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THE EFFECT OF SUPRA-ALVEOLAR FIBER TRANSECTION ON THE RATE OF CUSPID RETRACTION

by

MICHAEL JORDAN HORII

Submitted in partial fulfillment of the requirements

for the Degree of Master of Science

Thesis Advisor: Lysle Elwin Johnston, D.D.S., M.S., Ph.D.

Department of Orthodontics

School of Dentistry

CASE WESTERN RESERVE UNIVERSITY

June 1972

THE EFFECT OF SUPRA-ALVEOLAR FIBER TRANSECTION ON

THE RATE OF CUSPID RETRACTION

Abstract

by

MICHAEL JORDAN HORII

It is generally accepted that the reorganization of supra-alveolar fibers following tooth movement is important to the post-treatment stability of orthodontic therapy. Moreover, it has been suggested that these fibers may influence the pattern of active tooth movement. Accordingly, a clinical investigation was conducted to characterize these influences. Nine patients whose treatment required the extraction of four first bicuspids consented to participate in the study.

All four first bicuspids in each patient were extracted on the same day and a six week period was allowed for healing of the extraction site. In each quadrant all patients were fitted with commercially available .016 X .016"preformed sectional retraction arches, activated to seven ounces. Lateral twenty-five degree cephalograms and study models were taken at this appointment. On the following week the supra-alveolar fibers were transected in the two quadrants designated previously by restricted randomization. Each appliance was then activated weekly and direct intra-oral measurements obtained. At the conclusion of the eight week experimental period, final lateral

cephalograms and study models were taken. The data were analyzed graphically and by a blocked, split plot, two-way analysis at variance with nine replications.

The results of this study show that elimination of the supra-alveolar fibers has no significant effect upon the rate of movement. This lack of effect may indicate that hyalinization of the periodontal ligament, rather than fibrillar reorganization, is the rate-limiting factor in the lag phase and that bone resorption is the rate-limiting factor in the post-lag phase of orthodontic tooth movement.

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DEDICATED

To My Parents

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ACKNOWLEDGMENT	iv
DEDICATION	v
LIST OF TABLES	vii
LIST OF PLATES	ix
LIST OF FIGURES	x
INTRODUCTION	1
REVIEW OF THE LITERATURE	2
METHODS	14
RESULTS	47
DISCUSSION	69
SUMMARY AND CONSLUSIONS	76
APPENDIX I	78
LITERATURE CITED	80

LIST OF TABLES

Table		Page
I	Experimental Design.	15
II	Analysis of Variance Table	46
III	Intra-Oral Measurements: Average Space Closure.	49
IV	Intra-Oral Measurements: Total Space Closure.	49
V	Means: Intra-Oral	51
VI	Experimental Side Space Closure: Maxillary Arch	51
VII	Control Side Space Closure: Maxillary Arch.	52
VIII	Experimental Side Space Closure: Mandibular Arch. . . .	52
IX	Control Side Space Closure: Mandibular Arch	53
X	Analysis of Variance: Intra-Oral Data	54
XI	Model Measurements: Total Space Closure	56
XII	Means: Models	56
XIII	Analysis of Variance: Model Data.	58
XIV	Cephalograms: Total Space Closure	59
XV	Means: Cephalograms - Total Space Closure	59
XVI	Analysis of Variance: Cephalograms - Total Space Closure.	61
XVII	Cephalograms: Molar Movement.	63
XVIII	Means: Cephalograms - Molar Movement.	63
XIX	Analysis of Variance: Cephalograms - Molar Data	65
XX	Cephalograms: Cuspid Movement	66

Table		Page
XXI	Means: Cephalograms - Cuspid Movement	66
XXII	Analysis of Variance: Cephalograms: Cuspid Data. . . .	68
XXIII	Summary of Relative Statistics	72

LIST OF PLATES

Plate		Page
I	Frontal View - Teeth in Occlusion.	18
II	Right Side - Teeth in Occlusion.	20
III	Left Side - Teeth in Occlusion	22
IV	Occlusal View - Maxillary Arch	24
V	Occlusal View - Mandibular Arch.	26
VI	Surgical Procedure - Maxillary Buccal.	29
VII	Surgical Procedure - Maxillary Lingual	31
VIII	Surgical Procedure - Mandibular Buccal	33
IX	Surgical Procedure - Mandibular Lingual.	35
X	Post-Surgical.	37
XI	Measurement Armamentarium.	39

LIST OF FIGURES

Figure		Page
1	Intra-Oral Recording Landmarks.	40
2	Study Model Measurements.	42
3	Cephalometric Measurement Procedure	44
4	Average Weekly Tooth Movement	50
5	Total Movement: Study Models	57
6	Total Movement: Cephalograms	60
7	Molar Movement: Cephalograms	64
8	Cuspid Movement: Cephalograms.	67

INTRODUCTION

The treatment methods of the contemporary orthodontist afford relatively efficient and sophisticated means by which successful treatment may be attained. However, there still remain certain areas which, when subjected to controlled investigation, may broaden the knowledge of certain basic mechanisms, and ultimately lead to the improvement of orthodontic therapy.

Orthodontists, understandably, have long been concerned with the physiology of tooth movement and the biomechanical principles involved. As will be described, observers have conducted numerous studies into the physiology of tooth movement as related to sub-alveolar tissue and bone function. Certain of these relationships have been established well; however, studies of the supra-alveolar tissues and their effect on tooth movement have been attempted to a far lesser degree. Investigations in this area have been concerned primarily with post-treatment ramifications, retention, and relapse. It has been found, as will be shown, that these fibers influence stability greatly and are a causative factor in relapse. Similarly, it may be inferred from the literature that these fibers might reasonably be expected to influence the rate and pattern of active tooth movement. Accordingly, an attempt will be made to characterize these effects in a controlled clinical investigation.

REVIEW OF THE LITERATURE

The Supporting Periodontal Tissues

The supporting periodontal tissues constitute the connective tissue organ which surrounds the tooth and attaches it to the bony alveolus, adjacent teeth and surrounding gingival tissues and mucosa. Most contemporary oral anatomists have agreed that the teeth are retained in the alveolar arch by three principal groups of supporting fibers: (1) the gingival fibers, which have one portion (dentogingival) originating in the cementum, radiating and terminating in the connective tissue of the gingiva; another (alveologingival) arising from the alveolar crest and terminating in the gingiva; and finally, the circular fibers, running in a figure-eight pattern between adjoining teeth, (2) the transseptal fibers, running just superior to the alveolar crest and directly connecting adjacent teeth, and (3) those fibers of the periodontal ligament connecting alveolar bone to cementum. The two groups, gingival and transseptal, are commonly referred to as the supra-alveolar fibers.

Until recently, it was thought that there were only inelastic white collagenous connective tissue fibers in the supporting tissues (elastic and reticular fibers being restricted to blood vessels). These collagenous fibers, however, follow a wavy course between attachments, thus permitting a "pseudoelastic" function. More recently, however, Fullmer (1958, 1960, 1966) has demonstrated histochemically the

existence of oxytalan fibers in the human periodontium. Although electron microscopy supports the thesis that oxytalan fibers are a distinct connective tissue, Fullmer has suggested that they might be elastic fibers which cannot be differentiated from pre-elastic fibers. Furthermore, he has found that these fibers are concentrated primarily in the transseptal region, although they may be found throughout the entirety of the periodontium to varying degrees. It has been speculated, following animal studies by Edwards (1968) and Boese (1969), that oxytalan fibers are a contributing factor in rotational relapse, in that these fibers increase in size and number in areas subjected to mechanical stress and might maintain continual tension on their attachments by stretching. Thus, a contraction force might be generated which would tend to return the tooth to its original position.

Periodontal Ligament Function

The periodontal ligament serves not only as pericementum for the tooth, but also as periosteum for the alveolar bone. In his classic research, Reitan (1951, 1960) has demonstrated precisely the reactions and behavior of the sub-alveolar tissues when subjected to orthodontic forces. They adapt to tooth movement by: (1) progressive osteogenic activity (and, fortunately, cementogenic activity to a far lesser degree) which plays an active role in the shortening of the extended fibers and in reattachment of new fibers formed during tooth movement, and (2) the stretching of the wavy collagen fibers and the reorientation of their direction to permit a certain amount of tooth movement.

Supra-Alveolar Fibers and Active Tooth Movement

Perhaps understandably, early orthodontic thought centered around bone, with little attention being paid to the surrounding and underlying soft tissues. Early investigators concluded that resistance to tooth movement was a function of the "hardness" of the bone itself. To circumvent this seemingly rigid mechanical barrier, men such as Jackson (1896), Guilford (1898), Bryan (1905), and Skogsburg (1927, 1932), advocated septotomy and corticotomy procedures. Black (1936), however, recognized that the influence of bone in maintaining the teeth in their positions within the alveolus was much overrated. He stated:

> Hard and rigid as the bones of the skeleton seem in the dried state, bone is a very plastic tissue during life and is subject to more or less constant resorptive and rebuilding processes. It will not stand against a connective tissue constancy of stress.

Long before Black, however, Angle (1899) demonstrated an insight into a possible influence of the supra-alveolar structures and was the first to offer a practical clinical solution. He noted that, during canine retraction, not only did the septum of bone just mesial to the canine closely follow the moving tooth, but also in some instances even the lateral incisor to quite an extent, presumably due to the strength of fibers comprising the periodontal attachment. He felt "it would be reasonable and wholly in keeping with good practice to sever them prior to tooth movement and in cases of difficult retention." He reported that in retraction of the canine it was best

to exert tension for two to three days in order to tighten the fibers and then to sever the fibers on the mesial of the tooth to a depth of one third the length of the root. He claimed this could be used to great advantage in expediting tooth movement. However, the genius of Angle outstripped the knowledge and understanding of his contemporaries and the procedure failed to gain any further recognition. Further observations and investigations concerning the importance of the supra-alveolar fibers as related to orthodontic therapy have followed; however, a comprehensive knowledge of what the complete effect might be is still unavailable.

Aside from Angle's educated guessing, significant studies in the area began with Oppenheim (1911). In experiments on monkeys, he concluded that the powerful fibers stretching across the septa were the most resistive tissue with which the orthodontist had to deal. Many workers agreed. McCauley (1924) stated that he felt they had a great influence in maintaining contact between the teeth and in causing one tooth to follow an adjoining tooth when subjected to orthodontic forces. Kronfeld (1939) concluded that the transseptal fibers functioned in maintaining the mesio-distal relationship between neighboring teeth and in stabilizing the teeth against separating forces. Waldron (1942), speaking of a situation in which molars were being moved distally, felt the distal movement of anterior teeth was enhanced by the tension exerted by the transseptal fibers located in the interdental space.

Erickson, Kaplan and Aisenberg (1945) found that subepithelial tissues did not conform to tooth movement as does bone and could always be found between the teeth, irrespective of the amount of alveolar bone supporting them. They found that during tooth movement the transseptal fibers on the pressure side were relaxed, coiled and compressed; on the tension side they were remarkably persistent. As the tooth moved, they became stretched and were able to carry the adjacent tooth in the direction of the force. It was also observed that the transseptal fibers remaining in the interdental papillae following extraction fuse with the connective tissue scar over the alveolus, forming a new, but elongated, group of transseptal fibers. These findings were similar to those of an earlier study by Chase and Revesz (1944), who extracted second deciduous molars of monkeys and closed the extraction site orthodontically. Examination of these areas revealed both an orderly reorganization and the presence of a group of fibers strongly resembling transseptal fibers after a period of five weeks. It was concluded that, because of the manner in which these fibers regenerated and because of their compression during tooth movement, they constituted an etiologic factor in orthodontic relapse.

Supra-Alveolar Fibers and Relapse

In recent times, the possibility that supra-alveolar fibers contribute to orthodontic relapse has promoted numerous investigations. Studies of importance began with Thompson, Myers, Waterman and Flanagan

(1958). Utilizing monkeys as their experimental animal, they performed gingivectomies around teeth which had been approximated through extraction sites. They concluded that bone is deposited and resorbed rather easily, but that the supra-alveolar fibers are relatively refractory to reorganization. As a result, teeth tend to maintain their original position and resist any change. These workers suggested that gingivectomies release the tension created by orthodontic movement and allow new fibers to form without tension, thus significantly decreasing the incidence of relapse.

