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A Morphological Comparison of Orthodontically Treated Dentitions, Five Or More Years Out of Active Treatment, and Normal Dentitions

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**A MORPHOLOGICAL COMPARISON OF ORTHODONTICALLY
TREATED DENTITIONS, FIVE OR MORE YEARS
OUT OF ACTIVE TREATMENT,
AND NORMAL DENTITIONS**

by

Robert J. Noetzel

**A Thesis Submitted to the Faculty of the Graduate School
of Loyola University in Partial Fulfillment of
the Requirements for the Degree of
Master of Science**

June

1968

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ABOUT THE AUTHOR

Robert Noetzel was born in Chicago, Illinois on March 13, 1939.

He began his preidental education in 1956 at Loyola University, Chicago, Illinois, where he attended one year. The following year and one-half he attended Wilson Junior College, Chicago, Illinois. The following year he returned to Loyola University and completed his preidental education.

In 1960, he entered the Chicago College of Dental Surgery at Loyola University, Chicago, Illinois, and was graduated in June, 1964.

He entered the armed forces and served as an Air Force dental prosthetic officer for two years at Francis E. Warren A.F.B. Cheyenne, Wyoming.

In 1966, he began his graduate studies in oral biology in the orthodontic department at Loyola University.

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To my wife and children, I dedicate this effort.

To Dr. Joseph Jarabak, who provided me an opportunity to study orthodontics, and under whose guidance I received my first year of orthodontic training at Loyola University.

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CHAPTER I

INTRODUCTION

One must keep in mind an "ideal normal" occlusion when planning treatment for an orthodontic case. Perfect correction however, in the sense of an ideal normal is often impossible and often impracticable. In view of this, one accepts certain variation from the ideal normal or, in other words, aims for an "acceptable normal." To what extent these deviations may be accepted depends upon the existence of these deviations amongst acceptable normal dentitions in nature. Certain limitations due to genetic, environmental and mechanical factors may compel one to concede acceptance of slight variations from the abstract ideal normal.

Dr. Angle's definition of normal occlusion is as follows: "Occlusion is the normal relations of the occlusal inclined planes of the teeth when the jaws are closed." Dr. Angle also said, "The normal denture in its completeness includes not only the jaws, alveolar process, dental arches, and especially the roots and the periodontal membrane, but also the muscles of the lips, cheeks, tongue and mouth, the nasal passages, palate and throat, as these assist the teeth in performing

their functions and are also powerful factors in establishing and maintaining either harmony or inharmony of development and arrangement of the teeth, and this just in proportion as they are singly, collectively, normal or abnormal in their own development and function."

Dr. Strang defined normal occlusion as: "Normal occlusion is that structural composite consisting fundamentally of the teeth and jaws characterized by a normal relationship of the so-called occlusal inclined planes of teeth that are individually and collectively in architectural harmony with their basal bones and cranial anatomy, exhibit correct proximal contacting and axial positioning and have associated with them a normal growth, development, location and correlation of all environmental tissues and parts."

In this definition we have a complete description of the ideal which is one of the basic principles upon which the science of orthodontics is founded. If it were possible to obtain this ideal in every case of malocclusion that is treated, stability would follow. When permanent stability is not achieved in treated cases, it may be concluded that some of the details in the complete picture are missing.

The primary objectives in orthodontic treatment are the improvement and maintenance of esthetics, and the improved

function and stability of the treated malocclusion. Every orthodontist has the responsibility to his patients, his profession and himself to study cases after retention to determine the stability of his orthodontic results. Since time seems to be the final judge of all orthodontic therapy, the longer the patient has been free of retention appliances the more fruitful and enlightening is the study.

It is the purpose of this investigation to determine how orthodontically treated dentitions five or more years out of active treatment compare with the "acceptable normal" occlusion.

CHAPTER II

REVIEW OF THE LITERATURE

One of the earliest diagnostic aids used in orthodontics to record permanently a malocclusion or a normal arrangement of teeth was the plaster cast. The value of an accurate set of articulated models of teeth was stressed by Angle in 1895. From Angle's time to the present, orthodontists have been able to derive valuable information from plaster casts. The data in this review is derived essentially from plaster casts.

A. Studies based on normal dentitions:

Many studies of tooth disharmonies have been made on plaster casts. Various systems of diagnosis have been devised based on measurements taken from plaster casts. Arch pre-determination suggested by Hawley (1905) is one of these. The Hawley Index is based on the Bonwill principle of the standard arch. By placing a celluloid chart over the cast, one could supposedly see at a glance the deviation of the cast from the ideal arch described on the chart.

Pont (1909) formulated the theory that wide or broad teeth require a broad arch and narrow teeth require a less wide arch in order to show normal dental alignment. Measurements were

made of casts of many arches showing no crowding of teeth. The width of the maxillary four incisors was correlated with the first inter-premolar and first intermolar arch breadth. From these measurements and correlations, Pont provided a table of arch widths based on tooth widths. Thus, by the use of the Pont Normal Tooth Index, the approximate amount of change required in the arch could be determined.

Gilpatric (1919) analysed arches which varied in tooth substance from seventy-eight millimeters to one-hundred and one millimeters for the upper arch, measuring from the buccal groove of one first molar to the buccal groove of the other first molar, and the corresponding tooth substance for the lower arch, which he found varied with the upper from eight millimeters to twelve millimeters. He has from his analysis produced a set of charts showing the dimensions of the arches varying between the extremes mentioned. He made twenty-seven celluloid charts, one millimeter between each chart. By measuring the teeth on the case to be treated, a chart with comparable measurements could be laid over the cast, and deviations from the ideal arch form could be noted.

Neff (1949) suspected that everything else being normal, an orthodontic or non-orthodontic normal will settle to the degree of overbite indicated by the "anterior coefficient."

He felt that one could predetermine the amount of overbite in a finished case by applying what he termed the "anterior coefficient." He measured the mesiodistal diameters of both maxillary and mandibular anterior teeth on two hundred sets of casts. He then divided the maxillary sum by the mandibular sum and thus arrived at the "anterior coefficient." For an ideal overbite, he stated that the "anterior coefficient" must be 1.20 to 1.27.

Bolton (1958) made a series of measurements on models of fifty-five cases showing excellent occlusions. From the measurements he established certain ratios by which he claimed he could predetermine post-treatment results. The first was a ratio of the sum of the mesiodistal widths of all the teeth from first molar to first molar in the maxillary arch, to the sum of the mesiodistal widths of the same teeth in the mandibular arch. When the twelve maxillary teeth were compared with the twelve mandibular teeth in a ratio as sum mandibular twelve/sum maxillary 12×100 equals over-all ratio, a statistically significant mean, standard deviation, and coefficient of variation were found to exist. They were 91.3 plus or minus 0.26, 1.91 and 2.09 per cent respectively. The second was a ratio of the maxillary six anteriors to the mandibular six anteriors. The anterior ratio involves the

six maxillary anterior teeth and the six mandibular anterior teeth as $\frac{\text{sum mandibular six}}{\text{sum maxillary 6}} \times 100$ equals anterior ratio. Equally significant findings were obtained. For a mean of 77.2 plus or minus 0.22, the standard deviation was 1.65 and the coefficient of variation was 2.14 per cent.

Bolton (1962) made clinical application of his tooth size analysis. The main body of the work is concerned with the clinical application of the ratios. Treatment problems of various types were selected. The technique, the actual measurements, and interpretation were demonstrated from several different types of malocclusion.

1. Hypothetical ratios were developed to demonstrate changes in result as arch length is increased or decreased.
2. The consideration of mesiodistal width in making the proper premolar extraction choices was brought forth. The excellence of occlusion in the extraction case may often be improved by the removal of a mandibular premolar that is larger than the maxillary premolar.
3. The extraction cases presented, along with their respective tooth-size analyses, were varied to demonstrate the application of size ratios to as many different situations as possible.

Iyer and Desai (1963) studied plaster casts of one hundred Indian male adults with normal occlusion and pleasing facial appearance. The extent of "acceptable normal" overbite, overjet, slight incisor crowding, spacing, rotations, posterior crossbites, canine occlusion and canine inclination was evaluated as compared with ideal normal. The findings showed:

1. In overbite, nearly two-fifths of the lower incisor was covered by the upper incisor. There was no correlation between overbite and eruptive heights of the incisors or molars.
2. Incisor crowding and incisor spacing was noted in nearly all cases.
3. A low percentage of posterior crossbites precludes them from being normally acceptable.
4. Canine inclination to occlusal plane showed that vertical upper canines and even distally tipped lower canines were within reasonable limits of acceptance.
5. Canine occlusion was cusp-to-cusp in one-half the cases and ideal in the other half.

