1964

A Roentgenographic Study of the Orthodontic Movements Exhibited by the Mandibular First Molar Teeth During Final Space Consolidation Utilizing Edgewise Forces

Ernest S. Follico
Loyola University Chicago

A ROENTGENOGRAPHIC STUDY OF THE ORTHODONTIC MOVEMENTS EXHIBITED BY THE MANDIBULAR FIRST MOLAR TEETH DURING FINAL SPACE CONSOLIDATION UTILIZING EDGEWISE FORCES

by

Ernest S. Follico

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
1964

AUTOBIOGRAPHY

Ernest S. Follico was born in Los Angeles, California on August 13, 1936. His elementary school education was received in Los Angeles. He graduated from Garfield High School in Los Angeles in June 1954.

In September 1954 he entered the University of Southern California for four year of pre-dental studies.

In September 1958 he moved to Chicago, Illinois to begin professional training at Loyola University School of Dentistry.

The author began his graduate studies in June of 1962 at Loyola University, Chicago, Illinois.

ACKNOWLEDGEMENTS

I wish to extend my sincere gratitude to all my teachers and colleagues both past and present for their inspiration, encouragement and fellowship.

In particular I want to thank Dr. Joseph R. Jarabak, for his supervision and guidance in developing this thesis, and for his support as a friend throughout my graduate studies.

I wish to express my appreciation to Mr. James A. Fizzel for his help and interest in this work, especially in the statistical discipline and analysis of the data.

To professors Nicholas J. Brescia and Y. T. Oester for serving as members of my advisory board.

To Drs. Erwin Stier and Robert Krvavica without whose previous work this thesis could not have been undertaken.

To Dr. Jack G. Mann and Mr. John Blickenstaff for their aid in producing the photographs so essential to this work.

To my wife, Gloria, for her untiring assistance in the construction and typing of this thesis and for her love and encouragement through all the years of my professional education.

TABLE OF CONTENTS

LIST OF FIGURES

TABLE

CHAPTER I

INTRODUCTION

A. Introductory remarks

Orthodontics has grown and developed from a purely mechanical art into a biomechanical science through the efforts of research. During its evolution its inheritance has been rich. It has borrowed from the allied sciences of anatomy, biology, physical anthropology, physiology, physics and applied mechanics. From its relationship with these abstract disciplines, orthodontics is slowly emerging as a biophysical science.

Research in orthodontics has shown that tooth movement is made possible by adjustments in the periodontal ligament and the process of bone resorption and bone formation stimulated by the application of pressure and tension. It demonstrated clinically and experimentally that there is a range of optimum forces which cause physiologic tooth movement to occur at an increased rate. Force systems can be developed employing light tension from small diameter arch wires to produce tooth movements believed to be more in keeping with the biophysical requirements of the teeth and their enviornment.

The intra-oral roentgenogram and histologic studies of the same teeth moved orthodontically show a close correlation between the two methods of assessment of periodontal and alveolar changes. All of the investigators agree that during tooth movement the width of the periodontal space and the thickness of the lamina dura increase on the tension side and decrease on the pressure side.

The literature reveals that the historic evolution of the diagnostic procedure has been marked by the untiring efforts of a great many investigators both in research and in clinical practice. Research in later years should in no way be considered as an attempt to disqualify those investigators or their findings. Instead, the clinician should clarify and possibly improve on the basic premises so carefully established by the pioneers of orthodontics.

B. Statement of the problem

The present study was designed to appraise and analyze the radiographic changes in the periodontal space, cribriform plate surrounding the mandibular molar teeth and to determine the amount and direction of tooth movement taking place in patients entering the completion stage of orthodontic treatment. At this time residual spaces are closed and there is a final axial rearrangement of teeth for esthetic and functional purposes. During this time forces applied to the mandibular molar teeth usually have two components, one in the horisontal while the other is in a vertical direction. In this, the mandibular posterior teeth move anteriorly while the maxillary anterior teeth move posteriorly.

This study will serve as a comparison to similar work done on patients treated with light differential forces by Gantt (1960), Kemp (1961) and Krvavica (1963).

An intra-oral roentgenographic appraisal was used to determine bone resorption and apposition in the mesial, distal and apical regions. Because roentgenograms are only two dimensional, buccal and lingual tipping movements, or small axial rotations will not be shown on these roentgenograms, nor can the exact distance of tooth movement be determined. It is believed that this method will accurately show those areas of tissue activity by the changes in the periodontal space and cribriform plate which demonstrate the direction and type of tooth movement taking place at a precise time. In addition to the method of evaluation described above, a cephalometric assessment was made to appraise the type and amount of tooth movement that occurred.

CHAPTER II

Review of the Literature

In reviewing the literature we find that the studies done on tooth movements have progressed and improved as knowledge grew in this area. Before the advent of histologic and radiographic data, some of the early observers as Kingsley (1877), Farrar (1888) and Walkhoff (1900) explained their observations on empirical concepts that teeth moved because alveolar bone was bent and there was displacement of supporting bone structures.

The first histologic investigation dealing with orthodontically moved teeth was done by Sandstedt (1901). He placed appliances on the incisors of a dog and moved the teeth toward the labial or lingual. He then prepared sections through the jaws, which showed osteoclasts and bone resorption on the side of pressure and osteoblasts and bone formation on the side of tension.

Oppenheim (1909), performed similar, but more extensive experiments on the incisor teeth of a young monkey, using arch wires anchored to the molars. He studied tipping, extrusion and depression of teeth by orthodontic means. He showed that wherever pull is exerted, new bone is formed. The new bone is arranged in the direction of the pulling force. Wherever pressure is exerted upon the alveolus, the bone is resorbed thus creating space in which the teeth can move.

Neither Sandstedt nor Oppenheim knew the magnitude of the forces they applied in their investigations but simply classified them subjectively as light, medium and heavy. Both men observed under the heavy forces the phenomenon "undermining resorption", an active resorption in the adjacent marrow spaces working toward the pressure area.

Schwarz (1932), using an auxiliary spring appliance measured the forces resulting from the various parts of the spring which were in contact with different teeth along the spring. He concluded that the most favorable forces from the biologic standpoint were the forces not greater than capillary blood pressure, about 23 grams per square centimeter. Schwarz also emphasized that in tipping the force varies at different levels of the root, being greatest near the alveolar crest and at the apex and decreasing gradually until it is zero at the tilt axis. As a consequence, the tissue reaction varies in accordance with the magnitude of the force.

Gottlieb and Orban (1931), found physiologic (teeth in function) periodontal ligament width to be greater than biologic (non-functioning teeth) width and also found that when a force caused the periodontal ligament to become compressed beyond its biologic width the adjacent bone began to resorb.

Kellner (1928), reported cementum to be thin in functioning teeth, thick in non-functioning teeth, periodontal ligament wider in functioning teeth, narrower in non-functioning teeth.

Klein (1928), and Kronfeld (1931), showed that the periodontal ligament not only varies with function but also with age, being wider in young.

Collidge (1937), concurred with earlier findings on the width of the periodontal ligament. He also observed that the periodontal ligament of a drifting tooth was considerably wider on the tension side than on the pressure side and varied with individuals, teeth and different areas of the same tooth.

The periodontal ligament is involved in bone alterations in two ways: (1) periodontal fibers transmit forces from tooth to alveolar bone, (2) bone forming and destroying cellular elements are often to be found in the periodontal ligament. The factors which have an effect on this process of change in the periodontal ligament and bone when an activated orthodontic appliance is placed are: (a) the magnitude of the force in grams or ounces, (b) the distance the force is active and (c) the length of time the force is applied.

Regardless of how movement might be classified, the periodontal ligament reacts biologically as stated above.

It was evident that controlled orthodontic treatment is the direct result of successfully controlled forces. According to Case and Angle, the most important of the laws of force regarding orthodontic mechanics was Newton's Third Law: "To every action there is an equal and contrary reaction." Applied orthodontically, this means that whatever the force exerted on a tooth may be, it causes reactive forces either elsewhere on the same tooth or on adjacent teeth. It has also been pointed out that the teeth themselves are not units of anchorage, but rather means of attaining attachment to the underlying bone through the medium of the periodontal ligament.

Huettner and Whitman (1958) in their experiments on monkeys using the edgewise technique found that in every one of the animals used there was always a posterior movement of the anterior teeth and at the same time, there was a mesial movement of the posterior teeth which were used as resistance or anchorage units.

They found histologically that "tip-back" bends were the most damaging orthodontic movement and that torquing was the second most damaging. The so-called "tip-back" bends did not prevent mesial movement of the posterior segments but did produce the most severe root resorption. They also found that tipping the molar teeth in a distal axial inclination did not enhance their resistance to forward movement.

Storey and Smith (1952), used helical spring units activated to various force magnitudes to move canines distally. First permanent molars, together with second premolars were used as anchor units for the springs to move canines distally into the first premolar extraction spaces.

They found an optimum range of force for the maximum rate of movement of mandibular canine teeth to be 150-200 grams. The maximum rate of mesial movement of the molar anchor unit occurred in the high range of force values; 300-500 grams were applied to the canine teeth. When the force was below 300 grams for the molar anchor unit, neither tooth moved appreciably.

Halderson, Johns and Moyers (1953), found that a force of over two pounds can be exerted by an edgewise wire. They also found that using a series of light round wires to start edgewise appliance treatment causes tipping and the forces are much lighter than it is possible to achieve with a standard edgewise wire.

Jarabak (1960), gave tangible values to the terms "light forces" and "excessive forces". Heretofore, these terms were used without specific meaning. The terms were subjective evaluations of forces by different operators varying greatly from operator to operator as they naturally would.

Orthodontic forces beyond 6-7 ounces have been shown to be excessive and result in a decreased rate of tooth movement. (Storey and Smith, 1952; Begg, 1954; Reitan, 1957; and Jarabak, 1960). A light orthodontic force ranges from about 1-4 ounces (30-120 grams), and intermediate forces from about 5-6 ounces (140-160 grams).

Jarabak and Fizzel (1963), have further elucidated on the biophysimal aspects of forces in orthodontics and given greater meaning to terms such as threshold, optimal, maximal and excessive forces. They have offered numerical force values for optimal forces for various teeth and have given quantitative figures to various spring rates showing how the influence of spring design can increase or decrease force magnitudes. They have shown us how to determine these forces experimentally and also how to measure them clinically, thus removing much guess work Furthermore they have taken the helical spring and shown how its parts make up a single unit of force and when combined with bracket attachments result in various force systems to accomplish desired tooth movements whether they be translation, tipping or rotational.

Reitan (1957), showed that one of the first signs of orthodontic forces exceeding 200 grams is reduction of cellular constituents in the periodontal ligament. This is later followed by hyalinization in the periodontal ligament.

Stuteville (1937-1938), Sicher and Weinman (1953), and Reitan (1951-1956), have all shown that the physiology of the periodontium and the cellular activity of the periodontal bone itself are affected in different ways depending on the type of orthodontic forces used and the degree of those forces used to control the movement of the teeth.

Wentz, Jarabak and Orban (1958), in tooth jiggling experiments on monkeys produced by traumatic occlusion (imitating cuspal interference in a bucco-lingual direction) observed some unique bone change characteristics. The histologic sections showed enlarged periodontal ligaments around the involved teeth, containing hyalinized connective tissue. As the jiggling movement continued, a cycle of crushing, undermining resorption and repair took place in the periodontal structures. There was no definite pressure or tension side, but rather the combined effect of both pressure and tension were recorded as the tooth was jiggled buccally and lingually. The periodontal ligament became increasingly wide until it was more than three times the original width, resulting in extreme mobility of the involved teeth. Later healing occurred but there was axial resorption of cementum and dentin. These findings are of particular interest to orthodontists since similar conditions can arise during certain types of tooth movement. Consequently we feel now, that it is of prime importance in treating orthodontic patients to first reduce any interferences of occlusion to facilitate the next steps in treatment and thus help reduce the possibilities of tooth jiggling.

Among the diagnostic and treatment aids, the roentgenray has long been used in the study of normal and pathologic conditions and has become an indispensable tool in medicine and dentistry, both in practice and research.

Although intra-oral roentgenograms are used routinely in dentistry for periodic caries check-ups and examinations, they are not so used in orthodontics once treatment has begun. By not using this medium periodically the orthodontist is overlooking about the only source of information available to him of what forces from his appliances are doing to the periodontal ligament, tooth roots and alveolar bone.

Walkhoff (1898), Ruediger and Dieck (1911) were among the first to describe bone changes and structure radiographically. Braunschweiger (1918) and Winkler (1921), studied the distribution of bone trabeculae in the mandible.