Reitan (1959), experimenting with dogs, rotated teeth orthodontically to study tissue rearrangement. Fiber rearrangement was considered complete when the fibers were observed to approximate a non-rotated, right angle relationship to the surface of the root. He found that the marginal gingival fiber bundles remained displaced and stretched even after two hundred thirty two days of retention. By way of contrast, fibers of the middle and apical areas of the root were rearranged after periods of one hundred forty-seven and eighty-three days, respectively, He attributed relapse to the prolonged contraction of these displaced gingival fiber bundles and other supra-alveolar structures, since they do not have the relatively plastic osseous tissue to eliminate residual tensions secondary to tooth movement. Reitan concluded that overrotation, early correction of the rotation, or transection of the stretched fibers would be of clinical value in preventing relapse.

Studies by Wiser (1967) and Boese (1969) have demonstrated experimentally on animals that removal of the supra-alveolar fibers results in greater stability of orthodontically rotated teeth. Boese noted that, following experimental rotation, the numbers of oxytalan fibers and the amounts of collagen in the supra-alveolar tissue increased. He concluded that his proliferative response, combined with the stable attachments of the transseptal fibers, was responsible for the relapse which occurred four to eight weeks following orthodontic rotation.

Experiments attempting to control rotational relapse by utilizing vertical incisions to transect the supra-alveolar fibers have resulted in varying degrees of success. Experimenting with dogs, Tospels (1967) made vertical incisions interdentally, both labially and lingually, and was unable to prevent relapse. Brain (1969) following rotational movements on dogs, incised the free gingival fibers on both the labial and lingual, extending the incision along the alveolar crest and continuing it to each adjacent tooth, not disturbing the periodontal ligament proper. He concluded that this procedure permitted a reduction of the forces of relapse by allowing for a favorable fiber rearrangement.

Edwards (1968) experimenting with dogs, described a simple tattooing procedure to show that attached gingiva, especially marginal gingiva, is displaced along with the tooth as it is rotated. Subsequently, in a clinical study, Edwards (1970) utilized this tattooing procedure and a vertical circumferential incision in an attempt

to lessen rotational relapse. He showed that the attached gingiva and to some extent the mucosa followed the direction of the rotation and reverted to their original position almost immediately following the surgical procedure. As had others, he felt a determinant factor in relapse might be the elastic-like oxytalan fibers found to proliferate in areas of stress and located primarily in the locale of the epithelial attachment and transseptal fibers. He concluded that the surgical detachment of these fibers significantly alleviated relapse without apparent damage to supporting structures.

In the most recent clinical investigation, Edwards (1971) described a procedure to prevent relapse following canine retraction in extraction cases. He considered the gingival cleft which frequently develops between orthodontically approximated teeth as a possible factor in relapse. He felt that there was an inability of the tooth to move through the gingival tissue, resulting in an accumulation of excess gingiva interproximally. Surgical removal of this tissue following approximation tended to alleviate relapse. He concluded that the relapse in this instance was due to the excessive, slowly adapting gingival fibers found to be high in oxytalan fiber content, rather than the transseptal and periodontal ligament fibers, which appeared to adapt readily to their new positions.

From the foregoing review, it is apparent that certain properties of supra-alveolar fibers have a definite influence upon retention following orthodontic tooth movement. Accordingly, if these

fibers do exert a mechanical influence sufficient to cause relapse, might they not also influence active tooth movement itself?

Tooth Movement and Force Magnitude

Throughout orthodontic history, there have been many investigations into tissue changes underlying tooth movement. In general, it has been concluded (Burstone, 1962 and Reitan, 1969) that orthodontic tooth movement occurs in three phases: (1) the initial phase, (2) the lag phase, and (3) the post-lag phase, each phase corresponding to a specific tissue change. The initial phase coincides with compression of the periodontal ligament and is characterized by very rapid tooth movement normally lasting for a few days. Immediately following the initial phase, the lag phase begins, and continues generally for two to three weeks, during which there is no movement or a very low rate of movement. Burstone (1962) suggests that this "lag" is caused by the compression of the periodontal ligament against the alveolus, resulting in the formation of cell-free areas (hyalinization). Reitan (1960, 1969) found not only that hyalinization, but also the "stretching and displacement of fibrous tissue and its subsequent reaction" contributed to the resistance and delay. All fibers within the system were assumed to produce a counter-force, the greatest force being attributed to the supra-alveolar fiber bundles, because they were so slowly reorganized. Of interest, was the fact that following movement these counter-forces were of sufficient magnitude to produce hyalinization and indirect bone resorption on the opposite

side of the alveolus. However logical, this hypothesis must, at present, be regarded as mere conjecture; the extent of supra-alveolar fiber influence has never been quantitated.

The third phase of tooth movement is characterized by a gradual or sudden increase in the rate of tooth movement, as the areas of hyalinization are removed by undermining resorption and rearrangement of the fiber system occurs.

In studies of optimum force and types of tooth movement, Reitan (1957), Burstone (1962), and Hixon et al. (1969, 1970) noted that for each of the two basic movements (tipping and bodily), rate is dependent upon magnitude and method of force application. Initial tooth movement is characterized as a tipping movement, regardless of the mechanism of retraction or degree of force exerted. In the comprehensive studies of Hixon et al. (1969, 1970) it was concluded that higher forces per unit root area (to three or four grams per square millimeter) up to three hundred grams of total force constituted the range of "optimum forces," inasmuch as they proportionately increased the rate of biologic response. It must be noted however, that these studies have determined only "optimal forces" for a specific unit to be moved and have given little consideration to the anchor unit. Since orthodontic forces are recripocal, a truly optimal force would be one which not only increases the rate of movement of the specific unit, but also will not allow significant movement of the anchor unit, thus creating both an optimal and a differential force.

In the evaluation of forces in orthodontics and their relationship to the pattern of movement, studies have essentially centered around the second and third phase of tooth movement. Investigators have attempted to ascertain optimal forces, along with optimal modes of delivery, the assumption being that a reduction in the degree and duration of hyalinization would facilitate a more physiologic, rather than pathologic type of movement.

At present, whole "philosophies" of orthodontic therapy are built around such incompletely characterized terms as "optimal" forces and "differential" forces. Unfortunately, there are insufficient data to choose among the various conflicting and, at times, mutually exclusive clinical hypotheses. Perhaps understandably, the attention of most investigators has been drawn inexorably to the biology of bone as a tissue and as an organ. In contrast supra-alveolar fibers have been considered seriously only from the standpoint of relapse. It would, however, be difficult to sustain an argument that supra-alveolar fibers exert counter-forces only when active therapy is finished. From the standpoint of physics, it is obvious that they must do so throughout the entire course of orthodontic treatment. It will be the purpose of the present investigation to examine whether or not these counter-forces are of sufficient relative magnitude to materially alter the course of active tooth movement.

Statement of the Problem

It is the working hypothesis of this study that the elimina-

tion of the supra-alveolar fibers following the initial phase of tooth movement will:

(1) Alter the lag phase of tooth movement, either by decreasing its duration or magnitude.

(2) Increase the effect of the force applied, while still remaining in the range of "optimum forces."

(3) Increase the relative anchorage potential of molars and bicuspids.

METHODS

Sample

Nine patients were selected randomly (five Class I and four Class II) from patients presenting for orthodontic treatment and whose diagnoses, following standard diagnostic procedures, dictated the removal of four first bicuspids and distal retraction of canines. A careful clinical and radiographic examination was completed on each patient to avoid the possibility of post-treatment periodontal complications. Sulcular depth and general condition of the periodontium were noted. Following a thorough explanation of the study and the possible complications, consent in writing was obtained from patients and parents. The only other criterion was the complete eruption of all other teeth anterior to the permanent first molars (Appendix I).

Experimental Design

A table of random numbers was used to assign treatments to various patients, subject to the restriction that each treatment appear an equal number of times in each arch and in each quadrant. Table I illustrates the experimental design.

Clinical Procedure

The first permanent molars, second bicuspids and cuspids were fitted with preformed and prewelded .022 X .028" siamese edgewise brackets on the cuspid and bicuspid and .022" buccal tubes on the

TABLE I

EXPERIMENTAL DESIGN[a]

Patient	Maxillary		Mandibular	
	Right	Left	Right	Left
1	x			x
2	x		x	
3		x		x
4		x	x	
5	x			x
6	x		x	
7	x			x
8		x	x	
9		x		x

[a]The quadrant selected to receive the surgical procedure is designated by "x".

molars. A lingual cleat was welded to the molar and bicuspid bands so that these teeth could be ligated together on both the buccal and lingual in order to gain anchorage potential and to achieve a reduction in the degree of rotations (Daprano, 1971).

All four first bicuspids were extracted on the same day and a six week period was allowed for healing of the extraction site to occur (Daprano, 1971).

In all four quadrants, each patient received an .016 x .016" Ricketts sectional retracting arch (A-518--520, Rocky Mountain Dental Products Co.; Denver, Colorado), and with the aid of a tension gauge (Dontrix-Richmond Orthodontic Stress and Tension Gauge, Unitek) each appliance was activated to seven ounces (approximately two hundred grams) of force, this force being well within the "optimum range" determined by Hixon et al. (1969, 1970).(Plates I - V)

Following one week of activation, the initial phase of tooth movement was completed. After recording intra-oral measurements and again activating the appliances, the supra-alveolar fibers were transected in the two experimental quadrants. Surgery was accomplished following a papillary injection, by making an incision with a #12b Bard-Parker blade interproximally through the interdental papilla on the mesial side of the canine. The incision was carried to the height of the alveolar crest, severing only the fiber bundles above the bone. No attempt was made to detach the fibers from the canine or lateral, thereby avoiding the possibility of damage to the epithelial attachment and/or the periodontal ligament (Morris, 1961). Clinically,

