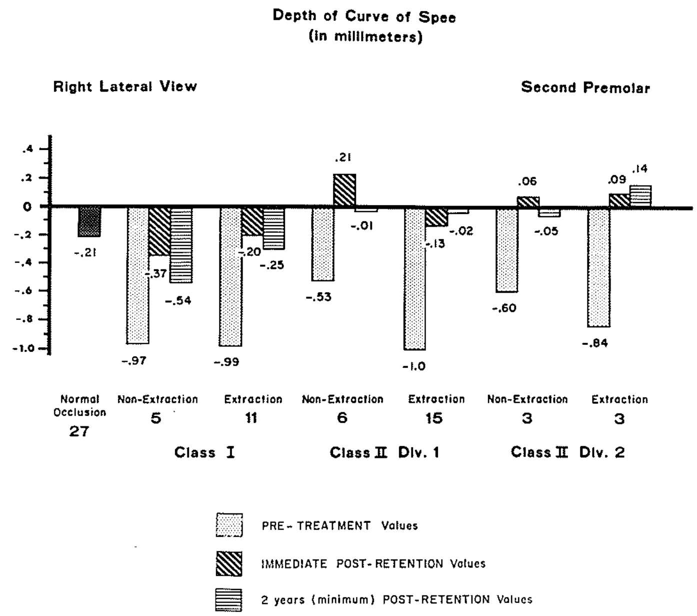

Figure 47. Graphic representation of the depth of the curve of Spee (in millimeters) of the right lateral view measured at the second premolar for the "acceptable" occlusion group and malocclusion group which was divided according to Angle's concept of occlusion.

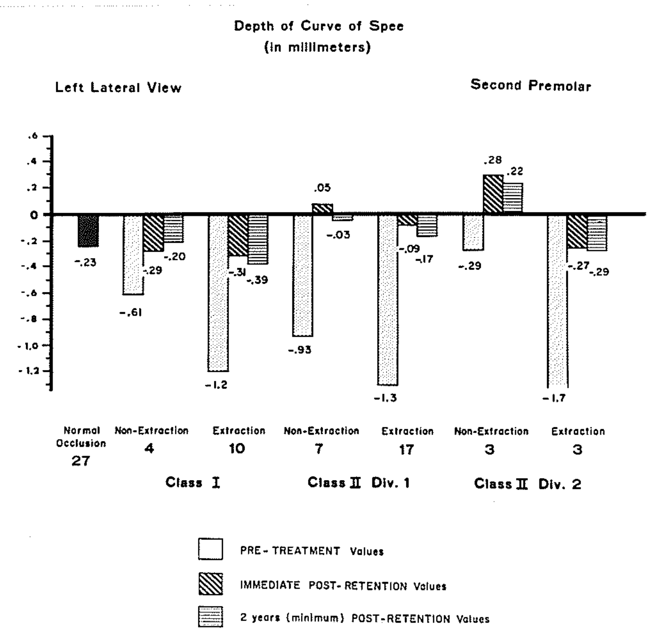

Figure 48. Graphic representation of the depth of the curve of Spee (in millimeters) of the left lateral view measured at the second premolar for the "acceptable" occlusion group and malocclusion group which was divided according to Angle's concept of occlusion.

molar (Figures 49 and 50). Both groups demonstrated that the mesio-buccal cusp occluded below the line of occlusion. Significant differences were noted between the mean values of the pretreatment and the immediate postretention values ($P < 0.01$). However, coincident with the other findings relative to the depth of the curve of Spee, no significant differences were noted between the two year postretention values as compared to the immediate postretention values.

Denture Midline Discrepancy

Due to the high standard deviations, no significant differences were detected in denture midline discrepancy between Angle's malocclusion classifications and the "acceptable" occlusion sample (Table VI). In addition, no significant differences were noted during the three stages of treatment for the malocclusion groups mean values; nor were any higher order interactions statistically significant in this measurement. The only significant result of this measurement was to indicate that the maxillary and mandibular denture midlines were not coincident for the mean values of either the "acceptable" occlusion or malocclusion groups. A value of zero would have indicated that the denture midlines were coincident. The null hypothesis of the "t" test was rejected. This indicated that the denture midlines for both the "acceptable" occlusion and the pretreatment malocclusion group values were not coincident and were statistically significant at the 5 percent confidence level. The immediate postretention and two year postretention values of the malocclusion groups did not statistically differ from zero. This showed that the denture midlines were made coincident with treatment and were

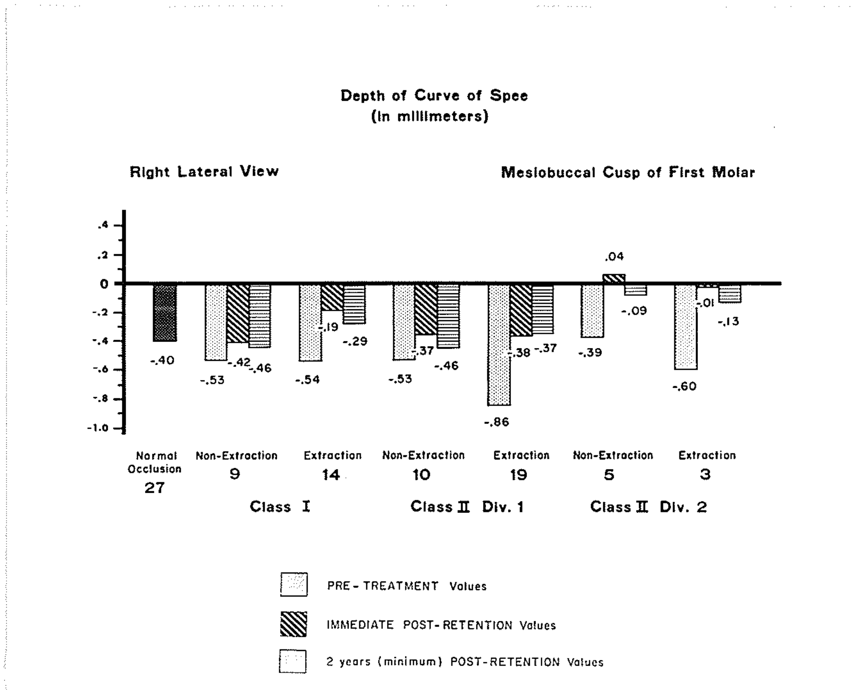

Figure 49. Graphic representation of the depth of the curve of Spee (in millimeters) of the right lateral view measured at the mesio-buccal cusp of first molar for the "acceptable" occlusion group and malocclusion group which was divided according to Angle's concept of occlusion.

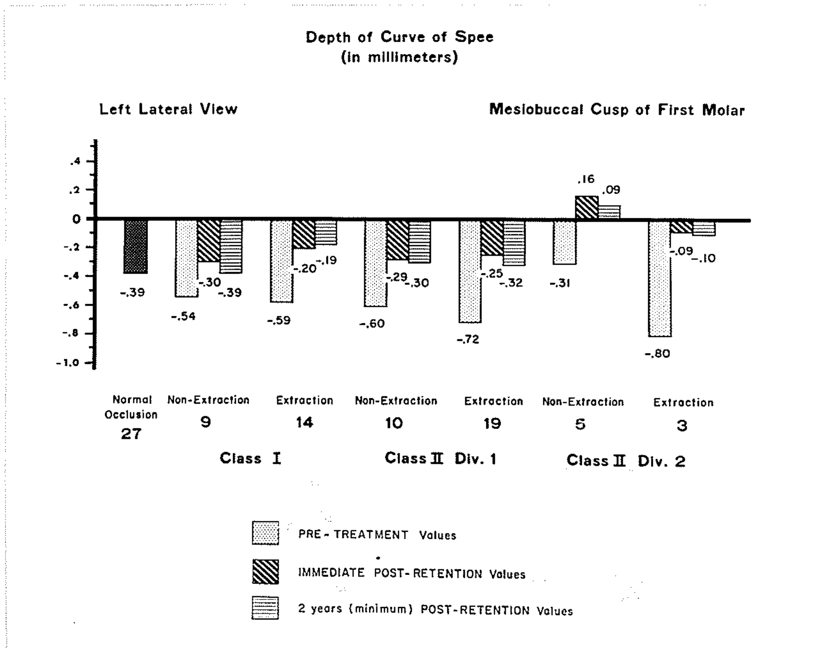

Figure 50. Graphic representation of the depth of the curve of Spee (in millimeters) of the left lateral view measured at the mesio-buccal cusp of first molar for the "acceptable" occlusion group and malocclusion group which was divided according to Angle's concept of occlusion.

TABLE VI

Midline Discrepancy

	Mean	Standard Error	"t" Value	Significance
"Acceptable" occlusion (27)	0.331	0.763	2.254	*
Angle Class I (18)				
Pretreatment	0.536	0.253	2.118	n.s.
Immediate post-retention	0.133	0.253	0.526	n.s.
Minimum 2 years postretention	0.144	0.253	0.569	n.s.
Angle Class II Div. 1 (29)				
Pretreatment	0.593	0.203	2.921	*
Immediate post-retention	0.060	0.203	0.296	n.s.
Minimum 2 years postretention	0.281	0.203	1.384	n.s.
Angle Class II Div. 2 (7)				
Pretreatment	0.787	0.332	2.370	*
Immediate post-retention	0.206	0.332	0.620	n.s.
Minimum 2 years postretention	0.521	0.332	1.569	n.s.

n.s. not statistically significant
* significant at the 5 percent confidence level
** significant at the 1 percent confidence level

TABLE VI Denture midline discrepancy in millimeters: means, standard error and significance for the "acceptable" occlusion and the malocclusion group divided according to Angle's concept of occlusion.

and were maintained in the postretention period.

Cuspid Relationship

The findings for cuspid relationship are graphically illustrated in Figures 51 and 52. Significant differences were detected between the "acceptable" occlusion sample values and the Angle Class I group values at the 1 percent confidence level. The "acceptable" occlusion sample differed from the three Class II groups at the 0.1 percent confidence level. The Angle Class I pretreatment cuspid relationship value differed from the Class II nonextraction group at the 1 percent confidence level. However, the Class I values differed from the Class II four premolar extraction and the Class II two maxillary premolar extraction groups at the 0.1 percent confidence level.

The stage of treatment analysis was significant at the 1 percent confidence level indicating that treatment had significant effects on this variable. The immediate postretention values for the Class I non-extraction and extraction groups differed from the pretreatment values at the 5 percent confidence level. The immediate postretention value of the Class II nonextraction and the Class II four premolar extraction as well as the Class II two maxillary premolar extraction differed from the pretreatment value at the 0.1 percent confidence level.

Comparison of the immediate postretention values indicated no significant differences between any of the groups at this stage of treatment relative to this variable. Similarly, no significant differences were noted between the two year postretention record values as compared to

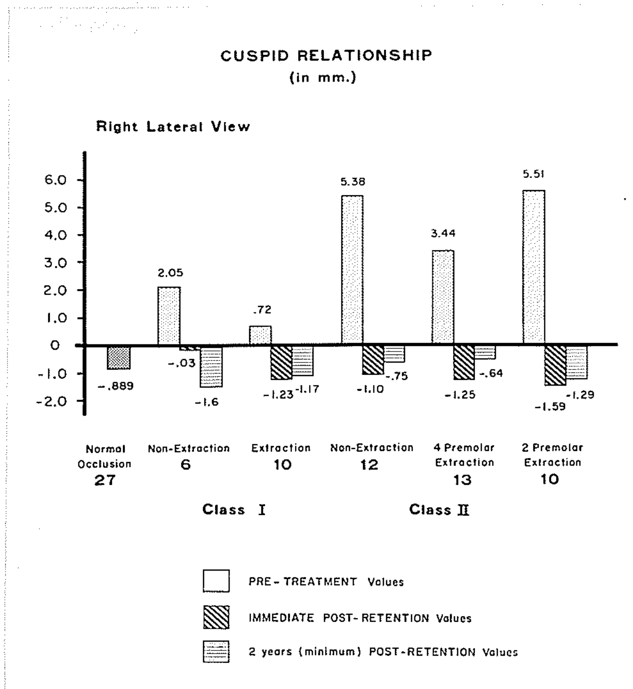

Figure 51. Graphic representation of the right lateral cuspid relationship (in millimeters) comparing the "acceptable" occlusion sample and the three stages of treatment of the malocclusion groups.

