CORRELATION OF MANDIBULAR SKELETAL DEVELOPMENT WITH ANCHORAGE PREPARATION: A CEPHALOMETRIC INVESTIGATION OF TWEED, BEGG, AND A MODIFIED NON-ANCHORAGE EDGEWISE TECHNIQUE

by

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GRADUATE STUDIES

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Abstract

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The purpose of this investigation was to compare and contrast three orthodontic treatment techniques as taught at the Case Western Reserve University Department of Orthodontics: the Tweed technique, the Begg technique, and a modified, non-anchorage, edgewise technique. The focus was directed toward noting whether a significantly different mandibular skeletal growth pattern was produced among any or all of these techniques, as compared to each other or a control group.

The sample consisted of 119 subjects, comprising 15 males and 15 females for each of four groups, except for the female half of the control group in which only 14 lateral cephalograms were acceptable.

A multifactorial analysis of variance, Tukey's Test and Freidman's Analysis were used to test for significant statistical differences among the measurements taken from the pre-and post-treatment lateral cephalograms.

As a result of this investigation, the following conclusions were drawn:

1. No statistically significant differences for mandibular skeletal measures were found among the three techniques examined.

2. The Begg group was found to have a significantly greater increase, at the time of debanding, in the SN-OP angle when compared to the control, but not significantly greater than the Tweed or the non-anchorage edgewise groups.

3. The control group was found to be significantly different from all three treated groups in ramus width and corpus length changes. This was attributed to the fact that the treated cases had four first bicuspids extracted while the control did not.

4. Examination of mean trends showed that the Tweed technique was slightly more consistent with changes seen in normal growth.

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INTRODUCTION

This study will examine three orthodontic treatment techniques, Tweed, Begg, and a contemporary edgewise technique, to determine if specific mandibular changes and condylar growth responses relate to anchorage preparation, as described by the Tweed philosophy. Linear and angular measurements taken from tracings of lateral cephalometric radiographs will be analyzed for statistical differences. A group of untreated cases will serve as a control.

Since the Class II malocclusion was defined by Angle (1907), discussion of it has occupied a prominent place in orthodontic literature. There has been little disagreement as to what constitutes the dental morphology of a Class II; however, many concepts have been proposed concerning its etiology and orthodontic treatment. Out of these conflicting concepts, many different philosophies, based on treatment procedures, were developed. These opposing points of view did much to divide the orthodontic profession early in its history.

One such point arose when it was observed that dramatic changes in the facial skeleton take place during orthodontic therapy. The question was: Did the treatment create the changes in the facial skeleton or were they merely the result of growth? A review of the literature demonstrates that there are about as many articles written in favor of orthodontic therapy affecting growth and the facial skeleton as there are supporting the concept that orthodontic changes are only of a dental nature, not affecting the underlying basal structures.

The Tweed philosophy suggests that, through its mechanics, enhancement of mandibular development, condylar response and promotion of lower midface can

be influenced. Using the high pull headgear to the anterior of the maxillary archwire, Class III elastics to prepare anchorage, followed by Class II intermaxillary traction, Phelps (1978), suggest that a hyperpropulsive effect on the mandible might occur due to the holding position in which the mandibular posterior teeth are placed, and in so doing, stimulate a greater than normal condylar growth response. There is, however, no direct evidence presently available to either suggest or refute an actual increase in condylar growth response, and thus the basis for this study exists.

REVIEW OF THE LITERATURE

Growth responses of the condylar cartilage and temporomandibular joint structures to anterior displacement of the mandible were described in a histologic study on monkeys by Breitner (1931). Since then, many similar laboratory experiments have demonstrated that mandibular anterior displacement engenders increased chondrogenic activity. The rationale for the entire school of functional jaw orthopedics, as founded by Andresen and Häupl (1953), is base upon this philosophy. Baume and Derichsweiler (1961), reported on the condylar growth response to functional jaw orthodontic treatment. With the use of fixed incline planes on the dentition of two monkeys, results showed obvious differences compared with the control monkey, both in gross morphologic and roentgenographic appearance of the condylar head. The structural arrangement indicated increased cartilage proliferation in a predominantly backward direction; endochondral ossification was most active in the posterior portion. Baume and Derichsweiler concluded that this study provided evidence that the condylar growth site can respond to functional therapy.

A similar finding with respect to condylar proliferation has been reported by Charlier, Petrovic and Stutzmann (1969), who demonstrated the effects of mandibular hyperpropulsion on the prechondroblastic zone of forty-eight young rat condyles. Additonal growth of condylar cartilage was shown to occur by stimulating the cells of the prechondroblastic zone. They also reported establishing the existence of a causal relationship between the intensity of condylar growth and the amount of periosteal bone appostion on the posterior border and rear of the inferior border of the mandible.

In an attempt to clarify the reaction of the temporomandibular joint to anterior displacement of the mandible during the growth period, and once established, the stability of the acquired position, Stöckli and Willert (1971) also examined the tissue reaction of the temporomandibular joint during the growth period of eight monkeys. Again, adaptive tissue changes in the temporomandibular joint could be induced by mechanical stimuli. Absence of any histopathologic symptoms revealed that, during the growth period, the temporomandibular joint has a high potential for compensating tissue adaptations and that the new condylar position exhibited a high resistance against relapse, even when the supporting appliances were removed.

In a study by McNamara (1973), the nature of intrinsic musculoskeletal adaptations resulting from experimental alterations of the orofacial environment was examined in sixty-four rhesus monkeys. By modifying oral sensory stimuli, anterior positioning of the mandible was accomplished during functional jaw movements at four defined stages of maturations. Serial electromyography, serial cephalometric radiographs with metallic implants, and histologic analysis were used. His findings were consistent with past studies suggesting that the adult temporomandibular joint is stable and resistant to change, while the growing articular complex is responsive to functional changes. The nature and extent of these specific skeletal and dental adaptations depends upon the level of maturation of the animal.

In a clinical study, Browne (1959) reported that fifteen Class II, division I patients who were treated by functional jaw orthopedics showed a statistically significant difference in rate of growth in mandibular length than did an untreated

group. The treated patients exhibited a greater mean total growth value than the untreated patients, and the mean amount of mandibular growth in the experimental group exceeded that of the control group by 0.17 mm. per month.

Similar results were found by Marschner and Harris (1966). Mandibular growth was compared between an untreated Class II population and a similar population undergoing treatment with an activator or similar appliances. The control group consisted of twenty-three untreated Class II males with a mild to moderate Class II growth pattern, and the experimental group consisted of twelve male Class II patients. A series of mandibular tracings from lateral cephalometric radiographs was examined. The resulting growth curves showed a significant difference (5% level) between the means of the two samples at the ages studied (9 - 12 years), with the treated group demonstrating more growth.

The previously cited works tend to support the possibility that hyperpropulsion has an effect on the growth of the mandibular condyle. Hiniker and Ramfjord (1966) examined anterior displacement of the mandible in adult rhesus monkeys, and their histological findings confirmed previous temporomandibular joint studies only in that mild adaptive changes occurred. They suggested that these changes were insignificant, non progressive and possibly reversible without treatment. The study also concluded that the main accommodation to the induced anterior mandibular displacement took place in the dentition rather than in the temporomandibular joint. Although the study was performed on adult monkeys, Hiniker and Ramfjord stressed the importance of adapting the occlusion to the temporomandibular joint rather than hoping for the joints to adapt to the occlusion.

Sleichter (1957) examined cephalometric and laminagraphic tracings of eight young patients treated by use of a functional jaw appliance to stimulate condylar growth.He reported that orthodontic therapy is not capable of effective stimulation of condylar growth. Although the treatment outcome was felt to be quite gratifying, he concluded that the results were more likely due to changes in position of the teeth and possibly the alveolar bone than changes in the growth pattern of the craniofacial skeleton.

Baumes's (1961) results, in studies of craniofacial development, differ from Hiniker and Ramfjord. He reports that condylar cartilage never loses its growth potential by maturation. Baume maintains that condylar cartilage, in contrast to epiphyseal cartilage, is highly responsive to mechanical stimulation. Also, he believes that youthful form of membraneous bone is genetically determined, but that the specificity of bone-forming tissue diminishes with progressive maturation and becomes highly adaptive to environmental influences, as shown by jaw deformations due to extrinsic habits.