The conclusions drawn from the study prompted the authors to suggest that although one should strive for correction according to "ideal normal," it is sometimes impracticable; therefore an acceptable normal should be considered.

B. Studies based on orthodontically treated dentitions out of active treatment:

Prior to 1943 many case reports have been given which included models taken several years after all mechanical support had been removed but a careful analysis of the factors involved in these successful end results were notably absent. Since that time various orthodontists have expressed their views.

Strang (1943) concluded that the most vulnerable segments of the dentures are the mandibular incisor and canine areas and that ninety per cent of recurrent malalignment appears primarily in these regions.

Tweed (1944) analysing many successfully treated cases concludes that the mandibular incisors must be positioned in a normal relation to their basal bones. So positioned, they are in mechanical balance and best resist the forces of occlusion that will otherwise surely result in their displacement. It is his opinion that it is necessary to remove dental units in all those cases where there exists a discrepancy between tooth structure and basal bone.

Litowitz (1948) measured the plaster casts of twenty treated malocclusions before and after treatment and subsequent to retention. The study revealed that increases in lower arch length gained during treatment tended to decrease after

retention, and that expansion gained by treatment similarly showed a loss after retention. Expansion between the first premolars demonstrated the least relapse tendencies of any of the teeth in the buccal segments. In general, it was noted that the cases which exhibited the greatest amount of growth during the time covered by treatment showed the least amount of disturbance of the axis and positions of the teeth and the smallest degree of relapse subsequently.

Walter (1953) studying the casts of thirty-four non-extraction cases, out of retention a "reasonable" length of time, found that the maxillary and mandibular arch lengths increased, overbite increased approximately one-fourth, and mandibular and maxillary arch widths and intercanine width decreased but not to the original dimensions. His investigation seems to indicate that the statement that the dental arch can not be permanently widened or lengthened is incorrect.

Goldstein (1953) analysing the casts of thirty-four non-extraction cases two or more years out of retention noticed a certain degree of return toward pre-treatment conditions. There was a cusp-to-cusp relation of canines, increase in overbite and a slipping of proximal contacts.

Pringle (1955) studied the casts of ten patients five or more years out of treatment. Eight of these were Class II,

Division I, six of which were treated after the maxillary first premolars were extracted. He noted a deepening of the overbite in all cases, crowding and broken contact points in the mandibular incisor regions, a decrease in the distances from mandibular first molar to canines and a return of intermolar distances to the original widths. In the Class II, Division I extraction cases the distance between maxillary central incisors and first molar teeth was stable. No change in mandibular intercanine widths was observed.

Dona (1955) analysed the casts of twenty-two treated malocclusions of which twelve were non-extraction. The length of time out of retention was two to six years. The findings of his study may be summarized as follows:

1. Intercanine and intermolar widths revealed a strong tendency to return to the original if increased, or remain the same if not violated.
2. Overbite has a tendency to return to the original measurement after retention.
3. Overjet, after retention, tends to return slightly toward the original, but never extreme as it was in the malocclusion state of the denture.
4. Arch length has a tendency to decrease following retention.

5. Rotations have a strong tendency to return toward the original, but never to the extent found in the malocclusion state of the denture.

He states that the teeth are still moving following the retention period until they settle into a balanced state.

Peak (1956) examined the canine arch width and canine overbite measurements of casts of forty-three treated malocclusions, the last of which were made six or more months after removal of retention. He found that a majority of the cases revealed a decrease in canine overbite in both extraction and non-extraction groups. A comparison of canine arch expansion between the non-extraction and extraction groups indicated that expansion was more stable in the extraction group. There is a strong tendency in both groups for the canines to return to their original intercanine distance.

Strang (1958) reiterated what he observed in 1943, that in many of his treated cases, subsequent to the removal of retaining devices, the mandibular incisors began to rotate and overlap. This was succeeded by a similar disruption of anterior tooth alignment in the maxillary arch.

Pfluger (1959) analysed the mandibular casts of four non-extraction and seventeen extraction patients. The casts were made at the initiation of retention and no less than six months

after retention was discontinued. He found that there was a decrease in intermolar width and inner arch length, a tendency for intercanine widths to return to the original dimensions if increased in treatment and an increase in overbite in seventeen cases.

Riedel (1960) stated that teeth tend to move back toward their former positions and mandibular arch form cannot be permanently altered by appliance therapy. He points out that Dona's thesis (1955) revealed that in all instances mandibular canine width returned to or maintained the original width after retaining appliances had been removed for several years.

Riedel himself examined twelve cases five years or longer out of retention and found that all had returned to their original intercanine width. In another instance he examined eight non-extraction and five extraction cases out of retention several years. He found that the extraction cases maintained a greater canine width increase than the non-extraction while molar width increase was not maintained in the extraction but was in the non-extraction.

Steadman (1961) studying the casts of thirty-one patients one or more years out of retention, observed that the maxillary and mandibular intermolar distances remained as treated in one-half of the cases while the rest either increased or

decreased. Intercanine width when increased to a small degree was stable in most cases.

Stackler (1961) used the casts of twenty Class II, Division I extraction cases out of treatment a minimum of five years. His observations were that spaces remaining at extraction sites after treatment tend to close because posterior teeth tip mesially. He found no evidence of space development at the extraction sites. Deep overbites did occur and the mandibular incisors had a tendency to tip forward to a small degree.

Martin (1962) did a cast analysis on thirty-two cases, twelve extraction and twenty non-extraction, all of which were at least one year out of retention. In both groups the maxillary and mandibular intermolar widths, the mandibular arch length and intercanine distances decreased. The maxillary arch length increased in the extraction group and decreased in the non-extraction group.

Salzmann (1965) relates that from many years of clinical experience he had come to the conclusion that in each individual there exists a certain morphogenetic pattern. If treatment can be designed to restrict movements within the possibilities and capabilities of this pattern then a satisfactory result will follow, if not, then orthodontic failure is inevitable.

Subtelny and Sakuda (1966) analysed the casts of extraction

and non-extraction patients having records available up to several years out of retention. One group of twenty-five presented crowding and collapse in the mandibular incisor region while another twenty-five did not. In both groups the arch lengths decreased with age and the intercanine widths, if expanded, returned to their former dimensions. In the non-extraction cases, a difference was noted between the two groups. Those exhibiting collapse of mandibular incisors had an initial expansion in the molar region and a subsequent return to the former width, while in the remainder, expansion had been stable. The intermolar distance in the extraction cases decreased in both groups.

CHAPTER III

MATERIALS AND METHODS

A. Selection and characteristics of the sample:

The plaster records used in this investigation were of twenty male orthodontic patients, nineteen or more years of age and five or more years out of treatment, and fifty adult Caucasian males having normal occlusion.

The sample of the orthodontically treated patients consisted of twenty males with an average age of twenty-one years. The plaster records were selected from the retention files of five hundred individuals. The twenty selected had complete post-treatment records. Eleven cases were extraction and nine were non-extraction. The pre-treatment records revealed eight Class I, eleven Class II, Division I, and one Class III malocclusion.

The sample of the normal occlusions was obtained from five hundred university students who were examined intraorally and extraorally. From this group, fifty individuals were chosen meeting the following criteria:

1. Presence of all teeth (third molars excluded)
2. No previous orthodontic treatment

3. Normal gingival condition and good oral hygiene
4. Symmetrical facial development presenting a pleasing appearance and profile
5. Absence of temporomandibular joint disturbance
6. Class I molar relation (angle) on both right and left sides
7. Symmetry of maxillary and mandibular arch
8. Anterior overbite not in excess of five millimeters
9. Anterior overjet not in excess of five millimeters
10. Curve of Spee not in excess of three millimeters on either side
11. Broken contacts causing no more than five millimeters
12. Spacing not in excess of five millimeters in either arch
13. No teeth rotated over twenty degrees

The age of the subjects in this sample ranged from twenty years, eleven months, to thirty-six years, three months (mean age twenty-five years, six months).

Each subject was given a number which was subsequently used to identify his records. This provided an easy method for labeling and identifying the records and prevented a prejudiced appraisal of the findings which might have resulted had the

subject's name had been used.