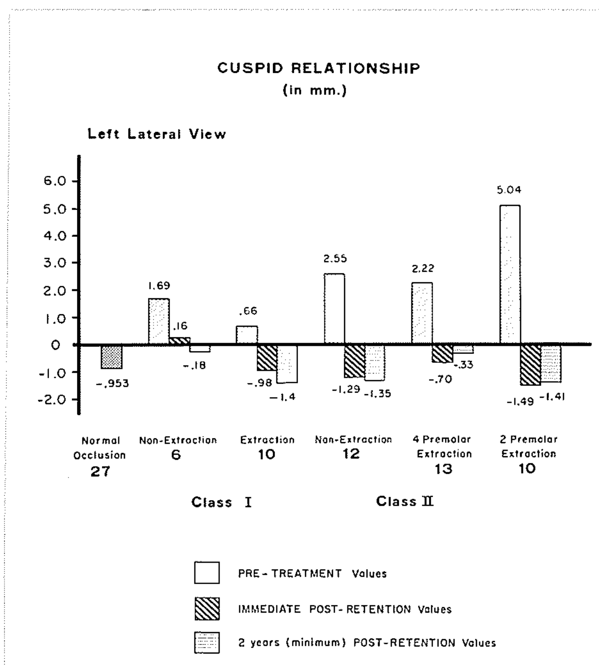

Figure 52. Graphic representation of the left lateral cuspid relationship (in millimeters) comparing the "acceptable" occlusion sample and the three stages of treatment of the malocclusion groups.

the immediate postretention values for any of the malocclusion groups. These findings were consistent for both the right and left cuspid relationships.

Molar Relationship

Graphic representation of this variable is illustrated in Figures 53 and 54. No significant differences were noted beteen the "acceptable" occlusion and pretreatment Angle Class I malocclusion group values. However, the "acceptable" occlusion and Class I group pretreatment values differed from the Angle Class II groups at the 0.1 percent confidence level. The Class II two maxillary premolar extraction group differed from the Class II nonextraction and Class II four premolar extraction groups at the 5 percent confidence level.

The stage of treatment analysis comparison indicated this variable was not significantly altered during treatment in either the Class I nonextraction or extraction groups. For all three Class II groups, that is, the nonextraction, four premolar extraction and two maxillary premolar extractions, the immediate postretention values differed from the pretreatment values at the 1 percent confidence level. Comparison of the immediate postretention values indicated that the Class I nonextraction and extraction groups did not differ from each other nor did the Class II nonextraction or Class II four premolar extraction group differ from the Class I group values immediate postretention. The Class II maxillary premolar extraction group differed at the immediate postretention stage of treatment from the Class I extraction and nonextraction groups at the 0.1 percent confidence level.

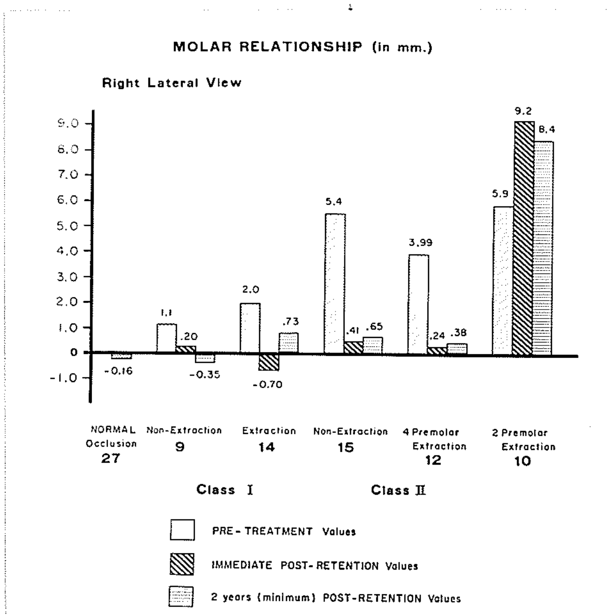

Figure 53. Graphic representation of the right lateral molar relationship (in millimeters) comparing the "acceptable" occlusion sample and the three stages of treatment of the malocclusion groups.

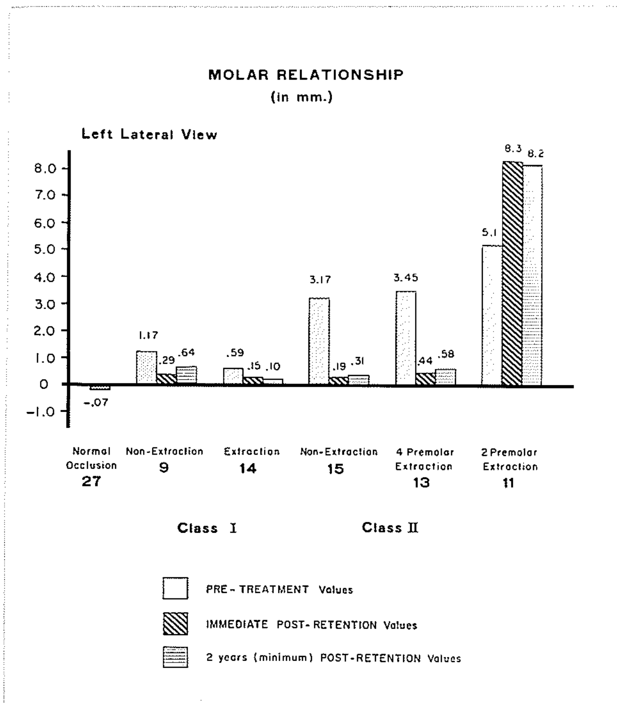

Figure 54. Graphic representation of the left lateral molar relationship (in millimeters) comparing the "acceptable" occlusion sample and the three stages of treatment of the malocclusion groups.

The comparison of the two year postretention molar relationship values with those obtained immediate postretention shows no significant differences. These results were consistent for both right and left molar relationship.

Arch Form - Curve Fitting

Comparison of the varying curves ranging from polynomial equations to the sixth power to the equation for a parabola indicated that the parabolic equation $Y = B_2X^2 + B_1X + B_o$ had the best "goodness of fit" to the "acceptable" occlusion samples for both the maxillary and mandibular dental arch forms. The values for the constants B_2, B_1 and B_o for each of the 27 "acceptable" occlusion group samples for both the maxillary and mandibular arches, may be found in the Appendix.

The "acceptable" occlusion group values were then combined to compute constant values for a mean curve representing the entire sample. The following mathematical formulas were obtained as illustrated in the next two equations representing the maxillary and mandibular arches for the arch form described by the mid-incisal edge and buccal cusp tip locations.

(i) Mean mathematical description of "best fit" for the maxillary dental arch:

$$Y = 0.04509\ X^2 - 1.82908\ X + 25.08742$$ Multiple R 0.96559

(ii) Mean mathematical description for the "best fit" for the mandibular dental arch:

$$Y = 0.05025\ X^2 - 1.96241\ X + 29.76977$$ Multiple R 0.96435

Scattergrams of the curve fitting procedure are illustrated in Figures 55 and 56 for the maxillary and mandibular arches, respectively. It should be noted that a multiple R value around 0.96 demonstrates that the mean mathematical curves have fitted the sample dental arches almost perfectly.

The following mathematical formulas represent the maxillary and mandibular arch form identified by the facial periphery of the dental units.

(i) Mean mathematical description of "best fit" for the maxillary dental arch:

$$Y = 0.03856\, X^2 - 1.56448\, X + 21.66271$$ Multiple R 0.96777

(ii) Mean mathematical description of "best fit" for the mandibular dental arch:

$$Y = 0.03771\, X^2 - 1.47675\, X + 24.29334$$ Multiple R 0.96829

Scattergrams of the curve fitting procedure are illustrated in Figures 57 and 58 for the maxillary and mandibular arches respectively.

Intertooth Widths

Differences were noted between the maxillary and mandibular mean intertooth arch width changes during active treatment significant at the 5 percent confidence level. The maxillary intertooth width increases were found to be consistently greater at each tooth site than those effected in the mandibular arch. However, return toward the pretreatment value in the postretention period was consistently greater in the mandibular arch

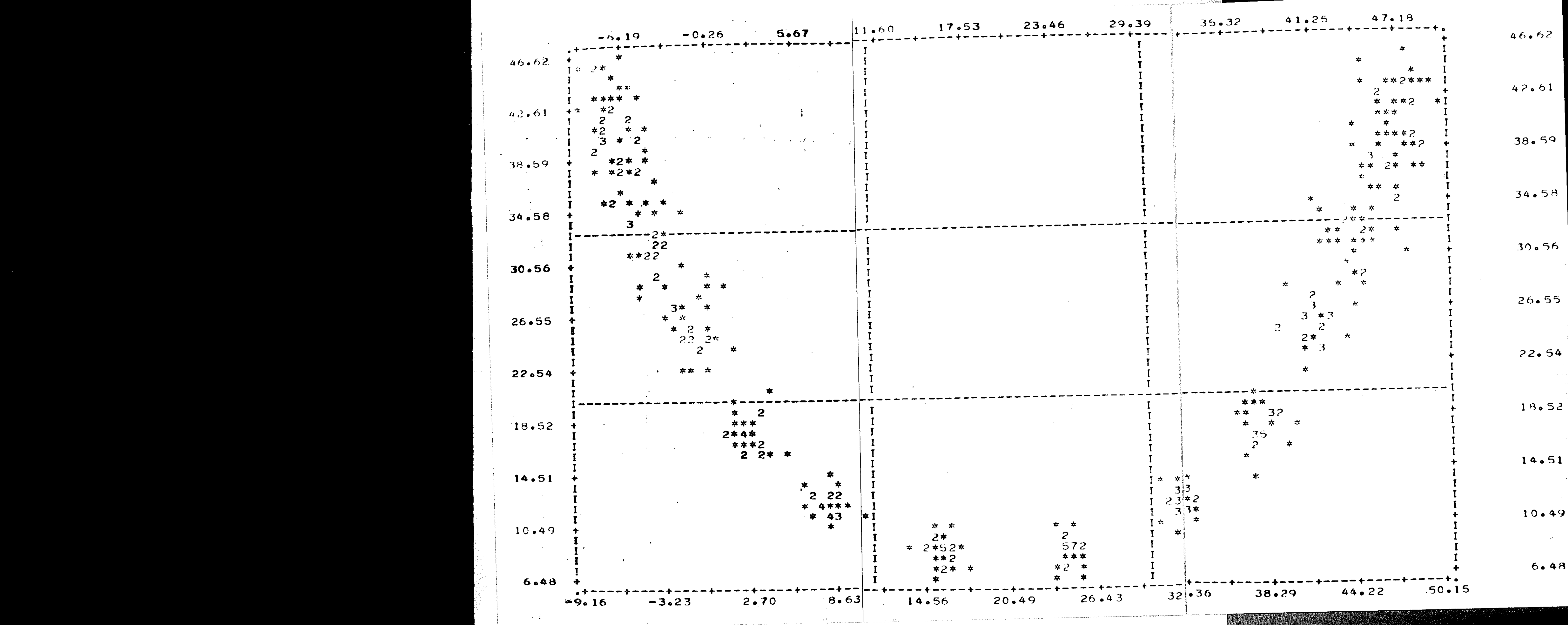

Figure 55. Scattergram of the maxillary arch curve fitting procedure represented by the mid-incisal edge and buccal cusp tip locations.