Brescia (1959), studied the architecture of the alveolar spongiosa and classified it into two distinct patterns each having a subgroup. The first type showed a regular horizontal arrangement of the spongy trabeculae running from the walls of the socket of one tooth to the next. The second type shows an arrangement of the spongiosa trabeculae that is irregular but with a much greater number of trabeculae in any specific area of the alveolar process.

Beck, Grim and Massler (1945), made correlations of the density of bone in histologic sections to the degree of radiopacity on the respective roentgenogram. They have found in all instances the histologic picture confirmed the roentgenographic observations in every detail.

Teleroentgenography, described by Schwarz (1957), is a comparatively new technique which unfortunately is hardly used in dentistry. In teleroentgenography, the roentgenray tube is placed at a distance of about six feet from the film to obtain parallelism of rays, thus avoiding distortion. It and cephalometrics have been used in dentistry as an aid in the diagnosis of malocclusions. In another form it has also been used to study fractures of the teeth and jaws, periodontal disease and in locating foreign bodies and impacted teeth.

Gantt (1960), Kemp (1961), Stier (1962) and Krvavica (1963) employed teleroentgenograms in their studies of the movement of the mandibular first molars which were used as anchor units during orthodontic treatment. An appraisal was made based on the dimensional changes in the periodontal space and lamina dura as shown on intra-oral roentgenograms. Gantt and Kemp found that during the up-righting of the molar teeth using the Loyola University Light Wire Technique, the most prevalent movement of the anchor teeth was simultaneous extrusion and a distal tipping, the tilt axis being located near the apex or middle one-third of the distal root. As a result of this axial change, the mesial root elevated. Krvavica, studying the same teeth for patients treated with light wire appliances during the reduction of Class II molar relationship and the closing of residual spaces (known as consolidation) found the predominate tooth movement was a mesial migration of the crown on the average of 1.28 mm. and .57 mm. of the roots in extraction cases and 1.04 mm. of crowns and .66 mm. for roots in non-extraction cases.

Gramling (1962), showed by measurements made on cephalometric headplates of forty children having an average age of twelve years, that in both extraction and non-extraction cases there was a labial tipping of the mandibular incisor five degrees due to the combined effect of banding and leveling with the use of edgewise forces.

Taylor (1962), in the study of 101 patients treated with the edgewise technique, measured pre and post treatment cephalograms and found that anchorage loss in extraction cases was 3.6 mm. in the maxillary arch and 4.1 mm. in the mandibular arch. In both instances over one-half the extraction site was lost.

Stier (1962), employing Tweed Edgewise Technique found the mandibular first molars, during leveling, moved bodily in a mesial direction in majority of the cases. While during the stage of anchorage preparation the crowns were tipped distally far less than the roots mesially. The axis of tipping was located in the majority of cases within the cervical one-third of the two roots near the cemento-enamal junction (in the intra-radicular area of the alveolar crest).

Krvavica (1963), continuing the above study (Stier), found that the mandibular first molars were mesially translated by tipping when class II forces were applied to an edgewise appliance.

CHAPTER III

MATERIALS AND METHODS

A. Materials

The sample in this study originally comprised thirteen children undergoing orthodontic treatment at the Loyola University School of Dentistry. Since the start of the study six of the children have finished active treatment leaving seven for the final observation in this serial study.

The patients, five female and two male, were all treated in accordance with the principles of the edgewise technique, outlined by Tweed. Six cases required extraction of four first bicuspids. One case was treated non-extraction. The distribution of the subjects by age is seen in Table I.

In a previous study, Stier (1962), used these same patients to determine tooth movements in mandibular molar teeth during stages of separation, leveling and anchorage preparation.

In 1963 Krvavica used these patients to determine mandibular first molar changes during stages of class II forces.

The study involving this group of patients is a continuation of the original problem and is concerned with tooth movement during stages of space consolidation and completion of treatment.

B. Methods of study

The data used in this study was from two sources, lateral cephalometric headplates and intra-oral roentgenograms of the mandibular first molars, using the Universal Cephalometrix apparatus (Figure 1). The fixed distance between the Universal cephalostat (head-holder) and the focal point of the roentgen tube was sixty inches for lateral headplates.

A headspanner for orientation of the head, constructed by F. W. Steiner of Chicago, Illinois, was adapted (Gantt) and attached to the crossbar of the Universal cephalometric apparatus in a position thirty inches from the focal point of the roentgen ray tube (Figure 2). This reduction of target distance permitted a reduction of exposure time while still taking advantage of the central ray in order to minimize the enlargement factor. The use of a headspanner was necessary in order to prevent distortion errors due to movements of the subject's head, and to allow the operator to replace the subject into the headspanner in the same spatial relation to the roentgen-ray tube each successive time a record was taken.

An adapter (Figure 3) was constructed to attach the headspanner to the transverse bar of the Universal apparatus. This adapter consisted of the following parts: (1) a vertical arm which was attached to the horizontal transverse bar of the Universal Cephalometric apparatus; (2) a horizontal arm with a sleeve which fit over the vertical arm of the adapter and was attached to it at a right angle. The headspanner also had a sleeve which fit over the horizontal arm of the adapter. These two sleeves were secured in a position by large thumb screws which allowed the arms to befully adjustable. The sleeves were drilled and tapped and outfitted with set screws and lock nuts which gave the sleeves a very close tolerance fit.

1. Aligmment of ear-rods and calibration of the adapter arms

The two ear-rods of the headspanner were slotted and marked with lead indicators in their respective centers, thus providing an index by which they could be aligned with the central ray. A series of trial-and-error adjustments were made until the centers of the ear-ports were in direct alignment as shown by the exact super-position of the two lead indicators on a roentgenogram (Figure 4). This position was then defined as "zero" and suitable reference lines were marked on the horizontal and vertical adapter arms. Millimeter scales were fastened to both horizontal and vertical arms in such a manner that the zero points of the millimeter scales coincided with the reference markings on the adapter arms. The continued accuracy of the earpost alignment was checked each time before taking a new series of data on each subject.

3. Alignment of mandibular first molar area with the Central Ray

From each of the lateral head-plates taken before treatment, a tracing was made which included the Frankfort Horizontal Plane and the mandibular first molars. On these head-plates the central rays had passed through the ear-rods of the cephalostat as originally adjusted and fixed by the Universal Manufacturing Company. A perpendicular was drawn inferiorly from the Frankfort Horizontal Plane, through the center of the ear-post images to the level of the lower border of the mandible. A second line, parallel to the Frankfort Horizontal was then drawn posteriorly from the center of the mandibular first molar until it crossed the previously established vertical line. The crossing point of the two lines represented the zero point from which the horizontal and vertical coordinates X and Y were measured in millimeters (Figure 5). Assuming the horizontal coordinate measured sixty millimeters and the vertical fifty millimeters, the headspanner was then adjusted along the millimeter scales on the horizontal and vertical adapter arms to these respective values. When the patient's head was positioned in the headspanner, the mandibular first molar was in a position previously occupied by the ear-rods. This means the central ray was now passing through the center of the mandibular first molar instead of the ear-rods.

The roentgenographic film used for the lateral headplates was 8 x 10 inch high speed, blue brand, Kodak Medical x-ray film. The cassettes were equipped with DuPont high speed intensifying screens which served to reduce secondary radiation and to provide greater contrast on the x-ray. The machine setting for each exposure was 87 KVP and 25 MA with an exposure time of one-half second. The film used for the intra-oral records was DuPont code D-2, double coated dental x-ray film. The machine setting was the same as above with an exposure time of two and one-half seconds for each film.

C. Measurements

The subjects were placed in the head positioner after it had been adjusted to the previously established measurements for each individual. Two intra-oral roentgenograms were then taken of both the right and left mandibular first molar areas prior to treatment. These films were the first series and were marked I A and I B (patient's right side), and I C and I D (patient's left side). Subsequent series were marked with the patient's number and the series number in accordance with the above technique. The replications were taken to provide a measure of experimental error.

After uniform processing, keeping the developing time, temperature and concentration of solutions constant to insure good quality, the finished x-rays were scrutinized as to contrast and density. If it was found that the x-rays, intra-oral or lateral headplates did not meet desired standards of density, they were brought up to correct density quality by means of a logetronic Contact Printer (Model CP-18) (Figure 6). The Logetron is defined as a scanning servo-modulated light source for use in photographic printing. It provides an automatic means for producing uniform prints from negatives having a random distribution and wide range of density variations. With the availability of this new piece of equipment we were able to improve on inferior original x-rays without subjecting the patients to added radiation.

The roentgenograms of the first series were then transilluminated on a tracing table. Under a stationary three power magnifying lens, the root images of the mandibular first molars were marked in four areas in the following manner:

TABLE I

DISTRIBUTION OF THE SUBJECTS BY AGE

	AGE (YEARS)		TOTAL
	13		1
	14		2
	15		2
	16		2
MEAN	14.71	TOTAL	7

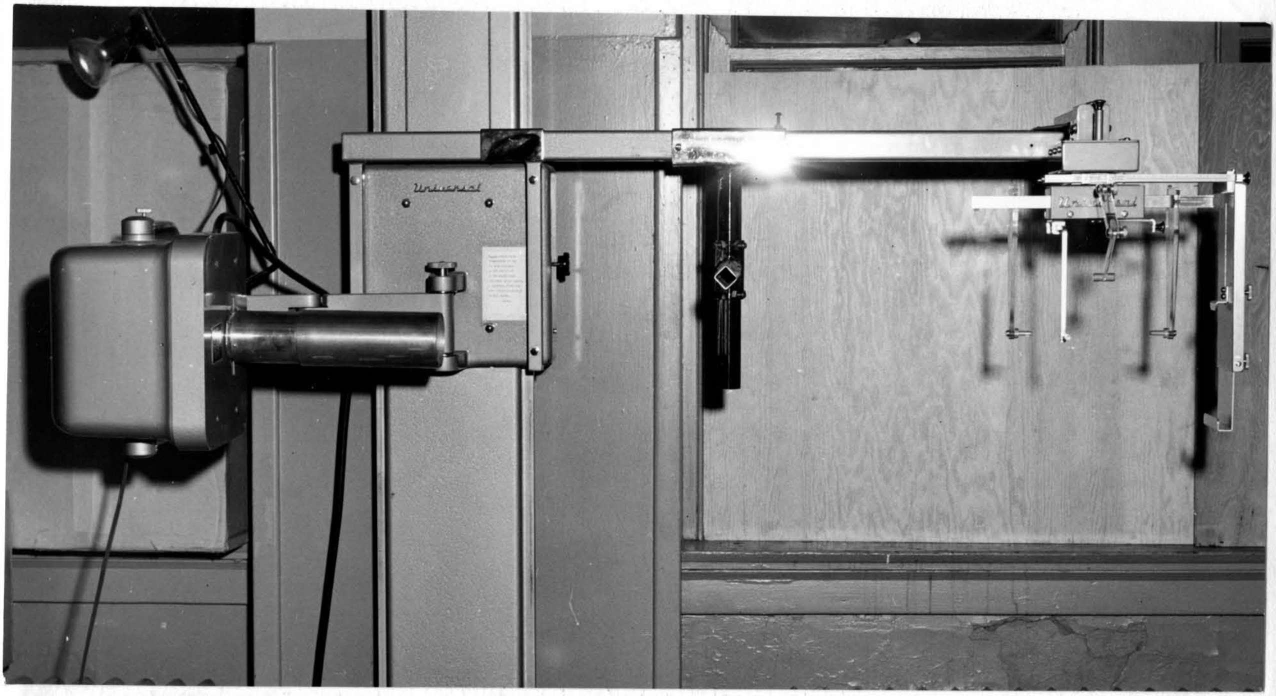


FIGURE 1

THE UNIVERSAL CEPHALOMETRIX UNIT

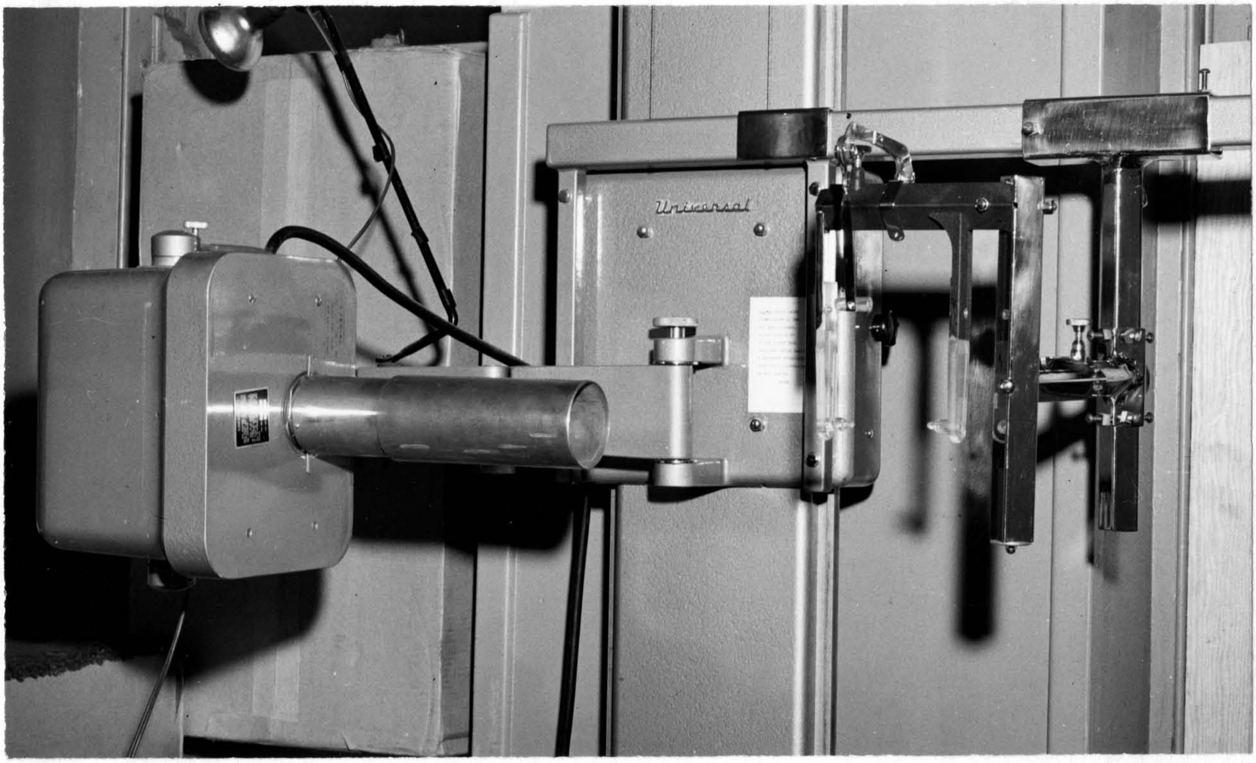


FIGURE 2

THE HEADSPANNER MOUNTED ON

THE UNIVERSAL CEPHALOMETER

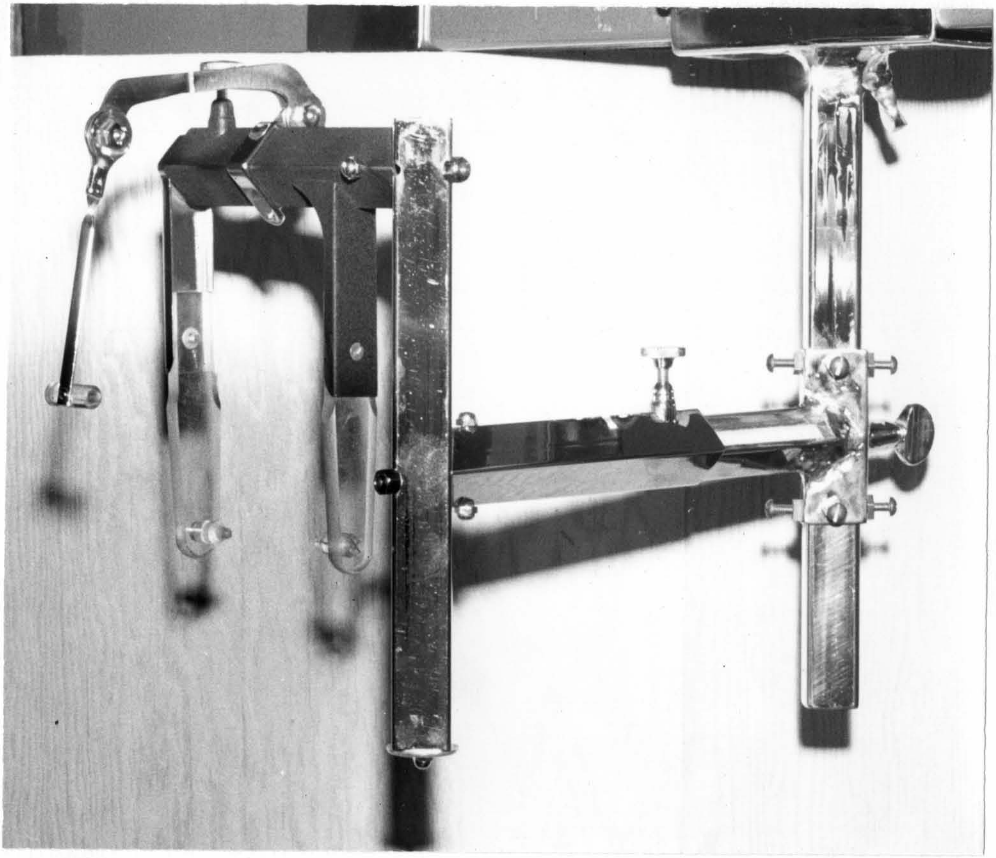


FIGURE 3

HEADSPANNER WITH VERTICAL

AND HORIZONTAL ADAPTER ARMS

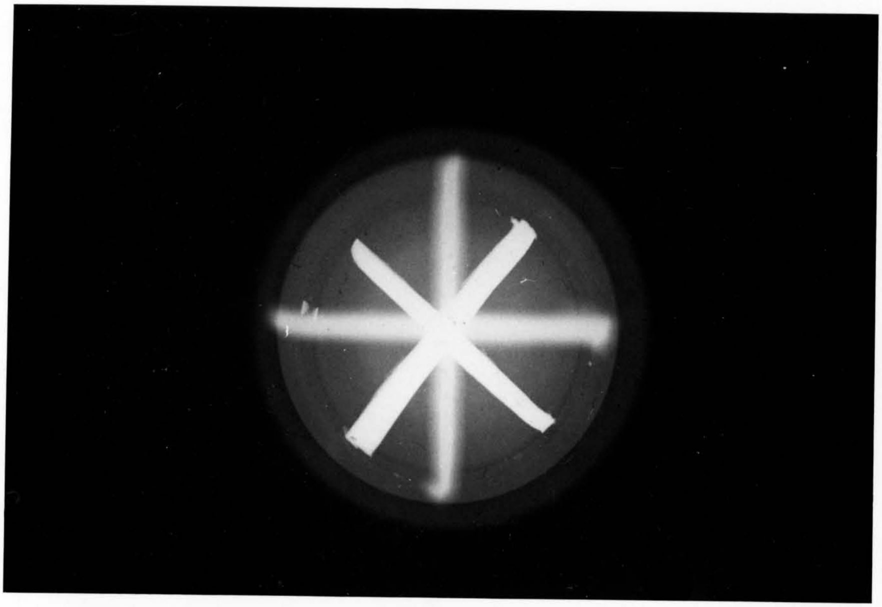


FIGURE 4

SUPERIMPOSED LEAD INDICATOR SHOWING
THE ALIGNMENT OF THE EAR-POSTS WITH
THE CENTRAL RAY

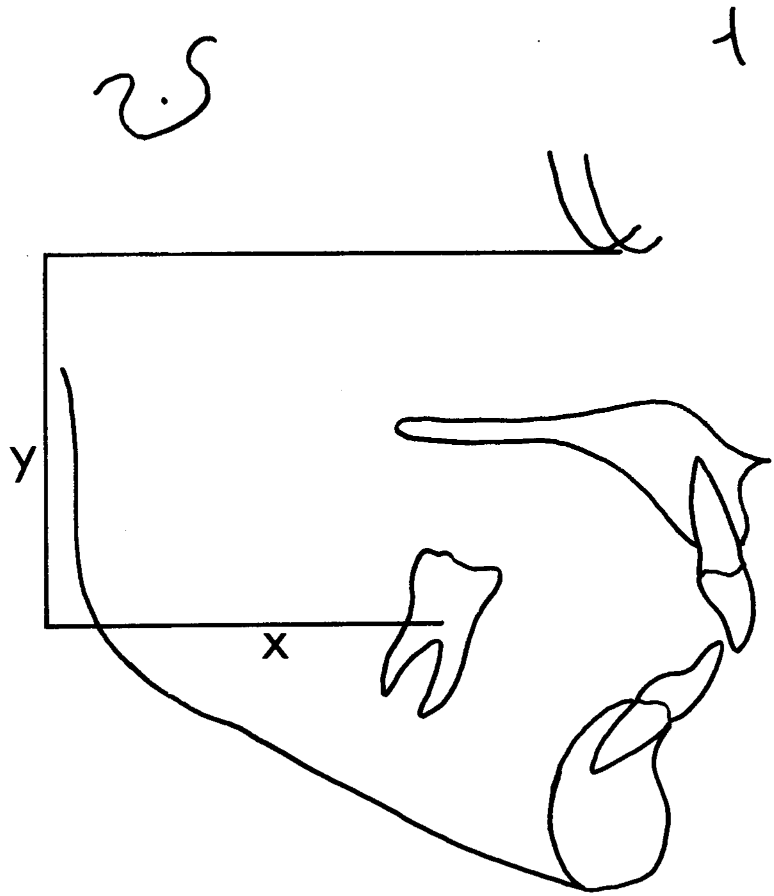


FIGURE 5

TRACING OF A LATERAL HEADPLATE
INCLUDING THE X AND Y
COORDINATES

FIGURE 6

LOGETRONIC CONTACT PRINTER

With a fine pointed needle, the film was perforated in the marginal area of the mesial root about one millimeter from the periodontal space where the latter was best distinguishable. This marking was designated as "point A". The same procedure was followed in marking point B (apical area of mesial surface of mesial root), point C (marginal area of distal root,) and point D (apical area of distal surface of distal root), (Figure 7).

Each film of the first series thus marked was then superimposed individually over each of its follow-up films in subsequent series in order to transfer the perforation marks to the same areas. Thus, the comparison of the periodontal space around each tooth was made very nearly at the same level in each successive series. After all roentgenograms were marked and bound as slides, they were projected on to a white cardboard screen at a fixed distance of eight feet from the lens, which distance was maintained throughout the observation period. A magnification factor of 20:1 was established and re-checked by projecting a slide of a metric scale in such a manner that a distance of two millimeters on the slide measured forty millimeters on the screen. The slide projector used was a Kodak Cavalcade with a Kodak Ektanar Projection Lens, 5 inch, F 12.8.