B. Methods of obtaining new records:

Maxillary and mandibular impressions were taken on each of the twenty orthodontically treated patients. The impressions were poured immediately with # 1 snow-white plaster. The plaster models were trimmed so that the top and bottom were parallel and all sides perpendicular to the mandibular occlusal plane. Twenty sets of casts were trimmed in this manner.

Maxillary and mandibular impressions were taken on each of the fifty students. The impressions were poured immediately with # 1 snow-white plaster. The plaster models were trimmed so that the top and bottom were parallel and all sides perpendicular to the mandibular occlusal plane. Fifty sets of casts were trimmed in this manner.

C. Linear and visual relationships to be used:

The plaster records of the sample will be studied to facilitate an understanding of the differences and similarities of normal and orthodontically treated dentitions. The following measurements and relationships were studied:

1. Maxillary and mandibular intermolar width -- The width across the arch in the molar region.
2. Maxillary and mandibular inter-premolar width -- The

width across the arch at the first and second pre-molar regions.

3. Maxillary and mandibular intercanine width -- The width across the arch at the canine area.
4. Maxillary and mandibular arch length -- The length of the arch on a straight line from the molar region to contact point of the central incisors.
5. Palatal depth -- The depth of the palatal vault from the occlusal plane to the deepest portion of the hard palate.
6. Cuspid overbite -- The superior-inferior relationship of the maxillary cuspids to the mandibular cuspids.
7. Anterior overbite -- The superior-inferior relationship of the incisal edges of the maxillary incisors to the mandibular incisors.
8. Anterior overjet -- The antero-posterior relationship of the incisal edges of the maxillary incisors to the mandibular incisors.
9. Mandibular anterior discrepancy -- The arch length discrepancy from mesial of right canine to mesial of opposite canine.
10. Curve of Spee -- The degree to which the mandibular occlusal plane varies from a flat plane.

D. Determination of the linear and visual relationships:

The instruments used in the cast analysis were the following:

1. Boley gauge calibrated to 0.1 millimeter
2. Clear plastic protractor
3. Celluloid arch symmetry grid
4. Steel millimeter ruler calibrated to 0.5 millimeter
5. Sharp pencil

The parallel beaks of the Boley gauge were reduced to sharp points. This was achieved by reducing their external surfaces only. Holes were drilled along the center line of the arch symmetry grid so that it could be used in palatal depth determination.

The following is a description of the methods used to determine the measurements and relationships. All linear measurements were made to 0.5 millimeter.

1. Intermolar width -- The sharpened beaks of the Boley gauge were placed in the central pits of opposite molars. The measurement was taken directly from the gauge and recorded. In those teeth where the occlusal surfaces had been restored the beaks were placed in the center of the occlusal surfaces opposite the lingual grooves in mandibular molars and

buccal grooves in maxillary molars.

2. Inter-premolar width -- In the maxillary arch the beaks of the Boley gauge were placed in the center of the central groove of opposite premolars. In the mandibular arch beaks were placed from the buccal cusp tip to the opposite cusp tip. The distance was noted and recorded.
3. Intercanine width -- The beaks of the Boley gauge were placed on the cusp tips of opposite canines. In those cases where cusp tips had been worn due to attrition, the center of the flattened area was taken as the measuring point.
4. Arch length -- One beak of the Boley gauge was placed in the central pit of the molar, the other was placed at the incisal proximal contact of the central incisors. Both sides of the arch were measured and added together for total arch length. If a diastema or broken contact was present between the incisors the beak point was positioned midway mesially-distally and buccally-lingually.
5. Palatal depth -- The arch symmetry grid was placed on the occlusal surfaces of the premolar and first molar teeth. A straight piece of 0.45 wire was dropped

through one of the midline grid holes until it hit the deepest portion of the hard palate. The grid was removed while keeping the steel pin stationary. The length of the pin from the bottom surface of the grid was measured with a metric ruler and recorded.

6. Overbite -- Casts were placed in occlusion and viewed from the front so that the occlusal plane was level with the investigator's eyes. The vertical overlap of the maxillary central incisors was marked with the tip of a sharp pencil on the labial surfaces of the mandibular incisors. The distance from the mark to the incisal edges of the teeth was measured and recorded.
7. Overjet -- With casts in occlusion, the distance from the labial surface of the mandibular incisors to the lingual-incisal edge of the maxillary central incisors was measured and recorded. If one maxillary central was ahead of the other the overjet of both was measured, added, and an average taken. Attritional wear of maxillary incisors was not considered since only a few casts revealed any.
8. Mandibular discrepancy -- The Boley gauge was used to measure the amount of interproximal overlapping due

to rotated or displaced teeth from the mesial of one mandibular cuspid to the mesial of the opposite.

9. Curve of Spee -- The mandibular cast was held at eye level with the right side of the arch facing the investigator; the symmetry grid was placed on the occlusal surfaces so as to make contact with the highest cusp of the first molar and the highest tooth in the anterior region of the arch. The millimeter ruler was then used to measure the distance from the tip of the tooth most inferior to the under surface of the grid. The same procedure was followed for the left side. Both sides were added together and the average determined. The average, not the total, was recorded.

E. Statistical treatment of data:

The primary purpose of this investigation was to compare or determine the variations and/or similarities between orthodontically treated and normal dentitions. The population include fifty normal dentitions and twenty orthodontically treated dentitions. The orthodontically treated dentitions are divided into an extraction group, eleven in number, and a non-extraction group of nine.

All the data collected from linear measurement of these

CHAPTER IV

FINDINGS

The statistical analysis of the data obtained in this study is found in Tables I and II. Table I represents the ranges of the fifteen measurements, the mean, standard deviation, and the 95% confidence limits for the range of each value (mean \times 1.65 \times standard deviation). Table II represents the comparison of normal and orthodontically treated dentitions using the Student "t" test. Both the t value and the degree of probability are listed in Table II.

All cases selected for the normal population had a Class I (Angle) molar relationship bilaterally. Each set of casts was examined for exact interdigitation of the mesial-buccal cusp of the maxillary first molar with the buccal groove of the mandibular first molar. Nineteen of the casts showed ideal interdigitation on both right and left side. In nine of the casts one side was in ideal interdigitation, while the other had the maxillary molar slightly anterior. In four of the cases the mesio-buccal cusps of both maxillary molars were slightly anterior to the buccal groove of the mandibular molars. In thirteen cases there was an ideal interdigitation on one side,

while the maxillary molar was slightly posterior to the buccal groove of the mandibular molar on the opposite side. In two cases the maxillary molars on both sides were slightly posterior. In three cases the maxillary molar on one side was slightly posterior, and the maxillary molar on the opposite side slightly anterior.

The experimental range for this measurement was 2.3 millimeters anterior, to 2.7 millimeters posterior (means 0.146 millimeter anterior 0.985 millimeter posterior). These slight variations from "normal" Class I molar relationship were not of sufficient magnitude to disqualify a case from a classification of normal occlusion. In those cases showing some variation in the molar relationship, the premolars were in perfect interdigitation, indicating that mesial drift of the buccal segments was not the cause of the molar deviation.

Each case was examined in centric occlusion to determine the relation of the maxillary canine to the embrasure between the mandibular first premolar and canines. In thirteen cases the tip of both maxillary canine cusps was correctly related to the mandibular embrasure between the first premolar and canine. In twelve of the subjects the relationship on one side was ideal while the cusp tip was slightly anterior to the embrasure on the other. Twenty-one cases had the cusp tips

anterior to their respective embrasure on both sides of the arch. In three cases the maxillary cusp tip was posterior to the mandibular embrasure on one side, and had ideal intercuspation on the other side. Both maxillary canines were distal to the mandibular embrasures in one case. Two cases had the maxillary canine on the left side mesial to the mandibular embrasure and the maxillary canine on the right side distal to the mandibular embrasure.

In all cases where the maxillary canines were forward, the premolar occlusal relationship was normal, indicating that mesial drift of the maxillary buccal units did not cause the forward position of the canines. Ten of the cases had one or both molars forward; but even in these cases the premolar occlusion was quite normal. This fact also points out that mesial drift of the maxillary buccal segments was not the cause of the mesial positioning of the molars and canines. These occlusal adjustments can be explained by tooth size differentials.