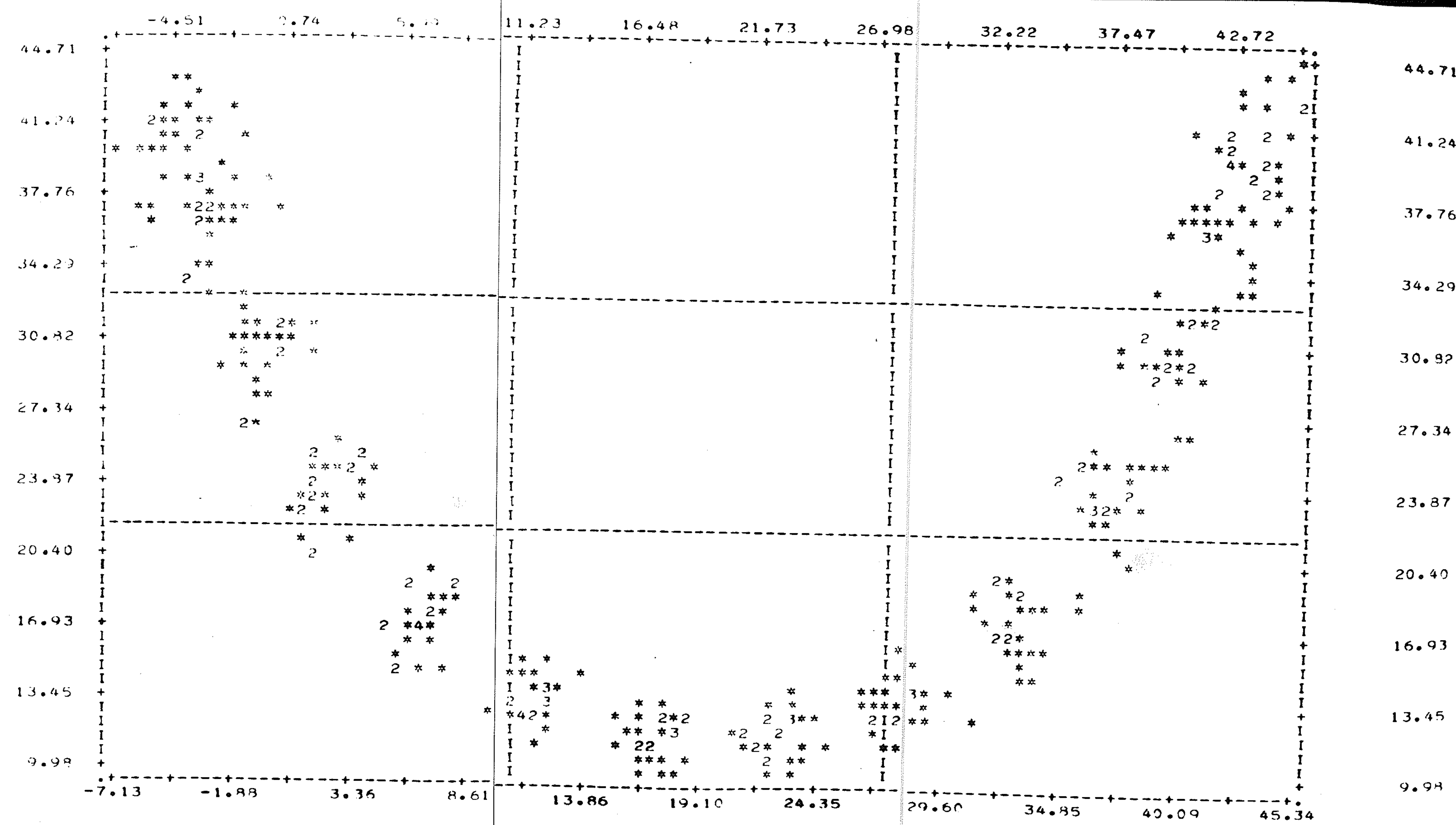

Figure 56. Scattergram of the mandibular arch curve fitting procedure represented by the mid-incisal edge and buccal cusp tip locations.

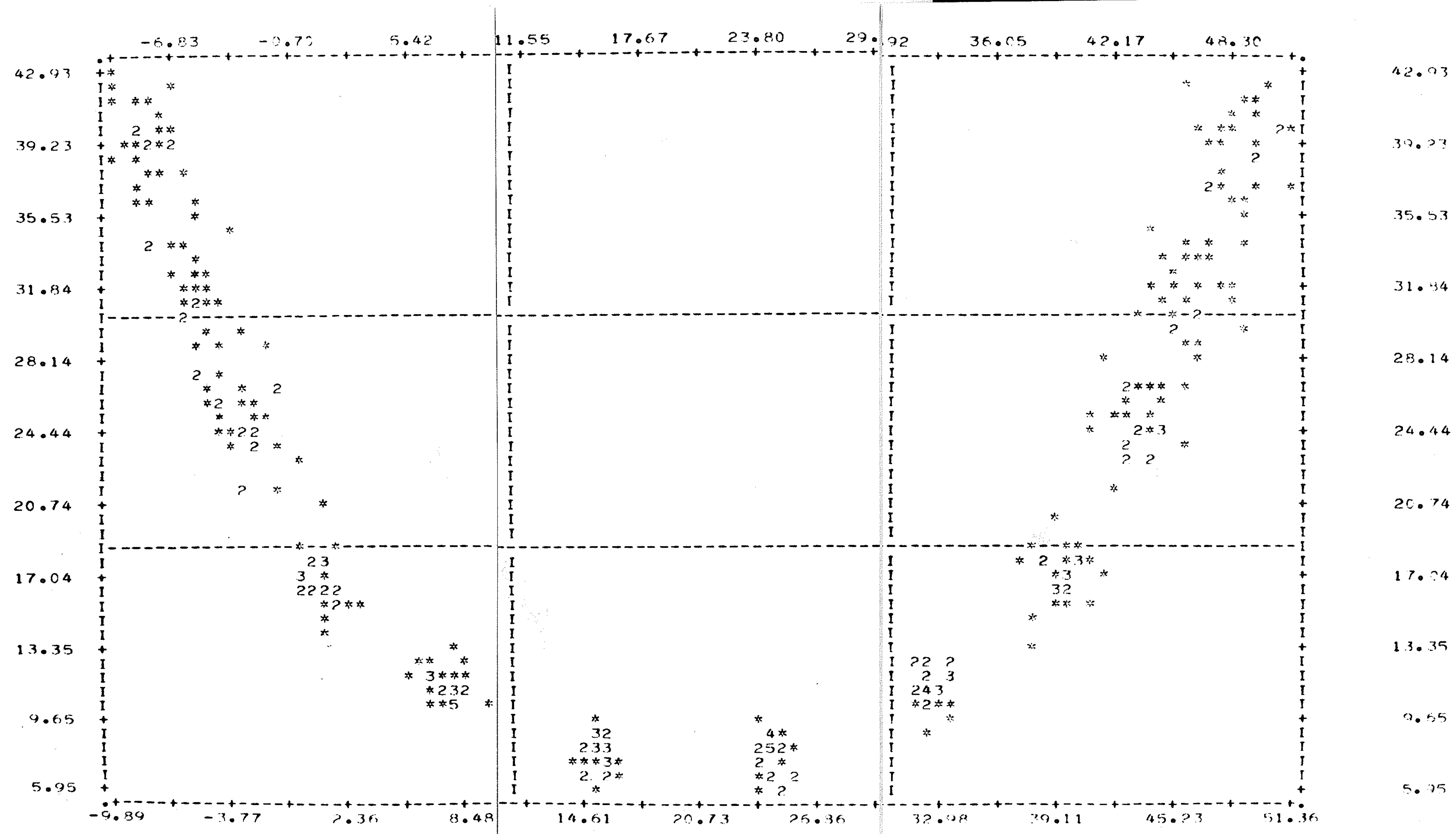

Figure 57. Scattergram of the maxillary arch curve fitting procedure represented by the facial periphery of the dental units.

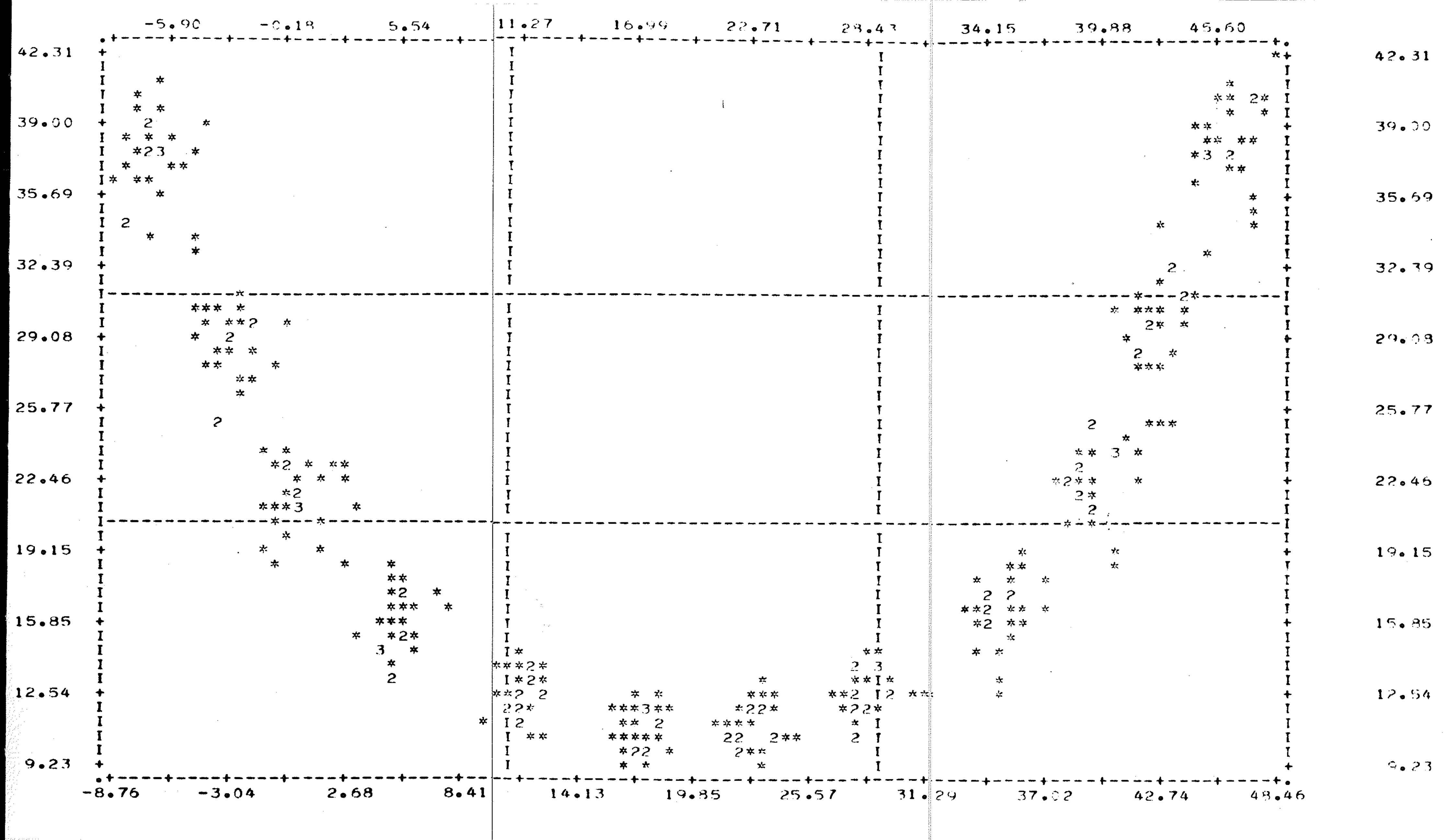

Figure 58. Scattergram of the mandibular arch curve fitting procedure represented by the facial periphery of the dental units.

at each site measured. Consequently, significant differences were noted between mean maintained change of intertooth arch width between the maxillary and mandibular arches significant at each of the sites at the 0.1 percent confidence level. Mean linear changes at each of the computed sites for this variable between the three stages of treatment are illustrated in Table VII.

The values indicate the consistent trend at each site in both arches for a return toward the pretreatment dimension in the postretention period.

Of particular interest was the finding that regardless of Angle's classification, nonextraction/extraction therapy no mean increase of mandibular intercuspid width was maintained in the postretention period (Figure 59).

Significant differences were noted in the nonextraction/extraction therapy by stage interaction only at the second premolar and the first permanent molar sites at the 5 percent confidence level, for the maxillary arch, while in the mandibular arch, statistically significant differences at the 1 percent confidence level were noted.

Although differences were noted between intertooth width computations for the same tooth at different identification points, the mean values indicated that none were statistically significant. Mean values illustrating the differences between the nonextraction/extraction therapy by stage interaction are illustrated in Table VIII and IX.