Serving to emphasize the findings by Baume was a report by Ware and Taylor (1968) on condylar repositioning following bilateral subcondylar vertical osteotomies on sixteen patients (age 14 - 39 years). They suggest that the mandibular condyle is capable of considerable remodeling as a result of altered function. They point out that the growth potential of the intermediate zone of condylar cartilage, while thinner in older patients, still retains a proliferative potential, and that this lends support to the concept that distraction of the condyle within the fossa may serve as a stimulus to compensatory condylar remodeling changes.

All of the above mentioned studies have been concerned with the effects of the functional jaw type of orthodontic mechanics and altered function of the mandibular condyle. As might be expected with such different methods of orthodontic therapy, opinions vary widely as to what can be achieved with conventional banding, elastics and extraoral force.

In an essay on orthodontics and facial growth, Wylie (1956) writes: "Orthodontists once believed without question that they could stimulate growth in the Class II mandible; later they came to disbelieve it; and now they are swinging back to their old point of view." Besides pointing out that many investigators feel that orthodontic treatment stimulates condylar growth and that condylar response can be elicited over a wide spectrum of ages, Wylie offers an explanation for a clinical condition that is encountered fairly frequently. The unilateral crossbite in deciduous dentition is nearly always functional, but in the adult it is nearly always morphologic. He says, "It is my suspicion that in these youngsters one condyle is held forward (just as both are held forward in Class II orthodontic therapy) until growth occurs in the single condyle (just as it does bilaterally in treatment) and when this occurs the condition is irretrievable. With this amount of evidence, some of it presumptive and some of it conclusive, orthodontic treatment may be seen to have a positive role in eliciting condylar growth."

Meach (1966) compared cephalometrically the profile changes in Class II division I patients treated by extraoral force with patients treated by functional jaw orthopedics. It was found that functional jaw orthopedics favorably influences the position of pogonion in the bony profile, as evidenced by a closing of the

Frankfort mandibular plane angle, a statistically significant increase in the facial angle, and a high percentage of forward positioning of the chin point. In concluding he states, "It appears that such improvements are brought about by a normalizing of the growth process of the Class II division I patient through alteration of the horizontal and vertical components of growth of the dentofacial complex, especially the mandibular condyle."

An investigation of dentofacial remodeling produced by intermaxillary forces in monkeys was undertaken by Adams, Meikle, Norwick and Turpin (1972). During application of Class II intermaxillary force they reported that the mandible was displaced anteriorly producing changes in the temporomandibular joint which varied depending on the age of the animal. In young individuals, endochondral ossification in the growth cartilage appeared to be directed more posteriorly than normal, with no sign of experimentally induced articular remodeling. In adult monkeys, the same force produced definite histologic changes on that part of the eminence compressed by the condyle. No recognizable alteration could be seen in the slight amount of condylar growth activity which was still present in the adult animals.

Shapiro (1973) examined the mandibular dental arch in orthodontically treated cases at least ten years out of retention. Using the distance articulare to pogonion as a measure of mandibular growth, an increase was found for all groups studied both during the treatment and during the post-retention period. He reported that the mean amount of increase for the total sample was similar during the two periods: 5.1 mm. during treatment and 4.7 mm. during the post - retention

period. There was no statistical distinction between extraction and non-extraction cases, but interestingly there was also no difference in the amount of growth between the Class I and the Class II groups. Shapiro also concluded that a number of male and female patients, where treatment had been completed in the late teens, exhibited a fair amount of growth in the post-retention period.

In a 1952 study of changes in temporomandibular joint relations associated with the treatment of Class II malocclusions, Ricketts (1952) found that in two thirds of the Class II cases, the condyle was held in a forward position either as a conditional position or accommodation in the interest of respiration and/or speech. The findings also suggest that bite jumping appliances do not seem to effect a compensatory change in the neck of the condyle or backward growth of the condyle into the fossa. Evidence from the study also has implications for the rationale of Class II treatment. For instance, the condyle was observed to be in a relatively more posterior position following treatment, thus perhaps discounting the often stated opinion that Class II elastics lead to a forward movement of the mandible.

Ricketts (1955), in a subsequent investigation, studied facial and denture changes during orthodontic treatment as analyzed by the nature of growth in the temporomandibular joint. Lateral cephalometric radiographs along with laminagraphs of the temporomandibular joint were used on 100 Class I cases and the same number of Class II cases. Facial changes appeared to be influenced by both the amount and direction of condylar growth. Growth was usually expressed along the long axis of the neck of the condyle, but the direction of this axis varied considerably. One of the interesting conclusions of the study was that condylar growth in

a backward direction contributed to vertical increase in the face and that the vertical direction of condylar growth actually produced forward movement of the chin, caused presumably by a rotation of the whole mandible. Such an observation contradicts the idea that forward pulling of the mandible by elastics contributes to backward developement of the condyle and results in forward movement of the chin. Ricketts found that in Class II cases, correction of the molar relationship is accomplished essentially by the growth of the mandible, tipping of the occlusal plane, and forward movement of the lower arch.

In an article by Moore (1959) on Class II malocclusion and the orthodontic treatment factors related to it, he postulates that one of the means to effect a Class II correction is through stimulation of horizontal and vertical growth of the mandible. Although he acknowledges that there is no way of determining whether orthodontic treatment affects mandibular development he does state, "it is known, however, that growth does occur and that it is very important in the successful treatment of the Class II malocclusion." Moore, in examining the repositioning of the mandibular body anteriorly in relation to cranial structures, stated that not one such case was found. This agrees with a study performed by Anderson (1955). In examining twenty-eight treated Class II division I malocclusions, where a successful result had been achieved, Anderson reported that anterior repositioning of the mandibular condyles, in relation to cranial landmarks, could not be found. Therefore, he concluded, repositioning the mandibular body anteriorly should not be relied upon as a possible treatment factor in producing a stable, successful end result.

Ricketts (1960), again, examined the influence of orthodontic treatment on facial growth and development. This time, in considering the Y axis as the most convenient method of viewing mandibular behavior, his findings suggested that the directional development could be influenced by treatment techniques. To some degree, these changes in facial growth and development were controlled by the orthodontist, but the underlying, basic growth pattern still predominated. It also appeard that the amount of the mandibular growth was not influenced by treatment.

Schudy (1964) felt that there is little morphologic difference between Class II division I and Class I malocclusions, stating that the growth pattern is very similar in both categories. In a comparison study of seventy-four Class II division I malocclusions treated by the conventional banding technique, and twenty-eight untreated Class I patients, he reported that treatment inhibited the flattening of the mandibular plane angle, and also inhibited the forward movement of pogonion, with the expected growth potential not being attained.

In a follow-up study by Schudy (1965), examining growth rotation of the mandible and its implication in orthodontic treatment, several conclusions regarding treatment, results, and goals were drawn. Most of his Class II cases had average horizontal growth. The principal problem, Schudy felt, is that there was apparently too much vertical growth. The difficulty is in the fact that the vertical component of growth limits the horizontal component. This in turn, limits the forward movement of the chin. When the first molars erupt into an end to end cuspal relationship, a little variation in vertical height can make the difference

between Class I and Class II interdigitation. As little as two millimeters reduction in molar height could at this point result in a Class I molar relationship without any forward movement of the condyle in the glenoid fossa. Schudy writes, "It has been said that the growth of the mandible is the principal determining factor of facial morphology. However, it is not the growth of the mandible per se which primarily determines its posture, but instead the vertical growth of the maxilla. If the trend of thought is that orthodontic treatment does not stimulate growth at the mandibular condyles, then we are quite sure that vertical growth of the alveolar process can be stimulated or inhibited, and in inhibiting it we simulate condylar growth."

Concerned with the effects of Class II elastics on the dento-facial complex, Meikle and Orth (1970) investigated radiographic and histologic changes in three adult monkeys. Histologic findings demonstrated the relatively minor nature of the alteration that did occur, especially if one was expecting any possible growth alteration or stimulation, although articular remodeling and early degenerative changes were observed in the temporomandibular joint. During the experimental period no changes in mandibular outline were apparent, but it was shown that Class II elastics produced a marked alteration in the dento-facial complex with downward and backward displacement of the maxilla. It was concluded that the growth cartilage, fibrocartilaginous articular tissue, and the interarticular disc in the temporomandibular joint enable it to withstand an altered environment. Furthermore, the presence of the relatively powerful muscles which maintain approximation at the articular surface enables the temporomandibular joint to resist forces which tend to separate or disarticulate its bones.