TABLE I

STATISTICAL EVALUATIONDIFFERENCES BETWEEN CASTS OF NORMAL
AND ORTHODONTICALLY TREATED DENTITIONS

<u>MEASUREMENTS</u>		<u>EXP. RANGE</u>	<u>MEAN</u>	<u>S.D.</u>	<u>95% CONFIDENCE LIMITS</u>	
					<u>HIGH</u>	<u>LOW</u>
Max. Arch Length	a)	85.1 to 68.8	78.43	4.08	85.15	71.70
	b)	80.5 to 62.0	70.91	4.54	78.40	63.42
	c)	81.0 to 72.0	76.22	3.04	81.23	71.21
Mand. Arch Length		75.3 to 61.7	69.56	3.35	75.09	64.03
		62.5 to 56.0	59.27	2.20	63.90	55.64
		72.0 to 62.0	67.22	2.79	71.82	62.62
Max. Inter-Canine Width		39.5 to 30.2	34.97	2.24	38.67	31.27
		39.0 to 30.5	34.86	2.43	38.86	30.86
		37.0 to 32.0	34.66	1.66	37.60	32.12
Mand. Inter-Canine Width		36.5 to 21.9	26.14	2.48	30.25	22.05
		26.0 to 23.0	25.22	1.31	27.38	23.06
		28.5 to 23.5	25.72	1.56	28.29	23.50
Max. First Inter-premolar Width		46.8 to 37.0	42.50	2.24	46.20	38.80
		38.0 to 34.0	36.22	1.57	38.00	33.00

a) Normal
b) Extraction
c) Non-extraction

TABLE I (CON'T)

STATISTICAL EVALUATIONDIFFERENCES BETWEEN CASTS OF NORMAL
AND ORTHODONTICALLY TREATED DENTITIONS

<u>MEASUREMENTS</u>		<u>EXP. RANGE</u>	<u>MEAN</u>	<u>S.D.</u>	<u>95% CONFIDENCE LIMITS</u>	
					<u>HIGH</u>	<u>LOW</u>
Max. Second	a)	53.2 to 42.0	48.21	2.82	52.86	43.56
Inter-premolar	b)	43.0 to 33.0	37.36	2.86	42.08	32.64
Width	c)	45.0 to 33.5	40.77	3.23	46.10	35.44
Mand. First		38.5 to 29.2	34.19	2.30	37.98	30.40
Inter-premolar		37.0 to 32.0	34.44	1.59	36.99	32.00
Width						
Mand. Second		44.5 to 34.2	40.19	2.58	44.45	35.93
Inter-premolar		38.5 to 33.0	34.95	1.54	37.49	32.41
Width		44.5 to 38.0	40.33	1.87	43.41	37.25
Max. First		54.0 to 41.4	47.64	3.56	53.51	41.77
Intermolar		52.0 to 39.0	44.36	3.25	49.72	39.00
Width		50.0 to 44.0	47.61	2.02	50.94	44.28
Max. Second		60.4 to 46.8	49.59	2.26	53.32	45.86
Intermolar		62.0 to 46.0	52.27	3.82	58.57	45.97
Width		57.0 to 50.0	53.72	2.24	57.42	50.02

a) Normal
b) Extraction
c) Non-extraction

TABLE I (CON'T)

STATISTICAL EVALUATION

DIFFERENCES BETWEEN CASTS OF NORMAL
AND ORTHODONTICALLY TREATED DENTITIONS

<u>MEASUREMENTS</u>		<u>EXP. RANGE</u>	<u>MEAN</u>	<u>S.D.</u>	<u>95% CONFIDENCE LIMITS</u>	
					<u>HIGH</u>	<u>LOW</u>
Mand. First Intermolar Width	a)	46.5 to 35.4	41.96	2.64	46.32	37.60
	b)	41.5 to 35.0	38.09	2.12	41.58	34.60
	c)	46.0 to 38.5	42.61	2.05	45.99	39.23
Mand. Second Intermolar Width		53.7 to 42.0	48.14	2.98	53.06	43.22
		48.5 to 41.0	45.64	1.96	48.87	42.41
		51.5 to 46.0	48.05	2.03	51.40	44.70
Palatal Depth		23.0 to 12.0	19.92	2.35	23.80	16.04
		24.0 to 18.0	21.27	1.89	24.39	18.15
		22.5 to 16.5	20.05	1.94	23.25	16.85
Incisor Overjet		3.5 to 0	1.51	1.00	3.16	-0.14
		3.0 to 0	1.50	0.74	2.72	-0.28
		3.0 to 0	1.17	1.08	2.95	-0.61
Incisor Overbite		5.0 to 0	2.97	1.20	4.95	0.99
		6.0 to 1.0	3.64	1.40	5.95	1.33
		6.0 to 0.5	3.16	1.63	5.85	0.47

a) Normal
b) Extraction
c) Non-extraction

TABLE I (CON'T)

STATISTICAL EVALUATION

DIPPERENCES BETWEEN CASTS OF NORMAL
AND ORTHODONTICALLY TREATED DENTITIONS

<u>MEASUREMENTS</u>		<u>EXP. RANGE</u>	<u>MEAN</u>	<u>S.D.</u>	<u>95% CONFIDENCE LIMITS</u>	
					<u>HIGH</u>	<u>LOW</u>
Curve of Spee	a)	2.5 to 0	0.83	0.58	1.79	-0.07
	b)	1.5 to 0	0.77	0.33	1.31	-0.23
	c)	1.0 to 0	0.42	0.37	1.03	-0.19
Anterior Discrepancy		5.0 to 0	2.17	0.90	3.65	0.69
		3.0 to 0.5	1.43	0.91	2.93	-0.07
		4.5 to 0	2.00	1.35	4.22	-0.22

- a) Normal
- b) Extraction
- c) Non-extraction

TABLE II
STATISTICAL EVALUATION
CRITICAL VALUES OF t
COMPARISON OF CASTS OF NORMAL
VS. ORTHODONTICALLY TREATED DENTITIONS

<u>MEASUREMENT</u>	<u>t VALUE</u>	<u>PROBABILITY</u>
Max. Arch Length	a) 7.05	P < 0.001
	b) 0.312	P > 0.10
Mand. Arch Length	1.97	0.05 < P > 0.01
	0.27	P > 0.10
Max. Inter-Canine Width	0.037	P > 0.10
	0.025	P > 0.10
Mand. Inter-Canine Width	0.659	P > 0.10
	0.579	P > 0.10
Max. First Inter-premolar Width	0.980	P > 0.10
Max. Second Inter-premolar Width	9.090	P < 0.001
	0.129	P > 0.10
Mand. First Inter-premolar Width	0.169	P > 0.10
Mand. Second Inter-premolar Width	4.92	P < 0.001
	0.030	P > 0.10
Max. First Intermolar Width	0.343	P > 0.10
	0.136	P > 0.10

a) Extraction
b) Non-extraction

TABLE II (CON'T)
STATISTICAL EVALUATION
CRITICAL VALUES OF t
COMPARISON OF CASTS OF NORMAL
VS. ORTHODONTICALLY TREATED DENTITIONS

<u>MEASUREMENT</u>		<u>t VALUE</u>	<u>PROBABILITY</u>
Max. Second Intermolar Width	a)	2.36	P < 0.01
	b)	3.75	P < 0.01
Palatal Depth		0.580	P > 0.10
		0.180	P > 0.10
Incisor Overjet		0.000	P > 0.10
		0.289	P > 0.10
Incisor Overbite		0.500	P > 0.10
		0.120	P > 0.10
Curve of Spee		0.015	P > 0.10
		0.060	P > 0.10
Anterior Discrepancy		0.861	P > 0.10
		0.142	P > 0.10

a) Extraction
b) Non-extraction



CHAPTER V

DISCUSSION

A. General considerations:

Improvement and maintenance of esthetics, improved function and stability of the treated malocclusion are the primary objectives of orthodontic treatment. The success or failure of treatment depends on how satisfactorily these objectives have been fulfilled. It therefore behooves every orthodontist to study a sample of treated cases after retention to determine the stability of orthodontic treatment results.

Furthermore, every orthodontist should not only scrutinize his treated cases out of active treatment, but he should also compare his orthodontic results with an appraisal of normal occlusion. Both groups in this investigation were young adults (nineteen years plus) which is significant in the sense that normal growth had terminated.

B. "Acceptable normal" dentitions:

Young adults with normal occlusion were selected as a standard for this investigation because of the stability of their dental and cranial landmarks. Occlusal phenomena and bony structures are subject to changes incident to growth, which

may work to influence favorably or alter unfavorably the development of occlusion, until a person reaches maturity. Normal occlusion of the teeth in the young adult reflects the termination of a normal growth pattern and represents the criterion which should be used in the evaluation of treated malocclusion.