Arch Length

Highly significant statistical differences ($P < 0.001$) were noted

TABLE VII

INTERTOOTH ARCH WIDTH

Tooth Site	MAXILLARY ARCH			MANDIBULAR ARCH		
	Mean Change During Treatment	Mean Change in Post-Retention Period	Mean Maintained Change	Mean Change During Treatment	Mean Change in Post-Retention Period	Mean Maintained Change
Central Incisor						
a) mid-incisal edge	0.06	-0.10		0.15	-0.08	0.07
b) palatal/lingual	0.34	0.06	0.34	0.10	-0.08	0.02
Lateral Incisor						
a) mid-incisal edge	0.84	-0.15	0.69	0.56	-0.43	0.13
b) palatal/lingual	1.17	-0.43	0.74	0.61	-0.31	0.30
Cuspid						
a) cusp tip	0.64	-0.04	0.60	0.59	-0.91	
b) palatal/lingual	0.66	-0.13	0.53	0.21	-0.98	
First Premolar						
a) buccal cusp tip	1.62	-0.46	1.16	1.01	-0.69	0.32
b) palatal/lingual cusp tip	2.30	-0.81	1.49	0.52	-0.39	0.13
c) palatal/lingual	1.74	-0.53	1.21	0.67	-0.61	0.06
Second Premolar						
a) buccal cusp tip	2.38	-0.89	1.49	0.64	-0.77	
b) palatal/lingual cusp tip	2.01	-0.78	1.23	0.29	-0.75	
c) palatal/lingual	1.14	-0.51	0.63	0.21	-0.63	
First Molar						
a) MLingual cusp tip	0.13	-0.57		-0.27	-0.30	
b) DBu cusp tip	0.62	-0.54	0.03	-0.34	-0.27	
c) palatal/lingual	0.17	-0.51		-0.47	-0.35	

TABLE VII Mean intertooth width changes between the stages of treatment for both maxillary and mandibular arches.

INTERTOOTH WIDTH

CUSPID **Mandibular Arch**

Angle Classification		Mean change During Treatment (in mm.)	Mean change post-retention (in mm.)	Mean Maintained Change	Maximum Maintained Change
Class I	Non-Extr'n. 7	+ 0.3	− 0.3	0	− 2.3
	Extraction 12	+ 0.8	− 0.9	0	− 1.7
Class II Div. I	Non-Extr'n. 8	0	− 1.1	0	− 2.6
	Extraction 20	+ 1.0	− 1.4	0	− 1.7
Class II Div. 2	Non-Extr'n. 4	+ 1.4	− 1.2	+ 0.2	− 2.0
	Extraction 4	+ 0.1	− 0.5	0	− 2.5

Figure 59. Mean maintained mandibular intercuspid width.

TABLE VIII

INTERSECOND PREMOLAR WIDTH

Maxillary Arch

	Nonextraction (24)		Extraction (40)			
	Mean	Standard Error	Mean	Standard Error	Multiple Range Value	Significance
Pretreatment	41.73	0.152	41.77	0.207	0.211	n.s.
Immediate postretention	41.07	0.152	46.48	0.207	28.547	***
Minimum two years postretention	40.60	0.152	45.88	0.207	27.861	***

E.M.S. 1.07745

Mandibular Arch

	Nonextraction (30)		Extraction (34)			
	Mean	Standard Error	Mean	Standard Error	Multiple Range Value	Significance
Pretreatment	39.34	0.368	37.78	0.251	6.637	**
Immediate postretention	40.15	0.368	37.29	0.251	12.168	***
Minimum two years postretention	39.48	0.368	36.91	0.251	10.935	***

E.M.S. 1.7608

n.s. not statistically significant
* significant at the 5 percent confidence level
** significant at the 1 percent confidence level
*** significant at the 0.1 percent confidence level

TABLE VIII Intersecond premolar widths, stages of treatment by extraction/nonextraction interaction: mean, standard error and significance of differences.

TABLE IX

INTERFIRST MOLAR WIDTH

Maxillary Arch

	Nonextraction (24)		Extraction (40)			
	Mean	Standard Error	Mean	Standard Error	Multiple Range Value	Significance
Pretreatment	5.66	0.262	45.16	0.196	2.398	*
Immediate postretention	46.96	0.262	44.37	0.196	12.422	***
Minimum two years postretention	46.44	0.262	43.79	0.196	13.710	***

E.M.S. 1.3041

Mandibular Arch

	Nonextraction (30)		Extraction (34)			
	Mean	Standard Error	Mean	Standard Error	Multiple Range Value	Significance
Pretreatment	51.55	0.236	51.41	0.183	0.682	n.s.
Immediate postretention	52.91	0.236	50.28	0.183	12.817	***
Minimum two years postretention	52.39	0.236	49.80	0.183	12.622	***

E.M.S. 1.3421

n.s. not statistically significant
* significant at the 5 percent confidence level
** significant at the 1 percent confidence level
*** significant at the 0.1 percent confidence level

TABLE IX Mean interfirst molar widths: stage of treatment by extraction/nonextraction interaction: means, standard error and significance of differences.

in this variable during the three stages of treatment for both maxillary and mandibular arches. The nonextraction/extraction therapy by stage interaction was highly statistically significant at the 0.1 percent confidence level for both arches. Table X illustrates the mean values comparing the nonextraction/extraction by stage interactions. During active treatment the arch length of both the maxillary and mandibular arches were increased in the nonextraction component of the sample, while in the same active treatment period, arch length decreased in the extraction component of the sample. For both arches, regardless of the nonextraction/extraction therapy, the mean values of this variable decreased in the postretention period. Comparison of the nonextraction and extraction groups at both immediate postretention and two year postretention stages of treatment indicated statistical differences at the 0.1 percent confidence level. The Angle classification by stage interaction was not found to be statistically significant.

TABLE X

ARCH LENGTH

Maxillary Arch

	Nonextraction		Extraction			
	Mean	Standard Error	Mean	Standard Error	Multiple Range Value	Significance
Pretreatment	26.60	0.291	26.21	0.255	1.500	n.s.
Immediate postretention	28.23	0.291	21.87	0.255	24.460	***
Minimum two years postretention	27.16	0.291	21.50	0.255	21.768	***

Mandibular Arch

	Nonextraction		Extraction			
	Mean	Standard Error	Mean	Standard Error	Multiple Range Value	Significance
Pretreatment	22.82	0.184	22.16	0.215	3.299	*
Immediate postretention	22.86	0.184	17.76	0.215	25.292	***
Minimum two years postretention	22.29	0.184	17.12	0.215	25.842	***

n.s. not statistically significant
* significant at the 5 percent confidence level
** significant at the 1 percent confidence level
*** significant at the 0.1 percent confidence level

TABLE X Arch length, stage of treatment by extraction/nonextraction interaction: means, standard error and significance of differences.

DISCUSSION

CHAPTER V

DISCUSSION

General Considerations

The evidence from this study of a reasonably large group of orthodontically treated cases tended to support previous work cited in the literature review with regard to posttreatment stability. One overall trend was particularly noticeable throughout the data: that change in values as a result of treatment tended to return toward their pretreatment values during the postretention period. While generally true, this statement is somewhat of an oversimplication, depending on the variable under discussion. Riedel's theorum (1969) of retention which states that "teeth that have been moved tend to return to their former positions", is highly substantiated by the evidence of this investigation. However, because of the nature of this study performed on orthodontic dental casts, it was not possible to discern between the influence of the musculature, the apical base, transseptal fibres, bone morphology or other influencing factors on the relapse tendency observed. It is evident, nevertheless, that some variables specifically, curve of Spee, cuspid and molar relationship and overjet, tended to be more stable than others namely, dental arch asymmetry, intertooth width and overbite, in the postretention period.

Although it has been stated by Amott (1962) and restated in 1971 by Gianelly and Goldman that postretention results are not completely valid unless the cases have been out of retention for a minimum of five years, the lack of availability of such cases prevented adherence to this concept. It has also been observed by Harmon (1966) that recovery of a tooth towards its original position takes considerably less time than it does to orthodontically move a tooth to a new position. This author, however, agrees that the longer the postretention period is, the more likely that maximum recovery of tooth movement would have been realized. Nevertheless, it is felt that the results exhibited by this investigation were meaningful in that all of the cases were out of retention for a minimum of at least two years.

Dental Arch Asymmetry

The use of the midpalatal raphe as a reproducible axis of symmetry in this investigation concurs with its utilization by other investigators including Korbitz (1909), Korkhaus (1934), Haberle (1937), and others. It can be argued, however, that the soft tissue midpalatal raphe does not necessarily accurately represent the midpalatal suture representing the anatomic middle of the maxilla. The utilization of the midpalatal raphe, however, was felt to be much superior to the utilization, for example, of three landmarks found on the occlusal surface of the cast as proposed by Grunberg (1911).

Highly significant asymmetries were noted in both the normal occlusion and the malocclusion groups with the malocclusion group being most affected. The finding that the pretreatment malocclusion group values, as well as the "acceptable" occlusion sample, demonstrated significant asymmetries, was not surprising and concurs with the findings of others including Barr and Gron (1960), Lundstrom (1961), Lear (1968), Vincent (1965) and Jensen (1972), Biggerstaff (1974) and Pepe (1975). The results, however, are in direct contrast to those of Wahlig (1970), who in a study of the maxillary dental arch symmetry in twins, utilized a constructed midline in which he divided the arch into left and right arcs. When he compared the duplication and mirror differences on one side of the maxillary arch against the other side he found no evidence of asymmetry and concluded that the dental arch is generally a symmetrical structure. His method, however, is subject to the same criticisms as that of Grunberg's study in that landmarks for his constructed midline were selected from the dental arch. The results illustrating asymmetry are not unexpected because, as stated by Lundstrom (1961), symmetry is but "a theoretical concept" which is a principle of biology which is "applicable to large numbers but seldom, if ever, to the individual organism". Review of the literature cited indicates that in only few of the studies did the investigators quantify the entire dental arch but rather, utilized various measuring devices and assessed values for asymmetry at specific isolated sites.

This study, however, attempted to quantify the entire dental arch and compute one value representing dental arch asymmetry. The results indicated that although the number of cases exhibiting right side asymmetry biases slightly exceeded the left side asymmetry bias cases, dental arch asymmetry seemed to be randomly distributed. This finding was contrary to the findings of Jensen (1972) who found that both for his Trisomy 21 and control groups for all locations and for all ages, the left side of the dental arch was more distant from the midline than the right. In this study, dental arch asymmetry was found to be independent on a statistical level and randomly distributed according to Angle's malocclusion classification. This result, however, is not surprising in that the criteria of Angle's concept of occlusion are based on antero-posterior relationships of the dental structures of the maxilla to the mandible and have no input from the coronal or lateral dimension.

To date, there have been few studies reported on the effect of orthodontic treatment on dental arch symmetry. It was of particular interest to note in this study that during treatment one of two changes was being effected on the dental arch as a result of treatment. 1) That the dental arches were either made more symmetrical, which occurred in approximately 84 percent of the sample while, 2) in the rest of the sample the arches were made increasingly asymmetrical. The improvement of the dental arch symmetry is likely the result of the utilization of arch wire matrix guides and the utilization of preformed symmetrical arch wires. Those cases in which the dental arches were made increasingly asymmetrical are more difficult to explain. It was interesting to note that the pretreatment asymmetry values for the cases which were made increasingly asymmetrical during treatment, were not significantly different from the values of the "acceptable" occlusion sample. In fact, it is possible that pretreatment dental arches that were originally fairly symmetrical have been rendered asymmetrical as a result of poor mechanotherapy. Furthermore, these cases may go unnoted because dental arch symmetry is not a criterion upon which one categorizes the success of orthodontic treatment. Occlusal anteroposterior relationships, particularly cuspid and molar relationships as well as other variables under consideration in orthodontic treatment, have greater priority than symmetry in the assessment of successful treatment. It is obvious, nevertheless, that changes have been effected in the dental arches regardless of the effect of treatment upon dental arch symmetry.

The fact that the original asymmetry tends to return toward its pretreatment value in the postretention period, is a result consistent with findings of other variables in orthodontic treatment. The magnitude of the recovery toward the pretreatment value as well as the number of cases that tend to return toward their pretreatment value in the postretention period, was very substantial. A reason which may explain the tendency for the dental arch to return toward its pretreatment asymmetry was suggested in 1950 by Brodie who illustrated the asymmetry of the alveolar process which supports the dental units. This author suggests that superimposed upon the already generally observed tendency for teeth to return toward their original positions in the postretention period, is the tendency of the supporting alveolar bone complex to continue to grow in its asymmetrical form carrying with it the dental units. It has been postulated by Lundstrom (1961), that orthodontic treatment has little effect upon the apical base and that malocclusions are the result of apical base discrepancies. Other reasons have been postulated including asymmetrical muscular patterns and pillowing habits (Lear and Moorees 1968).