PLATE I

Frontal View - Teeth in Occlusion



PLATE II

Right Side - Teeth in Occlusion



PLATE III

Left Side - Teeth in Occlusion

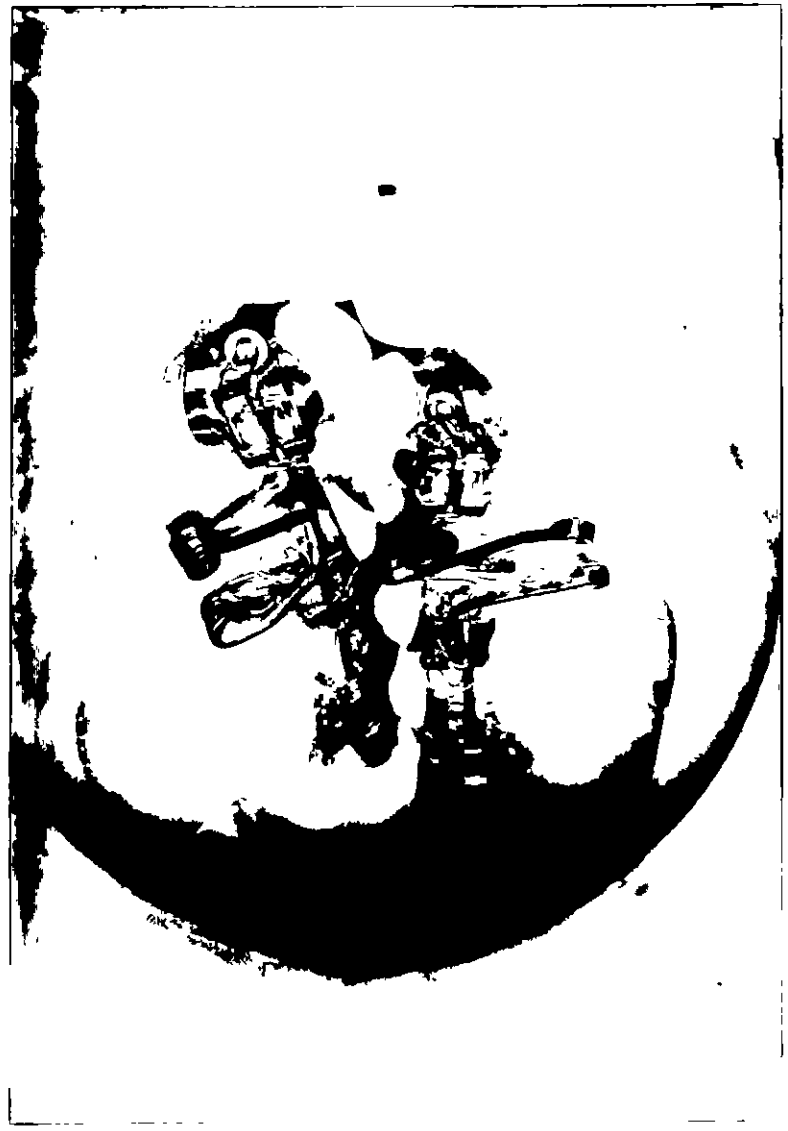


PLATE IV

Occlusal View - Maxillary Arch

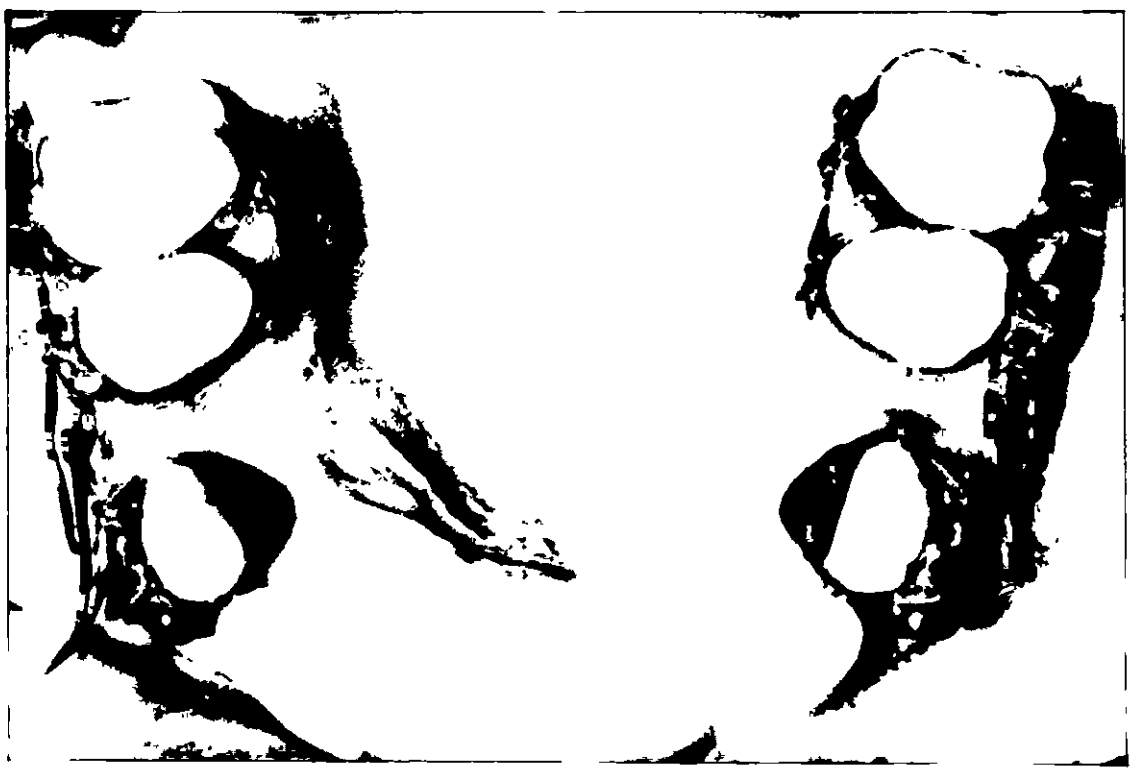


PLATE V

Occlusal View - Mandibular Arch



healing occurred rapidly and uneventfully; however, reorganization of the stretched fiber bundles within the soft tissue covering should have been slower than normal (three to four weeks, Dedolph and Clark, 1958) due to the tension of active tooth movement (Plates VI - X).

Weekly activation of appliances and recording of intra-oral measurements were then continued for a total period of eight weeks or until further space closure might jeopardize future treatment.

The rationale for selecting the Ricketts sectional arch closing loop appliance may be elaborated: (1) it represents a fairly typical clinical appliance, (2) it incorporates sufficient wire to allow relatively easy and accurate activation, (3) it constitutes a "frictionless" system and thus simplifies interpretation of the data.

Data Collection

Intra-Oral Measurements

In order to determine the amount of space closure, direct intra-oral measurements were taken for eight consecutive weeks prior to re-activating the appliances. The dimension measured was the distance between a notch cut into the molar buccal tube and the distal surface of the distal cuspid bracket (Figure 1). Readings were obtained to the nearest .01 millimeter with the aid of a pointed vernier callipers (Dental Corporation of America; Washington, D. C.) (Plate XI).

PLATE VI

Surgical Procedure - Maxillary Buccal

PLATE VII

Surgical Procedure - Maxillary Lingual



PLATE VIII

Surgical Procedure - Mandibular Buccal



PLATE IX

Surgical Procedure - Mandibular Lingual



PLATE X

Post-Surgical



PLATE IX

Measurement Armamentarium


Helios
GERMANY
DONTRIX

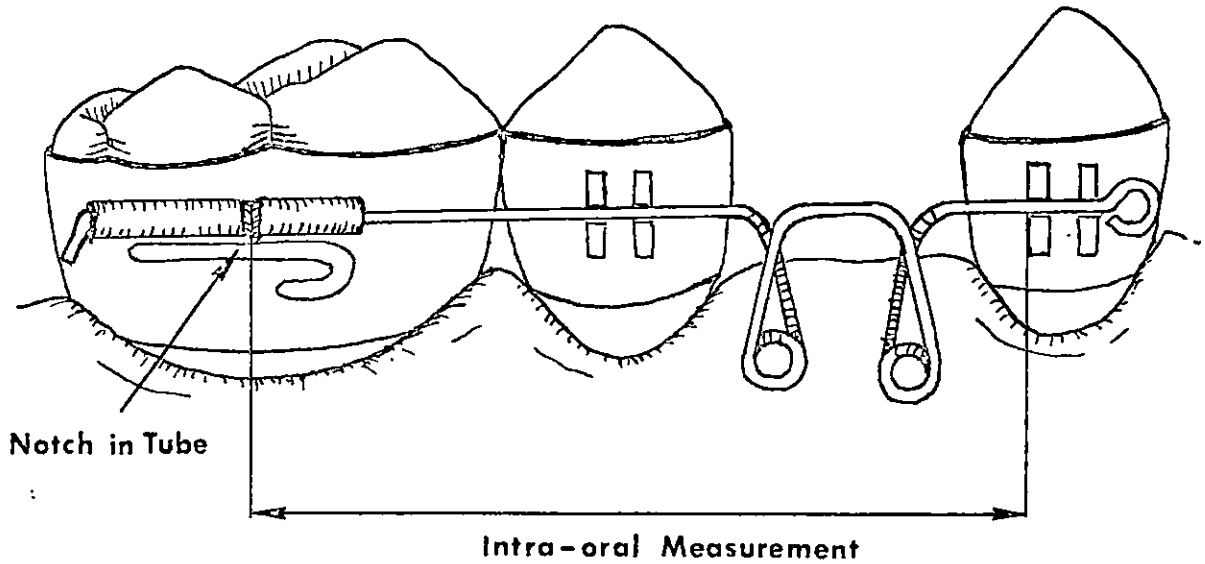


Figure 1. Intra-Oral Recording Landmarks

Study Models

In addition to the direct intra-oral measurements, study models, made prior to activating appliances and at the termination of the investigation, were utilized. The tip of the canine cusp and the tip of the buccal cusp of the second bicuspid served as reference points from which these measurements were made (Figure 2). By utilizing landmarks near the centers of these teeth to determine space closure, the rotational effects were, at least in theory, minimized vis-à-vis the intra-oral measurements. No attempt was made to determine whether the buccal segments moved mesially or the cuspids moved distally on either the study models or the intra-oral measurements; this problem was reserved for readings obtained from the twenty-five degree lateral cephalograms.

Cephalograms

A cephalometer (Ortho-Xray; Ottawa, Illinois) with the head holder rotated twenty-five degrees towards the film and the patient in rest position, was used in an attempt to obtain reproducable head orientation (Hixon, 1969). Also an "intra-oral grid" (Digiulio, 1970) placed in a wax bite, was used to quantitate distortions and magnifications. The grid is a section of one-eighth inch diameter, low density, polyethylene rod one hundred thirty-two millimeters long, with three-sixtyfourths inch stainless steel bearings centered at four millimeter intervals (Plate XI).

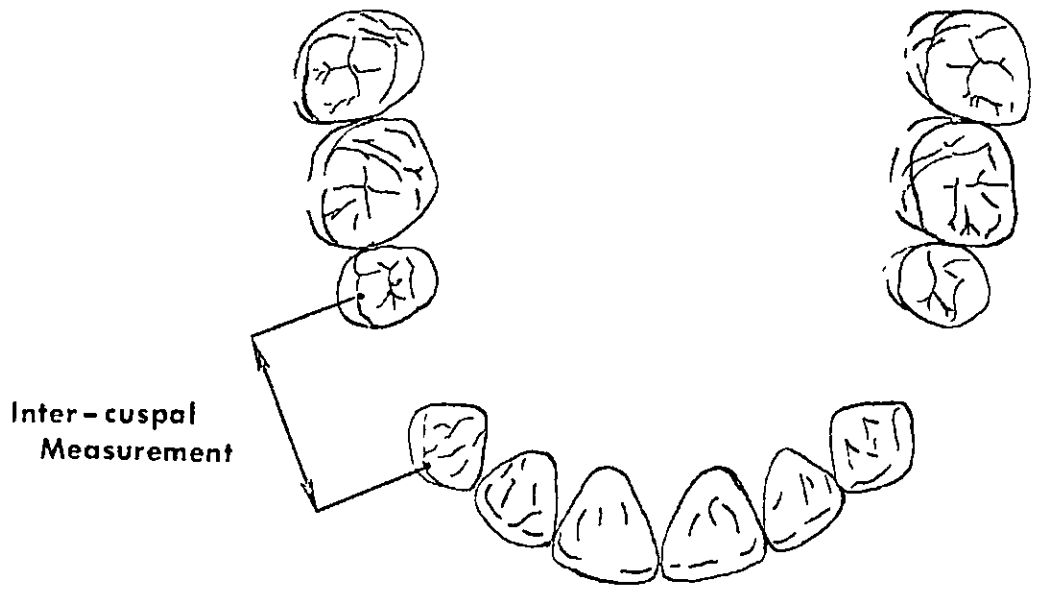


Figure 2. Study Model Measurements

The initial twenty-five degree lateral cephalograms in each series (right and left) were taken at the beginning of the study, just prior to appliance activation. Final cephalograms were taken at the end of the investigation, eight weeks later.

For purposes of superimposing, tracings of the molars, cuspids and radiographic landmarks of the maxilla and mandible were made for both initial and final cephalograms. With the aid of the intra-oral grid, each tracing was corrected for magnification, specifically in the region of the extraction site and actual cuspid and molar movements calculated by way of simple proportions (Daprano, 1971). The procedure may be illustrated for cuspids (Figure 3):

1. The actual distance from the center of the cuspid crown to an arbitrary reference line R was obtained by solving the equation, actual distance = $4(N)C/X$, where C and X are measurements obtained from the lateral cephalograms, N = number of intervals in dimension X, and 4 = the distance between intervals, in millimeters.

2. A tracing of all previously described landmarks was made for the second cephalogram (except the arbitrary line, R) and superimposed on the first, and the arbitrary line transferred to the second. This line was used as the base line from which measurements of the second cephalogram were made. The second measurements were corrected with the aid of the intra-oral grid as previously described.

3. The movement was recorded as the difference between the "corrected" measurements of the first film and the "corrected" measurements of the second film (C-C'). Calculations for the molars were executed in the same fashion (M-M'). The sum of the cuspid and molar movement was taken as the total space closure, (M-M') + (C-C').