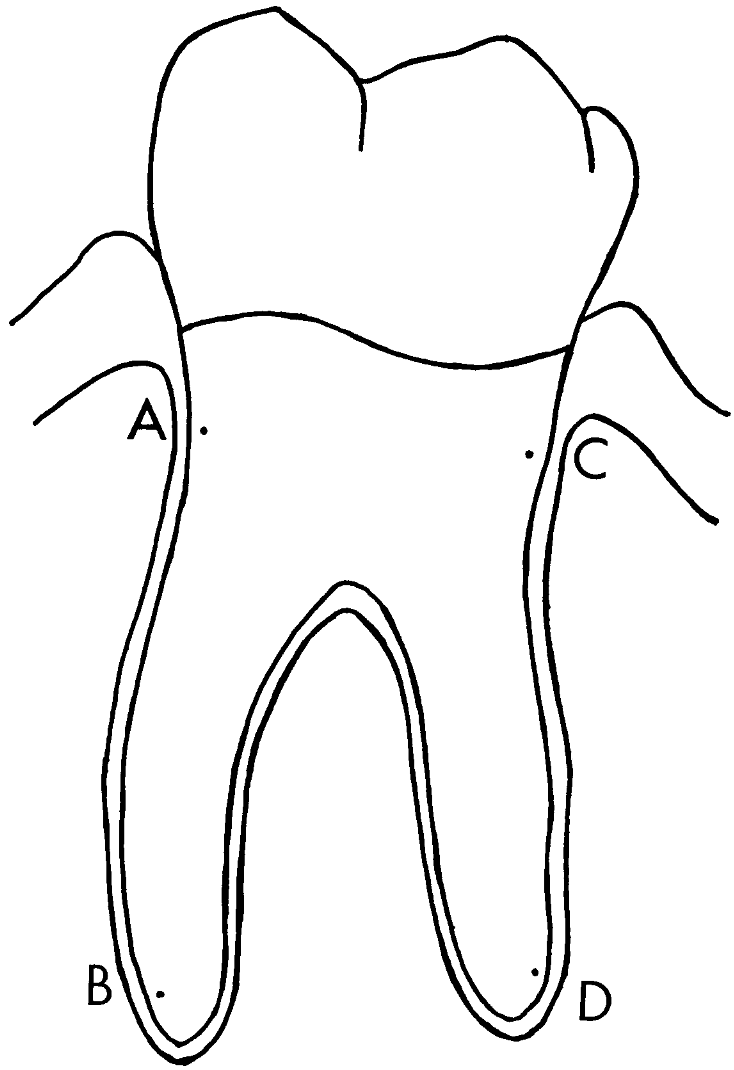


FIGURE 7

MARGINAL AND APICAL REFERENCE

POINTS A, B, C, AND D, AS MARKED

ON THE INTRA-ORAL ROENTGENOGRAMS

The changes in width of the periodontal space and the types of tooth movements were appraised as follows: A reference strip of plain white paper, one inch wide and ten inches long, was divided lengthwise into four sections (A,B,C,D), each corresponding to one of the four areas marked on the roentgenograms as described previously. In each section, a thin vertical line was drawn and labelled as the reference line (Figure 8). The first slide, Series Number I A of patient Number 1, was then projected on to the screen and the white paper strip was placed against the screen in such a manner that the reference line in section A coincided with the image of the outer border of the cementum, adjacent to point A (marginal area of the mesial root). The width of the periodontal space was estimated for this area and recorded on the reference strip by drawing a short vertical line with a fine pointed red pencil. This procedure was repeated for points B, C, and D, recording each width on the respective section of the same reference strip (Figure 9). The next slide projected was that of the same tooth after the next stage of treatment to be studied had been recorded. Using the same reference strip, the same procedure for recording the periodontal widths in the four areas was followed, except this time, a fine pointed pencil of another color was used.

In the first method of evaluating the data, the paper

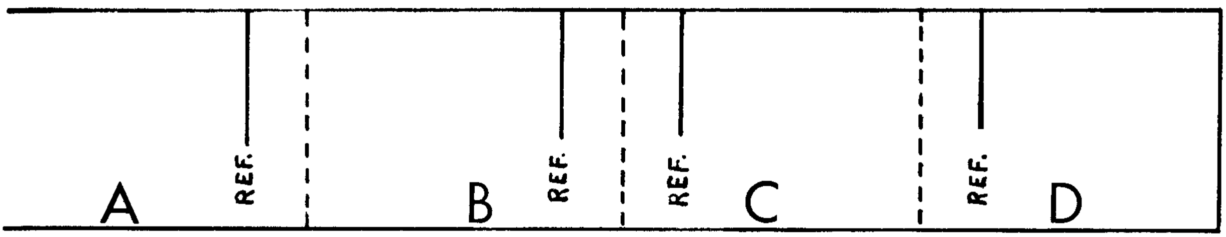


FIGURE 8

REFERENCE STRIP

EACH SECTION CONTAINS A REFERENCE LINE

CORRESPONDING TO ONE OF THE REFERENCE

POINTS A, B, C, D, WHICH WERE MARKED ON

THE INTRA-ORAL ROENTGENOGRAMS

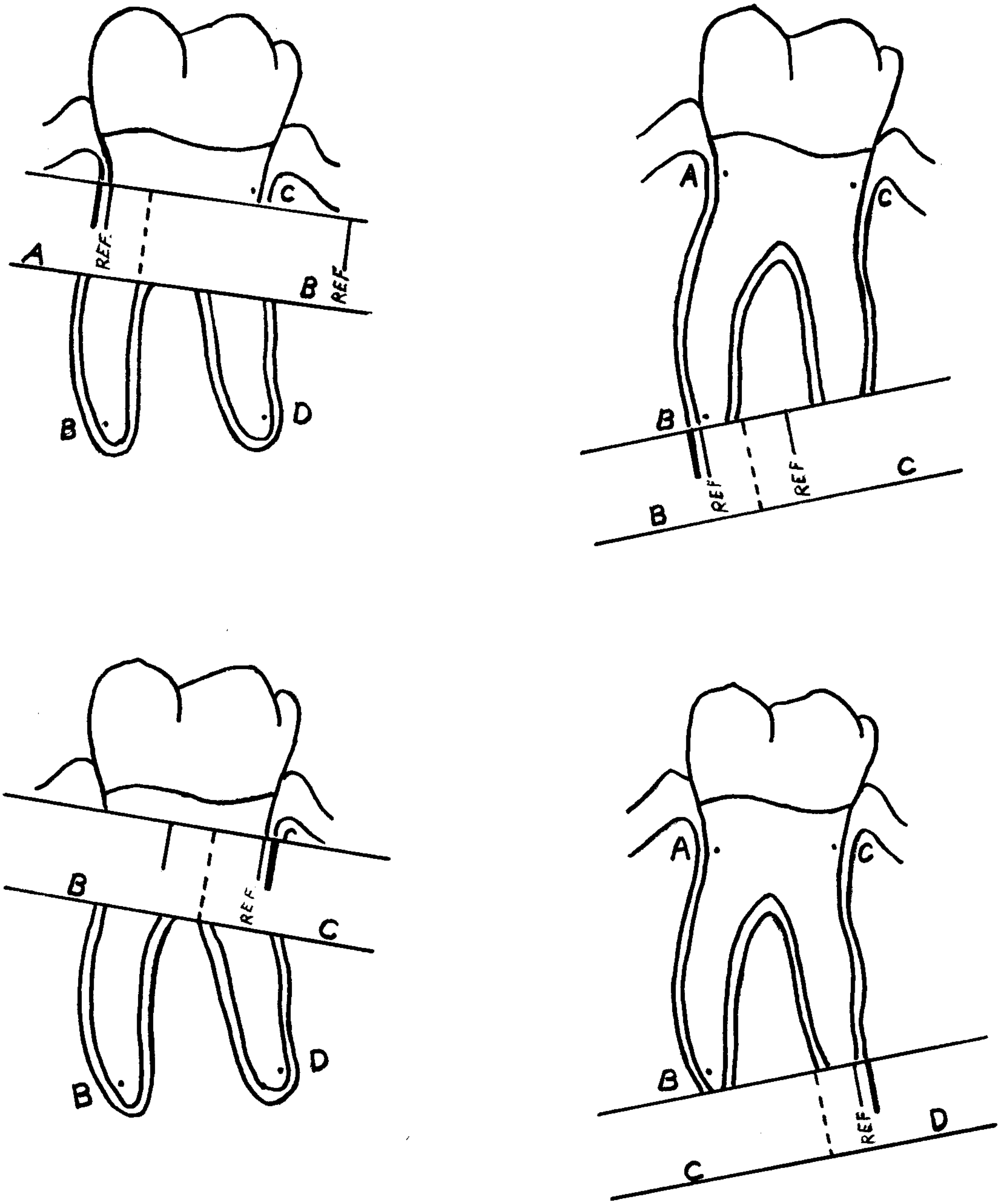


FIGURE 9

EVALUATION OF AREAS A, B,

C, D, PRIOR TO TREATMENT

strips which have just been described were employed to reveal the direction of change in the width of the periodontal space. A decrease was indicated if the second line fell between the first (red) line and the reference line. If the second line was recorded outside the red line, the space was evaluated as having increased. Correlation of the changes occurring at the four marked positions could then be made to reveal the type of tooth movement which took place in the interval being studied. This procedure was followed on each of the intra-oral x-ray films in each series.

The second method of evaluating these data was a visual subjective appraisal. The original pre-treatment film and its follow-up series were all projected simultaneously, which made it possible to compare visually any particular stage of treatment with any other and to obtain a composite picture of the type and direction of tooth movement. The findings from this visual appraisal were then interpreted and compared with those derived from the records on the reference strips.

The third method of evaluation required that measurements be made on cephalometric headplates taken after consolidation (space closing forces) had been utilized for a period of twelve weeks in order to determine the amount of tooth movement which occurred during this treatment interval.

This was then compared to headplates taken after class II forces (Krvavica) to measure the amount of mandibular molar movement during the space consolidation stage of treatment. Consolidating forces exert a mesial component of force on the mandibular molar teeth.

A tracing was made of each original headplate showing the mandibular symphysis, the inferior border of the body of the mandible, the angle at the junction between body and ramus, the posterior border of the ramus and the right and left mandibular first molars. The mandibular plane was then established by drawing a straight line between menton (most inferior point of mandibular symphysis) and the most inferior point at the angle of the mandible. A reference line was drawn perpendicular to the mandibular plane and tangent to the inner border of the symphysis. Two reference points were marked on each of the mandibular first molars, point C, in the area of the greatest convexity on the mesial outline of the crown and point R, at the apex of the mesial root. Straight lines parallel to the mandibular plane were traced from each reference point on the molars (point C and R) to the reference line tangent to the symphysis. The lines thus constructed are shown in Figure 10 as"c" and "r". The respective lengths of these lines were measured in millimeters and recorded in column "A" on a data sheet. The tracing

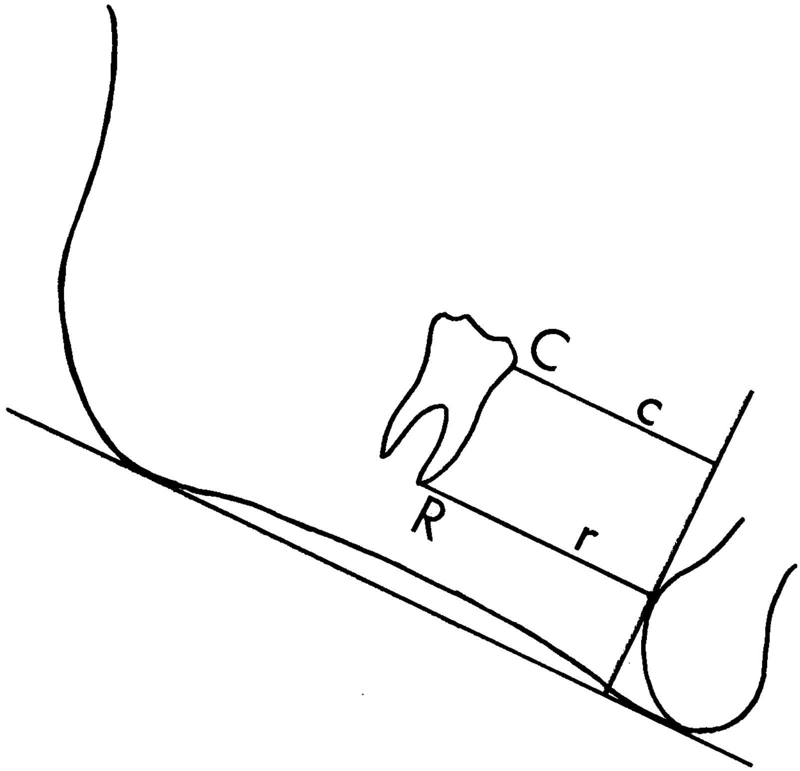


FIGURE 10

TRACING OF MANDIBULAR LANDMARKS FROM A LATERAL HEADPLATE TAKEN BEFORE TREATMENT. (c AND r REPRESENT THE DISTANCES OF THE CROWN AND APEX FROM THE REFERENCE LINE AT THE INNER BORDER OF THE SYMPHYSIS).

was then superimposed on the follow-up headplate and the outline of the right and left mandibular first molars at this stage of treatment were drawn on the same tracing in dotted lines. The same procedure was followed in measuring the distances c′ and r′ between the reference line and the tooth in its new position, and these distances were recorded in column "B" on the data sheet. The differences between the values in column A and Column B were calculated and recorded in column C on the data sheet. These differences were marked with positive or negative signs depending on whether the difference represented an increase or decrease in the respective measurements. The data were analyzed statistically and transformed into graphs in order to evaluate the types of tooth movements which occurred.

The cephalometric landmarks described above were selected for the following reasons:

(1) The inferior and posterior borders and the symphysis of the mandible were traced in order to facilitate an exact super-position of the tracings on the headplates.

(2) The inner border of the mandibular symphysis was chosen as the reference landmark because its cephalometric relation to the mandibular first molar facilitated the measuring technique and it is easily identified on the lateral headplate.