In a paper presented before the Angle Society, Phelps (1978), using tracings of lateral cephalometric radiographs, examined non-anchorage prepared cases with anchorage prepared cases. The main thrust of the study was to examine any significant increases in lower face development due to anchorage preparation. Since the results were favorable, the suggestion was made that perhaps through anchorage preparation, a hyperpropulsive condition is established when Class II mechanics are applied. Phelps feels that this may lead to a significant increase in the horizontal and vertical components of condylar growth, or at least in establishing a condition in which the mandibular condyle can grow in a direction more compatible with normal growth vectors.

The present study will examine through tracings of lateral cephalometric radiographs, three treatment techniques, Tweed, Begg, and a contemporary edgewise technique, to attempt to determine if mandibular changes and condylar responses relate specifically to anchorage preparation. The Tweed group was selected because of its use of anchorage preparation, the Begg group because of its use of Class II elastics throughout the entire active phase of treatment, and a modified edgewise technique in which no anchorage preparation was employed. A group of untreated cases, with a similar pattern of growth and development, will serve as a control.

METHODS AND MATERIALS

Source

The cephalograms analyzed for the treated groups were obtained from the files of the Case Western Reserve University, School of Dentirsty, Department of Orthodontics. Those of the control group were obtained from the Bolton Brush Study Center at Case Western Reserve University. The three orthodontic techniques examined for the treated groups consisted of Tweed mechanics, Begg mechanics, and modified edgewise mechanics in which no anchorage preparation was attempted.

Sample

A sample of 119 subjects comprising 15 males and 15 females for each of four groups. was selected, except for the female half of the control group, in which only 14 lateral cephalograms were acceptable.

Each individual satisified the followng requirements:

1. An ANB within the range of $3^{\circ} - 8^{\circ}$, with an average of:

    1. Tweed — 5.39° (male, 5.73°, female, 5.07°)
    2. Begg — 5.22° (male, 5.50°, female, 4.93°)
    3. Non-anchorage — 5.35° (male, 5.86°, female, 4.85°)
    4. Control — 5.30° (male, 5.52°, female, 5.08°)

2. Four first biscuspid extractions had been performed except for the control group.

3. Pre-and post-treatment lateral cephalograms were available. The post-treatment lateral cephalogram ranged from one month prior to debanding to within three months post-debanding.

4. Each individual must have mandibular third molars in which no root development had taken place up to the post-treatment cephalogram.

5. The cephalograms must be of good quality and slightly over exposed giving a relatively clear outline of the condyles.

Technical Information

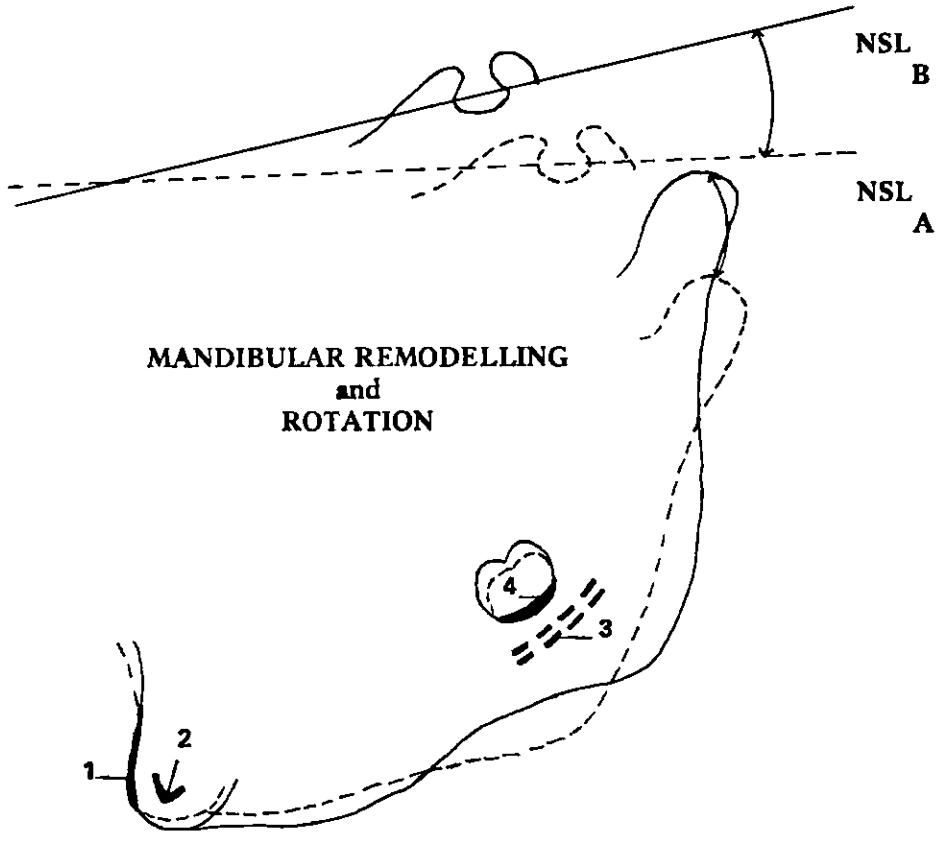
The cephalograms were taken with the Case Western Reserve's Broadbent - Bolton Cephalometer, as described by Broadbent (1931). The tracings were made on .003" frosted matte acetate. The angular measurements were read to the nearest degree with Unitek's Cephalometric Protractor designed by Dr. A. T. Baum. The linear measurements were read to the nearest tenth of a millimeter with dial vernier calipers (Helios Dial Calipers).

Measurements

To examine the mandible's response to orthodontic treatment by use of lateral cephalograms, it was felt that this could best be accomplished through use of a method described by Bjork (1969). Using implants, he verified that certain mandibular anatomic structures can be used as natural radiographic reference points, without need for implants, in analyzing changes taking palce within the mandible (Figure 1).

By superimposing two tracings of lateral cephalograms, representing pre-and post-treatment, and orienting them with reference to these structures, one may estimate the growth pattern of the mandible with a fairly high degree of accuracy. The growth rotation of the mandible relative to the cranial base can also be read

from the angle between the sella-nasion lines for the two tracings.



Longitudinal method of analysis of mandibular growth rotation from the angle between the nasion-sella lines, at two stages (A and B) after superimposition of the mandibles on natural reference structures: tip of the chin (1), inner cortical structure at the inferior border of the symphysis (2), trabecular structures related to the mandibular canal (3), and the lower contour of the molar germ (4), from the time mineralization of the crown is visible until the roots begin to form.

Figure 1 – Method of Superimposition according to Bjork (1969).

Mandibular length, as described by Wylie (1947), was also measured. This measure was felt to depict the total effective mandibular length most simply. From a line tagent to the lower border of the mandible, perpendiculars are erected at the most posterior point on the head of the condyle and at pogonion.

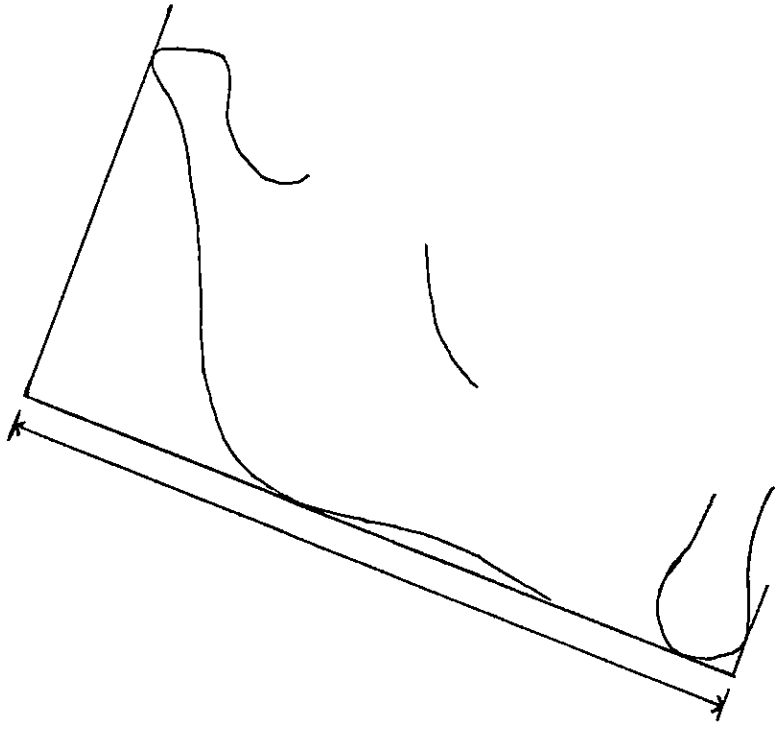


Figure 2 – Wylie's (1947) method of measuring mandibular length.