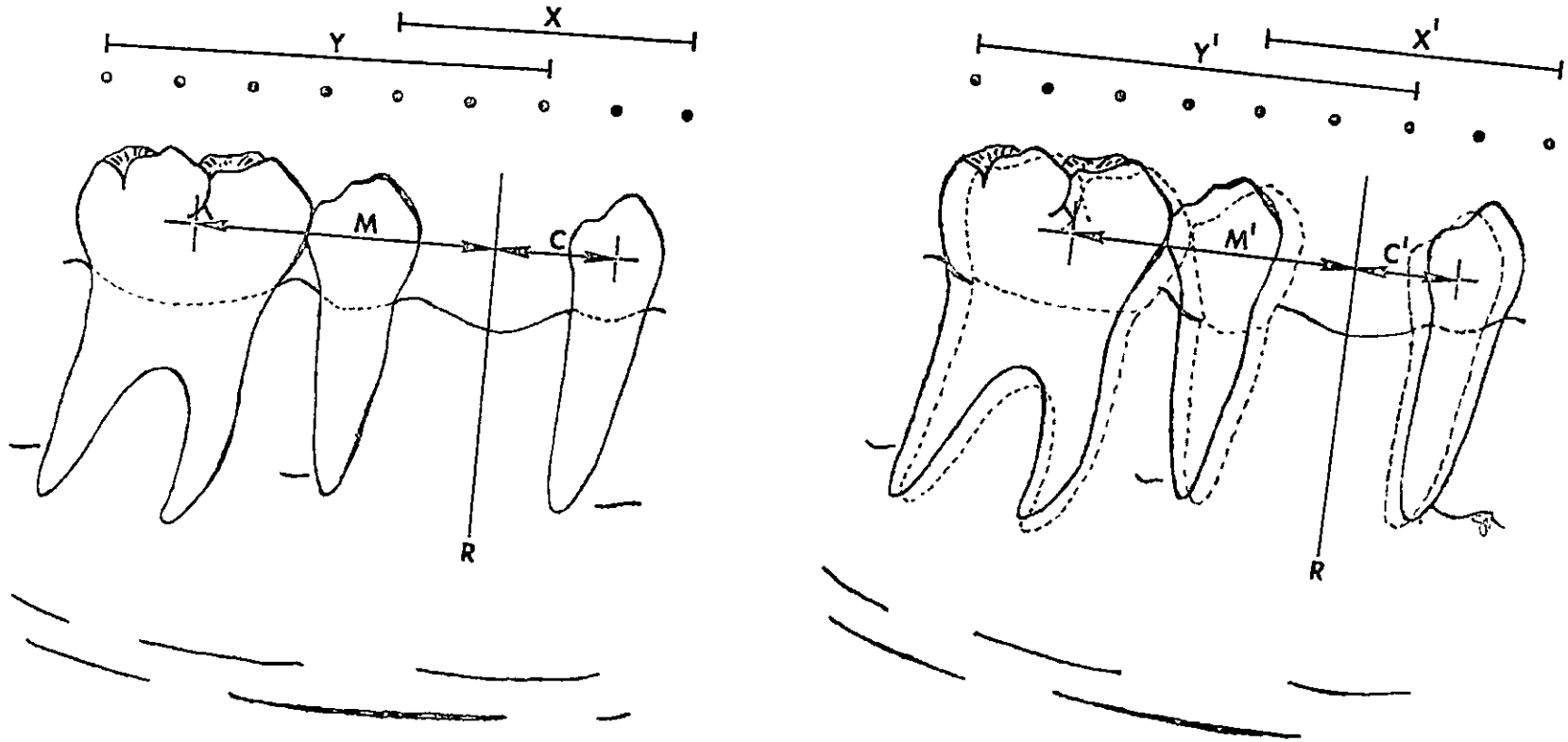


Figure 3. Cephalometric Measurement Procedure

Data Reduction

Calculations were performed on a programmable electronic calculator (Model 9100A; Hewlett-Packard Company; Loveland, Colorado). The statistical design employed was a randomized block, split plot, two-way analysis of variance with nine replications. The principle being: whole units, to which one or more factors are applied, are divided into sub-units to which levels of one or more additional factors are applied. Thus, each whole unit becomes a block for the sub-unit treatments (Steel and Torrie, 1960). In this instance, blocks or replications being patients, whole units being arches and sub-units being quadrants to which one of the two treatments are applied. The linear model for this design may be expressed as:

$$X_{ijk} = \mu + \beta_k + \alpha_i + \tau_j + (\alpha\tau)_{ij} + \varepsilon_{ijk} \text{ where,}$$

X_{ijk} = any measurement of the ith arch, jth treatment in the kth individual

μ = the population mean

β_k = the effect of the kth block ($k = 1,2,\ldots,9$ patients)

α_i = the effect of the ith arch ($i = 1,2$--maxillary or mandibular)

τ_j = the effect of jth treatment

$(\alpha\tau)_{ij}$ = the effect of interaction between the ith arch and j treatment

ε_{ijk} = the experimental error associated with the ith arch and the jth treatment in the kth individual

Details of the experimental design and the calculations involved may be inferred from Table II. Also, certain of the data were

examined from the standpoint of binomial probability (sign-test; Dixson and Massey, 1969).

TABLE II

ANALYSIS OF VARIANCE TABLE

Source	Degrees of[a] Freedom (df)	Sum of Squares (SSQ)	Mean Squares (MSQ)
Blocks (Patients)	r-1=8	$\frac{\Sigma X^2..k}{ab} - \frac{X^2...}{rab} = SS_{pt}$	
Arches	a-1=1	$\frac{\Sigma X^2.j.}{rb} - \frac{X^2...}{rab} = SS_{ar}$	$SS_{ar}/1$
$Error_{(a)}$	(a-1)(r-1)=8	$Subtotal_{(A)}-(SS_{pt}-SS_{ar})$	$SSQ_{error(a)}/8$
$Subtotal_{(A)}$	ar-1=17	$\frac{\Sigma X^2.jk}{r} - \frac{X^2...}{rab} = SS_A$	
Treatments	b-1=1	$\frac{\Sigma X^2..k}{ra} - \frac{X^2...}{rab} = SS_{tx}$	$SS_{tx}/1$
Arch X Tx. (Interaction)	(a-1)(b-1)=1	$\frac{\Sigma X^2.jk}{r} - \frac{X^2...}{rab} - SS_{ar} - SS_{tx} = SSint$	$SS_{int}/1$
$Error_{(b)}$	a(r-1)(b-1)=16	$Subtotal_{(B)}-(SS_{tx}+SS_{int})$	$SSQ_{error(b)}/16$
$Subtotal_{(B)}$	ar(b-1)=18	$\Sigma X^2ijk - \frac{\Sigma X^2ij.}{b} = SS_T$	
Total	abr=35	$\Sigma X^2ijk - \frac{X^2...}{rab} = SS_T$	

[a]Number of blocks (patients) =9=k; number of arches =2=i; number of treatments =2=j.

$F_{(1,16)}$ treatment = MSQ_{tx}/MSQ_{error} $\quad F_{(1,16)} \cdot 95 = 4.49$

$F_{(1,8)}$ arches = MSQ_{ar}/MSQ_{error} $\quad F_{(1,8)} \cdot 95 = 5.32$

$F_{(1,16)}$ arches x treatment = MSQ_{int}/MSQ_{error}

RESULTS

The results of the present study will be presented under three headings: (1) intra-oral measurements, (2) model measurements, and (3) measurements from the twenty-five degree lateral cephalograms.

All data could not be collected from every patient over the complete eight week period. Complete space closure of the maxillary experimental quadrant in Patient 1 forced estimation of data in model and cephalogram analysis and allowed utilization of intra-oral data through the seventh week only[1]. Similarly, in order not to jeopardize the future treatment of patients 4, 5, and 9 the investigation was terminated at 7, 7, and 6 weeks respectively.

---

[1]The formula for calculating a missing value, Y, may be expressed as:

$$Y = \frac{rW + b(a_j b_k) - (a_j)}{(r-1)(b-1)}$$, where

Y represents the missing sub-unit observations,
W is the total of the observed sub-units in the whole unit from which the observation is missing,
$(a_j b_k)$ is the total of observed sub-units that received the same treatment,
a_j is the total of observed sub-units that received the jth level of A,
r represents the number of replications (patients), and
b represents the number of treatments, 2.
One degree of freedom is subtracted from error (b) for each missing sub-unit (Steel and Torrie, 1960).

Intra-Oral Measurements

All patients exhibited the same general pattern of tooth movement; the relationship between average movement and time is presented in Table III and Figure 4. Individual totals and means are shown in Tables IV and V.

The first week of appliance activation produced an initial phase of very rapid tooth movement. In fourteen of eighteen quadrants maxillary movement exceeded that of mandibular, a significant difference according to the sign-test ($P<.05$). This was followed by a "lag phase" beginning with the second week and continuing into the third week. The surgical procedure had no apparent effect upon the magnitude or duration of the lag phase. The maxillary experimental lag phase was of a somewhat lesser magnitude than the control; however, the opposite was true in the mandibular arch. From the third to the fifth week there was a generalized increase in rate of movement. Beginning with the fifth week until completion of the experiment, mandibular movement tended to be relatively constant; maxillary movement, on the other hand, showed steady increases up to the end of the experiment.

There was no marked difference between the average weekly movement of experimental and control quadrants in either arch. Total movement was variable: experimental quadrants in the maxillary arch closed more than the controls, whereas in the mandibular arch the controls exhibited greater movement. Over-all, control quadrants demonstrated a slightly greater closure. Tables VI - IX summarize individual weekly space closure.

TABLE III

INTRA-ORAL MEASUREMENTS

AVERAGE SPACE CLOSURE
(millimeters/week)

Week	Arch			
	Maxillary		Mandibular	
	Experimental	Control	Experimental	Control
1	1.30	1.35	1.02	.90
2	.31	.25	.29	.45
3	.46	.53	.56	.50
4	.89	.80	.76	1.02
5	.86	.91	.90	.80
6	1.08	.94	.82	1.06
7	1.28	1.20	1.11	.93
Total	6.18	5.98	5.46	5.66

TABLE IV

INTRA-ORAL MEASUREMENTS

TOTAL SPACE CLOSURE
(millimeters)

Patient	Arch			
	Maxillary		Mandibular	
	Experimental	Control	Experimental	Control
1	8.3	6.4	6.0	5.2
2	7.6	6.4	6.1	5.9
3	5.5	5.4	4.8	5.7
4	4.5	3.6	3.4	5.2
5	3.7	2.8	3.4	4.7
6	5.1	6.3	4.8	5.9
7	3.5	4.9	4.7	4.5
8	6.6	6.8	6.6	5.6
9	4.2	5.2	3.4	3.5
Total	49.0	47.8	43.2	46.2

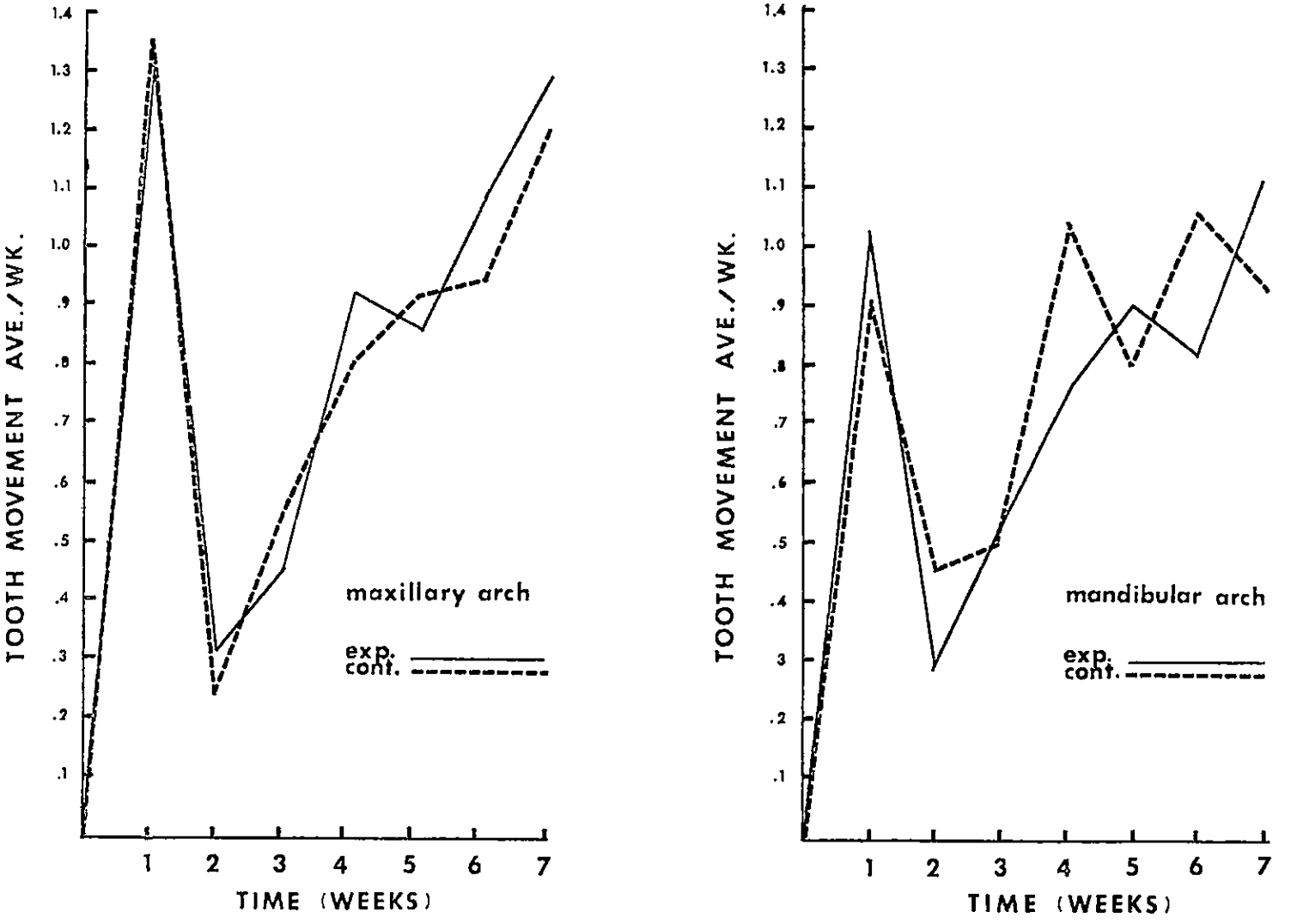


Figure 4. Average Weekly Tooth Movement

TABLE V

MEANS: INTRA-ORAL
(millimeters)