(3) The selection of the mandibular symphysis as a reference for the positions of the mandibular teeth was

preferred to other cranial cephalometric landmarks because the relation between cranium and mandible may change during orthodontic treatment. Thus by establishing a reference on the mandible, the position of the mandible would not affect the validity of the measuring technique.

D. Design of orthodontic appliance

Each of the subjects was fully banded. The last bands in the arch, whether placed on the first or second molars, were provided with 0.022 x 0.028 inch edgewise buccal tubes, 1/4 inch in length. The tubes were angulated 5° from the horizontal in order to give the teeth a distal tip-back when a straight arch wire was inserted into the tubes. In cases where second molars were banded, the first molar bands carried two single edgewise brackets. The premolar and canine bands were provided with one single edgewise bracket each, while those used for the maxillary central incisors were wide siamese, for the maxillary laterals medium siamese, and those for the mandibular incisors, junior siamese brackets. All of the brackets had zero degree torque slots and none of them were angulated in the horizontal plane (Figure 11).

Leveling was the first stage of treatment. The purpose of this stage is to align the brackets attached to the bands so an edgewise archwire can be fitted to the brackets with greater ease. The initial leveling archwires for the patients in this sample were fashioned from 0.016 inch diameter Semi-Spring Temper Elgiloy wire. They were formed individually and varied in design to fit each malocclusion. Prior to insertion, all archwires were heat-treated to spring hardness. In cases of severe crowding of the anterior teeth, lingually locked or rotated incisors, or partially erupted canines, the "Light Wire Differential Forces Technique" was employed only during the stage of leveling. For each broken contact between the four incisors, a vertical helical loop was bent into the anterior segment of the archwire. Between the lateral incisors and the canines, vertical helical expansion loops were engaged to level the brackets just in this initial stage. While the anterior segment of the arch wire contained the helical loops, its posterior segments were straight or only slightly curved for arch form. The helical loop arches were used in half of the cases but only during the leveling stage.

In cases with normally aligned anterior teeth, "ideal" arch wires with bent-in tie-back loops and mild tip-back bends were formed of Number 1 temper, 0.016 inch diameter Tru-Chrome wire (Figure 12). The tie-back loops were placed about one to two millimeters mesial to the buccal tubes and served to keep the arch wire taut by tying it back to the buccal hooks on the molar tubes.

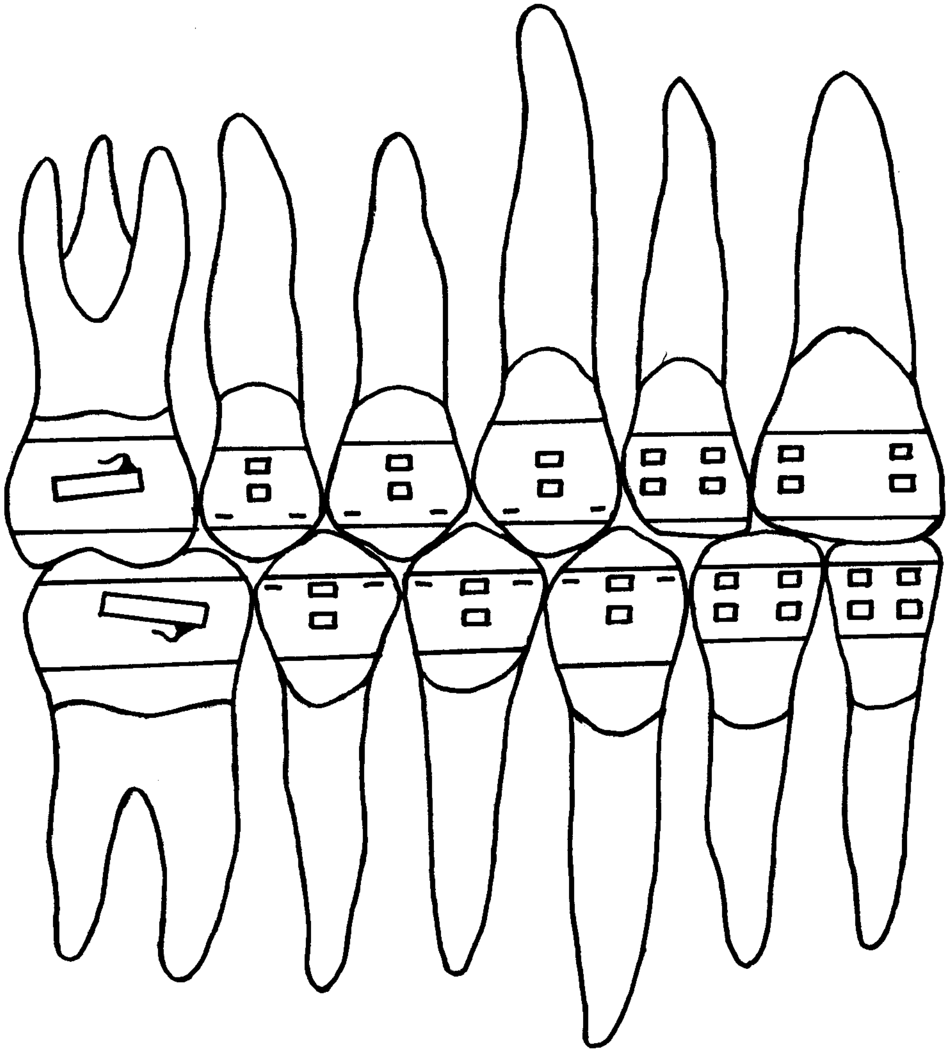


FIGURE 11

DIAGRAM OF EDGEWISE BRACKETS AND BUCCAL TUBES. THE BUCCAL TUBES ARE ANGULATED FIVE DEGREES FOR THE DISTAL TIPPING OF THE TERMINAL MOLARS. THE BRACKETS ARE NOT ANGULATED AND HAVE ZERO DEGREE TORQUE SLOTS.

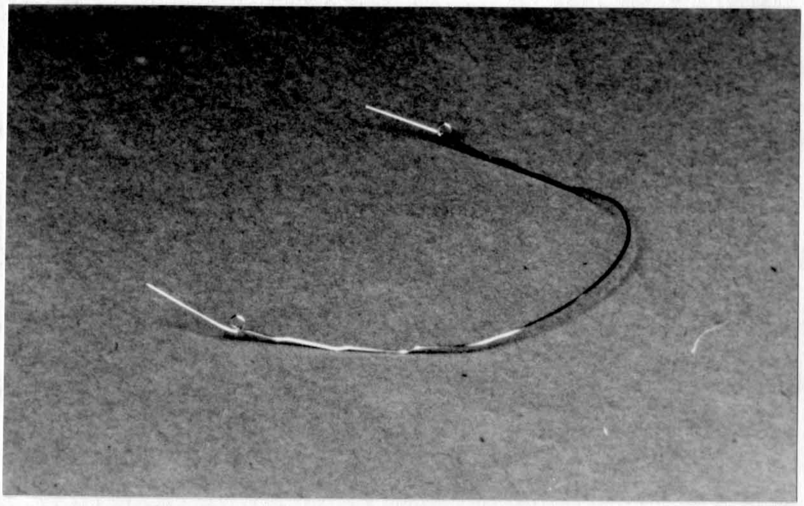


FIGURE 12

LEVELING ARCH WIRE WITH MILD TIP-BACK
BENDS AND TIE-BACK LOOPS CONSTRUCTED
FROM 0.016 INCH DIAMETER WIRE

The diameter of these leveling arch wires and the degree of their tip-back bends, were increased each appointment until the brackets were aligned to allow the engagement of rectangular arch wires. The phase of leveling was then completed by placing an ideal 0.021 x 0.027 inch, round edge, rectangular arch wire with bent in tie-back loops mesial to the buccal tubes (Figure 13).

After the leveling stage is completed, anchorage preparation is begun. According to Tweed, anchorage preparation is that phase of treatment when teeth selected for anchorage are tipped distally to a position from which they are assumed to resist anterior displacement more effectively. This is accomplished by incorporating tip-back bends into the arch wire in conjunction with a distal force applied to the mandibular arch. Class III elastics supplied the distal force which is effected through intermaxillary elastics which are extended diagonally from soldered hooks on the anterior segment of the mandibular arch wire, interproximally between the mandibular lateral incisors and canine teeth, to similar hooks on the buccal tubes in the posterior segments of the maxillary arch (Figure 14). In order to counteract the reciprocal mesial force on the maxillary arch resulting from these class III elastics, resistance bends are placed in the maxiliary arch wire and headgear is employed which exerts a distal force on the maxillary arch. The force incorporated into the headgear must be greater than the force resulting from the class III elastics in order to assure effective anchorage in the maxillary arch.

In extraction cases the retraction of the canines into the extraction sites is started when anchorage is partially prepared. This is accomplished by placing open coil spring mesial to the canine brackets. The four incisor teeth are bound together by a figure of eight ligature around the archwire just anterior to the coil and then carrying the ends of the ligature back crossing the strands and ligating them around the distal of the buccal tubes of the last banded tooth in the arch. The coil is now compressed against the canine bracket and carries these teeth distally. These activating ligatures are renewed at subsequent appointments until the distal movement of the canines is completed.

When the mandibular incisor teeth upright on denture base and have some lingual axial inclination and when the crowns of the posterior teeth are tipped distally, anchorage is considered to be prepared. The mandibular arch wire is changed to 0.0215 x 0.028 inch stabilizing arch wire to permit the use of class II elastics. The maxillary arch wire is changed to a 0.021 x 0.025 inch resilient arch wire to effect distal mass movement under class II elastic force. When space has developed mesial to the upper canines then in this arch we place Bull loops between canines and laterals to allow for the closing of these spaces. The Bull loops are activated by tying the arch back to the most distal maxillary molars that are banded. Class II elastic hooks are soldered incisally on the maxillary arch wire mesial to the canine bracket area. Class II elastics extend from this hook on the maxillary arch wire to a hook placed gingivally on the buccal tube on the terminal mandibular anchor molar (Figure 15). Distal movement of the maxillary teeth is continued until these teeth have been carried half the width of a premolar farther distally than normal and until the incisor teeth are biting end-to-end. This allows for a certain amount of return movement that always occurs when the elastics are removed.

All subjects were instructed to change the intra-oral elastics three to four times daily. The appointments were at three week intervals for check-ups and necessary appliance changes.

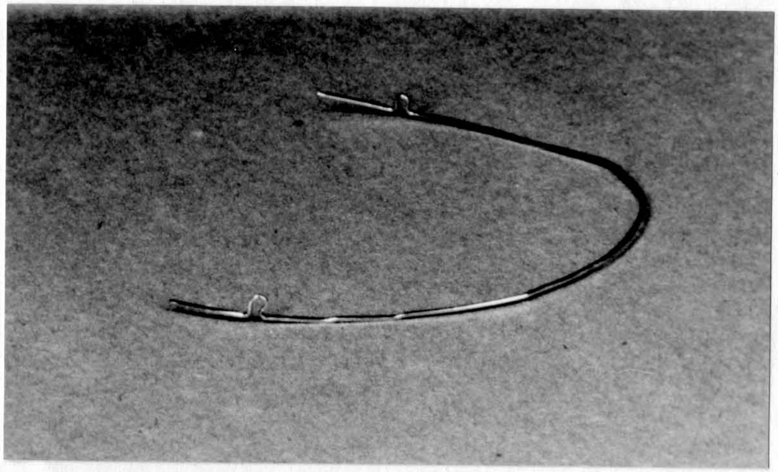


FIGURE 13

IDEAL RECTANGULAR LEVELING ARCH WIRE WITH TIE-BACK LOOPS, CONSTRUCTED OF 0.021 x 0.027 INCH NUMBER 1 TEMPER TRU-CHROME WIRE

FIGURE 14

LATERAL INTRA-ORAL VIEW OF 0.021 x 0.027 INCH RECTANGULAR ARCH WIRES WITH TIP-BACK BENDS IN CONJUNCTION WITH CLASS III ELASTICS AND CERVICAL HEADGEAR TO THE MAXILLARY ARCH AS UTILIZED IN THE EDGEWISE TECHNIQUE DURING ANCHORAGE PREPARATION

FIGURE 15

LATERAL INTRA-ORAL VIEW WITH CLASS II ELASTICS AND BULL LOOPS AS UTILIZED IN EDGEWISE TECHNIQUE DURING FINAL SPACE CONSOLIDATION

CHAPTER IV

EXPERIMENTAL RESULTS

The findings of this investigation will be reported in three parts corresponding to the three methods used for evaluation of the roentgenographic data. Part one is based on the interpretation of the markings on the reference strips described in Chapter III, part two deals with the findings from the visual appraisal of the serial slide projections, and the third part contains the findings derived from a cephalometric appraisal of the mandibular molar teeth. Parts one and two will disclose the types of tooth movements observed and part three will be concerned with the amounts of tooth movements.