TABLE I

ANGULAR MEASUREMENTS

	Measurement	Definition
1.	Sella-Nasion – Mandibular Plane Angle (SN-MP)	Angle of mandibular plane in relation to the sella-nasion plane.
2.	Y-Axis Angle	Angle of the sella-nasion plane to the sella-gnathion plane.
3.	Sella-Nasion – Occlusal Plane Angle (SN-OP)	Angle of the occlusal plane to the sella-nasion plane.
4.	Gonial Angle (Go.∠)	Angle formed by the intersection of the mandibular plane and a line from the most posterior point on the head of the condyle which passes along the most posterior border of the ramus.
5.	Angle of mandibular growth rotation.	Angle formed by intersection of the sella-nasion planes at the two ages observed – after the method of superimposition described by Bjork (1969).

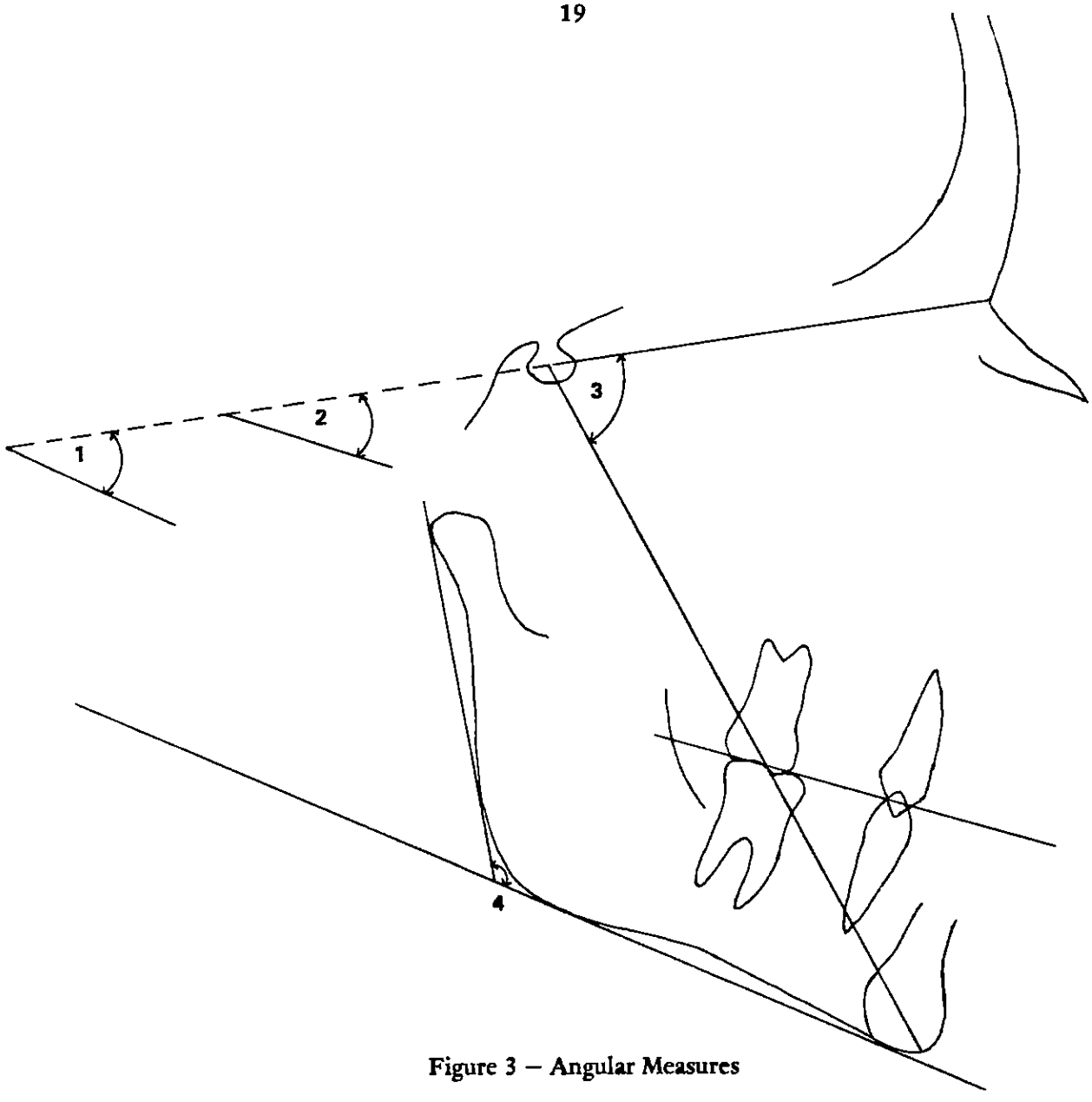


Figure 3 – Angular Measures

1. SN-MP 2. SN-OP
3. Y-Axis 4. Go.∠
5. Angle of Mandibular Growth Rotation (see Fig. 1)

TABLE II

LINEAR MEASUREMENTS

Measurement	Definition
1. Ramus Width	Distance measured along the functional occlusal plane between the anterior and posterior borders of the ramus.
2. Corpus Length	Distance measured along the functional occlusal plane from its intersection with the anterior border of the ramus to a perpendicular from the occlusal plane intersecting B point.
3. Mandubular Length	Distance along the mandibular plane and perpendiculars erected at the most posterior point on the head of the condyle and at pogonion.
4. Condyle Response	The combined vertical and horizontal distance measured from the most posterior point of the condyle in the initial tracing, to the most posterior point of the condyle in the post-treatment tracing using the intitial mandibular plane as a horizontal reference.

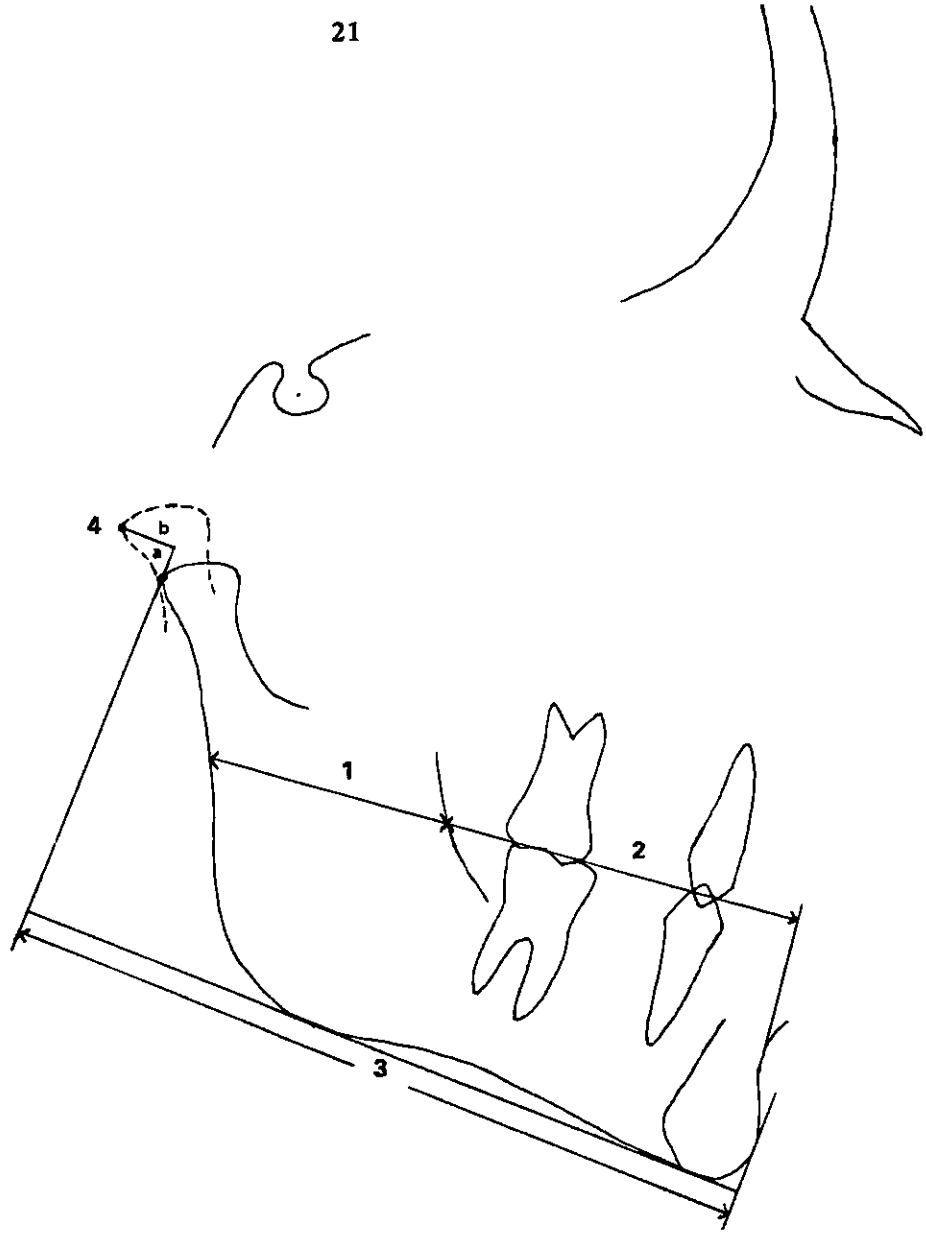


Figure 4 — Linear Measures
1. Ramus width
2. Corpus length
3. Mandibular length
4. Condyle response
vertical (a) + horizontal (b)