Arch	Experimental	Control	Mean
Maxillary	5.44	5.31	5.38
Mandibular	4.80	5.13	4.96
Mean	5.12	5.22	5.17

TABLE VI

EXPERIMENTAL SIDE SPACE CLOSURE
MAXILLARY ARCH
(millimeters)

Week	Patient 1	2	3	4	5	6	7	8	9
1	2.13	1.50	1.35	1.17	1.40	1.35	.61	1.14	1.05
2	1.00	.30	.17	.19	.25	.22	.01	.25	.41
3	1.03	.71	.48	.37	.09	.11	.41	.53	.45
4	1.24	.59	.68	1.04	.45	.45	.64	1.18	1.17
5	1.25	1.61	.92	.52	.61	.54	.62	.57	1.13
6	1.61	1.39	.83	1.20	.87	.92	.64	1.40	. .
7	. .	1.45	1.08	. .	. .	1.54	.79	1.52	. .
Total	8.26	7.55	5.51	4.49	3.67	5.13	3.54	6.59	4.21

TABLE VII

CONTROL SIDE SPACE CLOSURE
MAXILLARY ARCH
(millimeters)

Week	Patient 1	2	3	4	5	6	7	8	9
1	1.59	1.60	1.49	1.39	1.05	1.09	.83	1.25	1.85
2	.12	.31	.01	.03	.42	.14	.21	.58	.39
3	.69	.51	.39	.37	.04	.29	.78	.82	.64
4	1.51	.85	.85	.54	.18	.61	.41	.90	1.39
5	1.31	1.12	.86	.86	.54	.97	.65	.96	.88
6	1.22	1.21	.59	.42	.53	1.32	1.05	1.14	. .
7	. .	.76	1.18	. .	. .	1.92	1.01	1.12	. .
Total	6.44	6.36	5.37	3.61	2.76	6.34	4.94	6.77	5.15

TABLE VIII

EXPERIMENTAL SIDE SPACE CLOSURE
MANDIBULAR ARCH
(millimeters)

Week	Patient 1	2	3	4	5	6	7	8	9
1	1.24	1.53	.80	.90	.70	1.45	.79	1.15	.95
2	.25	.36	.24	.30	.44	.20	.28	.35	.19
3	1.13	.35	.48	.36	.44	.05	.59	.70	.59
4	1.27	.58	.58	.44	.51	.65	.95	1.08	.79
5	1.27	1.10	1.05	.75	.55	.75	.41	1.42	.83
6	.88	1.03	.95	.60	.80	.73	.74	.84	. .
7	. .	1.13	.71	. .	. .	1.25	.93	1.02	. .
Total	6.04	6.08	4.81	3.35	3.44	4.78	4.69	6.56	3.35

TABLE IX

CONTROL SIDE SPACE CLOSURE

MANDIBULAR ARCH
(millimeters)

Week	Patient 1	2	3	4	5	6	7	8	9
1	1.25	1.35	.90	.69	.74	.99	.50	.62	1.03
2	.52	.29	.71	.75	.58	.21	.25	.63	.12
3	.46	.51	.62	.55	.92	.37	.51	.25	.35
4	1.28	.85	.82	1.11	.94	1.33	.38	1.01	.96
5	1.02	1.02	.64	.67	.70	.80	.83	.53	1.02
6	.67	.88	1.04	1.39	.78	.75	1.13	1.81	. .
7	. .	.96	.98	. .	. .	1.48	.42	.80	. .
Total	5.20	5.86	5.71	5.16	4.66	5.93	4.52	5.65	3.48

Analysis of Variance

The results of the analysis of variance on the intra-oral data are presented in Table X.

TABLE X

ANALYSIS OF VARIANCE: INTRA-ORAL DATA

Whole Unit

Source	df	SSQ	MSQ
Blocks	8	40.9422	. .
Arches	1	1.5211	1.5211
Error (a)	8	5.4489	.6811
Sub-Total (A)		47.9522	

Sub-Units

Source	df	SSQ	MSQ
Treatments	1	.0900	.0900
Arch x Treat.	1	.4900	.4900
Error (b)	15	9.3200	.6213
Sub-Total (B)	34	9.9000	
Total		57.8522	

$F_{(1,15)}$ treatment = .1449

$F_{(1,8)}$ arches = 2.2333

$F_{(1,15)}$ arches x treatment =.7887

$F_{(1,15)}$ .95 = 4.54

$F_{(1,8)}$ .95 = 5.32

Model Measurements

The model measurements demonstrated a somewhat more definite pattern tham those taken intra-orally. The control quadrants showed more movement in six of nine cases in both the maxillary and mandibular arches. Thus, total movement of the controls was greater in both the maxillary and mandibular arches, thereby producing a greater over-all control mean movement. This difference, however, was not statistically significant (P>.05).(Tables XI, XII, Figure 5)

Analysis of variance

The results of the analysis of variance on the model data are presented in Table XIII.

Cephalograms

Total Space Closure

The cephalometric measurements, like the intra-oral and model measurements disclosed no definite trend. Total space closure as recorded is summarized in Tables XIV, XV, and Figure 6.

Analysis of Variance

The results of the analysis of variance on the cephalograms are presented in Table XVI.

Molar Movement

The results show the maxillary control molars had greater movement in seven of nine cases and that the mandibular control molars had greater movement in five of nine cases. Again, the over-all

TABLE XI

MODEL MEASUREMENTS: TOTAL SPACE CLOSURE
(millimeters)

Patient	Arch			
	Maxillary		Mandibular	
	Experimental	Control	Experimental	Control
1	6.1	6.4	5.6	5.7
2	5.8	5.4	5.2	4.4
3	3.7	4.5	4.4	4.7
4	4.6	3.4	2.7	4.2
5	2.2	2.7	2.2	3.3
6	4.0	6.1	3.1	3.6
7	2.6	3.0	3.2	5.0
8	5.1	5.9	6.0	5.0
9	5.4	4.8	3.8	3.4
Total	39.5	42.2	36.2	39.3

TABLE XII

MEAN: MODELS
(millimeters)

Arch	Experimental	Control	Mean
Maxillary	4.39	4.69	4.54
Mandibular	4.02	4.37	4.20
Means	4.19	4.53	4.36

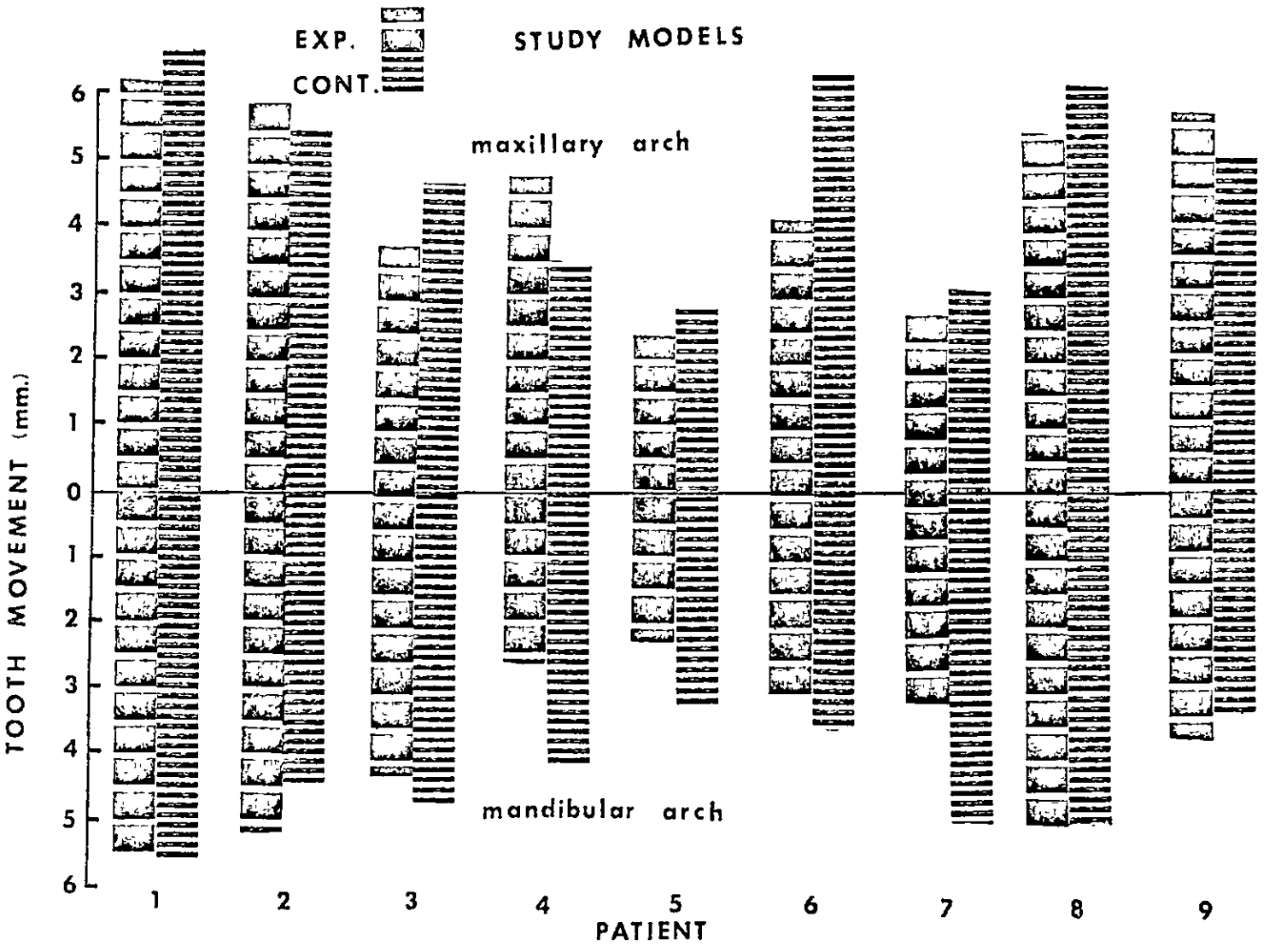


Figure 5. Total Movement: Study Models

TABLE XIII

ANALYSIS OF VARIANCE: MODEL DATA

Whole Unit

Source	df	SSQ	MSQ
Blocks	8	35.5550	. .
Arches	1	1.0678	1.0678
Error (a)	8	7.3572	.9197
Sub-Total (A)			

Sub-Units

Source	df	SSQ	MSQ
Treatments	1	.9344	.9344
Arch x Treat.	1	.0045	.0045
Error (b)	15	7.5611	.5041
Sub-Total (B)	17	8.5000	
Total	34	52.4800	