A. Interpretation of the reference strips

Only one combination of changes in the periodontal width was observed during the twelve week period when final space consolidation forces were in effect: An increase in the width of the periodontal space at points C and D (distal marginal and distal apical areas) with a corresponding decrease at points B and A (mesial marginal and mesial apical areas). This type of change was the result of a mesial translation.

In one of the recordings, the reference strip revealed no dimensional change. This coincided with the cephalometric measurements and visual appraisal. Examination of this child revealed practically no improvement toward the correction of the malocclusion had taken place during the prior five months of treatment. Other information revealed this child was a non-cooperative patient.

B. Visual Appraisal of the Intra-Oral Radiographs

As mentioned in Materials and Methods, there were four series of intra-oral x-rays taken throughout the entire treatment period. These are identified as follows:

I Before treatment

II After anchorage preparation (Stier 1962)

III After class II forces (Krvavica 1963)

IV After space consolidation (Follico 1964)

A study of the intra-oral x-rays in the last series indicates that the most common movement occurring during the final phase of treatment was a mesial bodily movement or translation of the first mandibular molar teeth. This was confirmed by the relation of the teeth to their surrounding structures and also thickening of the cribriform plate along the distal root surface from the marginal area at the alveolar crest to the apex.

C. Findings from the Cephalometric Measurements

1. General analysis

The measurements taken from the cephalometric headplates after class II forces and after final space closing (consolidation), revealed that the mandibular first molars moved bodily in a mesial direction with very little tipping. The measurements are tabulated on the data sheet in figure 16.

Column A contains the values of the right and left sides after class II forces; Column B shows the measurements taken after final space consolidation. The difference between A and B are recorded in Column C, indicating the amount of mesial movement. All the figures represent measurements taken in millimeters as described in the previous chapter. In every case except one, there was a mesial movement of the mandibular first molar teeth due to space consolidation forces. The amount the teeth came forward is quantitatively similar in all cases but number 11, where the right crown came forward 6 millimeters. The reason this occurred was that after starting treatment of this patient on a non-extraction basis, four first premolars finally had to be extracted in order to complete treatment satisfactorily. Lack of patient cooperation forced the change in treatment. This resulted in added force being placed on the mandibular first molars in the later stages of treatment, consequently a greater mesial movement occurred in these teeth.

2. Statistical analysis

The data shown in figure 16 were graphed in a histogram (Figure 17) and analyzed statistically by Fisher's Analysis of Variance. The computations of this analysis are shown in figure 18, and will be discussed in detail to show their importance in interpretating the results of this investigation.

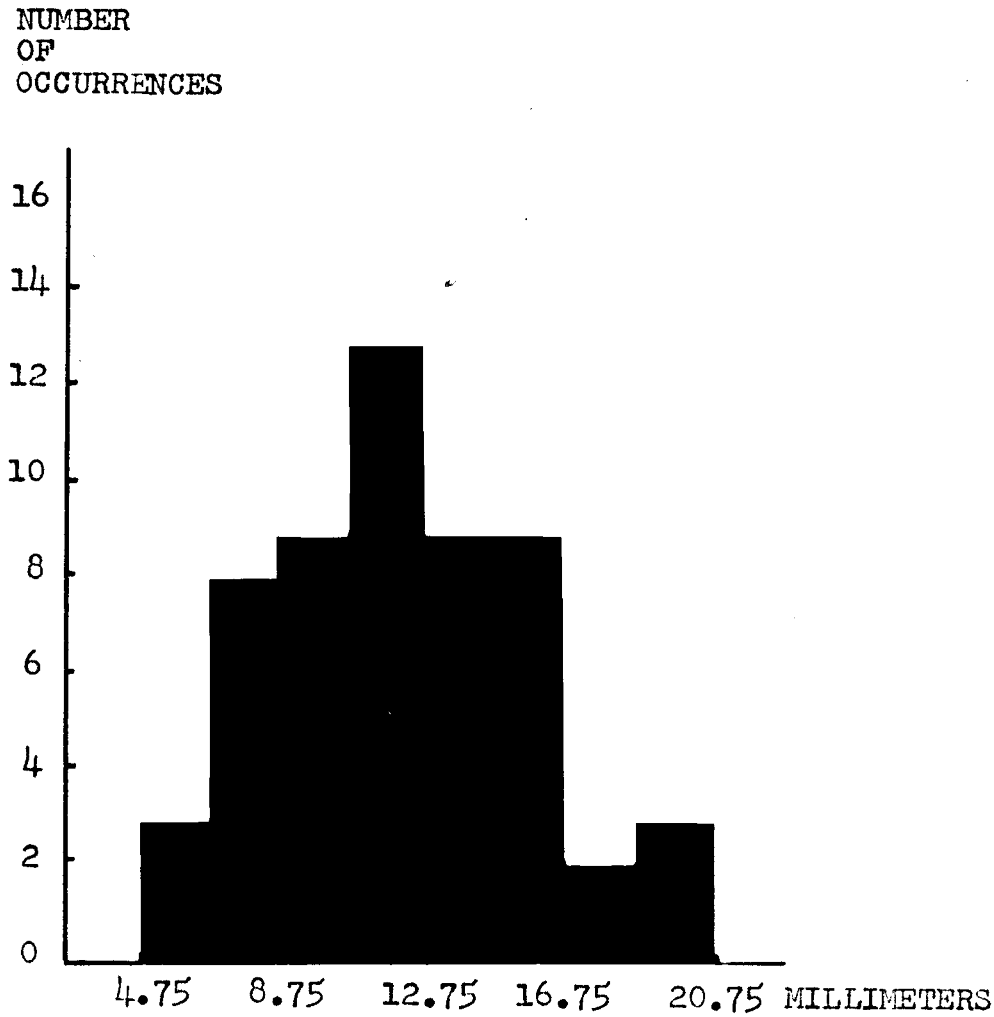
In appraising the work done it was interesting to note the magnitude of experimental error from all sources. This study displayed an error amounting to about ten percent of the mean measurement (coefficient of variation equals 0.104) which means that any given measurement could be expected to have an accuracy of plus or minus about three millimeters (the 99% confidence limits are plus or minus 3.46 mm.). This is higher than either of the two preceding experiments and resulted from the total sample size being reduced from 13 to 7 patients.

When looking at the analysis of variance table (ANOV TABLE, Figure 18) we see that the main effect in the upper portion of the table all show significant differences. The source of variation due to "patients" was expected to yield a significantly large mean square because the patients did not have identical mandibular dimensions due to varying growth patterns and arch forms. The large mean square due to "Sides" could be due

DATA SHEET

	A (BEFORE)		B (AFTER)		C (DIFFERENCES)	
PATIENT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT
CROWN	12	15	9	14	-3	-1
1						
APEX	8	15	6	12.5	-2	-2.5
CROWN	13	19	12	16.5	-1	-2.5
6						
APEX	9	14	7.5	10.5	-1.5	-3.5
CROWN	13	13	11	11	-2	-2
7						
APEX	11	11	9	9	-2	-2
CROWN	17	20.5	17	20.5	0	0
9						
APEX	11	16	11	16	0	0
CROWN	16.5	16.5	10.5	13.5	-6	-3
11						
APEX	15	15	12.5	14	-2.5	-1
CROWN	9	11	9	10.5	0	- .5
13						
APEX	5	7.5	5	7	0	- .5
CROWN	13.5	13.5	11.5	11.5	-2	-2
14						
APEX	8	8	7	7	-1	-1

FIGURE 16



HISTOGRAM OF THE CEPHALOMETRIC MEASUREMENTS

FIGURE 17

HISTOGRAM OF PATIENTS SHOWING NUMBER OF

TIMES EACH MEASUREMENT OCCURS

ANOV TABLE

SOURCES	D.F.	S.S.	M.S.	F	SIGNIFICANCE
PATIENTS	6	348.357	58.06	37.70	5% 2.49 1% xxx 3.63
SIDES	1	86.255	86.26	10.91	5% 1.99 1% x 13.74
TREATMENTS	1	35.362	35.36	14.28	5% 1.99 1% xx 13.74
POSITIONS	1	152.790	152.79	26.03	5% 1.99 1% xxx 13.74
P X S	6	47.401	7.90	5.13	5% 2.49 1% xxx 3.63
P X T	6	14.857	2.48	1.61	N.S.
P X POS	6	35.241	5.87	3.81	5% 2.49 1% xx 3.63
S X T	1	.040	.04	<1	N.S.
S X POS	1	.540	.54	<1	N.S.
T X POS	1	.540	.54	<1	N.S.
RESIDUAL	25	38.50	1.54		
TOTAL	55	759.89			

Standard Deviation of Error = 1.241 mm. and the 99% CONFIDENCE LIMITS ARE = (2.79 x 1.241) = ± 3.46 mm.

FIGURE 18

XXX = HIGHLY SIGNIFICANT VARIANCE RATIO

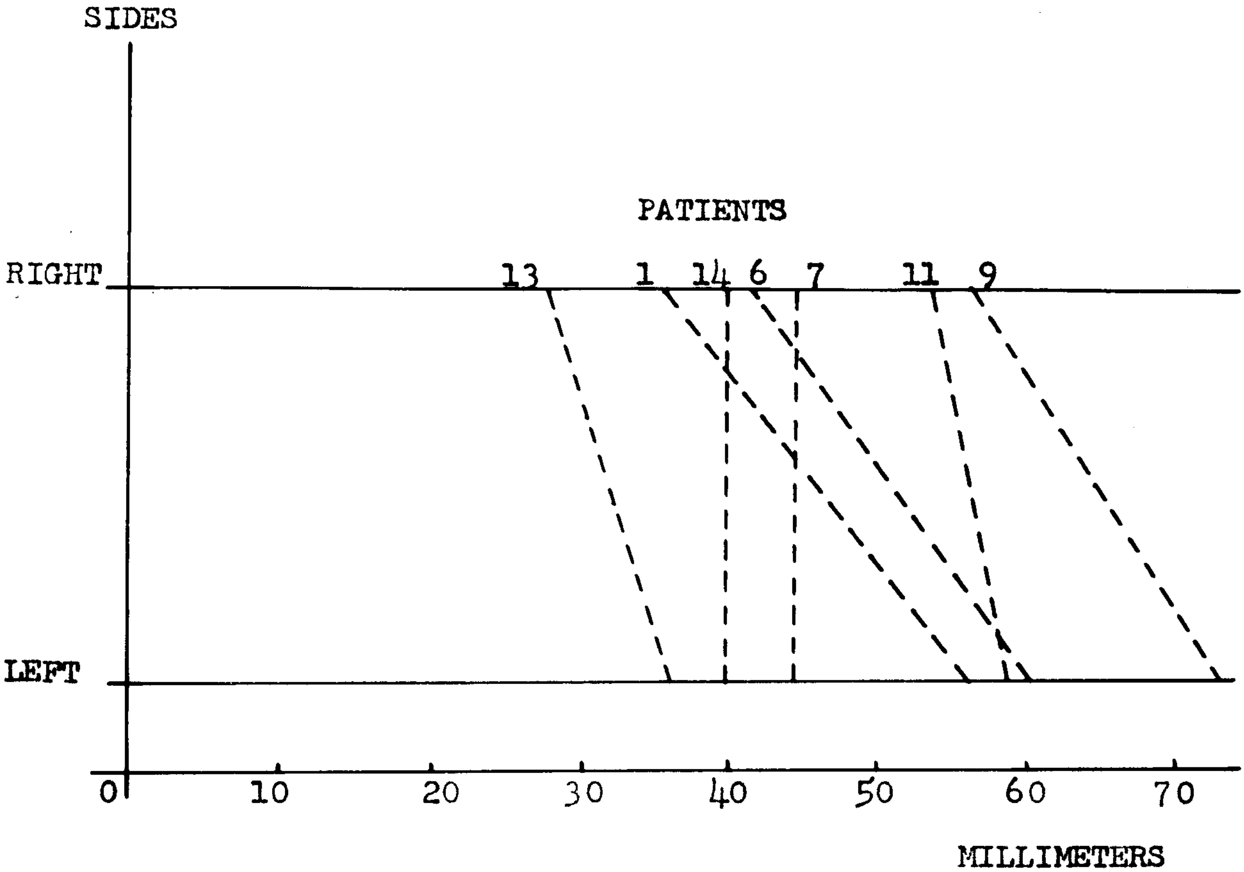
N.S. = NON-SIGNIFICANT VARIANCE RATIO

in part to the normal enlargement of an x-ray image occurring when the object is further away from the film cassette. For this reason comparison between the absolute measurements on the two sides is not totally valid. The large mean square due to "Treatments" was highly significant even with only one degree of freedom. This indicates that there were real differences in the locations of the mandibular first molars with respect to the reference line after space consolidation. The even greater mean square due to "Positions" indicates a true change in the angular position of the mandibular molars with respect to the reference line.

