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CANINE RETRACTION IN HEALED AND RECENT EXTRACTION SITES

by

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Submitted in partial fullfillment of the requirement

for the Degree of Master of Science

Department of Orthodontics

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CANINE RETRACTION IN HEALED AND
RECENT EXTRACTION SITES

Abstract

by

ANGELO ANTHONY DAPRANO

A clinical investigation was conducted to compare the rate of orthodontic space closure in healed and recent extraction sites. Nine patients who required extractions of four first bicuspids consented to participate in the study.

Two first bicuspids in each patient were extracted, and the remaining teeth in that quadrant received a .0215" x .028" rectangular wire stablizing appliance. After a four week healing period, the remaining two first bicuspids of each patient were extracted and all four quadrants were fitted with a commercially available .0215" x .0275" preformed sectional closing loop. Panoramic radiographs and study casts were taken at this appointment. Each appliance was activated to a weekly force of 360 grams and direct intra-oral measurements obtained. At the conclusion of the eight week experimental period final panoramic radiographs and study

models were taken. The data were analyzed graphically, by blocked two way analysis of variance with nine replications, and also binomial probability.

The results of this study show that, contrary to the popularly held notion, there is more tooth movement in healed extraction sites than in fresh sites. The difference, however, is too slight to warrant any special considerations in the timing of treatment procedures.

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DEDICATED

To my Family

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INTRODUCTION

Mechanotherapy in orthodontics has achieved a relatively high degree of sophistication. Despite this, there still remain certain areas of treatment which have not been subjected to controlled investigation.

One of the most fundamental problems which confronts an orthodontist today is the retraction of canines in four first bicuspid extraction cases.

Although researchers and clinicians alike have long expressed concern for, and interest in, biomechanical principles and their relation to tooth movement, appliances, and techniques, to date, only a few studies have been conducted concerning the timing of cuspid retraction after first bicuspid extraction.

An investigation will be conducted to compare the rate of canine retraction in a recent versus a healed extraction site by measuring the amount of space closure on nine patients.

The amount of displacement will be determined by analyzing: (1) direct intra-oral measurements, (2) measurements of panoral radiographs, and (3) measurements of beginning and final study models.

REVIEW OF THE LITERATURE

Introduction

The application of pressure to correct irregularities of the teeth was suggested as early as the first century A.D. by Gauis Plinius Secundus. Since that time, men such as Farrar (1771), Hunter (1771), and Spaulding (1858) have described methods of moving teeth by the application of forces.

Historically, the rearrangement of teeth has been effected in two ways. In the early eighteenth century when dental service was first seriously undertaken as an area of specialization, clinicians relied generally upon the extraction of teeth to provide room for the remaining malposed teeth. At this same time, however, there were some men, notably Fauchard, who relied on the expansion of the dental arch to gain the necessary space for alignment. Thus, the battle lines were drawn for what would prove to be a long and acrimonious debate.

It is not within the scope of this paper to become involved in the once highly controversial extraction debate (Angle, 1904; Case, 1904; Jackson, 1904; Brodie, 1944; Grieve, 1944; Hahn, 1944; Hellman, 1944; Tweed, 1950); extraction is now an accepted procedure.

Biophysical Principles

Problems encountered in orthodontics have prompted generations of investigators to examine the histologic response to tooth movement.

In recent times, the tooth and its supporting structures have been studied in great detail by, among others, Breitner (1940); Oppenheim (1944); Erickson, Kaplan, and Eisenberg (1945); Muhlemann (1954, 1967); Weinmann and Sicher (1955); Parfitt (1960); Korber (1967) and Picton (1967). The most notable and detailed studies, however, are those of Reitan (1951, 1957, 1958, 1962, 1964, 1969) who studied not only the supporting tissues but also the variation in tissue reaction caused by the magnitude, duration, and direction of the force.

Tooth Movement

In general, orthodontic movement occurs in three phases, each phase corresponding to specific tissue changes (Burstone, 1962; Reitan, 1969). The first phase coincides with a compression of the periodontal membrane, The second, or "lag phase," is a period in which the tooth does not move or, at most, moves at a very low rate. Burstone (1962) suggested that this phase is characterized by "non-vitalization"

and that tooth movement will not occur until the area of non-vitalization (hyalinization) is removed by osteoclastic resorption. This lag phase persists for approximately two weeks before tooth movement again proceeds.