$F_{(1,15)}$ treatment = 1.8536

$F_{(1,8)}$ arches = 1.1610

$F_{(1,15)}$ arches x treatment = .0089

$F_{(1,15)}$ .95 = 4.54

$F_{(1,8)}$ .95 = 5.32

TABLE XIV

CEPHALOGRAMS: TOTAL SPACE CLOSURE
(millimeters)

Patient	Arch			
	Maxillary		Mandibular	
	Experimental	Control	Experimental	Control
1	8.8	9.5	7.3	5.6
2	8.6	7.1	7.3	6.4
3	3.6	4.1	5.6	6.5
4	4.7	4.9	5.5	6.8
5	3.2	4.3	4.8	4.3
6	6.1	7.8	5.0	5.5
7	4.4	5.9	4.5	6.0
8	6.6	5.7	5.8	5.4
9	4.3	6.9	6.3	5.6
Total	50.3	56.2	52.1	52.1

TABLE XV

MEANS: CEPHALOGRAMS--TOTAL SPACE CLOSURE
(millimeters)

Arch	Experimental	Control	Mean
Maxillary	5.59	6.24	5.92
Mandibular	5.29	5.29	5.29
Means	5.69	6.02	5.86

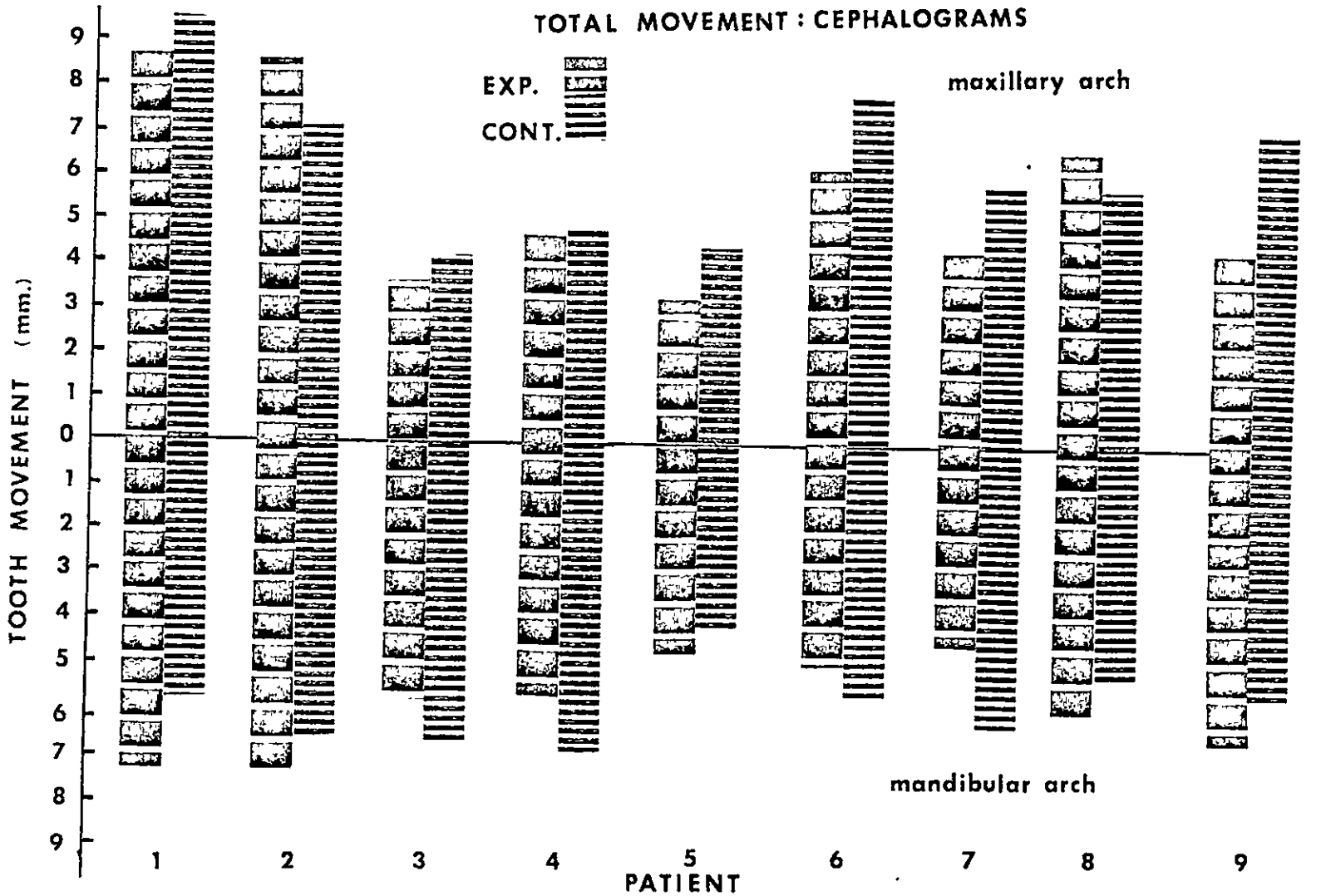

TOTAL MOVEMENT : CEPHALOGRAMS
EXP.
CONT.
maxillary arch
mandibular arch
TOOTH MOVEMENT (mm.)
9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9
PATIENT

Figure 6

TABLE XVI

ANALYSIS OF VARIANCE: CEPHALOGRAMS--TOTAL SPACE CLOSURE

Whole Unit

Source	df	SSQ	MSQ
Blocks	8	41.5372	. .
Arches	1	.1469	.1469
Error (a)	8	18.7706	2.3463
Sub-Total (A)		60.4547	

Sub-Units

Source	df	SSQ	MSQ
Treatments	1	.9669	.9669
Arch x treat.	1	.9670	.9670
Error (b)	15	11.3411	.7561
Sub Total (B)	17	13.2750	
Total	34	73.7297	

$F_{(1,15)}$ treatment = 1.2788

$F_{(1,8)}$ arches = .0626

$F_{(1,15)}$ arches x treatment = 1.2789

$F_{(1,15)}$ .95 = 4.54

$F_{(1,8)}$ .95 = 5.32

control mean movement was the greatest, but P≃.25. Results are presented in Tables XVII, XVIII and Figure 7.

Analysis of Variance

The results of the analysis of variance on the molar data are presented in Table XIX.

Cuspid Movement

The results of cuspid movement may be summarized as follows: (1) the maxillary control cuspids exhibited greater movement in eight of nine cases, (2) the mandibular control cuspids exhibited greater movement in four of nine cases, (3) the over-all control cuspid mean movement was greater than the over-all experimental cuspid movement. However, this trend proved to be of no statistical significance (P>.05). The results are presented in Tables XX, XXI and Figure 8.

Analysis of Variance

The results of the analysis of variance on the cuspid data are presented in Table XXII.

TABLE XVII

CEPHALOGRAMS: MOLAR MOVEMENT
(millimeters)

Patient	Arch			
	Maxillary		Mandibular	
	Experimental	Control	Experimental	Control
1	2.7	3.2	3.7	-.4
2	4.6	2.1	4.9	1.9
3	1.5	1.8	1.5	-.2
4	1.4	1.7	.2	3.8
5	.2	1.2	1.5	2.2
6	2.1	3.6	.5	2.2
7	1.7	3.1	.2	2.0
8	3.1	1.6	.8	1.0
9	.9	4.6	3.5	2.0
Total	18.2	22.9	16.8	14.5

TABLE XVIII

MEANS: CEPHALOGRAMS—MOLAR MOVEMENT
(millimeters)

Arch	Experimental	Control	Mean
Maxillary	2.02	2.54	2.28
Mandibular	1.87	1.61	1.74
Means	1.94	2.08	2.01

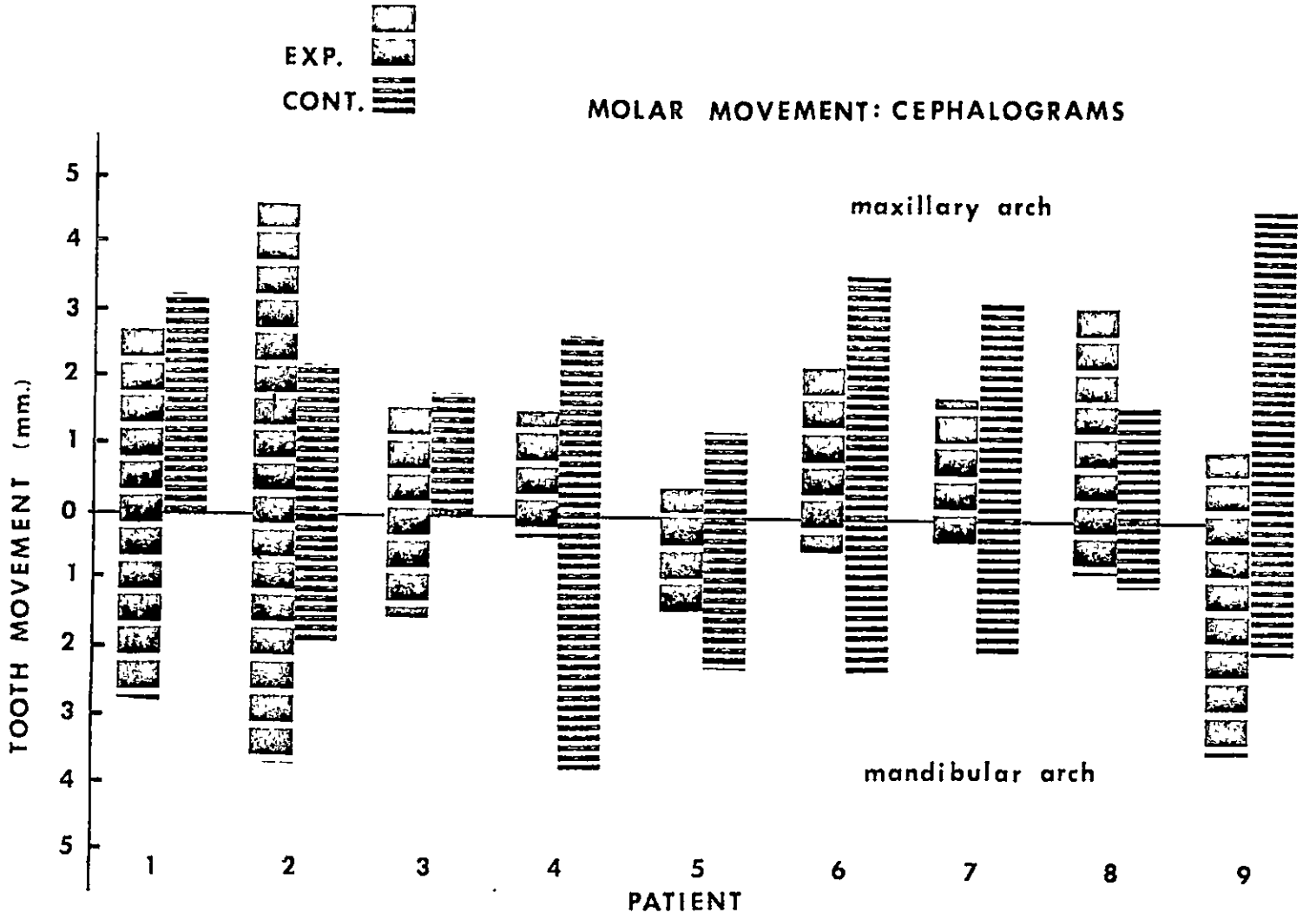

EXP.
CONT.
MOLAR MOVEMENT: CEPHALOGRAMS
maxillary arch
mandibular arch
TOOTH MOVEMENT (mm.)
5
4
3
2
1
0
1
2
3
4
5
1
2
3
4
5
6
7
8
9
PATIENT

Figure 7

TABLE XIX

ANALYSIS OF VARIANCE: CEPHALOGRAMS--MOLAR DATA

Whole Unit

Source	df	SSQ	MSQ
Blocks	8	16.2156	. .
Arches	1	2.6678	2.6678
Error (a)	8	7.0472	.8809
Sub-Total (A)		25.9306	

Sub-Units

Source	df	SSQ	MSQ
Treatments	1	.1600	.1600
Arch x Treat.	1	1.3611	1.3611
Error (b)	15	38.2239	2.5483
Sub-Total (B)	17	39.7450	
Total	34	65.6756	