The dentitions of the subjects used in this investigation conformed to requirements stated in the chapter on methods and materials. Mean values were computed for each measurement. A range for each measurement was established as a framework within which a value can vary and still remain an "acceptable normal" value. The significance of the established normal standards is discussed below.

The term "normal occlusion" implies the existence of a molar relationship consistent with an anterior overjet of two or three millimeters, assuming there is good alignment of the teeth in both arches. If the relationship of the maxillary and mandibular anterior teeth is to be esthetically and functionally correct, it follows then that a Class I (Angle) molar relationship (neutroocclusion) must obtain on both sides of the arch.

The relation of the maxillary canine to the embrasure between the mandibular canine and first premolar was examined in

each case. The canine interrelationship is dictated by neutroocclusion of the molars, tooth size discrepancy, and axial inclination of the canines in patients showing normal tooth alignment. Iyer and Desai (1963), in their examination of casts of one hundred Indian males with normal occlusion, showed that one-half of their subjects had normal canine relationships and the other half end to end canine relation. They suggested that some discrepancy in size of the maxillary and mandibular teeth might account for this relationship.

The mesiodistal angulation of the maxillary canine has a definite bearing on the mesiodistal position of the cusp tip of the tooth. Similar observations were made by Iyer and Desai (1963) and Thomas (1966). Thomas demonstrated a wide range of canine angulation (maxillary, 102.1° , to 69.9° ; mandibular 110° , to 71°) in his study. Approximately one-half of the cases studied presented "ideal" canine occlusion. The majority of cases had maxillary canines slightly forward of the proper mandibular embrasure.

In all cases, regardless of the slight variations in the interdigitation of molars and canines, the premolar occlusion was found to be normal. That is, the maxillary second premolar interdigitated in the embrasure between the mandibular first molar and second premolar, and the maxillary first premolar

interdigitated in the embrasure between the mandibular second premolar and first premolar. In nearly every case, the buccal cusps of the maxillary premolars approximated correctly in their respective mandibular embrasure. The premolar occlusion, therefore, was much less diverse than the occlusion of the molars and canines.

The mean figure for incisor overbite in the normal population was $2.97\text{mm} \pm 1.20\text{mm}$. The mean figure for overbite in this study would be larger than one would find in a population of children with normal occlusion. The mature denture tends to become less procumbent as the individual approaches adulthood. The crowns of the maxillary and mandibular incisors tip lingually and the amount of overbite tends to increase with age. Although incisal attrition tends to offset the increase in overbite, adults generally have a greater measured anterior overbite than children with normal occlusion.

The mean value for incisor overjet in this study was $1.51\text{mm} \pm 1.00\text{mm}$. A minimal amount of overjet can be observed clinically when the canines are in a Class I relationship and all the anterior teeth in both arches are in tight contact. Several arrangements of the anterior teeth can prevent the attainment of a good overjet condition even though the canines are in a Class I relationship. These are: (1) tooth mass

discrepancy between maxillary and mandibular anterior teeth; (2) broken contact points due to crowding in the mandibular anterior teeth; (3) spacing of the maxillary anterior teeth; (4) combination of above.

Mandibular anterior arch length discrepancy was found to exist in nearly all the subjects of this group. Forty-seven of the fifty candidates had some broken contact points between the mandibular anterior teeth. The mean value for mandibular arch length discrepancy was $2.17\text{mm} \pm 0.90\text{mm}$. Normal physiologic mesial drift of the teeth is known to occur in nearly all human dentures. The affect of this phenomenon frequently manifests itself in crowding of the anterior teeth in man in modern culture. Crowding due to physiologic mesial drift is not seen in primitive cultures because their food is more abrasive, and causes interproximal wear of the teeth. Diet of modern man consists almost entirely of soft foods, and therefore, interproximal wear rarely occurs in his denture. As a person becomes older, the mandibular anterior teeth become less pro-cumbent. The crowns of the anterior teeth tend to tip lingually and the roots labially. Crowding of the adult denture frequently occurs in this region because of the absence of interproximal abrasion.

The width across the arch in the canine, premolar and molar

regions seem to be of little diagnostic value.

C. Orthodontically treated dentitions:

Orthodontists studying their treated malocclusions five or more years after treatment are cognizant of changes that do occur. The beginning orthodontist and even the orthodontic student soon discovers that post-treatment changes are inevitable and that permanent stability is unattainable. The altering of the spatial arrangement of the teeth in malocclusion into an environment which the orthodontist will control for an extended period of time, to his dismay, does not effect a result of lasting quality and stability.

Measurements of both groups were made in the antero-posterior, medio-lateral and vertical planes. The actual dimensions of each measurement was determined and recorded (Appendix I and II). The data was treated statistically and is listed in Table I and II.

D. Discussion of findings - extraction cases:

The mean value for incisor overbite in the extraction group of orthodontically treated dentitions was $3.64\text{mm} \pm 1.40\text{mm}$ versus $2.97\text{mm} \pm 1.20\text{mm}$ in the normal dentitions. Litowitz (1948), Walter (1953), Goldstein (1953), Pringle (1955), and Stackler (1961) found the overbite of non-extraction and extraction cases to increase in varying degrees. The greater

degree of incisor overbite in the extraction cases may be the result of relapse in the vertical plane and/or differential growth in the dento-facial complex. The return of overbite after cessation of mechano-therapy and removal of retainers has plagued orthodontists for decades. Cognizance of the significance of anterior and posterior vertical dimension is of necessity if an orthodontist is to treat his cases to an acceptable incisor overbite relationship.

The mean value for incisor overjet in this group was $1.50\text{mm} \pm 0.84\text{mm}$ versus $1.51\text{mm} \pm 1.00\text{mm}$. Although Dona (1955) observed that overjet has a slight tendency to return to the original dimension, the latter values demonstrate no significant difference between the groups in this relation.

Mandibular anterior arch length discrepancy was found to exist in all the subjects of this group. Strang (1943) concluded that the most vulnerable segment of the dentures are the mandibular canine and incisor areas. Pringle (1955) made note of crowding and broken contacts in the mandibular incisor regions. Strang (1958) observed what he had in 1943; that in many cases subsequent to the removal of retaining devices, the mandibular incisors began to rotate and overlap. Salzmann (1957) found many cases of mandibular incisor collapse in the post-treatment observation of extraction cases. The magnitude

of the discrepancy was smaller ($1.43\text{mm} \pm 0.91\text{mm}$ versus $2.17\text{mm} \pm 0.90\text{mm}$) than the value ascertained in the normal dentitions. The lesser degree of discrepancy may be accounted for by the increase of available anterior arch length by distal driving mandibular canines. Reduction of the interproximal surfaces (stripping) of the mandibular anterior teeth may also account for the minor differences between the two groups.

Both the inter-premolar and intermolar distances decrease in extraction cases. The latter can be accounted for by the anterior movement of teeth into an area of lesser medio-lateral dimension. The following differences between the extraction cases and normal dentitions were noted:

1. Maxillary second inter-premolar - $37.36\text{mm} \pm 2.86\text{mm}$
versus $48.21\text{mm} \pm 2.82\text{mm}$
2. Mandibular second inter-premolar - $34.95\text{mm} \pm 1.54\text{mm}$
versus $40.19\text{mm} \pm 2.58\text{mm}$
3. Maxillary first intermolar - $44.36\text{mm} \pm 3.25\text{mm}$
versus $47.64\text{mm} \pm 3.56\text{mm}$
4. Mandibular first intermolar - $38.09\text{mm} \pm 2.12\text{mm}$
versus $41.96\text{mm} \pm 2.64\text{mm}$

Pfluger (1959) analyzed only the mandibular casts of non-extraction and extraction cases and found a decrease in intermolar width. Riedel (1960) found molar width increase was not

maintained in extraction cases but was in non-extraction. Pringle (1955) and Dona (1955) found that intermolar width generally returned to original dimensions in both extraction and non-extraction cases. Subtelny and Sakuda (1966), in examining the casts of non-extraction and extraction cases several years out of retention found that half of the non-extraction cases and all the extraction cases revealed a decrease in molar expansion.

As anticipated the maxillary and mandibular arch length decreased respectively; maxillary ($70.91\text{mm} \pm 4.54\text{mm}$ versus $78.43\text{mm} \pm 4.08\text{mm}$) and mandibular ($57.27\text{mm} \pm 2.20\text{mm}$ versus $69.56\text{mm} \pm 3.35\text{mm}$).