An attempt was made in this investigation to analyze the suggestion by Tirk (1965), Reitan (1967) and Riedel (1960 and 1969), that "malocclusions should be overcorrected as a safety factor". Analysis of the data, however, illustrated that very few cases had been overcorrected relative to dental arch asymmetry and the data did not allow the author to draw any conclusions in this regard. The results are consistent with the suggestion that the dental arches should be overcorrected during treatment in an effort to increase the stability of the resultant improvement of dental arch symmetry. Nevertheless, it would seem difficult clinically to effect an overcorrection of a severe dental arch asymmetry. In fact, as has been demonstrated by the results, few, if any cases in the sample under investigation, were made perfectly symmetrical as assessed by the symmetry indices utilized. It does, however, suggest that a future investigation should be initiated to attempt to overcorrect severely asymmetrical dental arches and study the stability of the improvement in symmetry in the postretention period.

Another area which the author feels deserves further study is to test the hypothesis that the relapse toward the pretreatment value of the dental arch asymmetry is a result of growth of the supporting alveolar bone. One investigation would be to repeat the same study on a group of treated adult nongrowing patients.

It has been noted in the results that the mandibular arch asymmetries are greater than the maxillary arch values. It has been observed by this author, as well as others, that the denture midlines of the maxillary and mandibular arches do not coincide. This would account for an increased mandibular arch asymmetry value.

It has been noted in the review of the literature that the majority of the studies on dental arch asymmetry have been restricted to the maxillary arch utilizing such instruments as the symmetrograph by Korkhaus. This is understandable, in that the mandibular arch does not present an easily definable baseline for measurement. Further to this, adequate transfer devices of the maxillary midline axis of symmetry had not been developed. The author feels that the transfer method utilized in this investigation is superior to the right angled instrument utilized by Jensen (1972). However, any transfer method is subject to the same criticism and inaccuracies because the transfer technique requires that the models be positioned such that the teeth are in occlusion. Nevertheless, as pointed out by Jensen, a more reliable method has yet to be developed.

Another interesting finding of this investigation was that dental arch symmetry stability was independent of extraction procedures as an adjunct to orthodontic treatment. The decision to extract or not to extract teeth in any given case is made on other factors such as the magnitude and degree of crowding, the relationship of the dental units to the apical base, profile, age, amongst other criterion and that dental arch symmetry, except in grossly asymmetrical cases, is not considered as a factor upon which the extraction of teeth would be predicted.

The methodology of this study may be used to further investigate dental arch asymmetry. For example, an investigation of longitudinal records may determine if dental arch asymmetry varies with age. In addition, although the existence of dental arch asymmetry has been documented, this project, because of its nature, was unable to answer the underlying question of why dental arch asymmetry occurs. Future attention should be directed at identifying factors responsible for dental arch asymmetry.

Intertooth Width

Examination of the data presented concerning intertooth width dimensions disclose significant and clinically important observations. The observation that the maxillary arch was able to tolerate more expansion of intertooth widths than the mandibular arch, concurred with the findings of Amott (1963) and Rose (1969). These observations are based on the fact that the mandibular arch is the contained arch. Another reason for this observation is that the oral musculature has a greater influence on the mandibular arch than the maxillary arch. The influence of the musculature comparing the maxillary and mandibular dental arches, however, has been controversial.

The evidence of this investigation has indicated that all dental unit intertooth widths measured demonstrated a return toward the pretreatment dimension in the postretention period. Of particular clinical interest was the postulate of maintaining original intercanine width throughout treatment in order to insure a stable result (McCauley (1944), Strang (1946, 1949, 1952), Webster (1948), Dona (1952), Jones (1956), Peak (1956), Riedel (1960 and 1969), Steadman (1961), Martin (1962), Amott (1962), Arnold (1963), Kelly (1959), Welch (1965), Rose (1969), Harris (1970), Davis (1971), Renger (1973), Shapiro (1974)). The data presented in this study concurs with these findings but suggests that mandibular intercuspid width tends to continue to decrease in the postretention period. The central tendency of the intercanine width in the postretention period was to revert to a value lesser than the original intercanine dimension following the two year postretention period. The interpretation of these findings suggests that intercanine width of the original malocclusion should serve as the maximum value for the mean intercanine width to be expected following the postretention period. The results of this investigation lend support to McCauley's concept of intercanine width as an uncompromising dimension.

It would be erroneous, however, to imply that there are no exceptions to the tendency of mandibular intercuspid width to assume its original or a lesser value. It is important to recall that the values that have been considered in this investigation are mean central tendencies and, as was pointed out in the results, there are exceptions to this mean tendency.

This author concurs with the suggestion by Steadman (1961), when he stated that orthodontic tooth movement and retention will produce lasting changes only in those patients in whom the forces acting upon the intercuspid widths have changed in such a manner during treatment and retention as to support the repositioned teeth in their newly acquired positions. This postulate has been reiterated by Renger (1973) and King (1973), who suggest that there is a limit to the amount of expansion that can be tolerated and once this theoretical limit is surpassed, recovery of the intercuspid and intermolar widths occur.

No definitive criteria have yet been established to differentiate which patients will successfully maintain intercanine width expansion. In this regard, Shapiro (1974) has suggested that Angle Class II, Division 2 subjects demonstrate a significantly greater ability to maintain treatment intercanine width expansion than other Angle malocclusion groups. This investigation, however, was unable to substantiate this finding. In fact, there were no significant differences in the ability to maintain intercuspid width amongst the Angle classification of malocclusion groups.

The evidence of this investigation is in direct conflict with the results reported by Walters (1953 and 1962) in which 62 percent of his extraction cases maintained an average 1.4 mm increase of intercanine width while 62 percent of his nonextraction cases maintained an average increase of 2 mm of intercanine width.

No discernable differences were detected in the stability of intercuspid width regardless of whether extraction therapy was or was not utilized as an adjunct to orthodontic therapy. Strang, in 1949, evolved the hypothesis that an increase in intercanine width could be gained by the distal movement of the canines into the extraction spaces. The question arises then as to whether or not extraction therapy had any effect on the resultant mandibular intercanine widths of this sample. Statistical analysis indicated that extraction had no significant effect on the amount of resultant intercanine widths. This concurs with the findings of other investigators including Arnold (1963), Welch (1965), and Harris (1970). Two possible conclusions can be arrived at relative to Strang's hypothesis: First, if the hypothesis is correct, then adequate distal movement of the cuspids into the extraction space of this sample, was not realized; or secondly, that Strang's hypothesis is not valid. Because this investigation did not encompass assessment of the retraction of cuspids into the extraction space, further study of this sample utilizing cephalometric radiographs might prove revealing.

Statistical analysis of intermolar width changes indicated that extraction therapy had a significant effect on decreasing intermolar width. The explanation advanced for this observation by Strang (1949), was that the decrease of intermolar width was the result of mesial movement of the first molars into the extraction spaces and thus, into a narrower buccal dimension of the arch. Again, if this explanation is valid, then it seems reasonable to expect that distal movement of the canines into a wider buccal dimension of the arch would effectively increase the resultant intercanine width. As previously mentioned, however, discussion of antero-posterior tooth movement is beyond the scope of this investigation. An investigation correlating anterior-posterior movement of canines and molars against intercanine and intermolar arch widths, would be of great clinical import.

The results of this investigation relative to intermolar width, indicated that in cases utilizing extraction of teeth as a part of treatment, the intermolar width decreased during active treatment and continued to decrease in the postretention period. The intermolar width in the nonextraction group was increased during active treatment and although the mean values indicated a tendency to return toward pretreatment values, a resultant increase in intermolar width was maintained in the postretention period. In the maxillary arch, a mean resultant increase of 0.78 mm was observed at the end of the postretention period, in the nonextraction cases. In the extraction cases a further mean decrease of 0.58 mm of intermolar width was observed in the postretention period.

In the mandibular arch, the nonextraction sample indicated a mean intertooth width increase of 1.36 mm during active treatment and a resultant decrease of 0.55 mm. The extraction group demonstrated a mean decrease of 0.87 mm during active treatment and a further mean decrease of 0.48 mm in the postretention period.

These results are in direct conflict with the opinion expressed by McCauley (1944), who felt that both intermolar and intercanine width, particularly of the mandibular arch, are uncompromising dimensions and should be maintained as originally presented.

Although the results of this investigation concur with the findings of Walters in his studies of 1953 and 1962 the resultant maintained intermolar width increases are modest in comparison to the findings reported by that author. The results of this investigation of changes in intermolar width of the cases treated with the extraction of teeth more closely concur with the findings of Welch (1965), who observed that the postretention intermolar width tends to be less than its pretreatment value regardless of whether or not this dimension was increased or decreased during treatment. His samples consisted of 34 extraction cases at least five years out of retention.

As a general observation, the results of intermolar width concurred with those of Shapiro (1974), who observed that intermolar width decreased more significantly in the extraction cases than the nonextraction cases from pretreatment to postretention. Much of the treatment intermolar width expansion was maintained in the nonextraction group although the trend was to return toward the pretreatment dimension. In addition, in the extraction group, intermolar width was decreased during treatment and continued to decrease during the postretention period. These results and observations, however, are in direct conflict with the study of Harris (1970), who observed that intermolar width which was increased, continued to expand after the completion of treatment and retention.

As already noted earlier, the inference drawn from these results have been based on central tendencies. Exceptions to the central tendency have been observed and these observations lend some support to the suggestion of Rose (1969), reiterated by King (1973), that intermolar width can be expanded or contracted within controlled limits without affecting the stability of the denture. As yet, no definitive criterion have been established either to identify the patient or define the outer extremes of the "controlled limits".

Arch Form

As outlined in review of the literature, several geometric curvilinear configurations have been suggested for the description of dental arch form. The major three of which were the parabola, the ellipse and the catenary curves. Although it is possible to generate various different curves derived from varying landmarks representing each dental unit, only two curves were considered in this study. The first curve considered included the mid-incisal edges of the anterior teeth and the buccal cusp tips mesial to and including the first molars; the second curve was described utilizing points on the facial or outer surfaces of the teeth. In orthodontics, concern is directed to the outer curve which represents the facial surfaces of the teeth for it is here that the orthodontic appliances apply forces intended for tooth movement. The sample utilized to assess arch form were the 27 "acceptable" occlusion patients from the study of Banack, Cleall and Yip (1972), of grade six, 12 year old Winnipeg school children. As a result, the distal extension of arch form considered was the first molars of both arches. Limiting the region studied to that portion of the dental arch mesial to including the first permanent molars, has been criticized in the studies of both Currier (1966) and Neilans (1968), who suggest that a more complete dental arch form should include second permanent molars and, where possible, third permanent molars. The conflicting results of this investigation compared to those of Currier and Neilans, can be accounted for in part by the difference in the region of the dental arch included in the investigation. It is felt that this study can be defended on the basis that second molars, particularly in the maxillary arch, are not always banded in orthodontic treatment. However, it must be realized that because of the availability of the sample and the inconsistency of the eruption of the second permanent molars, they were not included in the present investigation.

It was the original intent of this study to investigate all three curves including the parabola, the ellipse and the catenary curve as well as polynomial equations to the sixth power. When the data was subjected to mathematical curves of the parabola and polynomial equations ranging to the sixth power, it became obvious that the parabola had a very high degree of fit to both arches and both curves: the first, through the mid-incisal edges and the buccal cusp tips, as well as, the curve representing the facial periphery of the dental units. This investigation did not concur with the results reported by Pepe (1975), who suggested that the coefficients of the sixth degree polynomial equation were superior to the more simplified mathematical equation of the parabola.

It must be realized, however, as suggested by Biggerstaff (1972) and Lavelle (1975), that variations exist in the dental arch form of varying races and this may account for the differences found between investigators utilizing individuals of other racial backgrounds than those of this study.

It is the feeling of this author, however, that the most basic difference in the results of other investigations and this study is that second and third permanent molars were not considered in the analysis of dental arch form. Comparing the catenary curve with that of the parabola it is obvious that they closely resemble each other and differ only in that the arms of the catenary curve do not tend to approximate straight lines as they are always curved however slightly.