$F_{(1,15)}$ treatment = .0628

$F_{(1,8)}$ arches = 3.0285

$F_{(1,15)}$ arches x treatment = .5341

$F_{(1,15)}$ .95 = 4.54

$F_{(1,8)}$ .95 = 5.32

TABLE XX

CEPHALOGRAMS: CUSPID MOVEMENT
(millimeters)

Patient	Arch			
	Maxillary		Mandibular	
	Experimental	Control	Experimental	Control
1	6.2	6.3	3.6	6.0
2	4.0	5.0	2.4	4.5
3	2.1	2.3	4.1	6.7
4	3.3	3.2	5.3	3.0
5	3.0	3.1	3.3	2.1
6	4.0	4.2	4.5	3.3
7	2.7	2.8	4.3	4.0
8	3.5	4.1	5.0	4.4
9	3.4	2.3	2.8	3.6
Total	32.2	33.3	35.3	37.6

TABLE XXI

MEANS: CEPHALOGRAMS--CUSPID MOVEMENT
(millimeters)

Arch	Experimental	Control	Mean
Maxillary	3.58	3.20	3.64
Mandibular	3.92	4.18	4.05
Means	3.75	3.94	3.84

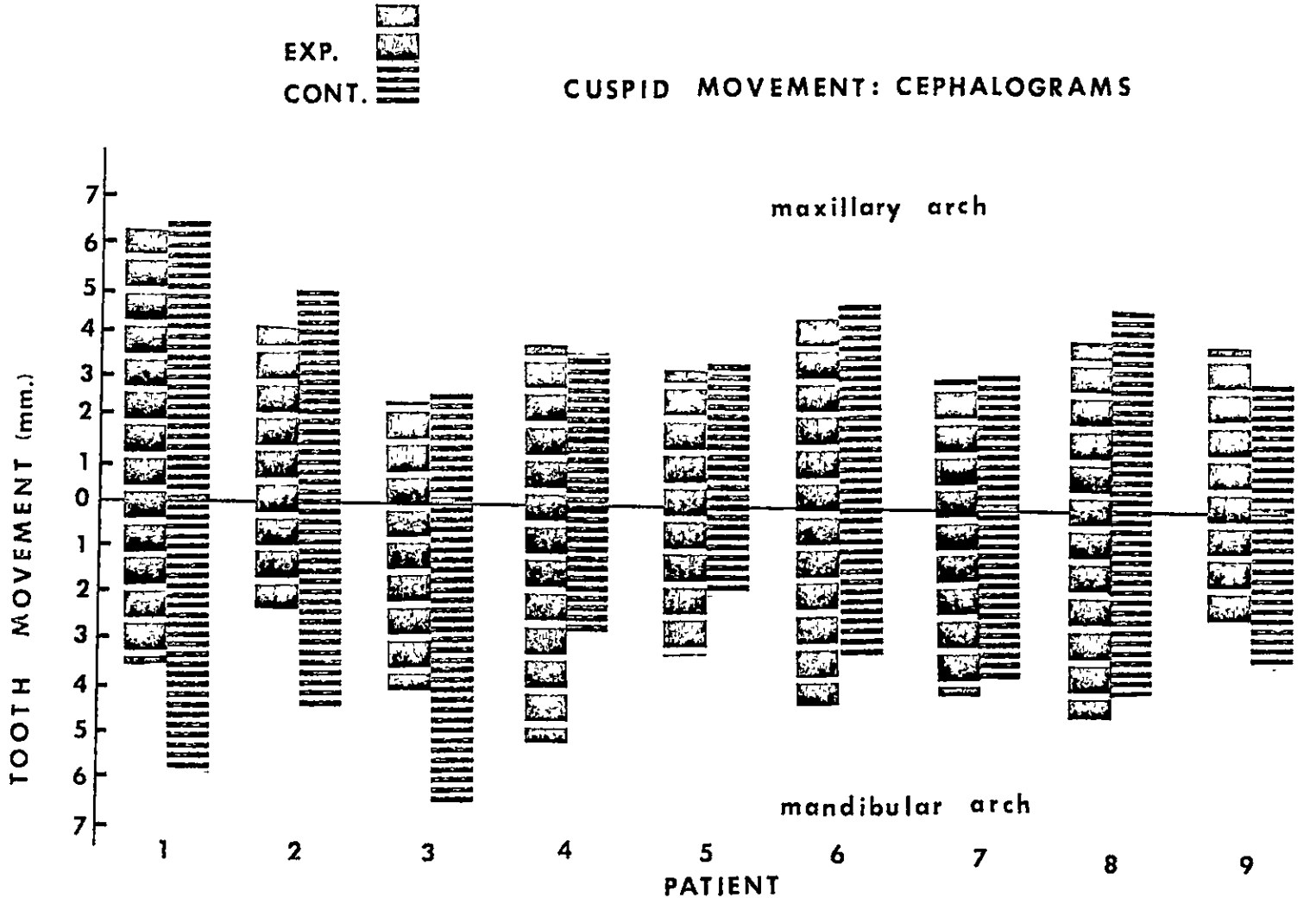

EXP.
CONT.
CUSPID MOVEMENT: CEPHALOGRAMS
maxillary arch
mandibular arch
TOOTH MOVEMENT (mm.)
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
1
2
3
4
5
6
7
8
9
PATIENT

Figure 8

TABLE XXII

ANALYSIS OF VARIANCE: CEPHALOGRAMS--CUSPID DATA

Whole Unit

Source	df	SSQ	MSQ
Blocks	8	19.2789	. .
Arches	1	1.5211	1.5211
Error (a)	8	15.7889	1.9736
Sub-Total (A)		36.5889	

Sub-Units

Source	df	SSQ	MSQ
Treatments	1	.3211	.3211
Arch x Treat.	1	.0400	.0400
Error (b)	15	14.0789	.9386
Sub-Total (B)	17	14.4400	
Total	34	51.0289	

$F_{(1,15)}$ treatment = .3421

$F_{(1,8)}$ arches = .7707

$F_{(1,15)}$ arches x treatment = .0426

$F_{(1,15)}$ .95 = 4.54

$F_{(1,8)}$ .95 = 5.32

DISCUSSION

Pattern of Tooth Movement

This investigation revealed a general pattern of tooth movement which can be described as follows: The first week (initial phase) was characterized by very rapid tooth movement. It should be noted that this early rapid tooth movement was of greater magnitude in the maxillary arch than that observed in the mandibular arch. In the second week, began a "lag phase" in which the teeth had a very low rate of displacement. Spontaneously, beginning with the third week the teeth underwent a sharp increase in rate of movement. By the fifth week, movement in the mandibular arch, although still somewhat variable, showed a tendency to level off; whereas, movement in the maxillary arch still shower steady increases up to the end of the experiment.

This pattern of tooth movement follows that as described by earlier investigators (Burstone, 1962; Reitan, 1960, 1969). The initial phase corresponds to the compression of the periodontal ligament and is to be expected in any tooth movement. The tendency toward greater maxillary movement during this period may be explained by the difference in bone density, the more porous maxillary bone allowing more bending of the alveolus to occur. Upon examination of the data in regard to the control quadrants, the initial phase saw 1.35 millimeters and .90 millimeters of movement in the maxillary and mandibular

arches, respectively (Tables III and IV). By deducting the average thickness of the periodontal ligament, .21 millimeters (Coolidge, 1937), it may be assumed that alveolar bone bending accounted for 1.14 millimeters of maxillary movement and .69 millimeters of mandibular movement during the initial phase. Thus, resulting in a .45 millimeter difference maxillary and mandibular control movement. Similarly, alveolar bone bending in the experimental quadrants accounted for 1.09 millimeters and .81 millimeters of initial movement in the maxillary and mandibular arches, respectively, thus showing a .28 millimeter difference (Tables III and IV).

The "lag phase" has been assumed to result from pressure-hyalinization of the periodontal ligament and to an unknown degree, the resistance of supra-alveolar fibers to stretching and displacement. In this instance, the duration of the lag was minimal and lasted only a few days. This may be due to the fact that a relatively light and continuous force was applied. It appears that although the supra-alveolar fibers can logically be assumed to exert a counter-force which may contribute to the lag phase, it cannot be assumed to be the rate-limiting factor, inasmuch as the transection of the fibers did not alter the form of the lag phase. Direct frontal resorption is temporarily delayed and tooth movement is not resumed until undermining resorption begins in the bone underlying the hyalinized tissue.

As the last remnants of hyalinization are resolved and a more normal mechanism of bone resorption asserts itself, the rate of movement increases and finally remains relatively constant. This tendency

was noted in the mandibular arch, but at the termination of the experimental period this relative constancy had not been reached in the maxillary arch. It may be hypothesized that this was due to the differences in bone density and that this leveling off would have occurred shortly thereafter, had the experiment been continued for a longer period.

The fact that following the lag phase, movement increases as hyalinization is resolved, offers interesting speculation as to what the effect might be if the fibers were to be transected at this point. Since here, the fibers, in theory, are exerting a greater counter-force due to greater uncoiling and stretching, also hyalinization is becoming less of a barrier. Results of a study done in this manner might reveal a significant effect.

Space Closure

The study model measurements disclose that, over-all, the average amount of space closure was 4.36 millimeters (Table XII). In contrast, the intra-oral measurements show 5.17 millimeters of space closure (Table V). The lateral cephalograms indicate there was 5.86 millimeters of total space closure (Table XV).

It is apparent there is a considerable variation among the measurement procedures. Intra-oral measurements are more affected by rotations than are model and cephalometric measurements. The difficulty in tracing suitable skeletal landmarks for superimpositioning purposes makes the cephalometric measurements somewhat less accurate[2]. Thus, the absolute amount of space closure must be obtained from the

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[2]The utilization of metallic implants with this procedure would make these measurements more reliable.

model measurements. The amount totals approximately 4.36 millimeters/ seven week period for this sample.

Reliability of Measurements

A summary of the pertinent statistics of the three measurement methods is presented in Table XXIII.

TABLE XXIII

SUMMARY OF RELATIVE STATISTICS

Source of Data	Analysis of Variance Summary		
	TxMSQ	Error MSQ	F
Study Models	.9344	.5041	1.8536
Intra-Oral	.0900	.6213	.1449
Cephalograms	.9669	.7561	1.2788

The intra-oral measurements were assumed to be more reliable then either the cephalograms or study model measurements due to the distinct landmarks as described in Methods. However, this clinical conviction was not substantiated when comparing the estimates of error variance (Error MSQ) from the three measurement procedures. The intra-oral measurements had a mean squares due to error which fell between those of study model and cephalogram measurements. The error inherent in the cephalogram method had the greatest value, whereas the study model method had the lowest value. For this reason the study model measurements were deemed most valid for obtaining the

absolute amount of space closure, although there is no significant difference among these estimates of variance.

Anchorage and Differential Force

Measurements obtained from the lateral cephalograms were utilized as the means for evaluating anchorage loss. The study showed that thirty-six percent of the space closure was accounted for by the movement of the molar on the experimental side in the maxillary arch. The maxillary arch control side showed forty-one percent of the movement was that of the molar. The mandibular arch showed thirty-two percent of the movement on the experimental side was molar movement while the control side had twenty-eight percent of the space closure (Tables XIV and XVII).

The over-all mean movement showed that thirty-four percent of the total space closure in both experimental and control quadrants, was attributed to mesial molar movement (Tables XV and XVIII). It must be noted, however, that in six of the thirty-six observations molar movement was greater than that of the cuspid (Tables XVII and XX).

Experimental Versus Control

The data from the intra-oral, study model and lateral cephalograms indicated that there was no significant difference in total tooth movement between control and experimental quadrants. The differences in amount of space closure can be attributed to the different methods of recording the data and other uncontrolled variability.

An examination of all mean movement for all methods of data collection disclosed a tendency for control quadrants to have more space closure than the experimental quadrants. Statistical analysis however, revealed no significant difference.