The success of the reduction of the Curve of Spee is evident by the values ($0.73\text{mm} \pm 0.48\text{mm}$) for the orthodontically treated versus ($0.83\text{mm} \pm 0.58\text{mm}$) for the acceptable normal. The remaining linear measurements in Table I and II demonstrate no significant difference in contrast to the normal group.

E. Discussion of findings - non-extraction cases:

In this investigation the non-extraction cases were in closer proximity to the norms of the "acceptable normal" than the extraction cases. This seems logical to the investigator since malocclusions are treated on this basis usually when apical base is sufficient, potential growth is favorable,

skeletal and dental relationships are reasonably good and one's own esthetic values are attainable. Of course, minor deviations from this general criteria do occur which place a case on the borderline between extraction and non-extraction. The knowledge and experience of the orthodontist determines which path shall be followed.

The mean value for incisor overbite in the non-extraction group of orthodontically treated dentitions was $3.16\text{mm} \pm 1.63\text{mm}$ versus $2.97\text{mm} \pm 1.20\text{mm}$ in the normal and $3.64\text{mm} \pm 1.40\text{mm}$ in the extraction group. The difference may be accounted for by the greater degree of stability in dentitions treated on a non-extraction basis.

The mean value for incisor overjet in the non-extraction group is $1.17\text{mm} \pm 1.08\text{mm}$ versus $1.51\text{mm} \pm 1.00\text{mm}$ in the normal and $1.50\text{mm} \pm 0.74\text{mm}$ in the extraction group.

Mandibular anterior arch length discrepancy was found to exist in all groups. The mean value for anterior discrepancy in the non-extraction group was $2.00\text{mm} \pm 1.35\text{mm}$ versus $2.17\text{mm} \pm 0.90\text{mm}$ in the normal and $1.43\text{mm} \pm 0.91\text{mm}$ in the extraction group. The non-extraction group represents less anterior arch length discrepancy than normal, but it demonstrates more than that found in the extraction group. The latter was substantiated by the facts that; canine expansion was greater in the

extraction cases with the canines generally being moved distally into a wider part of the arch, and a concomitant increase in anterior arch length. Although the anterior discrepancy is originally less in non-extraction cases, the forward relationship of the mandibular incisors to apical base at the end of treatment could be responsible for the return of the discrepancy. This is a logical explanation for those who had no pre-treatment discrepancy but develop one in the post-treatment period.

The final significant finding worth discussion is the dimension of the maxillary second intermolar width. The mean value for the maxillary second intermolar distance was $53.72\text{mm} \pm 2.24\text{mm}$ versus $49.59\text{mm} \pm 2.26\text{mm}$ in the normal and $52.27\text{mm} \pm 3.82\text{mm}$ in the extraction group. Both orthodontically treated groups represent greater maxillary second intermolar width than the normal group. The latter was the probable result of distal movement of the maxillary first molars during mechano-therapy. It has been demonstrated that this type of force application has a tendency to displace maxillary second molars laterally in a buccal direction.

This investigator feels that this study has demonstrated that orthodontically treated dentitions, five or more years out of treatment, compare favorably with "acceptable normal"

dentitions. Although the orthodontist treats the dentition to a good occlusion in most situations, he is confronted with the forces of occlusion, mechanical, and biological phenomena which result in changes of tooth position. Therefore, the ideal relationships of teeth to teeth, teeth to alveolar process, alveolar process to apical base, and apical base to cranial osteology are seldom if ever all attained through orthodontic treatment, thus changes in tooth position become inescapable.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

This was an investigation to determine how orthodontically treated dentitions five or more years out of active treatment compare with the "acceptable normal" dentition.

Fifty cast records of normal Caucasian male dentitions and twenty casts of orthodontically treated Caucasian male dentitions were measured. The mean age of the normal subjects was twenty-five years, six months. The orthodontic group was divided into an extraction group, eleven in number, and a non-extraction group of nine. All of the orthodontic subjects were nineteen or more years old and five or more years out of treatment.

Fifteen linear measurements were made on the casts of the two groups to acquire an understanding of the differences and similarities of normal and orthodontically treated dentitions. The statistical analysis of the data obtained in this study represents the ranges of fifteen measurements, the mean, standard deviation, and 95% confidence limits for the range of each value. The Student "t" test was used in comparison of

the normal and orthodontically treated dentitions. Both the t value and degree of probability were determined. The statistical results in the orthodontically treated group were divided into an extraction and non-extraction group so a more significant comparison could be made.

Conclusions

The following may be concluded from this study:

1. Variations from normal occlusion occur in all human dentures. A description of normal occlusion can serve only as a guide for comparison with "individual normal" occlusion.
2. There is a wide range of variation for each measurement in both "acceptable normal" and orthodontically treated occlusions.
3. Crowding of all mandibular anterior teeth occurs in nearly all adults both normal and orthodontically treated dentitions in the sample studied. A small amount of anterior arch length discrepancy should be considered normal in adults.
4. Overbite and overjet values of the orthodontically treated dentitions were within the normal range.
5. Intermolar and inter-premolar distances were significantly less in the extraction group of the

- orthodontically treated dentitions.
6. Maxillary and mandibular arch length were significantly less in the extraction group of the orthodontically treated dentitions.
 7. Morphologically, orthodontically treated dentitions compare favorably with "acceptable normal" dentitions.

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APPENDIX I

LINEAR MEASUREMENTS

<u>NORMAL</u> <u>SUBJECT</u>	<u>MAX. ARCH</u> <u>LENGTH</u>	<u>MAND. ARCH</u> <u>LENGTH</u>	<u>MAX. INTER-</u> <u>CANINE WIDTH</u>	<u>MAND. INTER-</u> <u>CANINE WIDTH</u>	<u>MAX. FIRST</u> <u>INTER-PREMOLAR</u> <u>WIDTH</u>
1	73.2mm	66.0mm	33.0mm	25.2mm	43.2mm
2	78.3	67.3	34.3	25.4	41.0
3	82.5	70.6	38.0	26.6	47.3
4	78.8	69.6	35.2	27.5	43.2
5	82.5	74.0	34.0	26.5	42.5
6	83.5	70.0	37.0	26.5	43.5
7	75.0	68.6	35.0	26.7	43.5
8	85.1	75.0	35.0	25.5	43.0
9	79.6	68.6	33.5	27.0	41.0
10	75.5	66.5	32.0	24.6	40.8
11	79.6	68.1	36.3	25.5	44.8
12	81.0	72.6	36.5	30.3	46.8
13	78.0	69.0	34.3	23.5	39.5
14	78.0	65.5	32.5	23.5	41.0
15	82.0	73.2	33.8	29.0	40.0
16	77.0	66.5	35.0	25.4	39.7
17	80.3	70.5	35.8	27.0	42.0
18	77.8	70.4	35.8	27.0	42.7
19	79.7	70.0	34.7	26.7	43.2
20	80.4	71.3	39.5	30.0	46.5
21	75.9	68.9	32.8	24.3	41.5
22	76.0	68.7	34.0	25.4	41.2
23	77.9	70.3	33.5	24.3	41.7
24	72.5	65.6	34.5	25.0	43.2
25	84.9	74.9	38.4	28.2	42.8

APPENDIX I (CON'T)

LINEAR MEASUREMENTS

<u>NORMAL</u> <u>SUBJECT</u>	<u>MAX. ARCH</u> <u>LENGTH</u>	<u>MAND. ARCH</u> <u>LENGTH</u>	<u>MAX. INTER-</u> <u>CANINE WIDTH</u>	<u>MAND. INTER-</u> <u>CANINE WIDTH</u>	<u>MAX. FIRST</u> <u>INTER-PREMOLAR</u> <u>WIDTH</u>
26	78.8mm	73.7mm	38.3mm	28.8mm	46.0mm
27	77.7	68.5	36.4	27.0	43.3
28	76.6	68.8	33.2	24.6	41.7
29	72.6	73.2	33.3	23.3	40.5
30	82.3	74.9	34.0	25.2	43.0
31	79.7	70.3	39.5	29.8	46.4
32	74.3	65.1	33.8	24.6	40.6
33	75.8	67.3	33.3	22.5	40.8
34	88.8	75.3	39.2	28.8	44.4
35	83.4	73.8	35.6	36.5	45.0
36	82.6	73.5	35.5	26.3	43.5
37	76.9	68.3	38.0	27.3	44.8
38	77.5	68.9	33.2	26.5	39.5
39	72.3	65.3	31.2	21.9	39.6
40	82.0	74.3	35.6	23.8	43.0
41	75.7	61.7	35.0	23.5	43.7
42	72.3	71.0	32.3	25.4	37.8
43	78.9	68.1	37.8	27.5	46.3
44	72.9	68.0	32.5	27.2	38.5
45	74.5	65.6	32.8	25.0	41.5
46	77.9	67.0	35.4	25.2	44.0
47	87.7	75.2	38.7	28.3	46.0
48	79.2	67.2	35.8	26.4	44.0
49	76.2	67.2	33.5	22.0	38.5
50	68.8	64.4	30.2	22.7	37.0