There were only two of the 2-factor interactions of significance. The first of these was "Patients x Sides". The fact that this mean square was large indicates that the difference between the location in alveolar bone of the right and left mandibular first molars was not the same in all patients. Figure 19 shows a graphical representation of these locations for each patient. In this graph the right side measurements for patients number 1, 6, 7, 9, 11, 13 and 14 are shown on the top line and the left side measurements are on the bottom line. The measurements equal the combined total of the crown and apex of each side before and after space consolidation and have been computed for all 7 patients in a separate "Patients x Sides" table which is part of the Analysis of Variance computation. The corresponding measurement points for each patient are connected by dotted lines for ease of comparison. If all these dotted connecting lines were parallel, or nearly so, then they would suggest no interaction: but some of them are vertical while others are diagonal, that there is a difference in the teeth measured from the midline in these patients is significantly illustrated in this graph.

The second significant 2-factor interaction was "Patients x Positions". The large mean square indicates that some of the patients had the angular position of their mandibular first molars different from that of other patients. The graphical representation of this interaction is shown in figure 20. The dotted connecting lines shows similarities in patients in the distance of crowns and roots from the reference line. In all of the cases it was observed that the crowns were still more distal than were the apices. This indicated that mandibular first molars had not yet recovered from anchorage preparation.

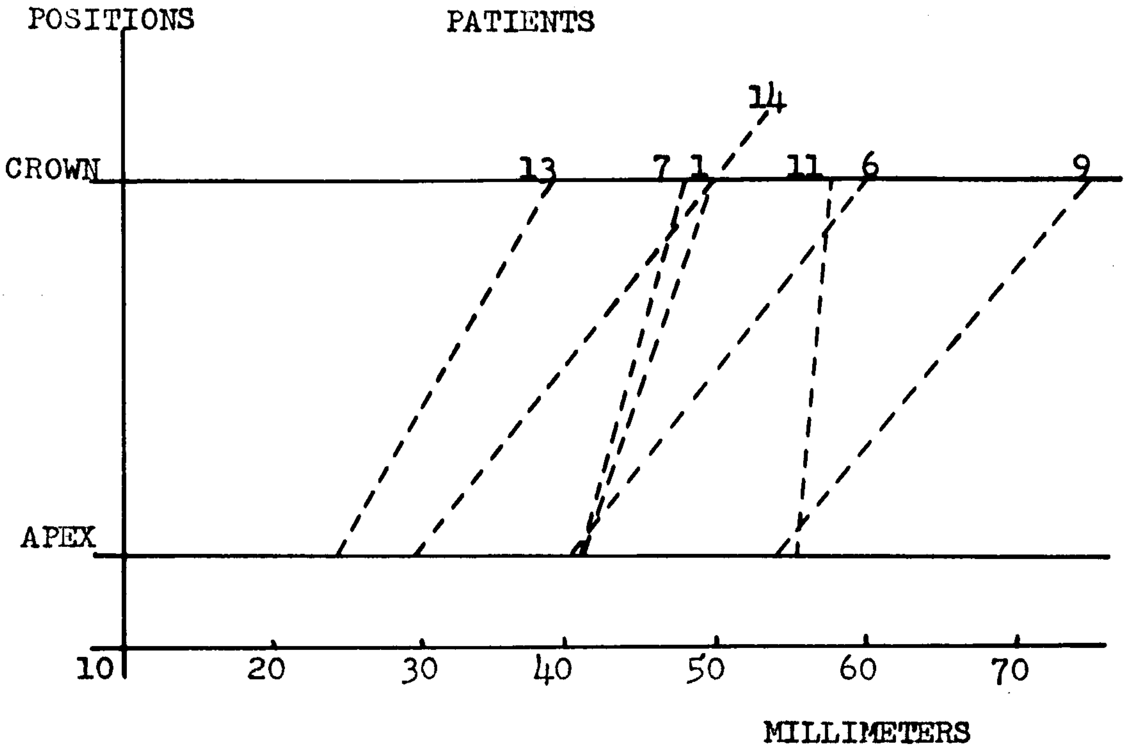
A special graph has been made for displaying the relative positions of crowns and roots of all seven patients at each of the phases of treatment. This is shown in figure 21. Tooth positions before treatment indicate that the crowns were closer to the inner border of the symphysis than were the apices;



GRAPH OF PATIENTS X SIDES INTERACTION

FIGURE 19

THE LACK OF PARALLELISM OF THE DOTTED CONNECTING LINES INDICATES AN APPARENT DIFFERENCE BETWEEN THE RIGHT AND LEFT SIDE MEASUREMENTS IN SOME OF THE PATIENTS



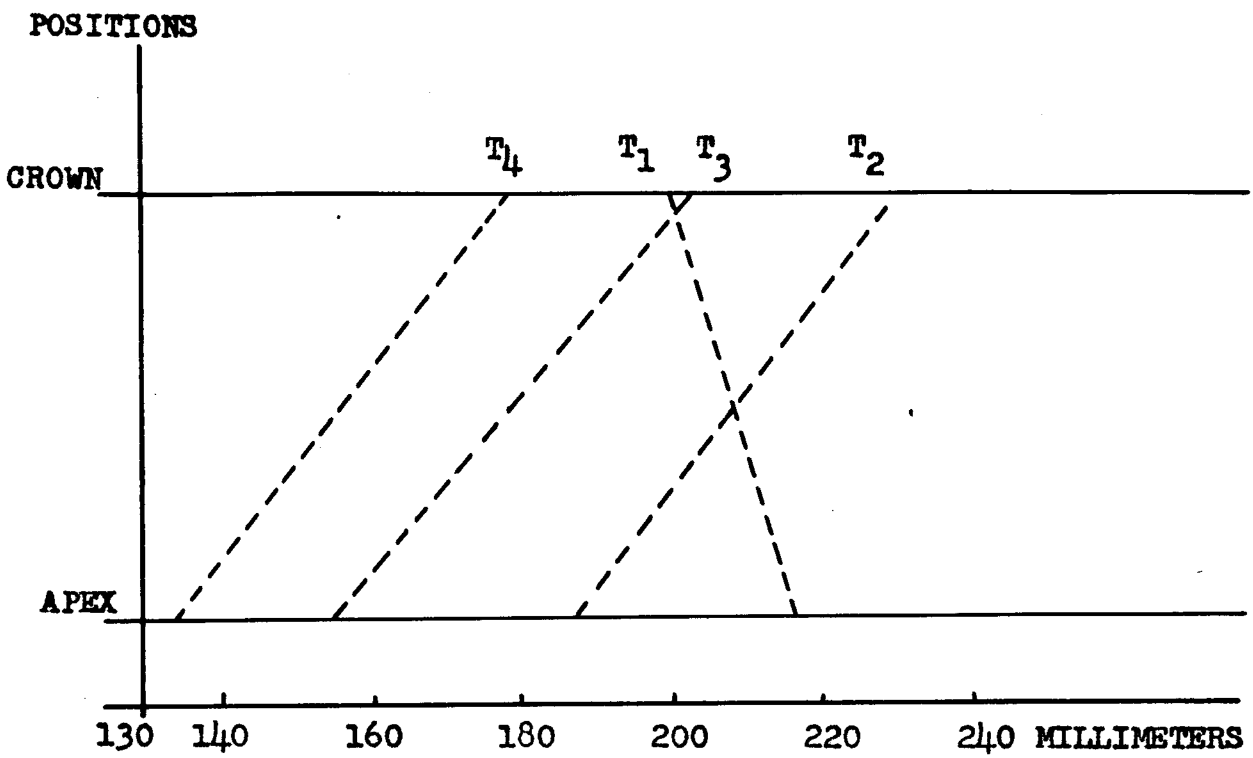
GRAPH OF PATIENTS X POSITIONS INTERACTION

FIGURE 20

THE DOTTED CONNECTING LINES SHOW SIMILARITY

IN PATIENTS RELATIVE DISTANCE OF POSITIONS

OF CROWNS AND ROOTS FROM SYMPHYSIS



GRAPH OF POSITIONS X TOTAL TREATMENTS INTERACTION

T_1 BEFORE TREATMENT

T_2 AFTER ANCHORAGE PREPARATION (STIER)

T_3 AFTER CLASS II FORCES (KRVAVICA)

T_4 AFTER CONSOLIDATION (FOLLICO)

FIGURE 21

THE DOTTED CONNECTING LINES ILLUSTRATE POSITIONS OF CROWNS AND ROOTS THROUGH ALL PHASES OF TREATMENT POINTING OUT THE COURSE TAKEN BY THE TEETH while T_2, anchorage preparation (Stier 1962) shows that the crowns were tipped distally an average distance of 2 mm. while the roots moved in a mesial direction on the average of 2.5 mm. After class II forces, T_3, (Krvavica 1963), it was found that the crowns moved mesially an average of 3.06 mm., as did the roots an average of 3.36 mm. In the final space consolidation phase, T_4, the crowns continued their forward movement, averaging 1.80 mm. while the roots also moved forward on the average of 1.40 mm. This forward movement of the mandibular first molar teeth is a combination of translation and very slight tipping.

CHAPTER V

DISCUSSION

The goal of orthodontics is the correction of malocclusions and the placement of teeth in such positions that their own functional dynamics will tend to maintain the correct occlusion. Achievement of the treatment goals are individualized and limited by genetic composition and physical development of the patient. This means that the biologic aspect of malocclsions and their etiological factors involved demand the orthodontist be thoroughly schooled in the basic sciences. In the area of clinical orthodontics it is becoming apparent that biologic knowledge is not enough, but that it must be coupled with the disciplines of analytical mechanics and applied physics before it realizes a true level of scientific status.

In designing this study, the desire was to determine the type and direction of movement which occurred in the mandibular first molar teeth during the final space consolidation phase and, to the end of treatment. These patients were treated with the Edgewise technique in accordance with principles outlined by Tweed. A study and evaluation of the change which occurred in the periodontal space, as determined from intra-oral radiographs, presented the data from which an evaluation of the tooth movements were made.

The quantitative analysis was based on cephalometric measurements taken on lateral headplates. The method of obtaining the intra-oral x-rays and cephalometric measurements was explained in detail in the chapter on Materials and Methods.

The findings of this investigation will be discussed, based on the different methods of evaluation and the mechanics and force systems responsible for the tooth movement exhibited.

It was observed that during the phase of space consolidation to the completion of treatment, the mandibular first molars demonstrated the same type of movement; according to all the methods of evaluation. This consistantly was a mesial translatory movement of the crowns and roots in both extraction and non-extraction treatment which resulted in a distinct widening of the periodontal space on the distal root surface of both marginal and apical points measured. Stier (1962), in the initial phase of this study found that during the leveling stage there was a bodily mesial movement of these teeth in a majority of cases. He also found that during anchorage preparation the prevalent type of tooth movement was a distal tipping of the crowns and a concomitant mesial movement of the roots with the point of rotation located in the cervical one-third of the root. The mesial movement of the roots exceeded the distal movement of the crowns an average of 0.5 mm. Krvavica (1963), observing these same patients through the stage of class II forces, found that with the reversal of mechanics from class III (anchorage preparation) to class II forces there was a mesial movement of the crowns on the average of 3.06 mm., while the roots moved an average of 3.36 mm. in the same direction. Following these patients to the completion of treatment it was found that the mesial movement of the mandibular first molars continued but to a lesser degree. From the cephalometric measurements recorded on the data sheet (Figure 16), the mesial movement of the crowns of these teeth averaged 1.80 mm. while the roots came forward on the average of 1.40 mm. This was a mesial translation and tipping movement.