It has been suggested by Brodie (1953) that the sphincteric action of the buccinator and superior constrictor muscles of the pharynx on the posterior teeth affect the distal segments of the dental arch form in the maxillary arch such that they would not form straight lines but start to recurve. It is this recurving attributed to the buccal pressures effected by the oral musculature which accounted for the suggestion of the catenary curve by MacConaill and Scher (1949) and Scott (1957) and the ellipse suggested by Currier (1966) and Neilans (1968). This author, however, tends to concur with the suggestion of Musich and Ackerman (1973), who suggested that if the arch form is only going to be assessed from the first molar to the contralateral first molar, it is probably not important whether a catenary, ellipse, or parabolic curve is chosen as the "mean curve". For orthodontic purposes, as compared to anthropometric or anthropologic purposes, the very high "goodness of fit" of this sample with that of the simple equation for the parabola, support its acceptance.

Brodie (1953) stated that the mandibular arch would more likely be influenced by the musculature of the tongue, the position of the mandibular condyles, the forces of occlusion, as well as the morphology of the teeth.

The findings of this investigation of the two mandibular arch curves are contrary to those of MacConaill and Scher (1949), Currier (1966) and Neilans (1968), who found a better "goodness of fit" with the catenary curve as compared to that of the ellipse or parabola. In addition, as previously mentioned, Shapiro (1973) pointed out that the catenary parameter "a" demonstrated a large standard deviation around the mean and provided some difficulty in the application of the catenary curve as a mathematical equation.

This study did not include the analysis of the ellipse or the catenary curve. In addition to these, the possibility exists that some, as yet untested curvilinear configuration, might provide an even better "goodness of fit". However, it is suggested that the parabola is a viable starting point for clinical orthodontics. The results of this investigation on dental arch form concur with other proponents of the parabolic curve including Bonwell (1885), Broomell (1902), Hawley (1904), Angle (1907), Remson (1964), as well as Mills and Hamilton (1965).

The results of this investigation also differ from those reported by Currier and Neilans, who suggested that little variation is allowed in selection of points before the curve being tested becomes a different curve. The mean values of the "acceptable" occlusion sample indicated that the differences between the mathematical curves described for the mid-incisal edge and buccal cusp tip locations as compared to the curve representing the facial periphery of the dental units, differed only at the third significant figure of the multiple regression value. These differences were not only statistically insignificant but, more importantly, have no clinical significance.

Few studies in the literature have reported on changes in the dental arch form with treatment. It would be of great interest to apply the parabolic equation to study changes as a result of treatment in the dental arch form of this sample and subsequently evaluate the stability of changes effected in dental arch form. Riedel was referring to linear dimensions, specifically intercanine and intermolar widths, when he suggested in one of his theorums of retention that "arch form, particularly in the mandibular arch, cannot be permantly altered by appliance therapy". It would be very interesting to test this postulate utilizing the equation for the parabola on the treated cases of this investigation and compare the results with those reported by Shapiro (1973) using the catenary curve. In addition, another potentially revealing study which would have great clinical application would be an investigation of the coordination of the maxillary and mandibular dental arch forms.

It is important to note the comment advanced by Hawley (1904) when he cautioned against the strict use of any method in determining arch form and suggested that it serve as a guide and that each case is individual unto itself and must be treated accordingly.

The results suggest that the degree of lack of absolute fit to the mathematical curve is another expression of the lack of perfect symmetry of dental arch form previously illustrated in this study.

Overbite

The results are consistent with the findings of Steadman (1940), who reported that the mean overbite of subjects with acceptable occlusion was 3.1 mm with a high standard deviation of 1.9 mm. The values derived in this investigation indicate that the mean overbite of the "acceptable" occlusion sample was 3.3 mm with a standard deviation of 1.87 mm indicating a great deal of individual variation.

The evaluation of the malocclusion groups indicated that the Class II, Division 2 group demonstrated the greatest degree of anterior overbite. This is consistent with the classic criteria of Angle's classification of malocclusion in which a high degree of overbite is pathognemonic of the Class II, Division 2 malocclusion group. The observation that overbite was decreased in all malocclusion groups during treatment and then had a tendency to return in the postretention period toward its pretreatment value, is consistent with the overall findings of this investigation. The results are consistent with the findings of Cole (1948), Dona (1952), Walter (1953), Hasstedt (1956), Stackler (1958), McGill (1960), Ludwig (1967), Rose (1967), Smith (1969), Simons and Joondeph (1973) and Hernandez (1969) as well as Levin (1972) and Dempsey (1974). However, the above findings are in direct conflict with those of Amott (1962), who suggested that overbite was decreased during treatment and that it continued to decrease in the postretention period.

The observation that overbite was decreased further in the nonextraction cases as compared to the extraction cases, is consistent with the finding of McGill (1960). This can be explained, in part, by the treatment techniques employed. In nonextraction cases, overbite is decreased, in part, by intrusion of the incisors, proclination of the anterior teeth of both arches, as well as the extrusion of molars as a result of extraoral forces applied by headgear. As a general rule, however, in extraction cases, although overbite is affected by the intrusion of the anteriors and the extrusion of the posterior teeth, the inherent tipping effect of the mechanics utilized in space closure influences the amount of overbite improvement. The mechanics at our disposal in clinical orthodontics are not adequate to provide complete bodily retraction of teeth, but rather, have a tipping component. Another conceivable comment is that inadequate attention is directed to improvement of this variable in the treatment planning of cases requiring extraction of teeth as an adjunct to orthodontic treatment.

The findings of this investigation are coincident with those of Hernandez (1969), who suggested that there was a greater increase in overbite relapse in extraction cases as compared to nonextraction cases. The results of this study concur with the suggestion of Riedel (1960 and 1969) and restated by others including Smith (1969), who suggested that deep bites should be overtreated as a safety factor.

As noted in the review of the literature, several investigations utilizing lateral cephalometric radiographs, comparing overbite with other skeletal planes, have resulted in several postulates. One of which is Schudy's (1963) suggestion of a symbiotic relationship between the interincisal angle and the degree of anterior overbite. The studies of Smith (1969), Hernandez (1969), Simons and Joondeph (1973) have supported Schudy's contention. Levin (1972), however, was unable to demonstrate any significant correlations between overbite and interincisal angle. Correlative relationships between other skeletal planes and growth patterns with overbite have been suggested by other authors. A follow-up investigation of this sample utilizing lateral cephalometric radiographs perhaps would be able to provide additional information on this subject.

Curve of Spee

The results of this investigation are consistent with the suggestion by Andrews (1969), who observed that the curve of Spee of a "normal" occlusion sample is flat or very gently curved. The finding of this investigation, that the cusp tip of the cuspid lies above the plane of occlusion, might lend support to the suggestion (Roth, 1969) of cuspid protected occlusions. It must be realized, however, that this investigation was a static study performed on orthodontic plaster models and the inference to dynamic function is strictly conjecture.

The total malocclusion group demonstrated a more pronounced curve of Spee differing significantly from that of the "acceptable" occlusion sample. The results were consistent with the findings of Braun and Schmidt (1956), who were unable to observe significant differences in the depth of curve of Spee between Angle's malocclusion classifications. These results, however, are not consistent with the findings of Jaraback and Fizzell (1963), who suggested that the curve of Spee was most pronounced in the Class II, Division 1 malocclusion groups and least pronounced in the Class I, Class III and Class II, Division 2 malocclusion groups.

The effect of treatment resulted in a flattening of the curve of Spee which was highly significant for all malocclusion groups. This observation is consistent with the objectives of orthodontic treatment as proposed by Strang (1950) and others.

No differences were detected between the extraction/nonextraction of teeth as an adjunct to orthodontic treatment in the effective reduction of the depth of the curve of Spee. This concurs with the results of Barnett (1964), who reported that the extraction of teeth during orthodontic treatment did not produce deeper curves of Spee following treatment.

Although it has been suggested in the literature that the curve of Spee has a great tendency to return in the postretention period, the observations of this investigation do not concur, but rather, are in concert with the findings of Spell (1967) and Turner (1973), who found that a flattened curve of Spee was a relatively stable variable in orthodontic treatment. Turner (1973) reported that 92 percent of his treated cases showed a permanent levelling for his type A curve of Spee, while 84 percent showed a permanent change in his type B curve.

It is of great interest to note the observations of this investigation which suggest that the curve of Spee is not a gentle consistent curve from the incisal edge of the lower incisor to the disto-buccal cusp of the first molar, but rather a composite of two curves. The first, from the incisal edge of the central incisor to the cuspid which lies above the line of occlusion and then, a second gentle curve between the cusp tip of the cuspid and the disto-buccal cusp of the first permanent molar (Figure 60).

Overjet

The pretreatment values of this variable are consistent with the classic description of Angle's system of malocclusion classification. The Class II, Division 1 group demonstrated the greatest values and differed significantly from the Class I and Class II, Division 2 groups.

Consistent with other findings of this study, treatment had significant effects upon this variable. Although all of the malocclusion groups demonstrated the same tendency to return toward their pretreatment

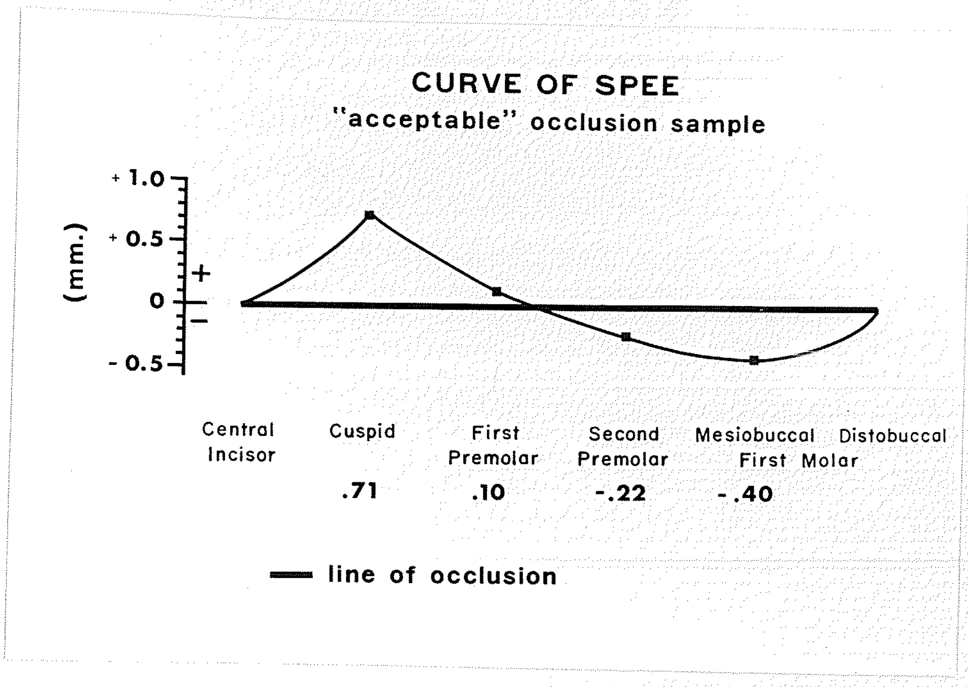

Figure 60. Graphical representation of the curve of Spee of the "acceptable" occlusion sample.

overjet value in the postretention period, it is noted that the only statistically significant difference was exhibited by the Class II, Division 1 sample, which also demonstrated the greatest pretreatment overjet. It was interesting to note that the extraction of teeth as an adjunct to orthodontic treatment had no significant difference in the correction of this variable during treatment, nor did it demonstrate any differences in postretention stability. Findings of this investigation indicating the relative stability of overjet in the postretention period are consistent with the findings of Dietz (1972), who suggested that some of the posttreatment relapse tendencies in this variable were due to the lingual collapse of the mandibular incisors. Although this may be a factor, it must be cautioned that when crowding ensues in the anterior dental segment, it is possible that the mandibular right central incisor can be displaced further labially, resulting in a maintenance or further decrease of overjet in the postretention period. It is very important then to identify and realize the inherent problems in measuring this variable.

In addition, the lack of relapse in the postretention period of this variable may, in part, be due to the asynchronous horizontal component of mandibular growth. Further investigation of this sample utilizing lateral cephalometric radiographs, may be able to confirm this postulate and identify any correlations which may exist between overjet and skeletal and dental cephalometric planes and changes of this variable both during treatment and in the postretention period.