APPENDIX I (CON'T)

LINEAR MEASUREMENTS

<u>NORMAL</u> <u>SUBJECT</u>	<u>MAX. SECOND</u> <u>INTER-PREMOLAR</u> <u>WIDTH</u>	<u>MAND. FIRST</u> <u>INTER-PREMOLAR</u> <u>WIDTH</u>	<u>MAND. SECOND</u> <u>INTER-PREMOLAR</u> <u>WIDTH</u>	<u>MAX. FIRST</u> <u>INTERMOLAR</u> <u>WIDTH</u>
1	48.0mm	34.5mm	39.3mm	45.2mm
2	46.8	35.5	42.0	48.0
3	53.2	35.6	42.7	51.0
4	48.7	37.5	41.5	47.3
5	47.8	34.5	39.7	48.5
6	46.5	35.5	41.7	44.2
7	49.6	37.0	42.5	51.3
8	51.5	35.0	42.6	52.3
9	48.0	35.0	42.8	47.3
10	47.0	33.0	38.8	41.5
11	48.5	34.6	41.5	47.7
12	51.8	37.0	44.4	50.7
13	42.0	31.5	37.4	43.3
14	49.0	31.5	38.7	50.5
15	45.5	32.5	37.7	46.2
16	45.5	30.3	36.9	46.5
17	46.5	33.0	39.2	36.7
18	49.5	32.4	39.5	48.6
19	50.5	35.0	43.3	50.5
20	52.4	37.0	44.5	54.0
21	46.3	33.2	38.8	48.0
22	48.2	32.5	39.0	48.0
23	49.4	33.7	41.0	47.3
24	49.1	34.4	39.4	47.3
25	43.9	34.5	34.5	47.6

APPENDIX I (CON'T)

LINEAR MEASUREMENTS

<u>NORMAL</u> <u>SUBJECT</u>	<u>MAX. SECOND</u> <u>INTER-PREMOLAR</u> <u>WIDTH</u>	<u>MAND. FIRST</u> <u>INTER-PREMOLAR</u> <u>WIDTH</u>	<u>MAND. SECOND</u> <u>INTER-PREMOLAR</u> <u>WIDTH</u>	<u>MAX. FIRST</u> <u>INTERMOLAR</u> <u>WIDTH</u>
26	52.4mm	37.3mm	43.6mm	52.0mm
27	47.7	35.2	39.8	45.4
28	46.9	35.1	39.6	48.4
29	46.2	32.8	40.0	43.0
30	48.0	33.3	37.3	47.0
31	51.2	37.0	41.8	50.8
32	46.4	31.0	36.3	47.5
33	47.5	32.6	39.4	49.6
34	49.0	35.0	40.0	47.5
35	51.5	36.3	43.8	52.0
36	50.7	35.0	40.6	50.6
37	50.9	36.8	41.4	47.3
38	46.2	30.0	39.6	46.8
39	44.5	29.2	36.9	45.6
40	50.0	33.7	42.6	48.6
41	48.9	30.8	35.7	51.2
42	43.5	38.5	43.5	43.0
43	51.2	36.9	41.8	49.2
44	43.4	35.7	42.7	43.0
45	46.6	34.3	38.0	46.4
46	50.9	35.5	41.8	50.6
47	51.9	35.6	41.9	50.3
48	51.7	36.3	43.0	51.0
49	44.0	29.9	35.3	45.5
50	42.0	29.4	34.2	41.4

APPENDIX I (CON'T)

LINEAR MEASUREMENTS

<u>NORMAL</u> <u>SUBJECT</u>	<u>MAX. SECOND</u> <u>INTERMOLAR</u> <u>WIDTH</u>	<u>MAND. FIRST</u> <u>INTERMOLAR</u> <u>WIDTH</u>	<u>MAND. SECOND</u> <u>INTERMOLAR</u> <u>WIDTH</u>	<u>PALATAL</u> <u>DEPTH</u>
1	49.4mm	39.5mm	42.8mm	17.0mm
2	52.8	43.3	49.9	18.0
3	56.3	44.0	49.0	18.0
4	52.8	41.8	47.5	22.5
5	54.5	42.5	48.0	23.0
6	52.3	37.7	45.5	21.0
7		45.0	53.7	20.0
8	57.3	45.0	51.0	20.0
9	55.0	43.3	50.0	23.0
10	50.7	41.7	46.4	20.5
11	53.5	41.4	47.7	21.0
12	54.0	44.6	51.5	20.0
13	47.0	37.5	41.8	18.0
14	55.9	44.0	51.0	15.5
15		39.8	43.7	23.0
16	56.5	38.5	47.0	20.0
17	52.0	40.7	46.7	22.0
18	55.0	42.5	47.8	21.5
19	55.7	46.5	51.0	20.0
20		46.2	52.7	22.0
21	54.5	41.2	49.0	22.0
22	56.3	42.0	50.3	18.0
23	51.5	40.8	48.7	20.0
24	50.2	40.7	44.5	18.0
25	52.7	40.6	47.4	21.0

APPENDIX I (CON'T)

LINEAR MEASUREMENTS

<u>NORMAL</u> <u>SUBJECT</u>	<u>MAX. SECOND</u> <u>INTERMOLAR</u> <u>WIDTH</u>	<u>MAND. FIRST</u> <u>INTERMOLAR</u> <u>WIDTH</u>	<u>MAND. SECOND</u> <u>INTERMOLAR</u> <u>WIDTH</u>	<u>PALATAL</u> <u>DEPTH</u>
26	57.5 ^{mm}	46.4 ^{mm}	51.3 ^{mm}	23.5 ^{mm}
27	55.7	38.0	47.5	23.0
28	57.5	41.3	49.3	25.0
29	50.0	38.5	42.0	19.0
30	54.4	40.6	45.5	19.0
31	55.6	43.5	48.5	19.0
32	53.0	39.6	46.0	16.0
33	54.3	43.7	50.3	23.0
34		40.6	46.6	20.0
35	56.4	46.2	52.4	21.0
36	56.7	44.3	51.2	20.5
37	55.5	41.8	49.3	20.0
38	54.6	40.5	48.4	22.5
39	52.3	39.7	46.4	21.0
40	54.7	41.4	47.3	20.0
41	60.4	39.0	44.2	22.0
42	48.5	43.0	47.3	13.0
43	54.6	44.8	48.7	20.0
44	48.9	46.0	55.0	12.0
45	52.8	40.7	46.4	23.5
46	56.2	43.8	49.8	21.0
47	57.9	44.0	49.5	21.0
48	57.5	45.7	51.7	21.0
49	51.7	38.9	46.0	11.0
50	46.8	35.4	42.0	12.0

APPENDIX I (CON'T)

LINEAR MEASUREMENTS

<u>NORMAL SUBJECT</u>	<u>INCISOR OVERJET</u>	<u>INCISOR OVERBITE</u>	<u>CURVE OF SPEE</u>	<u>MAND. ANT. DISCREPANCY</u>
1	2.0mm	1.0mm	1.0mm	1.5mm
2	3.0	3.5	1.5	1.5
3	3.0	4.5	2.5	2.5
4	2.0	3.0	1.5	2.5
5	2.5	3.0	0.0	1.5
6	2.5	2.5	1.5	2.0
7	0.5	3.0	1.0	2.0
8	1.0	3.0	0.5	2.0
9	1.0	2.0	1.0	2.0
10	1.0	3.0	0.5	2.0
11	3.0	3.0	1.5	2.0
12	0.5	1.5	0.5	1.5
13	3.5	4.0	0.5	3.0
14	2.0	4.0	0.5	0.5
15	0.5	3.0	1.0	1.5
16	0.5	3.0	0.5	4.0
17	1.0	2.0	1.0	2.5
18	0.0	0.0	0.0	1.5
19	1.5	4.0	0.5	4.0
20	1.5	2.0	0.5	2.0
21	3.0	5.0	1.0	2.5
22	3.0	2.0	0.5	5.0
23	0.5	3.5	0.5	1.0
24	0.5	3.5	0.5	2.0
25	2.0	4.0	1.5	3.0