Also included with the measurements was a correlation of the age of the individual when treatment began along with the treatment time required (measured by the difference in time from the date on the initial cephalogram to the date on the post-treatment cephalogram).

Since this investigation was conducted to compare the actual changes that occurred during active therapy, net changes in treatment were recorded, rather than changes per month or per year.

Statistical Design

The experimental design for the present investigation employs a competely randomized, multivariate analysis of variance (Clyde, 1969). The linear design for each univariate analysis assumes a fixed effect model.

Where main effects were found to be significant, comparisons were performed using the Tukey method of multiple comparison. This method is appropriate and sensitive for comparing several means. The means are ranked in descending order of magnitude and evaluated according to a criterion of the highest significant difference.

The calculations for analyses of variance and the Tukey analysis, were performed with the aid of a Univac 1108 computer, (owned and operated by Chi Corporation, Cleveland, Ohio) employing a multivariate analysis of variance program (Clyde, 1969). A 95% level of confidence was chosen for inclusion or deletion of an independent variable.

FINDINGS

Descriptive Statistics

The mean treatment changes for all the cases along with the standard deviations of these changes are presented in Table III. The mean changes and standard deviations recorded separately for the male and female populations are found in Table IV and Table V, respectively.

Inferential Statistics

Univariate F Tests

Table VI presents the results of the univariate F test for all cases examined. A P value less than .05 (95% level of confidence) was selected to determine if a given result was statistically significant. Also, the results of the univariate F tests were recorded for the male and female samples individually, and are presented in Table VII and Table VIII, respectively.

Results of the Univariate Analyses of Variance

The statistically significant results of the univariate analysis of variance for all the cases, along with the male and female population break down is presented in Table IX. The level at which these variables are statistically significant is also presented.

Significant Differences Among The Means

Table X represents the results of the Tukey analyses for comparing the means of each significantly different variable with each other, that is, which treatment is

significantly different from the other treatments for that variable.

TABLE III
MEANS AND STANDARD DEVIATIONS
ALL CASES

TECHNIQUE		TIME	SN-MP	Y-AXIS	SN-OP	Go *L*	GROWTH ROTATION
TWEED	MEAN	25.967	−.100	.300	1.200	.200	.700
	S.D.	5.690	2.454	1.664	2.882	3.773	2.136
NON-ANCHORAGE	MEAN	25.433	.200	.433	.833	−.733	.400
	S.D.	6.033	1.808	1.073	3.505	2.638	1.886
BEGG	MEAN	24.133	.667	1.000	1.867	−.700	−.600
	S.D.	6.967	1.516	1.438	3.608	2.200	2.159
CONTROL	MEAN	24.759	−.448	.241	−.448	−1.103	.517
	S.D.	4.413	2.010	1.185	2.487	3.277	1.617

TABLE III (continued)

TECHNIQUE		CORPUS LENGTH	RAMUS WIDTH	MANDIBULAR LENGTH	CONDYLE RESPONSE	AGE
TWEED	MEAN	4.917	−.963	3.607	7.277	13.304
	S.D.	2.873	1.708	3.539	4.015	.879
NON-ANCHORAGE	MEAN	4.033	−.877	3.227	6.910	13.156
	S.D.	3.650	1.375	2.617	3.447	.970
BEGG	MEAN	4.180	−.310	3.030	6.347	12.856
	S.D.	2.884	1.384	2.826	2.105	1.059
CONTROL	MEAN	1.997	.366	3.741	7.048	12.821
	S.D.	2.855	1.343	2.422	3.657	.996

TABLE IV
MEANS AND STANDARD DEVIATIONS
MALES

TECHNIQUE		TIME	SN-MP	Y-AXIS	SN-OP	Go ∠	GROWTH ROTATION
TWEED	MEAN	26.733	.333	.667	1.400	–.267	–.200
	S.D.	5.535	2.160	1.397	2.898	3.615	1.568
NON-ANCHORAGE	MEAN	23.667	.067	.400	–.067	–.733	.733
	S.D.	5.010	1.580	1.056	2.963	2.939	2.017
BEGG	MEAN	24.133	1.200	1.667	2.533	–1.533	–1.600
	S.D.	6.300	1.373	1.633	4.565	2.167	2.098
CONTROL	MEAN	23.400	–.333	.200	–.400	–1.333	.667
	S.D.	2.098	1.676	1.373	2.586	2.440	2.024

TABLE IV (continued)

TECHNIQUE		CORPUS LENGTH	RAMUS WIDTH	MANDIBULAR LENGTH	CONDYLE RESPONSE	AGE
TWEED	MEAN	5.120	−.647	4.480	8.493	13.523
	S.D.	3.722	1.412	3.042	3.923	.783
NON-ANCHORAGE	MEAN	4.480	−.987	4.207	8.513	13.267
	S.D.	4.209	1.623	2.071	3.235	.982
BEGG	MEAN	4.253	−.087	3.173	6.333	12.833
	S.D.	3.549	1.568	2.832	2.823	1.099
CONTROL	MEAN	2.827	.440	4.293	7.740	12.855
	S.D.	2.721	1.208	2.891	4.239	.931

TABLE V
MEANS AND STANDARD DEVIATIONS
FEMALES

TECHNIQUE		TIME	SN-MP	Y-AXIS	SN-OP	Go *L*	GROWTH ROTATION
TWEED	MEAN	25.200	−.533	−.067	1.000	.667	1.600
	S.D.	5.931	2.722	1.870	2.952	3.994	2.293
NON-ANCHORAGE	MEAN	27.200	.333	.467	1.733	−.733	.067
	S.D.	6.603	2.059	1.125	3.863	2.404	1.751
BEGG	MEAN	24.133	.133	.333	1.200	.133	.400
	S.D.	7.800	1.506	.816	2.274	1.959	1.765
CONTROL	MEAN	26.214	−.571	.286	−.500	−.857	.357
	S.D.	5.727	2.377	.994	2.473	4.074	1.082

TABLE V (continued)

TECHNIQUE		CORPUS LENGTH	RAMUS WIDTH	MANDIBULAR LENGTH	CONDYLE RESPONSE	AGE
TWEED	MEAN	4.713	−1.280	2.733	6.060	13.085
	S.D.	1.777	1.958	3.880	3.852	.940
NON-ANCHORAGE	MEAN	3.587	−.767	2.247	5.307	13.044
	S.D.	3.076	1.122	2.800	2.941	.978
BEGG	MEAN	4.107	−.533	2.887	6.360	12.878
	S.D.	2.151	1.185	2.913	3.465	1.054
CONTROL	MEAN	1.107	.286	3.150	6.307	12.785
	S.D.	2.816	1.517	1.704	2.822	1.095

TABLE VI

UNIVARIATE F TESTS
ALL CASES

VARIABLE	P LESS THAN
Treatment Time	N.S.*
SN - MP	N.S.
Y - Axis	N.S.
SN - OP	.05
Go ∠	N.S.
Mandibular Growth Rotation	N.S.
Corpus Length	.005
Ramus Width	.005
Mandibular Length	N.S.
Condylar Response	N.S.
Age	N.S.