Reitan (1969) stated that hyalinization is common to all types of tooth movement, is an unavoidable consequence, and is dependent upon the magnitude of forces employed to move the teeth. If the force is sufficiently light, tipping will occur, and hyalinization will be of shorter duration and of lesser magnitude. Thus, with light forces, a good many cell nuclei persist and the fibrous tissue remains partly unaltered or semi-hyalinized.

The third phase is characterized by a gradually increasing rate of movement.

Role of Force Magnitude

The concept of optimum force originated with such men as Gottlieb (1922); Orban (1927); Schwarz (1928); and Oppenheim (1942). The term "optimal force", however, is used more commonly with reference to a clinical investigation by Storey and Smith (1952) in which a force of 150 grams was reported to be optimum for canine retraction. However, in more comprehensive, and presumably

more reliable studies, Hixon et al. (1969, 1970) state:

> When applied to canine retraction for a clinically useful period of time, there are no data to support the theory of optimum force. The most appropriate [theory] at this time postulates that higher forces per unit root area (to 3 or 4 grams per sq. mm) increase the rate of biologic responses (1969, p 455-6).

Types of Tooth Movement

The two basic types of movement are tipping and bodily movement. These depend upon the magnitude and method of force application. Of the two, tipping is the most common and is the type of movement that was achieved by Storey and Smith (1952) in their investigation. The findings of Hixon et al. (1969, 1970) support the work of Reitan (1957) and Burstone (1962) which characterized the initial tooth movement as a tipping movement, regardless of the mechanism of retraction or degree of force exerted. Hixon et al. (1969, 1970) failed in two attempts to eliminate tipping of all teeth and achieve bodily movement.

Role of Osteoid

Basically, the phenomenon of tooth movement can be summarized as follows: if the applied forces are within the limits of tolerance, the reaction of the tissue is osteoclastic resorption in the pressure areas and regular apposition of bone in the areas of traction. If the applied forces are beyond the limits of tolerance i.e.,

greater than 70 grams, osteoid tissue forms in the area of pressure and may, therefore, become a significant factor influencing the rate of tooth movement(Reitan,1969).

Animal studies of the healing socket have been undertaken by Amler, Johnson, and Salman (1960); Guranlnick (1968); Thoma (1969); Johansen (1970) and, most importantly to this paper, the investigation of Boyne (1966), in which the repair of the alveolar bone on 12 humans was examined. Histologically, according to Boyne, the first evidence of new bone formation in the socket itself was seen 10 days post operatively. Subsequent new bone continued to form until the 19th day, at which time it occupied approximately 1/3 of the entire alveolus. The particular configuration of the osseous repair at the 13th and 14th day was that of deposition of bone along the lateral wall and the fundus of the socket.

In studies involving tooth movement without extraction, Gottlieb (1922); Oppenheim (1942); and Sicher (1955) believed that osteoid tissue is less resorbable than bone. However, in young growing structure, some osteoid tissue is always present along the internal alveolar bone surface even under normal physiologic conditions (Reitan,1969). Schwarz in 1932 (supported by Orban, 1935) was of the opinion that the application

of light continuous forces would constitute the best basis for orthodontic treatment because the osteoid tissue which would be formed during the application of heavy forces would not have to be resorbed. However, in a study in 1951, Reitan reported that:

> It is therefore not in accordance with my findings to conclude that the persistence or increase in osteoid tissue at the pressure site plays any part in the genesis of resorbing cells (1951, p.184)

and Tweed (1966) in reporting on the works of Reitan stated:

> . . . this newly calcified osteoid bundle bone does not enhance the resistance of the tooth to mesial movement when force is applied. (1966, p.7)

Osteoid tissue definitely caused delay in the onset of direct resorption but ". . . only in experiments of short duration . . .up to 4 days." (Reitan, 1962, p.82)

Canine Retraction

With reference to the present state of the art of canine retraction, there is unanimous agreement that a healing socket is filled with granulation tissue that becomes osteoid tissue and finally mature bone (Amler, Johnson, Salman, 1960; Boyne, 1966; Thoma, 1969; Johansen, 1970). The foregoing takes approximately 19 days to become at least one third complete (Boyne, 1966). There are investigators who suggest that osteoid tissue is less resorbable than bone (Reitan, 1951) which suggest that osteoid in a healing extraction site might retard

canine retraction. Conversely, there are clinicians who suggest that retraction is easier in a fresh extraction site (Jackson, 1904; Stoner, 1969).