Denture Midline Discrepancy

The results suggest that perfect symmetry is but a theoretical concept and does not exist on an individual basis. The denture midlines of both the "acceptable" occlusion sample as well as the malocclusion group sample, were not coincident. Some interpretive comments with regard to this finding are that the maxillary and mandibular arch forms are not completely coordinated, thus, contributing to noncoincident anterior dental midlines. In addition, this variable can be affected by tooth size/tooth size discrepancy of the maxillary to the mandibular dental units indicated by a Bolton discrepancy. In the malocclusion groups, denture midline discrepancies can be further influenced by the degree of crowding and the resultant displacement of the dental units.

The finding that the immediate postretention and two year post-retention values of the malocclusion groups did not significantly differ from zero, indicated that the denture midlines were made coincident with treatment and were stable in the postretention period. It must be realized, however, that the large standard deviations greatly affect the statistical handling of this data and thus, the interpretation can be easily criticized.

Cuspid and Molar Relationships

When the raw data of this investigation are examined, it must be realized that the lateral view photographs of the orthodontic models were made with the midline perpendicular to the film as opposed to the way orthodontists conventionally examine orthodontic models in which the buccal segment is perpendicular to the visual plane. The purpose of photographing the models with the midline construction perpendicular to the film was an effort to enable in a future investigation of the same sample, the superimposition of the model analysis upon the lateral cephalometric radiographs which are taken with the midline approximately perpendicular to the radiographic film. The result of this variation in model positioning has resulted in the raw numerical data assuming an apparent Angle Class II tendency.

The findings of the analysis of cuspid relationship are consistent with the criterion utilized for Angle's malocclusion classifications. The difference detected between the "acceptable" occlusion sample and the Angle Class I malocclusion group can be justified on the basis that Class I malocclusion cases often demonstrate cuspids blocked mesially and labially out of the arch. The comparison of the "acceptable" occlusion sample and the Class I malocclusion group with the Class II malocclusion groups are consistent with Angle's classification of malocclusion.

The effects of active treatment indicated significant improvement of the cuspid relationship in the Class I malocclusion group. Consistent with the objectives of orthodontic treatment, Class I cuspid relationships were effected in the Class II malocclusion groups at the end of active treatment.

The finding that no statistical differences in cuspid relationship were noticed between the malocclusion groups at the immediate postretention period, suggests that regardless of Angle's malocclusion classification, a Class I cuspid relationship was obtained.

The data further suggests that cuspid relationship is a stable variable in the postretention period, regardless of Angle's malocclusion classification and whether or not extraction of teeth was incorporated as an adjunct to treatment. This author suggests that the stability of both cuspid and molar relationship as well as overjet, has been influenced by the horizontal component of mandibular growth.

Molar Relationship

That no significant differences were noted between the "acceptable" occlusion sample and the pretreatment Angle Class I malocclusion group values was consistent with the criteria of Angle's system of malocclusion classification. Consistent with this finding, the "acceptable" occlusion and Class I groups differed from the Angle Class II malocclusion groups at a very high statistical level.

During treatment it was noted that Class I molar relationship was maintained in both the Class I nonextraction and extraction groups. The findings also indicated that the Class II malocclusion cases treated either nonextraction or with four premolar extraction as an adjunct to orthodontic treatment, were successful in establishing a Class I molar relationship. Consistent with the objectives of the orthodontic mechanotherapy in cases treated with two maxillary first premolar extractions, a definitive Class II molar relationship was established.

The finding that molar relationship is a stable variable in the postretention period leads to the suggestion that Class I molar relationship may be influenced in the postretention period by the continued horizontal component of mandibular asynchronous growth. That a Class II molar relationship is stable in the postretention period is consistent with the postulates and suggestions of Thurow (1970) and others.

Arch Length

Arch length was increased during treatment in those cases treated without the extraction of teeth. This is consistent with findings noted in the literature. It has been suggested that the arches are levelled and existing crowding is alleviated by the proclination of incisors effectively increasing arch circumference and increasing arch length. In cases treated with extraction of teeth as an adjunct to orthdontic therapy, the finding that arch length decreases during treatment is consistent with the finding that the degree of crowding as measured in mms, is rarely as large as the sum of the mesio-distal dimension of the teeth extracted.

That arch length decreases in the postretention period, regardless of whether the cases were treated with or without the extraction of teeth, has been explained on the basis that in the nonextraction cases, the incisors tend to upright and retrocline in the postretention period toward their original axial inclinations. In cases treated with the extraction of teeth, the decrease in arch length in the postretention period has been interpreted as a result of the denture, particularly the lower incisors, being carried either into the palatal surface of the maxillary incisors or the perioral musculature as a result of latent horizontal component of mandibular growth. Further investigation of this sample utilizing lateral cephalometric radiographs might provide additional information with regard to this variable as it relates to other skeletal and denture planes.

SUMMARY AND CONCLUSIONS

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purposes of this investigation were to identify, quantify and analyze dental arch symmetry, to compare untreated "acceptable" occlusion case records against those obtained before orthodontic treatment and compare these pretreatment records against those obtained immediately postretention and a minimum of two years postretention. In addition, the changes effected in orthodontic variables including intertooth width, overbite, overjet, depth of the curve of Spee, cuspid and molar relationship, as a result of treatment as well as the stability of these changes in the postretention period were assessed.

The sample consisted of twenty-seven "acceptable" occlusion cases selected from a previous study of Banack, Cleall and Yip (1972), as well as a malocclusion group of sixty-seven cases, predominantly Class I and Class II division 1, but representative of all Angle's malocclusion classifications. The assessment of significant differences between the "acceptable" group and the malocclusion group values as well as the changes affected by orthodontic treatment and subsequent stability in the post-retention period, were determined by means of a factorial analysis of variance. From subjective and statistical analysis of the data, the following conclusions emerged:

1) Three symmetry indices were devised to quantitatively describe dental arch asymmetries.
2) Dental arch asymmetry is independent from and randomly distributed amongst Angle's malocclusion classifications.
3) The dental arches of the untreated "acceptable" occlusion sample were not perfectly symmetrical and differed statistically from the pre-

orthodontic treatment case values.

4) Pretreatment dental arch asymmetries tend to return in the post-retention period after the retaining devices have been removed. The extraction or nonextraction of teeth as an adjunct to orthodontic therapy, seemed to have no consistent effect on posttreatment dental arch symmetry stability.

5) Regardless of the orthodontic variable under investigation, the values tended to return toward their pretreatment values during the postretention period. Some of the orthodontic variables, however, tended to be significantly more stable in the postretention period than others.

6) Intertooth width changes, particularly expansion, were more consistently maintained in the maxillary than in the mandibular dental arch. In the mandibular arch, intertooth width increases were least tolerated in the cuspid region regardless of Angle's malocclusion classification or whether the extraction of the tooth was or was not incorporated as an adjunct to orthodontic therapy.

7) Intermolar width, regardless of arch, decreased more significantly in the extraction cases than in the nonextraction cases from pre-treatment to postretention. Although the trend was to return toward the pretreatment dimension, much of the treatment intermolar width expansion was maintained in the nonextraction group. In the extraction group, the intermolar width was decreased during treatment and continued to decrease during the postretention period.

8) The analysis of arch form based on mathematical geometric configurations suggested that the parabola had a very high "goodness of fit" to the dental arch form of both the maxillary and mandibular

dental arches for both curves investigated.

9) The configuration of the curve of Spee of the "acceptable" occlusion sample differed significantly from the malocclusion groups. The curve of Spee of the "acceptable" occlusion sample appeared to be a composite of two curves, the first from the incisal edge of the central incisor to the cuspid and then a second gentle curve between the cusp tip of the cuspid and the disto-buccal cusp of the first permanent molar.

10) No significant differences were observed in the depth of the curve of Spee between Angle's malocclusion classifications, nor were significant differences detected between the extraction/nonextraction of teeth as an adjunct to orthodontic treatment in the effective reduction of the curve of Spee. A flattened curve of Spee was found to be a relatively stable variable in the postorthodontic treatment period.

11) Overjet appears to be a relatively stable variable in the post-retention period, the reason for which has been ascribed in part to the latent asynchronous horizontal component of growth of the mandible.

12) Orthodontic treatment was successful in effecting a Class I cuspid relationship regardless of Angle's malocclusion classifications. Cuspid relationship is a stable variable in the postretention period regardless of Angle's malocclusion classification or whether tooth extractions were or were not incorporated as an adjunct to orthodontic treatment.

13) Orthodontic mechanotherapy was successful in effecting Class I molar relationships in both four premolar extraction cases as well

as nonextraction cases. Consistent with the objectives of the treatment, cases treated with the extraction of two maxillary first premolars resulted in a difinitive Class II molar relationship. Both Class I and Class II molar relationships were found to be stable in the postretention period.

14) Cases treated without the extraction of teeth resulted in the arch length being increased during treatment while those treated with the extraction of teeth resulted in a decrease of arch length during treatment. However, arch length decreased in the postretention period regardless of whether the cases were treated with or without the extraction of teeth.

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A P P E N D I X

DENTAL ARCH FORM - "ACCEPTABLE" OCCLUSION SAMPLE

(Mid-Incisal Edge and Buccal Cusp Tips)

Curve Fitting where $Y = B_2X^2 + B_1X + B_o$

Maxillary Arch

Subject No.	Multiple R	B_2	B_1	B_o
1	0.98930	0.04833	-2.00022	26.76209
2	0.98423	0.04294	-1.87832	25.52385
3	0.99706	0.05319	-2.15845	28.07801
4	0.98884	0.04372	-1.76513	24.00539
5	0.98466	0.04835	-2.05920	29.20632
6	0.99131	0.04836	-1.86225	22.90585
7	0.98380	0.05015	-1.98685	24.99134
8	0.99177	0.05428	-2.03937	25.22044
9	0.98786	0.04647	-1.92704	23.84554
10	0.98481	0.04821	-1.89739	25.23073
11	0.97772	0.04934	-2.07613	27.40839
12	0.99485	0.04938	-2.05922	30.28664
13	0.98372	0.04335	-1.78698	24.76462
14	0.99152	0.04096	-1.61120	22.47616
15	0.97959	0.05462	-2.11442	25.08713
16	0.98737	0.03939	-1.56538	21.59507
17	0.99402	0.04236	-1.77893	23.36226
18	0.99088	0.04106	-1.69489	24.40137
19	0.98963	0.04921	-1.98838	25.01361
20	0.98624	0.05078	-2.06428	26.94658
21	0.99484	0.04615	-1.84877	23.70091
22	0.97174	0.05105	-2.06644	25.86710
23	0.98707	0.04388	-1.75905	23.94703
24	0.98161	0.04914	-2.01937	25.33876
25	0.99616	0.04620	-1.85297	26.70531
26	0.98541	0.04364	-1.79424	24.62306
27	0.98641	0.03894	-1.54135	21.68578

TABLE XI Multiple R and constant values derived from the curved fitting procedure for the mid-incisal edge and buccal cusp tip locations of the maxillary arch.

DENTAL ARCH FORM - "ACCEPTABLE" OCCLUSION SAMPLE

(Mid-Incisal Edge and Buccal Cusp Tips)

Curve Fitting where $Y = B_2X^2 + B_1X + B_o$

Mandibular Arch

Subject No.	Multiple R	B_2	B_1	B_o
1	0.99241	0.05539	-2.01794	28.07591
2	0.98027	0.04536	-1.70145	25.87330
3	0.99685	0.06327	-2.43027	33.89636
4	0.98965	0.04808	-1.89348	30.22716
5	0.99142	0.05350	-2.16720	33.47726
6	0.99081	0.05590	-2.31514	32.53942
7	0.98963	0.05152	-1.96090	29.00254
8	0.99221	0.06979	-2.81208	36.82884
9	0.98541	0.05475	-2.13225	29.18929
10	0.99159	0.05252	-2.02767	31.71157
11	0.98550	0.05428	-2.11711	31.04200
12	0.99638	0.05447	-2.12038	33.17098
13	0.99512	0.04748	-1.90557	30.71697
14	0.98367	0.04694	-1.84232	28.03361
15	0.98264	0.06432	-2.59677	35.73863
16	0.98688	0.04391	-1.72326	25.66242
17	0.99682	0.04791	-1.87984	27.59105
18	0.99330	0.04403	-1.73551	28.10031
19	0.98684	0.05420	-2.14236	30.21585
20	0.99349	0.05405	-2.07349	30.88999
21	0.99117	0.05236	-2.06678	30.15088
22	0.97531	0.05648	-2.17417	29.54306
23	0.99182	0.05059	-1.92493	27.65887
24	0.98106	0.05419	-2.04841	27.45066
25	0.99789	0.05149	-2.00676	31.89404
26	0.99614	0.04722	-1.86467	29.61587
27	0.98755	0.04361	-1.69267	25.33161

TABLE XII Multiple R and constant values derived from the curved fitting procedure for the mid-incisal edge and buccal cusp tip locations of the mandibular arch.