*Not Significant

TABLE VII

UNIVARIATE F TESTS
MALES

VARIABLE	P LESS THAN
Treatment Time	N.S.*
SN - MP	N.S.
Y - Axis	.05
SN - OP	N.S.
Go ∠	N.S.
Mandibular Growth Rotation	.005
Corpus Length	N.S.
Ramus Width	.05
Mandibular Length	N.S.
Condylar Response	N.S.
Age	N.S.

*Not Significant

TABLE VIII

UNIVARIATE F TESTS
FEMALES

VARIABLES	P LESS THAN
Treatment Time	N.S.*
SN - MP	N.S.
Y - Axis	N.S.
SN - OP	N.S.
Go ∠	N.S.
Mandibular Growth Rotation	N.S.
Corpus Length	.005
Ramus Width	.05
Mandibular Length	N.S.
Condylar Response	N.S.
Age	N.S.

*Not Siginficant

TABLE IX

RESULTS OF UNIVARIATE
ANALYSES OF VARIANCE

POPULATION	VARIABLE	# CASES	F - RATIO	SIGNIFICANCE LEVEL
ALL	SN - OP	119	2.789	.043
ALL	Corpus Length	119	4.820	.004
ALL	Ramus Width	119	5.190	.002
MALE	Y-Axis	60	3.337	.025
MALE	Mandibular Growth Rotation	60	4.717	.005
MALE	Ramus Width	60	2.769	.049
FEMALE	Corpus Length	59	5.719	.002
FEMALE	Ramus Width	59	2.790	.048

TABLE X

SIGNIFICANT DIFFERENCES AMONG THE MEANS

POPULATION	VARIABLE	SIGNIFICANT DIFFERENCE
ALL	SN - OP	Begg significantly greater than Control
ALL	Corpus Length	Tweed and Begg significantly greater than Control
ALL	Ramus Width	Control significantly greater than Tweed and Non-anchorage
MALE	Y-Axis	Begg significantly greater than Control
MALE	Mandibular Growth Rotation	Non-anchorage and Control significantly greater than Begg
MALE	Ramus Width	Control significantly greater than Non-anchorage
FEMALE	Corpus Length	All treatments significantly greater than Control
FEMALE	Ramus Width	Control significantly greater than Tweed.

DISCUSSION

Though the literature abounds with articles relating mandibular growth and orthodontic therapy, an attempt was made in this study to examine and compare, through use of natural cephalometric landmarks as reference points, changes in mandibular skeletal development that occurred during three different orthodontic treatment techniques. The three techniques employed were Tweed, Begg, and a modified, non-anchorage, edgewise technique. A group of untreated cases served as a control.

In examining the significant differences among the means for the entire population, differences were found in the measurements SN-OP angle, corpus length, and ramus width.

The SN-OP angle was found to have a significantly greater increase when comparing the Begg group to the control. A possible reason for this increase in the Begg group is the constant use of Class II elastics throughout the entire treatment period, a procedure which the Tweed and non-anchorage group did not employ for this length of time. Even though the Tweed and non-anchorage groups used heavier forces, the constant downward force on the anterior portion of the palate is a likely explanation for this difference.

In corpus length change, the Tweed and Begg groups were found to be significantly greater than the control. This is probably due to the fact that the treated cases had extractions and, in protracting the mandibular posterior teeth, allowed for more of a remodeling change in that area. Although the non-anchorage group, which also had extractions, was not significantly different from the control, it did

show an increase more than twice that of the control and only .15 mm. less than the significantly different Begg group.

The same appears to be true for ramus width change in which the control was significantly greater than the Tweed and non-anchorage group and not quite significantly greater than the Begg group. This again appears to be related to the fact that the control group did not have extractions and the treated cases did.

Individual comparisons for significant differences among the means were also made for males and females. The significant differences found within the male population were changes in Y-axis, mandibular growth rotation and ramus width. Those for the female population were corpus length and ramus width.

The male population for the Begg group was significantly greater than the control group for Y-axis increase and significantly less than the control and non-anchorage group for mandibular growth rotation. A possible explanation for these changes might be due to a downward tipping of the occlusal plane together with an opening of the SN-MP angle, both of which are likely related to the constant use of Class II elastics. Male and female ramus width changes were significantly greater in the control group than the non-anchorage and Tweed groups, respectively. This correlates with the ramus width changes previously mentioned for the entire population. In the female corpus length change, all treatments were significantly greater than the control and quite likely due to the fact that remodeling changes occurred when the posterior teeth were protracted during the course of treatment.

In analyzing the mandibular changes that occurred during treatment, none of the variables measured for any one technique appear to support a skeletal change

similar to those reported in the mandibular hyperpropulsive experiments of McNamara (1973), Baume and Derichsweiler (1961), Stöckli and Willert (1971), and others. In examining the three measures relating to the lengthening of the mandible, namely, condylar response, mandibular length, and gonial angle, the means were not significantly different from each other or the control. This is not to say that the combined effect of each variable, for each technique, did not produce a somewhat different skeletal picture. In analyzing these three variables simply on the basis of whether the change was in a favorable direction for the correction of a Class II division I malocclusion, or in an opposite direction, the Tweed technique consistently demonstrated a recognizably more favorable pattern. Condylar response and mandibular length were slightly greater than the non-anchorage and Begg groups, but in gonial angle change the Tweed group was the only technique that displayed what may be considered a favorable response, that is, an opening of the gonial angle. Of course an opening of the gonial angle is contrary to the developmental change that occurs in a well proportioned Class I facial growth pattern where the ramus becomes more upright by lengthening vertically to allow for the considerable extent of vertical nasomaxillary growth (Enlow, 1975). It should be stated here that the non-anchorage and Begg groups, by closing the gonial angle, were successful in obtaining that which is normal development in a well growing face. The reason that it appears to be desirable in the Tweed group is that the effective mandibular length is increased by gonial angle opening, and along with a favorable growth rotation of the mandible, a net counter-clockwise rotation occurs. This is also found in the SN-MP angle change. Both the non-anchorage and

a Friedman's blocked analysis of variance for nonparametric data was employed. The test statistic, X_r^2, may be defined:

$$X_r^2 = \frac{12}{Nk\,(k+1)} \sum_{j=1}^{k} (R_j)^2 - 3N\,(k+1) \text{ where:}$$

N = the number of measures, k = the number of groups, and R_j = sum of the rankings for the j^{th} treatment. The statistic has an approximate χ^2 distribution, with k-1 degrees of freedom (Siegel, 1956). It should be mentioned here that with this analysis each variable measured is assumed to be of equal importance and, also, each outcome is independent of another variables outcome. Of course this independence and equality is neither the case nor possible here, but with this in mind, the overall differences among the rankings for the three techniques were not significant at the $P < .05$ level.

Before conclusions are stated, comments concerning the variability involved with this investigation should be mentioned. Probably the most important variability lies within the treatment objectives established by each instructor for his own technique and also each instructor's individual skill in carrying out his technique. Certainly what might be considered important to one treatment philosophy may have no bearing on what another philosophy might attempt to achieve. It is important to point out here that the measures recorded were intended to reflect only the changes that occurred while the appliances were in place, and that the Begg technique relies on a settling-in or rebound period before the active phase of treatment is considered complete (Williams, 1968).

Other areas of variability are the closeness with which each instructor scrutin-

the Begg technique moved the mandible in an unfavorable clockwise direction while the Tweed group had a more desireable closing of the SN-MP angle. To some degree this clockwise movement was also seen in the Y-axis and mandibular growth rotation measurements. The desireable response for the Y-axis would be a closing of the angle and, although all three techniques opened the Y-axis, it was the Tweed group that displayed a greater control of this angle in that it opened the least. Comparing the actual growth rotation of the mandible in relation to the cranial base, both the Tweed and non-anchorage groups showed a favorable rotation, with the Tweed group somewhat more positive. Although not significantly different, only the Begg group showed an unfavorable clockwise growth rotation of the mandible. From these measurements it appears that the Tweed group might be inhibiting vertical growth of the maxilla to a greater extent than the other techniques, a factor that Schudy (1965) felt to be quite important.

It may be argued that individual measures are not indicative on the overall effect of a treatment on the growth of the skeleton, and that a treatment viewed in its entirety may be consistent, antagonistic or synergistic with changes noted in normal growth. Thus, a more graphic way of displaying the overall responses obtained was employed (Table XI) where each treatment variable was assigned an ordinal rank. A rank, ranging from one to three (with three being the most desireable response), was assigned to each mean value and totaled to give a somewhat objective overall picture for each technique. The determination of favorable versus unfavorable is based on the nature of normal changes taking place in a well-growing face (Enlow, 1975). To test for statistical significance among the ranked means,

TABLE XI

Ranked Treatment Means.