An interesting comparison to the above result can be brought out by a similar work done by Gantt (1960), Kemp (1961) and Krvavica (1963). These men utilized the same method for gathering data as done in the Edgewise study but the technique utilized in treating the patients in their sample was the Loyola-Jarabak Differential Forces Technique. Gantt and Kemp found that during the initial phases of treatment, comparable to leveling and anchorage preparation in edgewise technique, the most prevalent movement of the mandibular molar teeth was a simultaneous extrusion and distal tipping, the axis being estimated near the apex or middle one-third of the distal root. During this change in axial inclination, the mesial root elevated. Krvavica, following these patients through class II forces and to the end of treatment, found that the predominant type of tooth movement was a mesial movement of the crowns on the average of 1.28 mm. and 0.57 mm. of the roots in extraction cases and 1.04 mm. for crowns and 0.66 mm. for roots in non-extraction cases. He concluded that this technique can be utilised to hold mandibular anchor units in place with little or no forward movement in extraction and non-extraction cases.

Let us now analyse the force systems responsible for the mesial translation of the mandibular first molars in the stage of class II and space consolidation forces as exhibited by the patients in this study treated with the edgewise technique. As explained previously under the heading "Appliance Design" in the chapter on Materials and Methods after anchorage has been prepared in the mandibular arch, the lower arch wire is changed to 0.0215 x 0.028 inch stabilising arch wire to permit the use of class II elastics. The class II elastics which are X-type orthospec will have a mesial force of 130-160 grams on the lower anchor unit and the same force in a distal direction to the upper arch when stretched over a distance of 25-30 mm. This class II force transmits components in a horizontal and vertical direction. With this force system we have designed an appliance that will translate the mandibular anchor unit mesially when activated.

> Before explaining why this takes place I must define two terms which will make the description more meaningful. First the term force which is the action of one body upon another. It may be either a push or a pull. Second the term couple which is a system of two forces acting upon a given body. These forces are equal, opposite and parallel but not collinear. They do not have the same action line nor the same point of application. In orthodontics to translate a tooth we must have a couple and a force.

When the rectangular lower arch wire is placed into the buccal tube on the mandibular molar tooth we develop a couple because of the two points of contact with the arch wire at the ends of the buccal sheath. Then to this we add the force from the class II elastic and thus create a system which translates the involved units. These forces defined according to analytical mechanics disciplines give a concise and clear understanding to the experimental results and thus enhance the meaning of the findings in this study.

The fact that there is no such thing as stationary anchorage has been brought out by Salzman, who feels that the entire mandibular denture is displaced mesially when the patients wear class II elastics.

Huettner and Whitman (1958), in their experiments on monkeys found that tip-back bends did not prevent the mesial movement of posterior segments. They concluded that fixed anchorage is non-existent. In this same experiment they found that tip-back movements produced the most severe root resorption.

In comparing the before and after treatment intra-oral x-rays of the patients in this study, it was possible in almost every instance to fully observe the mandibular first and second molars and second premolars. It was found that in 4 out of the 7 patients there was evidence of significant root resorption or cementum scalloping. In one of the patients there was impaction of mandibular second molars and in another, impaction of third molars due to excessive tip-back bends during anchorage preparation. Also most of the patients finished treatment with the mesial root of the mandibular first molar thrust against the root of the lower second premolar.

It has been said that root resorption is a scar of an orthodontic operation. In his text "Technique and Treatment with the Light Wire Appliances", Jarabak presumes root resorption is inevitable if the functional esthetic benefits of orthodontics are to be had, but points out that we try to objectively evaluate those causes that we can prevent or reduce and accept those which are physiologically inescapable.

CHAPTER VI

SUMMARY AND CONCLUSIONS

I. Summary

A. This investigation was a roentgenographic study of orthodontic tooth movement exhibited by the mandibular first molars during the stage of space consolidation and to the end of treatment. The treatment utilized was the Edgewise Technique as outlined by Tweed. This study was a continuation of work by Stier (1962) and Krvavica (1963).

The sample in this study originally comprised thirteen children. Since the start of the study, six of the patients have finished active treatment leaving seven for the final observations in this serial study. All patients underwent orthodontic treatment at the Loyola University School of Dentistry.

B. The types of tooth movements were determined by the interpretation of intra-oral roentgenograms taken during the treatment stages listed above. The amount of tooth movement in each case was derived from cephalometric measurements taken from lateral headplates.

Two methods were employed for the evaluation of the intra-oral roentgenograms. The first was based on the changes in the width of the periodontal space in four areas along the root as recorded on paper reference strips, from which it was possible to determine the types of tooth movements which occurred in a mesio-distal direction during each stage of treatment. The second method of appraisal was a visual interpretation of the dimensional changes exhibited in both the periodontal width and the thickness of the cribriform plate. In addition, the overall positional change of the tooth as a result of orthodontic treatment was evaluated by this procedure.

C. A total summary of the entire treatment procedure during the various stages found:

1. During leveling (Stier 1962), the majority of cases showed a mesial bodily movement.
2. After anchorage preparation (Stier 1962), the predominant tooth movement was a distal tipping of the crowns on the average of 2.0 mm. while the roots moved mesially an average of 2.5 mm.
3. Krvavica (1963), observing these patients after class II forces found that the prevalent type of tooth movement was a mesial movement of the crowns an average of 3.06 mm., while the roots moved an average of 3.36 mm. in the same direction.

4. In this study, through the final space consolidation stage to the end of treatment, the predominant tooth movement was a mesial movement of the mandibular first molar crowns on the average of 1.80 mm. while the roots moved an average of 1.40 mm. in the same direction. These figures indicate that the overall type of tooth movement was a translation and very slight tipping in both extraction and non-extraction cases.

II. Conclusions

1. The use of a headholder in conjunction with a long cone on the x-ray machine and a fixed target distance of thirty inches reduces distortions on intra-oral roentgenograms and makes it possible to align the teeth in buccal segments with the central ray to such a degree that replicate roentgenograms are nearly of a duplicate nature.

2. The intra-oral roentgenograms taken during this investigation have shown clearly that the width of the periodontal space and thickness of the cribriform plate were changed during orthodontic tooth movement and that these dimensional changes can be demonstrated roentgenographically. On the side of tension, the width of the periodontal space increased and

on the pressure side, it decreased. During the process of tooth movement, the cribriform plate became thicker and more radiopaque on the tension side, and it disappeared on the side of pressure. These findings substantiate those of previous investigations reported in the literature.

3. The predominant tooth movement of the mandibular first molars during final space consolidation with the edgewise mechanism and under the influence of class II elastics ("X" type orthospec) was a mesial translation and tipping in which the average mesial crown movement was slightly greater than the mesial root movement. This shows that tip-back bends did not prevent mesial movement of the mandibular posterior segments and the anchorage did not remain stationary.

4. The mechanical combination of a couple and force result in a bodily or translatory movement of the involved units.

5. Significant root resorption and impaction of teeth can result from heavy forces in conjunction with tip-back movements.

BIBLIOGRAPHY

Begg, P. R. 1956 Differential Force in Orthodontic Treatment. A. J. Orthodont., 42: 481-510.

Coolidge, E. D. 1937 The thickness of the human periodontal membrane. J.A.D.A. and D. Cos., 24: 1260-1270.

Elfenbaum, A. 1958 Alveolar lamina dura. D. Radiog. and Photog., 31: 21-29.

Gantt, J. P. 1960 A radiographic study of tooth movement determined by changes seen in the periodontal space of the mandibular molar teeth during anchorage preparation with light forces. M.S. Thesis, Loyola University Dental School.

Goldman, H., Millsap, J., and Brenman, D. 1957 Origin and registration of the architectural pattern, the lamina dura and the alveolar crest in dental radiograph. J. Oral Surg., Oral Med.,Oral Path.,10: 749-758.

Gottlieb, B., and Orban, B. 1931 Tissue changes in experimental traumatic occlusion with special reference to age and constitution. J. D. Res., 11: 505-510.

Gramling, J. F. 1962 An Analysis of the Changes During Banding and Leveling As Seen on the Lateral Cephalometric Roentgenograph. M. S. Thesis, St. Louis University Dental School.

Halderson, H. et al. 1953 Selection of forces for tooth movement. A summary of our present knowledge. A. J. Orthodont., 39: 25-34.

Huettner, R. J., and Whitman, C. L. 1958 Tissue changes occuring in the Macaque Rhesus monkey during orthodontic movement. A. J. O., 44: 328-345.

Jarabak, J. R. 1960 Development of a treatment plan in the light of one's concept of treatment objectives A. J. Orthodont., 46: 481-513.

Jarabak, J. R., and Fizzel, J. A. 1963 Technique and Treatment with the Light-Wire Appliances. The C. V. Mosby Company, Saint Louis.

Johnson, A. L. et al. 1926 Tissue changes involved in tooth movement. Int. J. Orthodont., 12: 889-898.

Krvavica, R. E. 1963 A Roentgenographic Study of the Orthodontic Movements Exhibited by the Mandibular First Molar Teeth During Class II Forces Utilizing Edgewise Mechanics and Light Wire Mechanics. M. S. Thesis, Loyola University Dental School.

Kemp, K. L. 1961 A roentgenographic study of tooth movement determined by the changes seen in the periodontal space of the mandibular molar teeth during anchorage preparation and space consolidation with light forces. M. S. Thesis, Loyola University Dental School.

Kronfeld, R. 1931 Histologic study of the influence of function on the human periodontal membrane. J.A.D.A., 18: 1242.

Massler, M. 1945 The lamina dura in roentgenographic interpretation. Angle Orthodontist, 15: 3-17.

________ 1954 Changes in the lamina dura during tooth movement. A. J. Orthodont., 41: 364.

Moyers, R. E. 1950 Periodontal membrane in orthodontics. J.A.D.A. 40: 22-27.

Oppenheim, A. 1944 A possibility for physiologic orthodontic movement. A. J. Orthodont. and Oral Surg., 30: 277.

Moyers, R. E., and Bauer, J. L. 1950 Periodontal response to various tooth movements. A. J. Orthodont., 36: 572-580;

Reitan, K. 1951 Initial tissue reaction incident to orthodontic tooth movement as related to the influence and function. An experimental histological study on animal and human material. Acta Odont. Scand., 9: Suppl. 6.

__________ 1956 Selecting forces in orthodontics. Br. Orthodont. Soc. Tr., 32: 108-126.

__________ 1957 Some factors determining the evaluation of forces in orthodontics. A. J. Orthodont., 43: 32-45.

Salzman, J. A. 1957 Orthodontics-Practice and Technics. J. B. Lippincott Company, Philadelphia.

Sandstedt, C. 1904, 1905 Einige Beitraege zur theorie der Zahnregulierung. Nord. Tandl. Tidskr., 5: 236, 6: 1.

Schwarz, A. M. 1932 Tissue changes incident to tooth movement. Int. J. Orthodont. and Oral Surg., 18: 331.

__________ 1957 Teleroentgenography in orthodontics. D. Abs., 2: 583-584.

Stier, E. F. 1962 A roentgenographic study of the orthodontic tooth movements exhibited by the mandibular first molar teeth during separation, leveling, and anchorage preparation with edgewise mechanics. M.S. Thesis, Loyola University Dental School.

St. John, E. C. and Craig, B. S. 1957 Am. J. Roent., Radium Therapy and Nuclear Med., 78: 124-133.

Storey, E., and Smith, R. 1952 Force in orthodontics and its relation to tooth movement. Austral. J. D. 56: 11-18.

__________ 1952 The importance of force in orthodontics. The design of cuspid retraction springs. Austral. J. D., 56: 291-304.

__________ 1953 Bone changes associated with tooth movement. A radiographic study. Austral. J. D., 57: 57-64.

Stuteville, O. H. 1937 Injuries to the teeth and supporting structures caused by various orthodontic appliances and methods of preventing these injuries. J.A.D.A. and D. Cos., 24: 1494-1507.

Taylor, C. M. 1962 Mesio-Distal Change of the First Permanent Molars in Extraction and non-Extraction Cases. M. S. Thesis, St. Louis University Dental School.

Updegrave, W. J. 1958 Normal radiotontic anatomy. D. Radiog. and Photog., 31: 57-65.

Wentz, F. M., Jarabak, J. R., and Orban, B. 1958 Experimental occlusal trauma initiating cuspal interference. J. Periodont., 29: 117-127.

APPENDICES

APPENDIX I

BEFORE TREATMENT

AFTER SEPARATION

APPENDIX II

AFTER LEVELING

AFTER ANCHORAGE PREPARATION

APPENDIX III

AFTER CLASS II FORCES

AFTER SPACE CONSOLIDATION

APPROVAL SHEET

The thesis submitted by Dr. E. S. Follico has been read and approved by members of the Departments of Anatomy and Oral Biology.

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.

DATE

Signature of Advisor