Revell (1964) proposed that the movement of teeth through areas of granulation tissue require pressures of lesser intensity.

A description of the Tweed method (Salzmann, 1950, p. 766) states that ". . . immediately following the extraction of premolars, the teeth in the buccal segments posterior to the space begin to tip forward." The retraction should

> . . . begin three to seven days following the removal of the first premolar tooth, since in this manner the canine teeth can be retracted more readily than after the alveolus is eliminated (Salzmann, 1950, p. 766)

The recent investigation of Murphey (1969) and Bauer (1969) suggest that retraction in a recent extraction site is less favorable than retraction into a healed extraction site; but, to date, this author is not aware of any investigation in which these widely divergent claims have been tested in a controlled clinical situation.

No doubt animal studies have a degree of relevance to humans. However, the biology of man is not exactly the same, and tissue responses are, therefore, not necessarily the same. Reitan (1964, p.246) reported:

> A comparison of human alveolar bone with that of animals, such as dogs and monkies reveals that the alveolar bone in animals is frequently more dense. . . .The experiments furthermore reveal that a dense alveolar bone may cause delay in the resorbing process.

Statement of the Problem

On the basis of the foregoing discussion, it was decided that a clinical comparison of the rates of canine movement into recent and healed extraction sites might reveal some of the potential clinical advantages or disadvantages of early retraction.

METHODS

Sample

Six females and three males, 12 to 16 years of age, who required the removal of four first bicuspid teeth and distal retraction of the canines were randomly selected from 100 patients who presented themselves for orthodontic treatment at Case Western Reserve Department of Orthodontics. The nature of the study, its significance and its potential hazards were explained in detail to each subject and his or her parents. Permission was, in each case, granted in writing. (Appendix I)

The only criteria, other than consent, established for selection were: (1) the complete eruption of all teeth anterior to the first permanent molars, and (2) the necessity of first bicuspid extractions as determined by standard diagnostic procedures.

Experimental Design

A table of random numbers was used to assign treatments to the various patients. Table 1 illustrates the experimental design.

TABLE 1

EXPERIMENTAL DESIGN

Patient	Quadrant			
	Left		Right	
	Upper	Lower	Upper	Lower
5	x	x		
7	x	x		
8		x	x	
9		x	x	
3			x	x
4			x	x
6			x	x
1	x			x
2	x			x

x is the first bicuspid in each quadrant extracted first

Clinical Procedure

The first permanent molars, second bicuspids and cuspids were fitted with preformed bands (Rocky Mountain Dental; Denver, Colo.,). The cuspid and premolar bands were prewelded with .022 x .028 inch siamese edgewise brackets and the molar bands were prewelded with .022 inch buccal tubes. A lingual button was welded to the molar and bicuspid bands so that these teeth could be ligated together (.010 inch steel ligature wire) on both the buccal and lingual in order to gain anchorage potential and to achieve a reduction in the degree of rotations.

Two first permanent bicuspids in each patient were extracted. A section of .0215" x .0275" "rectangular" wire with a mesial molar stop and a distal cuspid stop

was placed at each extraction site to ensure that no closure took place (Erickson, Kaplan, Aisenberg, 1945; Revell,1964). After four weeks of healing, the remaining two first bicuspids in each patient were extracted. At this time the .0215"x .0275"rectangular "holding wires" were removed and all four sites in each patient received a .021"x .025"preformed sectional closing loop appliance (Model No. 356; Unitek Corp., Monrovia, Calif.). A molar stop was soldered to the appliance and the distal portion securely held in place with .010" steel ligature wire. With the aid of a tension guage (Dontrix-Richmond Orthodontic Stress and Tension Gage, Unitek,) each appliance was activated to 360 grams (12 oz) of force and fixed by a screw lock (Model No. A-226; Rocky Mountain Dental) mesial to the cuspid bracket. The anterior arm of the appliance was then ligated with .010" steel ligature wire with passive bracket engagement in an attempt to maintain the original tooth position (Plate 1-5).