	TECHNIQUE		
VARIABLE	TWEED	NON-ANCHORAGE	BEGG
SN-MP	3	2	1
Y-AXIS	3	2	1
SN-OP	2	3	1
Go ∠	1	3	2
Growth Rotation	3	2	1
Corpus Length	3	1	2
Ramus Width	1	2	3
Mandibular Length	3	2	1
Condyle Response	3	2	1
TOTAL	22	19	13

izes the work performed by the students, the variability within the students themselves and also within the patients selected for this investigation. At the age level of the patients studied, it is quite possible to just include or just exclude a mandibular growth spurt during the treatment period examined.

Thus, with all the above in mind, it is felt that this investigation provides some evidence that no statistically significant differences for mandibular skeletal measures were found among the three techniques examined, but evaluation of the mean trends show that the Tweed technique was slightly more consistent with changes seen in normal growth.

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to determine, through the use of natural cephalometric landmarks as reference points, significant differences in mandibular skeletal development as they relate to three orthodontic treatment techniques utilized at the Case Western Reserve University Department of Orthodontics. The three techniques examined were, Tweed, Begg, and a modified non-anchorage edgewise technique. A group of untreated cases served as a control.

The sample consisted of 119 subjects, comprising 15 males and 15 females for each of four groups. except for the female half of the control group in which only 14 lateral cephalograms were acceptable.

A multifactorial analysis of variance, Tukey's Test and Friedman's Analysis were used to determine significant statistical differences within the measurements taken from the pre-and post-treatment lateral cephalograms.

As a result of this investigation the following conclusions were drawn:

1. No statistically significant differences for mandibular skeletal measures were found among the three techniques examined.

2. The Begg group was found to have a significantly greater increase at the time of debanding, in the SN-OP angle when compared to the control, but not significantly greater than the Tweed or the non-anchorage edgewise groups.

3. The control group was found to be significantly different from all three treated groups in ramus width and corpus length changes. This was attributed to the fact that the treated cases had four first bicuspids extracted while the control did not.

4. Examination of mean trends showed that the Tweed technique was slightly more consistent with changes seen in normal growth.

APPENDIX I

A. Definition of Cephalometric Landmarks – Modified After Thurow (1971)

1. Nasion (N) – The most forward point on the naso-frontal suture.

2. Sella Turcica (S) – The center of sella turcica, as estimated by inspection.

3. Gnathion (Gn) – The midpoint of the lower anterior curvature of the chin, midway between pogonion and menton.

4. B point – The deepest concavity on the labial surface of the bony symphysis.

5. Pogonion (Po) – The most anterior point on the labial outline of the bony symphysis.

6. Menton (Me) – The most inferior point on the outline of the bony symphysis.

B. Definition of Anatomic Planes

1. Mandibular Plane – A line connecting Me and the lowest point on the lower border of the mandible posterior to the antegonial notch.

2. Occlusal Plane (Functional) – A line connectiong the point of occlusion of the most posterior teeth with the point of occlusion of the most anterior biscuspids.

APPENDIX II

Raw Data – Tweed Group

Patient	SN-MP (degrees)	Y-Axis (degrees)	SN-OP (degrees)	Gonial Angle (degrees)	Corpus Length (mm.)	Ramus Width (mm.)	Growth Rotation (degrees)	Mandibular Length (mm.)	Condyle Response (mm.)	Treatment Time (Mo.)	Age (Yr. - Mo.)
1.	+2	+1	+2	+1	+5.5	–1.3	–1	+7.2	11.9	30	14–6
2.	–2	+1	+5	0	+10.5	–2.4	0	+2.4	3.3	19	14–1
3.	–2	0	–2	–3	+2.1	0	0	+0.8	5.8	26	12–8
4.	0	0	–2	–5	+0.2	+1.2	0	+1.4	6.5	34	12–9
5.	+5	+4	0	+9	+2.7	+1.3	–4	+10.1	10.2	24	12–6
6.	+3	+2	+3	+6	+3.9	0	–1	+7.5	11.6	27	13–10
7.	+1	+1	+2	–1	+4.9	0	0	+6.9	12.0	25	13–1
8.	+3	+2	+5	+1	+7.6	0	+2	+8.0	16.3	31	12–11
9.	0	–1	+3	–2	+5.8	–0.4	–1	0	2.4	27	14–5
10.	–1	–1	+2	0	+10.9	–4.2	+2	+4	6.7	19	12–11
11.	0	0	+6	–3	+9.9	–0.9	+2	+4	10.7	23	13–11
12.	0	0	–1	0	+3.0	0	–1	+6.1	7.3	35	14–3
13.	–3	–1	–2	–3	+1.0	0	+1	+2.3	6.1	29	14–5
14.	0	+2	–3	–2	0	–1.0	–1	+1.4	4.6	18	14–2
15.	–1	0	+3	–2	+8.8	–2.0	–1	+5.3	12.0	34	12–5
16.	+1	0	–1	+3	+2	–3.3	–2	+6.5	9.2	26	13–10
17.	0	0	0	+2	+1	–0.7	+1	+1	2.0	19	12–5
18.	+1	+1	+1	0	+4.8	–2.0	–1	+5	10.0	22	11–10
19.	–2	0	0	–3	+7.0	–3.5	+4	+1.3	8.6	23	13–11
20.	+2	0	+5	+6	+5.7	+0.3	+1	+6.2	5.6	18	12–6
21.	–1	0	0	–2	+6.2	–4.5	+2	0	3.1	32	13–11
22.	–1	0	+2	+6	+3.4	+0.7	+3	+5	3.8	26	11–8
23.	–3	0	+2	–5	+5.9	–2.4	+3	–4.0	5.4	24	12–11
24.	–1	0	+5	–4	+5.0	–1.5	+1	–1.4	0	25	13–2
25.	–6	–6	–4	–1	+3.8	–2.0	+7	–0.5	5.4	21	14–5
26.	+6	+3	+6	+8	+5.8	+3.3	–2	+10.6	10.3	33	12–6
27.	–2	–1	–1	–3	4.9	2.5	+1	+8.8	4.6	22	12–6
28.	–3	0	–4	–2	+7	0.7	+2	–0.8	3.6	18	14–3
29.	+1	+1	+2	+2	+5.4	0	+2	+6.0	8.7	31	12–2
30.	0	+1	+2	+3	+2.8	–0.4	+2	+5.5	13.6	38	14–3

(no.'s 1–15: males , 16 – 30: females)

APPENDIX III

Raw Data – Non-Anchorage Group

Patient	SN-MP (degrees)	Y-Axis (degrees)	SN-OP (degrees)	Gonial Angle (degrees)	Corpus Length (mm.)	Ramus Width (mm.)	Growth Rotation (degrees)	Mandibular Length (mm.)	Condyle Response (mm.)	Treatment Time (Mo.)	Age (Yr. - Mo.)
1.	+1	+1	+2	+2	+3.3	0	+1	+2.5	2.8	18	14–11
2.	0	–1	+2	+2	+7.4	–1.9	+1	+6.4	7.8	21	13–11
3.	+1	+2	+6	–6	+5.8	0	–1	+1.9	8.4	22	13–2
4.	+1	+1	–5	–1	–1.6	0	–2	+5.8	9.3	25	13–4
5.	–3	0	–4	+1	+1.1	–1.0	+3	+5.0	10.2	28	11–2
6.	+1	+2	0	–1	+8.8	–2.9	–1	+3.4	7.7	26	12–7
7.	0	0	–2	–3	+3.0	0	+1	+5.0	11.3	21	13–7
8.	–2	0	–1	–7	+5.6	–1.4	+4	–0.3	13.8	33	12–6
9.	–2	–1	+2	+3	+10.5	–1.9	+3	+8.3	14.6	28	14–3
10.	0	0	+1	–1	+8.7	–3.0	+1	+4.6	6.6	25	12–0
11.	+2	0	–4	+2	–5.5	+3.5	–2	+4.7	6.7	18	13–1
12.	0	0	0	0	+3.7	–0.5	0	+2.5	3.5	18	13–11
13.	0	+1	+2	0	+5.0	–1.7	–1	+4.8	8.5	16	14–5
14.	+3	+2	+2	+1	+3.4	–2.5	0	+3.3	6.8	26	13–6
15.	–1	–1	–2	–3	+8.0	–1.5	+4	+5.2	9.7	30	12–8
16.	+1	+2	+6	–4	+4.0	–2.0	–3	–4.2	1.7	23	14–4
17.	0	+1	–1	–3	+1.4	+1.0	0	+2.7	6.6	31	13–5
18.	–3	+2	–1	–1	+1.4	–1.9	–1	+0.7	2.4	20	14–0
19.	–1	0	–4	–4	–3.0	–1.0	0	–1.7	4.9	27	13–1
20.	–3	0	0	–4	+6.8	–2.0	+3	+2.2	8.2	27	12–11
21.	0	+1	–2	–1	+1.2	–0.6	–1	+2.4	4.2	24	12–7
22.	–1	–1	+2	0	+5.0	–0.4	+3	+4.0	9.4	31	10–11
23.	+1	0	+2	+2	+6.4	–2.0	+1	+2.0	4.9	33	11–5
24.	0	0	+3	–2	+4.5	0	0	+3.3	2.5	25	13–1
25.	+2	+2	+10	0	+8.0	–1.0	–1	+1.8	5.5	32	12–11
26.	+3	+2	+6	+1	+5.3	–1.8	–3	+0.5	0	16	14–10
27.	0	–1	–4	+4	–1.0	+1.7	+1	+5.9	6.3	28	13–1
28.	+1	–1	+3	0	+3.5	0	0	+6.7	10.9	34	13–3
29.	0	0	+1	–1	+3.7	–0.9	+1	+2.1	5.1	17	13–0
30.	+5	0	+6	+2	+6.6	–0.6	+1	+5.3	7.0	40	12–10