DENTAL ARCH FORM - "ACCEPTABLE" OCCLUSION SAMPLE

(facial periphery of tooth surfaces)

Curve Fitting where $Y = B_2X^2 + B_1X + B_o$

Maxillary Arch

Subject No.	Multiple R	B_2	B_1	B_o
1	0.98953	0.03862	-1.59715	22.29751
2	0.98799	0.03601	-1.56733	21.60851
3	0.99192	0.04562	-1.84980	23.96090
4	0.98721	0.03649	-1.45804	20.72022
5	0.98310	0.04234	-1.79676	25.36752
6	0.99083	0.04059	-1.59061	20.08193
7	0.98166	0.04280	-1.71330	21.92477
8	0.98970	0.04641	-1.74803	21.70386
9	0.98671	0.03832	-1.57761	19.77523
10	0.98483	0.04246	-1.67083	22.81427
11	0.98190	0.03987	-1.68446	23.26145
12	0.99326	0.04174	-1.73306	25.75782
13	0.98081	0.03505	-1.44598	20.98941
14	0.98671	0.03606	-1.43146	19.53452
15	0.98022	0.04382	-1.70303	21.40870
16	0.98036	0.03495	-1.40164	19.49108
17	0.99561	0.03722	-1.55099	20.37108
18	0.98664	0.03563	-1.46182	20.83140
19	0.98737	0.04254	-1.72823	21.95883
20	0.98521	0.04418	-1.78651	23.31655
21	0.98901	0.04071	-1.64736	21.10137
22	0.97499	0.04106	-1.67523	22.19842
23	0.98060	0.03852	-1.53409	20.48874
24	0.98441	0.04256	-1.74386	22.24452
25	0.99156	0.03979	-1.57769	22.50670
26	0.98167	0.03524	-1.45277	20.91695
27	0.98003	0.03450	-1.37366	19.48927

TABLE XIII Multiple R and constant values derived from the curved fitting procedure for the facial periphery of tooth surface locations of the maxillary arch.

DENTAL ARCH FORM - "ACCEPTABLE" OCCLUSION SAMPLE

(facial periphery of tooth surfaces)

Curve Fitting where $Y = B_2X^2 + B_1X + B_o$

Mandibular Arch

Subject No.	Multiple R	B_2	B_1	B_o
1	0.98792	0.03922	-1.43456	21.89338
2	0.98347	0.03555	-1.34863	21.38373
3	0.99571	0.04290	-1.66339	26.44280
4	0.99085	0.03383	-1.32990	24.35663
5	0.99550	0.04055	-1.63393	27.55197
6	0.99220	0.04228	-1.77535	27.34373
7	0.98953	0.03952	-1.50782	24.04557
8	0.98884	0.04950	-2.03184	29.42420
9	0.98465	0.04042	-1.60629	24.03168
10	0.98899	0.03881	-1.51734	26.19180
11	0.97916	0.03938	-1.55927	25.36100
12	0.99165	0.04037	-1.57244	26.61908
13	0.99013	0.03704	-1.49010	25.79947
14	0.98129	0.03518	-1.41026	23.96176
15	0.97511	0.04225	-1.68862	25.98907
16	0.97877	0.03207	-1.26288	20.53171
17	0.99905	0.03571	-1.39137	22.26273
18	0.99271	0.03552	-1.40104	24.46990
19	0.98688	0.03795	-1.52015	24.25544
20	0.98794	0.04003	-1.51699	24.47841
21	0.99058	0.04012	-1.57098	24.59525
22	0.98391	0.04109	-1.57761	24.00353
23	0.98690	0.03694	-1.40743	21.95549
24	0.98767	0.04077	-1.54173	22.55324
25	0.99664	0.03831	-1.48749	25.81605
26	0.99028	0.03706	-1.46598	24.89586
27	0.97943	0.03183	-1.23706	20.26734

TABLE XIV Multiple R and constant values derived from the curved fitting procedure for the facial periphery of tooth surface locations of the mandibular arch.

GLOSSARY

Landmarks Identified on the Occlusal Views of both Maxillary and Mandibular Orthodontic Models

Landmark

1. The distal aspect of the incisive papilla or its corresponding point on the mandibular model.
2. An easily identifiable point on the midpalatal raphe near the fovea centralis or its corresponding point on the mandibular model.
3. The distal contact point of the right first permanent molar.
4. The mesial contact point of the right first permanent molar.
5. The buccal height of convexity of the right first permanent molar.
6. The palatal height of convexity of the right first permanent molar.
7. The disto-buccal cusp tip of the right first permanent molar.
8. The mesio-buccal cusp tip of the right first permanent molar.
9. The mesio-lingual cusp tip of the right first permanent molar.
10. The disto-lingual cusp tip of the right first permanent molar.
11. The distal contact point of the right second premolar.
12. The mesial contact point of the right second premolar.
13. The buccal height of convexity of the right second premolar.
14. The palatal height of convexity of the right second premolar.
15. The buccal cusp of the right second premolar.
16. The palatal cusp of the second premolar.
17. The distal contact point of the right first premolar.
18. The mesial contact point of the right first premolar.
19. The buccal height of convexity of the right first premolar.
20. The palatal height of convexity of the right first premolar.
21. The buccal cusp tip of the right first premolar.

22. The palatal cusp tip of the right first premolar.

23. The distal contact point of the right cuspid.

24. The mesial contact point of the right cuspid.

25. The facial height of convexity of the right cuspid.

26. The palatal height of convexity of the right cuspid.

27. The cusp tip of the right cuspid.

28. The distal contact point of the right lateral incisor.

29. The mesial contact point of the right lateral incisor.

30. The facial height of convexity of the right lateral incisor.

31. The palatal height of convexity of the right lateral incisor.

32. The mid-incisal edge of the right lateral incisor.

33. The distal contact point of the right central incisor.

34. The mesial contact point of the right central incisor.

35. The facial height of convexity of the right central incisor.

36. The palatal height of convexity of the right central incisor.

37. The mid-incisal edge of the right central incisor.

38. The mesial contact point of the left central incisor.

39. The distal contact point of the left central incisor.

40. The facial height of convexity of the left central incisor.

41. The palatal height of convexity of the left central incisor.

42. The mid-incisal edge of the left central incisor.

43. The mesial contact point of the left lateral incisor.

44. The distal contact point of the left lateral incisor.

45. The facial height of convexity of the left lateral incisor.

46. The palatal height of convexity of the left lateral incisor.

47. The mid-incisal edge of the left lateral incisor.

48. The mesial contact point of the left cuspid.

49. The distal contact point of the left cuspid.

50. The facial height of convexity of the left cuspid.

51. The palatal height of convexity of the left cuspid.

52. The cusp tip of the left cuspid.

53. The mesial contact point of the left first premolar.

54. The distal contact point of the left first premolar.

55. The buccal height of convexity of the left first premolar.

56. The palatal height of convexity of the left first premolar.

57. The buccal cusp tip of the left first premolar.

58. The palatal cusp tip of the left first premolar.

59. The mesial contact point of the left second premolar.

60. The distal contact point of the left second premolar.

61. The buccal height of convexity of the left second premolar.

62. The palatal height of convexity of the left second premolar.

63. The buccal cusp tip of the left second premolar.

64. The palatal cusp tip of the left second premolar.

65. The mesial contact point of the left first permanent molar.

66. The distal contact point of the left first permanent molar.

67. The buccal height of convexity of the left first permanent molar.

68. The palatal height of convexity of the left first permanent molar.

69. The mesio-buccal cusp tip of the left first permanent molar.

70. The disto-buccal cusp tip of the left first permanent molar.

71. The disto-lingual cusp tip of the left first permanent molar.

72. The mesio-lingual cusp tip of the left first permanent molar.

73. The mesial aspect of the right first permanent molar.

74. The mesial aspect of the right cuspid.

75. A point between the central incisors tangent to the mesio-incisal line angles.

76. The distal aspect of the left lateral incisor.

77. The mesial aspect of the left first permanent molar.

Glossary of Landmarks Identified on the Lateral Views of the Orthodontic Models

Landmark

1. An orientation point located on the art portion of the orthodontic model apical to the gingival margin of the mandibular first premolar.

2. An orientation point located on the art portion of the orthodontic model located apical to the gingival margin of the mandibular first permanent molar.

3. A point in the buccal groove of the mandibular first permanent molar.

4. The incisal edge of the mandibular central incisor.

5. The incisal edge of the mandibular lateral incisor.

6. The cusp tip of the mandibular cuspid.

7. The cusp tip of the mandibular first premolar.

8. The cusp tip of the mandibular second premolar.

9. The mesio-buccal cusp tip of the mandibular first permanent molar.

10. The disto-buccal cusp tip of the mandibular first permanent molar.

20. The cusp tip of the maxillary cuspid.

21. The mesio-buccal cusp tip of the maxillary first permanent molar.

Glossary of Landmarks Identified on the Anterior View of the Orthodontic Models

Landmark

1. An orientation landmark located on the art portion of the orthodontic model apical to the gingival margin of the mandibular right lateral incisor.

2. An orientation landmark located on the art portion of the orthodontic models apical to the gingival margin of the mandibular left lateral incisor.

3. The gingival most point on the clinical crown of the mandibular right central incisor.

4. The contact point between the mandibular right and left central incisors.

5. Point identified by the overbite marking procedure on facial surface of the mandibular right central incisor.

6. The cusp tip of the mandibular right cuspid.

7. The cusp tip of the mandibular left cuspid.

8. Incisal edge of the mandibular right central incisor.

14. The contact point between the maxillary right and left central incisors.

GENERAL COORDINATE ANALYSIS PROGRAM

Purpose: To standardize sets of coordinate points and to calculate angular and distance relationships within them.

Method:

a) For each of a group of N subjects, a set of M coordinate (x,y) points is read in. New points may first be generated and added to the original ones. Each subject's points are then "standardized" by having them transformed to a common x-y axis, possibly magnified to bring them to "life size", and/or converted from inches to centimeters. The N subject's original and standardized points are optionally listed and the standardized points are optionally punched. Also, an "average" subject is calculated, having as points, the mean values of the group.

b) Then a series of selection cards is read, each requesting a certain operation to be performed on selected points in the N subject group and "average" subject. These operations can be data point checking, calculation of given angles or distances or rotation centers, etc. All this may be listed and/or punched.

The mean and standard deviation for each selection operation are listed also (and may be punched if desired).

COORDINATE ANALYSIS FOR CINEFLUOROGRAPHIC DATA

Purpose: Given a subject's set of coordinate (x,y) points, some of which are "fixed" (stationary) and others which "move", this program "standardizes" the points with respect to the fixed points and calculates angular and distance relationships between the moving points at their various "stages" of travel.

Method: a) For each subject of a group of N subjects, a fixed number NS of "stages" is read in. The stages represent a sequence of cinefluorographic records of the subject at various moments in his movement and each stage consists of NF predetermined "fixed" or stationary reference coordinate points plus NM predetermined "moving" points whose movement between stages is to be analyzed.

The subject's points at each stage are "standardized" by having them transformed to a common x-y axis based on the "fixed" points, possibly magnified to bring them to "life-size" and/or converted from inches to centimeters. This permits the later superimposition of the stages to analyze angular and distance, etc., relationships between the moving points at the different "stages" of movement.

b) The N subject's original and standardized points are optionally listed and the standardized points are optionally punched. Also, an "average" or "mean" subject is calculated and plotted if requested, having as points, the mean values of the group.

c) Then a series of selection cards is read each requesting that a certain operation to be performed on selected "moving" (and "fixed", if desired) points for each subject plus the "mean" subject. These operations can be data point checking, calculation of given angles or distances or rotation centers, etc., within or between stages. All this will be performed and the results listed and/or punched. The mean and standard deviation for each selected operation will be listed also.