It is commonly known that following the opening of the mid-palatal suture, the central incisors are drawn together by the pull of the transseptal fibers (Haas, 1961, 1965). In this instance the forces delivered by the supra-alveolar fibers are not superimposed on other processes having opposite effects and are thereby permitted visibly to exert their influence. Hence, if the technical assumptions of the present investigation are correct, transection of the supra-alveolar fibers should have increased the effective force acting on the canines. Thus, if bone resorption were directly proportional to effective force, greater retraction should have resulted. The negative result of the present investigation could, of course, be due to technical problems (early regeneration, incomplete transection) or to insufficient sample size (lack of power). However, there is evidence (Boester, 1972) that the magnitude of tooth movement is relatively independent of force between five and eleven ounces. Inasmuch as Boester employed the same techniques (Ricketts sectionals, weekly activation, measurement procedures, etc.) as in the present investigation, it is highly probable that severing the fibers had an effect, but that at seven ounces of activation, bone resorption was already proceeding at a maximal rate and thus could not be increased by adding to the effective force. For the present study, bone resorption,

rather than the presence or absence of supra-alveolar fibers appears to be the rate limiting factor. If this interpretation is correct, replication at two ounces of force should provide not only a positive result, but also (in conjunction with Boester's findings) an estimate of the counter-force exerted by the supra-alveolar fibers.

SUMMARY AND CONCLUSIONS

A study was conducted to evaluate the influence of the supra-alveolar fibers on active tooth movement. Transection of these fiber bundles was performed in randomly selected quadrants of nine randomly selected patients who presented for orthodontic treatment and who were diagnosed as four first bicuspid extraction cases.

The data were collected and analyzed in three categories:

(1) Direct intra-oral measurements to determine the total amount of space closure.

(2) Measurements derived from beginning and final study models to determine the total amount of space closure.

(3) Lateral twenty-five degree cephalograms to determine the total amount of space closure, the amount of distal movement of the cuspids, and the amount of mesial movement of the posterior segments.

The general pattern of tooth movement which emerged was one in which there was an initial phase of very rapid movement, followed by a "lag phase" of short duration, and finally by an increase in the rate of movement, ultimately terminating at a level of relative constancy.

The study model measurements proved to be the most reliable and most valid for determining the absolute amount of space closure, whereas the results of the intra-oral measurements were reliable but less valid due to the rotations produced during space closure.

The cephalogram measurements were utilized in assessing relative individual tooth movements on either side of the extraction site.

These measurements, however, possessed the greatest inherent error variance and thus proved to be less accurate in measuring space closure.

The results of the study are as follows:

(1) In terms of supra-alveolar fiber transection, space closure of experimental and control quadrants did not differ significantly, nor was there any difference in anchorage loss or cuspid retraction.

(2) Cuspid retraction significantly exceeded anchorage loss ($P<.05$), regardless of treatment; a 2:1 differential may be inferred.

(3) Maxillary movement was significantly greater than mandibular movement during the initial week of appliance activation, presumably due to increased alveolar bone bending.

(4) Bone resorption, rather than the presence or absence of the supra-alveolar fibers appears to be the rate limiting factor of orthodontic tooth movement.

APPENDIX I

Patient Consent Form

CASE WESTERN RESERVE UNIVERSITY

SCHOOL OF DENTISTRY

PATIENT CONSENT FOR STUDIES

Title of Project: The Effect of Supra-Alveolar Fiber Transection on Cuspid Retraction.

The following information is given to you regarding a clinical study of which you may become part, if you so elect. Please read the following items carefully, and if you would like to become part of the study, please sign at the bottom of the form.

1. The purpose of this study is to examine the effect of transecting the supra-alveolar gingival fibers prior to retraction of the canine into bicuspid extraction sites.

2. The patients are selected on the basis that all teeth involved in the investigation could be banded at one time.

3. Candidates to be selected for the investigation would be patients whose treatment plan has been arrived at by standard diagnostic procedures and approved by the Orthodontic staff. Specifically, it must call for the extraction of four first bicuspids in order to achieve the optimal orthodontic result.

4. Special appliances will be constructed for each patient and placed in the appropriate site at the beginning of the study. Patients will be seen weekly, to gather necessary data and to adjust appliances.

5. The candidate is assured that it is the consensus of the Orthodontic Staff that the investigation will in no manner affect the outcome of the proposed treatment and will not alter to any significant extent the period of orthodontic treatment.

6. At the end of the investigation each candidate will be treated to completion as they normally would have been if they had, or had not, participated in this investigation.

7. You will receive a reduction in the total fee.

8. You may withdraw from this study at any time.

I, the undersigned, understand that I have been asked to be a cooperating participant in this project to be conducted in the School of Dentistry at Case Western Reserve University. The studies above described have been explained to me by the Project Investigator, and I agree to participate therein as a volunteer patient.

In consideration of the foregoing, I hereby release the School of Dentistry of Case Western Reserve University and any of their servants and agents, from any and all claims and causes of action arising out of the foregoing project.

SIGNATURE_____ AGE_____ DATE_____

PARENTAL CONSENT_____ DATE_____

WITNESSED BY _____ DATE_____

LITERATURE CITED

Angle, E. H. 1899. Section of the peridental membrane and frenum labii. Den. Cosmos, 41: 1143-1149.

Angle, E. H. 1907. Treatment of Malocclusion of the Teeth. 7th ed. Chapter 6, S. S. White Dental Mfg. Co., Philadelphia.

Black, G. V. 1936. Operative Dentistry. pp. 9-32. Medico-Dental Pub. Co., Chicago.

Boese, L. R. 1969. Increased stability of orthodontically rotated teeth following gingivectomy in Macaca Nemestrina. Am J. Orthod., 56: 273-290.

Boester, C. H. 1972. An investigation of the concepts of differential and optimal force in canine retraction. Unpublished M.S. thesis, Case Western Reserve University, Cleveland.

Brain, W. E. 1969. The effect of surgical transection of free gingival fibers on the regression of orthodontically rotated teeth in the dog. Am. J. Orthod., 55: 50-71.

Bryan, L. C. 1905. Immediate correction of malposed teeth. Den. Cosmos, 47: 253-255.

Burstone, C. J. 1962. "The Biomechanics of Tooth Movement," in Vistas in Orthodontics. Chapter 5. Edited by E. S. Kraus, R. A. Riedel. Lea and Febiger, Philadelphia.

Chase, S. W. and Revesz, J. 1944. Reestablishment of transseptal fibers following extraction. J. Dent. Res., 23: 333-336.

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

Daprano, A. 1971. Canine retraction in healed and recent extraction sites. Unpublished M.S. thesis, Case Western Reserve University, Cleveland.

Dedolph, T. H. and Clark, H. B. 1958. A histologic study of muco-periosteal flap healing. J. Oral Surg., 16: 367.

Diguillo, J. 1970. Quantitative measurements from panoramic radiographs. Unpublished M.S. thesis, Case Western Reserve University, Cleveland.

Dixson, W. J. and Massey, F. J. 1969. Introduction to Statistical Analysis. 3rd ed., Chapter 17. McGraw-Hill, New York.

Edwards, J. G. 1968. A study of the periodontium during orthodontic rotation of teeth. Am. J. Orthod., 54: 441-461.

Edwards, J. G. 1970. A surgical procedure to eliminate rotational relapse. Am. J. Orthod., 57: 35-46.

Edwards, J. G. 1971. The prevention of relapse in extraction cases. Am. J. Orthod., 60: 128-141.

Erickson, B. E., Kaplan, H., and Aisenberg, M. S. 1945. Orthodontics and transseptal fibers. Am. J. Orthod., 31: 1-20.

Fullmer, H. M. and Lillie, R. D. 1958. The oxytalan fiber: A previously undescribed connective tissue fiber. J. Histochem. Cytochem., 6: 425-430.

Fullmer, H. M. and Lillie, R. D. 1960. A comparative histochemical study of elastic, pre-elastic and oxytalan connective tissue fibers. J. Histochem. Cytochem., 8: 290-295.

Fullmer, H. M. and Lillie, R. D. 1966. Histochemical studies of the periodontium. J. Dent. Res., 45: 469-479.

Guilford, S. H. 1898. Physiology and dynamics of tooth movement. Den. Cosmos, 40: 995-1003.

Haas, A. J. 1961. Rapid expansion of the maxillary dental arch and nasal cavity by opening the mid-palatal suture. Angle Orthod., 31: 73-90.

Haas, A. J. 1965. The treatment of maxillary deficiency by opening the mid-palatal suture. Angle Orthod., 35: 201-217.

Hixson, E. H., Atikian, H., Callow, G., McDonald, H., and Tracy, R. J. 1969. Optimal force, differential force and anchorage. Am. J. Orthod., 55: 437-457.

Hixson, E. H., Atikian, H., Callow, G., McDonald, H., and Tracy, R. J. 1970. On force and tooth movement. Am. J. Orthod., 57: 476-489.

Jackson, V. H. 1890. Proceedings of Dental Societies, First District Dental Society, State of New York. Den. Cosmos, 32: 293.

Kronfeld, R. 1939. Histopathology of the Teeth and Their Surrounding Structures. 2nd ed., pp. 353. Lea and Febiger, Philadelphia.

Morris, M. L. 1961. Healing of human periodontal tissues following surgical detachment from vital teeth: The position of the epithelial attachment. J. Periodontol., 32: 108.

McCauley, C. M. 1924. The peridental membrane from an orthodontic standpoint. Pacific Dental Gazette, 32: 474-479.

Oppenheim, A. 1911. Tissue changes particularly of bone, incident to tooth movement. Am. Orthod., 8: 57-68.

Orban, B. J. 1972. "The Periodontal Ligament," in Oral Histology and Embryology, Chapter 7. Edited by H. Sicher, S. N. Bhaskar. C. V. Mosby, St. Louis.

Reitan, K. 1951. The initial tissue reaction incident to orthodontic tooth movement as related to the influence of function. Acta Odontol. Scand., Suppl. 6, p. 61.

Reitan, K. 1957. Some factors determining the evaluation of forces in orthodontics. Am. J. Orthod., 43: 32-45.

Reitan, K. 1962. "Bone Formation and Resorption During Reversed Tooth Movement," in Vistas in Orthodontics. Edited by B. S. Kraus and R. A. Riedel. Lea and Febiger, Philadelphia, pp. 69-84.

Reitan, K. 1959. Tissue rearrangement during retention of orthodontically rotated teeth. Angle Orthod., 29: 105-113.

Reitan, K. 1960. Tissue behavior during orthodontic tooth movement. Am. J. Orthod., 46: 881-900.

Reitan, K. 1964. Effects of force magnitude and direction of tooth movement on different alveolar bone types. Angle Orthod., 34: 244-255.

Reitan, K. 1969. "Biomechanical Principles and Reactions," in Current Concepts and Techniques. Edited by T. M. Graber, Vol. 1, pp. 56-160. W. B. Saunders Co., Philadelphia.

Sandstedt, C. 1904. Einge Beitrage zur Theorie der Zahnregulierung Nordisk Tandläkare Tidsskrift. No. 4 (Cited in Stuteville, O. H., 1938.)

Schwarz, M. 1932. Tissue changes incidental to orthodontic tooth movement. Int. J. Orthod. Oral Surg. Rad., 18: 331-352.

Skogsburg, C. 1927. The permanent retention of the teeth after orthodontic treatment. Den. Cosmos., 69: 1117-1129.

Skogsburg, C. 1932. Septotomy in connection with orthodontic treatment Int. J. Orthod., 18: 1044-1057.

Steel, R. G. and Torrie, J. H. 1960. Principles and Procedures of Statistics. Chapter 12. McGraw-Hill, New York.

Stuteville, O. H. 1938. A summary review of tissue changes incident to tooth movement. Angle Orthod., 8: 1-19.

Talbot, E. S. 1896. Teeth irregularities and their surgical correction. Den. Cosmos, 38: 907-911.

Thompson, H. E. 1955. Speculations on the potentialities of connective tissue fibers. Am. J. Orthod., 41: 718-789.

Thompson, H. E., Myers, H. P., Waterman, J. M., and Flanagan, V. D. 1958. Preliminary macroscopic observations concerning the potentiality of supra-alveolar collagenous fibers in orthodontics. Am. J. Orthod., 44: 485-497.

Thompson, H. E. 1959. Orthodontic relapses analyzed in a study of connective tissue fibers. Am. J. Orthod., 45: 93-109.

Tsopels, G. 1967. A study of the influence of the supra-alveolar connective tissue fibers on the stability of orthodontically rotated teeth. M. S. thesis, Marquette University, Milwaukee.

Waldron, R. 1942. Reviewing the problems of retention. Am. J. Orthod., 28: 770-791.

Wiser, G. M. 1967. Surgical resection of the supra-alveolar fibers and the retention of orthodontically rotated teeth in the dog. M. S. thesis, Temple University, Philadelphia.

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