(no.'s 1–15: males , 16 – 30: females)

APPENDIX IV

Raw Data – Begg Group

Patient	SN-MP (degrees)	Y-Axis (degrees)	SN-OP (degrees)	Gonial Angle (degrees)	Corpus Length (mm.)	Ramus Width (mm.)	Growth Rotation (degrees)	Mandibular Length (mm.)	Condyle Response (mm.)	Treatment Time (Mo.)	Age (Yr. - Mo.)
1.	+1	+2	–6	–2	–4.3	–1.0	0	–3.7	7.3	24	11–1
2.	+5	+6	+8	+1	+1.0	+2.6	–6	+6.8	9.2	19	13–5
3.	+1	+3	+5	–4	+4.6	0	–3	+4.1	7.0	26	13–4
4.	+1	+3	0	–3	+5.1	0	0	+4.4	6.5	32	12–6
5.	0	+1	+3	–6	+2.1	+1.3	–3	–1.3	1.9	17	14–11
6.	0	0	+4	+1	+3.0	0	–2	+3.9	4.7	21	11–5
7.	+1	+1	–1	+2	+2.9	–0.5	+1	+6.7	9.9	17	11–7
8.	+2	0	+3	0	+8.4	–3.6	–3	+2.9	4.0	21	13–9
9.	+1	+2	+11	–2	+7.0	–0.5	–4	+4.0	6.8	22	12–10
10.	+2	+2	+4	–2	+5.5	0	+1	+6.1	12.1	36	12–2
11.	0	+1	+2	0	+5.8	–1.0	0	+4.4	8.4	33	12–0
12.	0	0	+2	–2	+7.2	–1.9	–1	+3.3	4.9	26	13–5
13.	+3	+3	+5	0	+2.7	+0.3	–3	+1.3	2.0	20	14–3
14.	+1	+1	–7	–3	+1.9	+0.4	+1	+3.0	5.3	31	13–7
15.	0	0	+5	–3	+10.9	+2.6	–2	+1.7	5.0	17	12–3
16.	–2	0	+2	–2	+2.5	+0.2	+1	–2.5	1.8	21	12–6
17.	0	–1	–1	0	+4.0	–0.4	+3	+3.4	10.2	16	13–6
18.	–1	0	+5	–3	+6.9	–2.1	–2	+0.3	2.2	24	12–5
19.	–2	0	0	0	+4.8	+0.6	+4	+6.3	10.0	28	12–5
20.	0	0	+1	+1	+3.0	0	+1	+3.6	4.5	16	10–6
21.	0	0	0	+3	+6.5	–1.2	0	+4.7	8.0	32	12–3
22.	+1	+1	+2	–1	+3.3	–0.1	+1	0	3.2	38	14–6
23.	+2	+2	–1	0	+1.7	–0.1	–2	+6.0	11.0	30	13–0
24.	+1	0	+4	0	+6.9	–1.3	+1	+3.1	5.4	31	13–4
25.	–2	0	–2	–2	+4.4	0	0	–2.0	2.7	18	12–0
26.	–1	0	+2	–1	+3.6	–0.7	0	+1.0	2.0	22	14–6
27.	+2	+1	+5	0	+7.3	+0.8	–1	+5.3	7.2	16	12–0
28.	+2	+2	+2	+3	+2.5	–2.0	–2	+4.8	8.2	15	12–9
29.	0	0	–2	+4	–0.3	+1.3	+2	+6.4	11.4	36	13–9
30.	+2	0	+1	0	+4.5	–3.0	0	+2.9	7.6	19	13–9

(no.'s 1–15: males , 16 – 30: females)

APPENDIX V

Raw Data – Control Group

Patient	SN-MP (degrees)	Y-Axis (degrees)	SN-OP (degrees)	Gonial Angle (degrees)	Corpus Length (mm.)	Ramus Width (mm.)	Growth Rotation (degrees)	Mandibular Length (mm.)	Condyle Response (mm.)	Treatment Time (Mo.)	Age (Yr. - Mo.)
1.	0	0	+4	+2	+6.0	−0.8	0	+1.8	2.5	24	12–10
2.	+1	+1	−1	+1	+1.6	−1.0	0	+2.2	3.4	16	11–9
3.	+2	+2	−3	−2	+2.7	+2.2	−3	+4.0	5.9	24	14–0
4.	−4	−1	−1	−6	+4.9	+0.5	+4	+5.0	13.9	24	14–1
5.	−3	−1	−4	−3	+2.7	+1.3	+1	+7.1	11.0	25	14–0
6.	−1	0	−4	−1	−1.2	+1.7	+1	+6.5	9.6	24	13–0
7.	−1	−1	−1	−1	+3.5	−2.0	−1	+1.3	4.6	24	14–0
8.	+1	0	−2	0	+1.6	0	+1	+9.5	12.6	24	12–0
9.	0	0	0	−1	+2.7	0	+1	0	2.0	24	12–2
10.	−1	0	+1	−1	+7.3	0	+5	+6.2	8.4	24	12–0
11.	−1	−1	−3	0	0	+1.4	+1	+6.2	15.1	24	13–0
12.	−1	−1	+1	−5	+2.9	+1.1	0	+2.8	5.0	24	12–0
13.	+2	+4	+1	−3	0	+2.2	−2	+2.0	5.5	23	12–1
14.	+1	0	+4	+3	+7.8	0	+2	+8.3	11.1	24	11–11
15.	0	+1	+2	−3	0	0	0	+1.5	5.5	23	14–0
16.	0	+2	0	−1	−5.0	+3.5	−1	+2.3	1.9	36	13–0
17.	+5	+1	−1	+7	−1.8	0	+2	+5.1	8.8	24	13–0
18.	+2	+1	+2	−1	+1.1	+0.8	−1	+4.5	7.5	24	12–0
19.	−4	−1	0	−8	+4.8	−1.4	+1	+2.0	9.6	25	12–0
20.	+1	+1	−4	+1	−1.2	+1.2	−1	+5.7	7.6	24	12–0
21.	−4	0	+2	−10	+3.2	+3.2	0	+4.3	1.0	24	13–0
22.	0	+1	0	+2	+4.3	−1.5	+1	+3.0	6.1	24	13–0
23.	0	+1	−6	+1	−1.4	−0.4	−1	+4.1	5.9	21	11–3
24.	−1	0	+3	0	+4.4	0	+1	+2.4	9.9	39	11–1
25.	0	+1	0	−3	+1.8	−0.8	0	0	3.5	20	14–4
26.	−1	−1	−2	+2	0	0	+1	+5.4	9.7	24	14–1
27.	−1	−1	−1	−1	+0.5	+0.5	+2	+1.9	4.0	34	14–3
28.	−3	−1	−2	+1	+1.6	−1.1	0	+1.7	7.5	24	14–0
29.	−2	0	+2	−3	+3.2	0	+1	+1.7	5.3	24	12–0

(no.'s 1–15: males , 16 – 29 : females)

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