APPENDIX I (CON'T)

LINEAR MEASUREMENTS

<u>NORMAL SUBJECT</u>	<u>INCISOR OVERJET</u>	<u>INCISOR OVERBITE</u>	<u>CURVE OF SPEE</u>	<u>MAND. ANT. DISCREPANCY</u>
26	0.0 ^{mm}	0.5 ^{mm}	0.0 ^{mm}	2.0 ^{mm}
27	1.0	3.0	1.0	2.5
28	3.0	4.0	1.5	3.5
29	1.0	2.5	0.0	2.0
30	2.0	4.0	0.0	1.5
31	2.0	3.0	0.5	1.0
32	2.0	4.0	0.5	2.0
33	0.5	3.0	0.5	2.0
34	0.5	3.0	0.0	0.0
35	2.5	4.0	0.5	1.5
36	0.5	5.0	2.0	1.0
37	1.0	4.0	1.0	1.0
38	0.0	0.5	0.0	1.5
39	0.5	4.0	0.5	1.5
40	1.0	4.0	0.5	3.5
41	3.0	2.0	0.0	3.0
42	2.0	4.5	1.0	3.0
43	3.5	0.5	1.0	2.0
44	0.5	2.0	1.5	2.0
45	1.5	3.5	0.5	3.0
46	1.5	3.0	2.0	4.0
47	1.0	3.0	1.0	3.0
48	2.0	4.0	2.0	1.5
49	1.0	4.0	1.0	2.0
50	0.5	0.5	1.0	3.0

APPENDIX II

LINEAR MEASUREMENTS

ORTHODONTICALLY TREATED DENTITIONS

<u>EXTRACTION</u> <u>SUBJECT</u>	<u>MAX. ARCH</u> <u>LENGTH</u>	<u>MAND. ARCH</u> <u>LENGTH</u>	<u>MAX. INTER-</u> <u>CANINE WIDTH</u>	<u>MAND. INTER-</u> <u>CANINE WIDTH</u>	<u>MAX. FIRST</u> <u>INTER-PREMOLAR</u> <u>WIDTH</u>
1	80.5mm	58.0mm	30.5mm	26.0	
2	74.0	61.0	39.0	27.0	
3	73.0	60.0	36.0	26.0	
4	74.0	62.5	36.0	23.5	
5	68.0	58.5	35.0	25.5	
6	62.0	56.0	32.0	26.0	
7	72.0	61.5	37.0	26.5	
8	67.0	59.0	37.0	24.5	
9	71.0	62.0	35.0	23.0	
10	68.5	57.5	32.0	23.5	
11	70.0	56.0	37.0	26.0	

NON-EXTRACTION

<u>SUBJECT</u>					
1	73.5	64.5	35.0	24.0	36.0
2	72.0	67.0	32.5	25.0	35.0
3	72.0	62.0	32.0	23.5	34.0
4	81.0	70.0	36.0	27.0	36.5
5	76.0	69.0	35.5	26.0	38.5
6	78.0	66.0	37.0	27.0	38.0
7	76.0	67.5	33.5	24.0	34.0
8	78.0	67.0	34.0	26.5	36.0
9	79.5	72.0	36.5	28.5	38.0

APPENDIX II (CON'T)

LINEAR MEASUREMENTS

ORTHODONTICALLY TREATED DENTITIONS

<u>EXTRACTION</u>	<u>MAX. SECOND</u>	<u>MAND. FIRST</u>	<u>MAND. SECOND</u>	<u>MAX. FIRST</u>
<u>SUBJECT</u>	<u>INTER-PREMOLAR</u>	<u>INTER-PREMOLAR</u>	<u>INTER-PREMOLAR</u>	<u>INTERMOLAR</u>
	<u>WIDTH</u>	<u>WIDTH</u>	<u>WIDTH</u>	<u>WIDTH</u>
1	43.0mm		36.0mm	52.0mm
2	40.0		36.0	47.0
3	37.0		35.0	44.0
4	37.0		34.0	45.0
5	38.0		34.0	44.0
6	33.0		36.0	42.0
7	41.0		38.5	47.0
8	37.0		35.0	43.0
9	36.0		33.0	43.0
10	34.0		33.0	39.0
11	35.0		34.0	42.0

NON-EXTRACTION

SUBJECT

1	42.0	33.0	38.5	47.0
2	40.0	32.0	40.0	46.5
3	39.0	34.5	38.0	44.0
4	40.5	34.5	40.0	47.0
5	45.0	37.0	44.5	50.0
6	33.5	35.0	41.0	51.0
7	40.0	33.5	39.0	46.0
8	43.0	33.5	40.0	48.0
9	44.0	37.0	42.0	49.0

APPENDIX II (CON'T)

LINEAR MEASUREMENTS

ORTHODONTICALLY TREATED DENTITIONS

<u>EXTRACTION</u>	<u>MAX. SECOND</u>	<u>MAND. FIRST</u>	<u>MAND. SECOND</u>	<u>PALATAL</u>
<u>SUBJECT</u>	<u>INTERMOLAR</u>	<u>INTERMOLAR</u>	<u>INTERMOLAR</u>	<u>DEPTH</u>
	<u>WIDTH</u>	<u>WIDTH</u>	<u>WIDTH</u>	
1	62.0mm	41.5mm	48.5mm	22.0mm
2	55.0	40.5	47.0	19.0
3	52.0	38.0	46.0	21.0
4	53.0	38.0	46.0	21.5
5	51.0	38.0	46.0	19.5
6	50.0	38.0	46.0	22.5
7	54.0	41.0	48.0	20.0
8	51.0	38.0	45.0	18.0
9	51.0	36.0	44.0	22.5
10	46.0	35.0	41.0	24.0
11	50.0	35.0	44.5	24.0

NON-EXTRACTION

<u>SUBJECT</u>	<u>MAX. SECOND</u>	<u>MAND. FIRST</u>	<u>MAND. SECOND</u>	<u>PALATAL</u>
	<u>INTERMOLAR</u>	<u>INTERMOLAR</u>	<u>INTERMOLAR</u>	<u>DEPTH</u>
	<u>WIDTH</u>	<u>WIDTH</u>	<u>WIDTH</u>	
1	50.0	33.0	38.5	20.5
2	57.0	32.0	40.0	22.0
3	51.0	34.5	38.0	22.0
4	52.5	34.5	40.0	18.5
5	55.5	46.0	51.0	21.0
6	54.0	44.0	47.0	18.0
7	53.0	42.0	49.0	16.5
8	54.0	42.0	48.0	22.5
9	56.5	45.0	51.5	20.0

APPENDIX II (CON'T)

LINEAR MEASUREMENTS

ORTHODONTICALLY TREATED DENTITIONS

<u>EXTRACTION</u>	<u>INCISOR</u>	<u>INCISOR</u>	<u>CURVE</u>	<u>MAND. ANT.</u>
<u>SUBJECT</u>	<u>OVERJET</u>	<u>OVERSITE</u>	<u>OF SPEE</u>	<u>DISCREPANCY</u>
1	1.0mm	2.0mm	0.0mm	0.5mm
2	2.0	4.0	1.0	0.5
3	1.5	4.5	1.5	0.5
4	2.0	4.0	1.0	3.0
5	1.0	3.5	0.5	1.0
6	1.5	1.0	1.0	2.0
7	1.0	3.0	0.0	1.0
8	1.5	5.5	1.0	1.5
9	0.0	2.5	0.5	2.0
10	3.0	6.0	1.0	2.0
11	2.0	4.0	1.0	2.0

NON-EXTRACTION

<u>SUBJECT</u>	<u>INCISOR</u>	<u>INCISOR</u>	<u>CURVE</u>	<u>MAND. ANT.</u>
1	2.0	5.0	0.5	2.0
2	0.0	0.5	0.5	1.0
3	0.0	2.5	1.0	4.5
4	0.0	2.0	0.0	1.0
5	1.0	6.0	0.5	2.0
6	1.5	4.5	0.5	1.5
7	2.5	3.5	1.0	4.0
8	0.5	2.0	0.0	2.0
9	3.0	2.5	0.0	0.0

APPROVAL SHEET

The thesis submitted by Dr. Robert J. Noetzel has been read and approved by the three members of his examining board.

The final copies have been examined by the Director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

May 7, 1968
(Date)

Ronald C. Hilgers
(Signature of Advisor)