One might question why the method described by Hixon and his associates (1970) was not used in the present study.[1] Several reasons may be offered: (1) It

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[1]The selection of a .021"x .025"rectangular wire closing loop for canine retraction presented a problem. Hixon et al. (1969) employed this type of appliance in an investigation of optimal forces. He discovered, however, that some of the variables introduced by tipping could not be controlled. Hixon et al.(1970) then conducted a second study in which the appliance of choice

PLATE 1

Frontal View - Teeth in Occlusion



PLATE 2

Occlusal View - Upper Arch

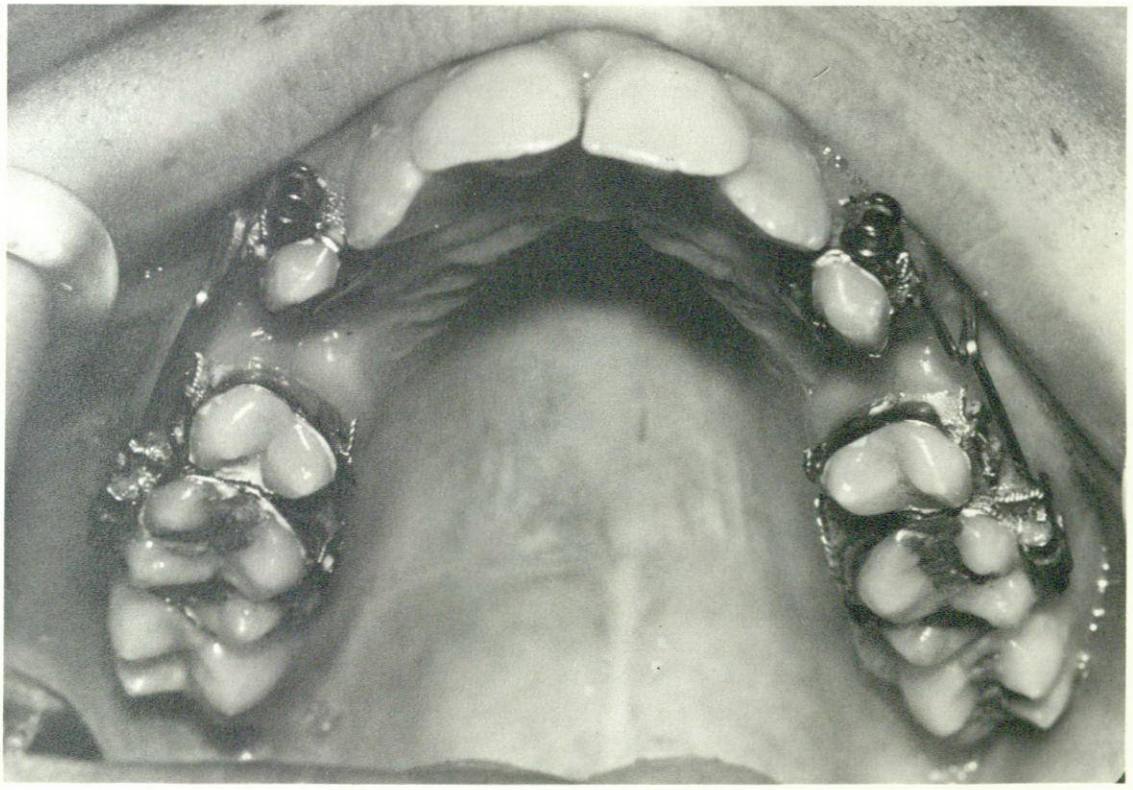


PLATE 3

Occlusal View - Lower Arch

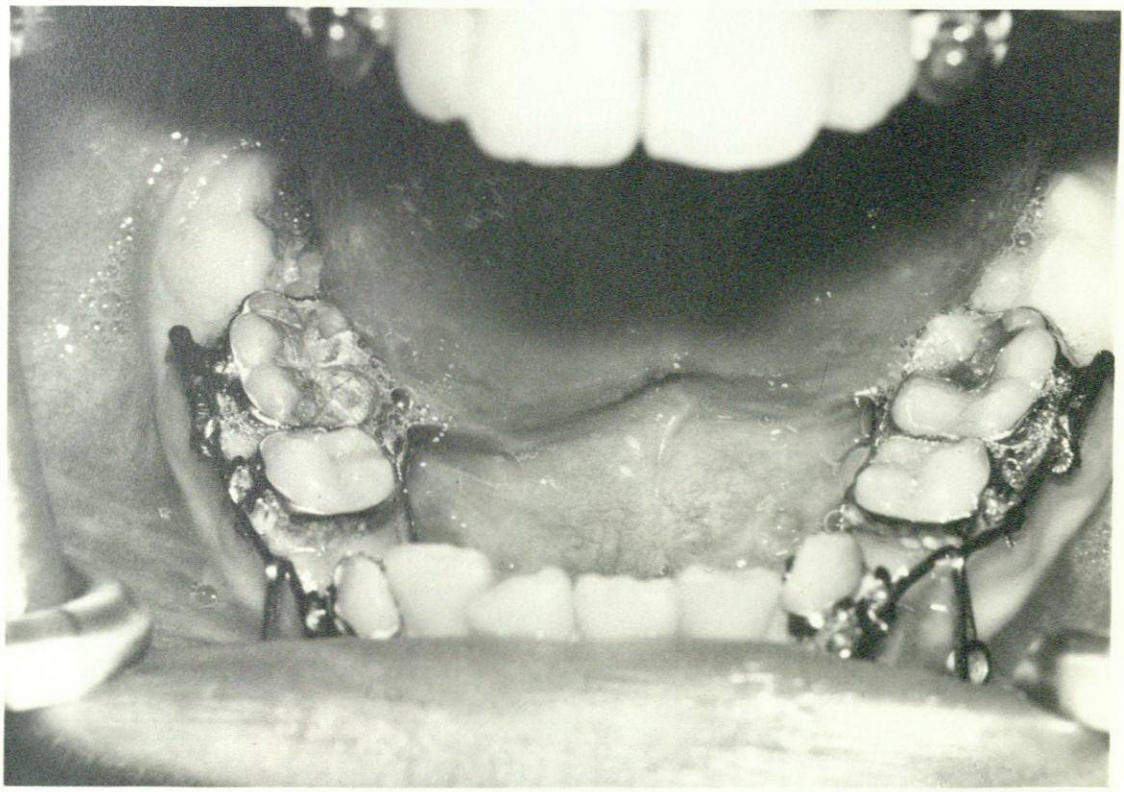


PLATE 4

Left Side - Teeth in Occlusion

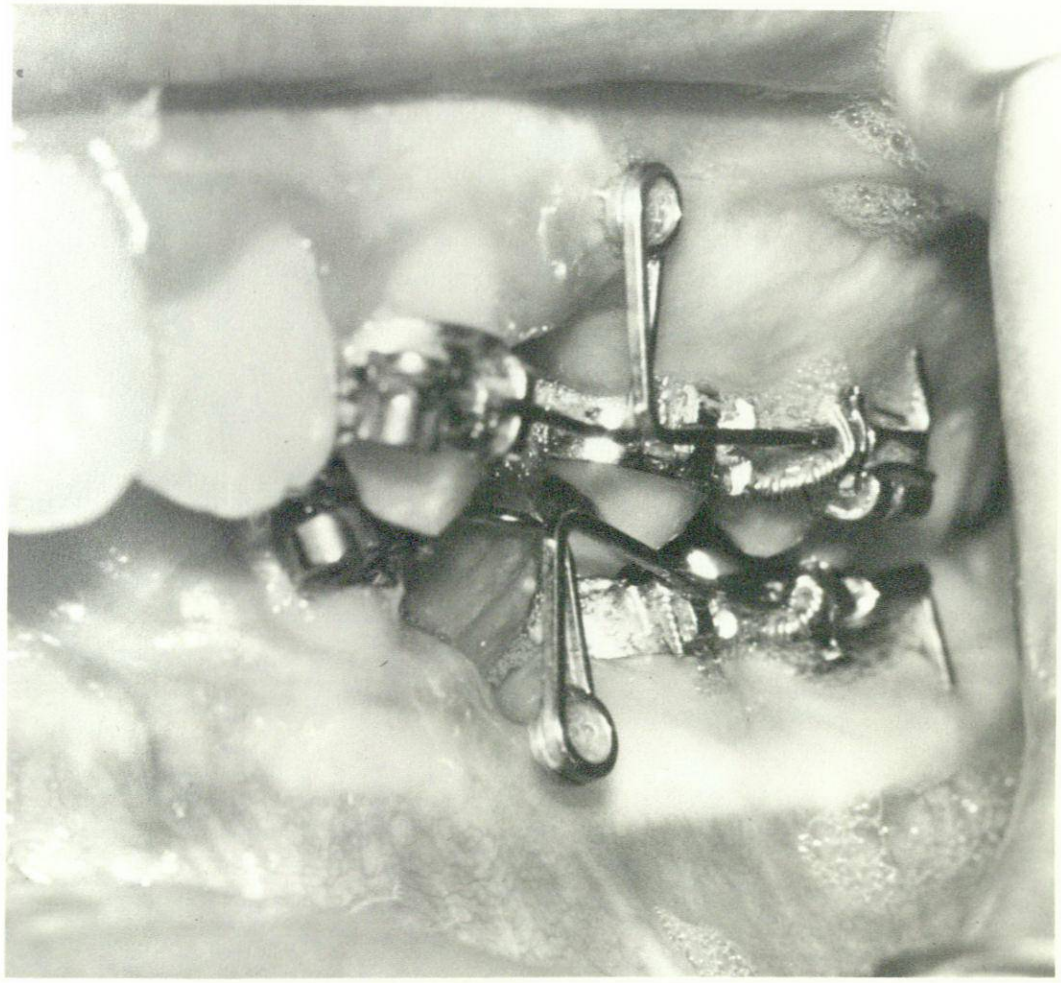
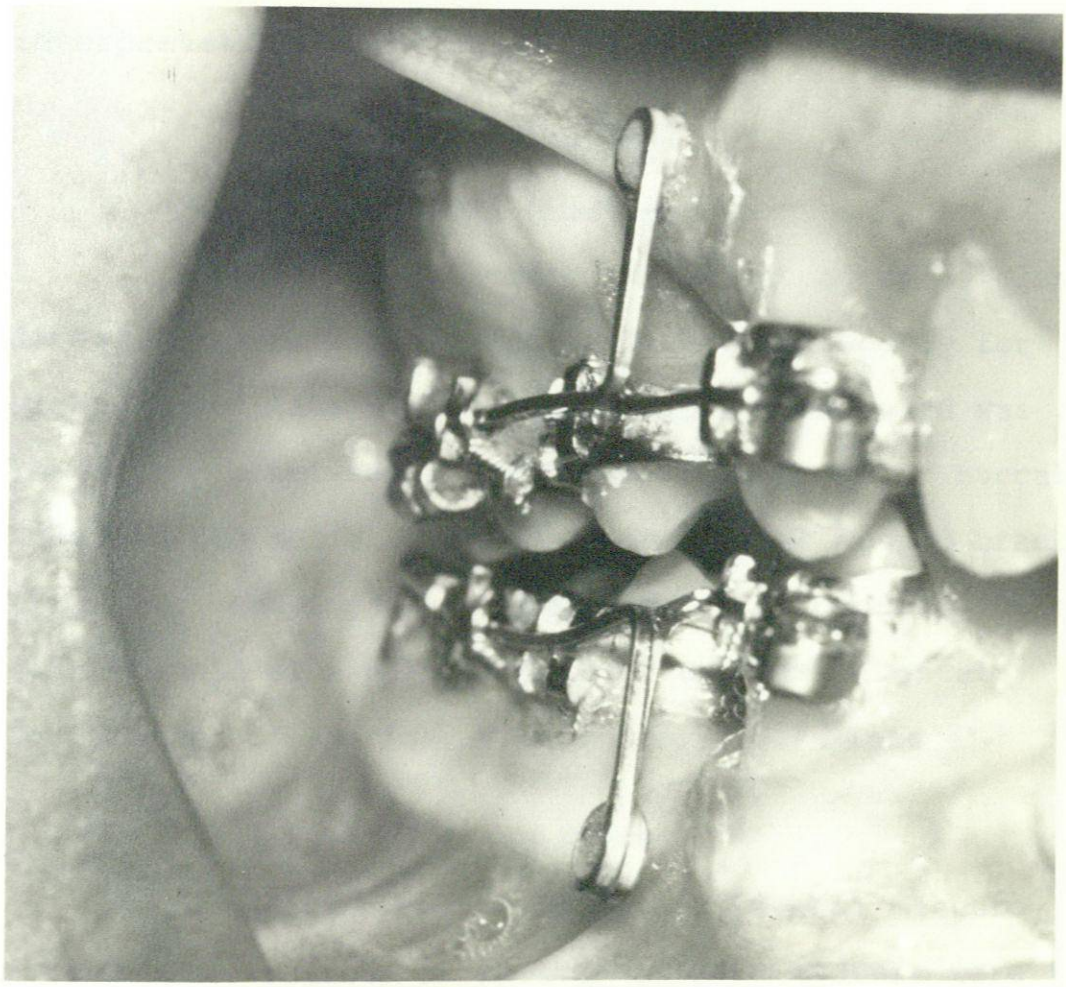


PLATE 5

Right Side - Teeth in Occlusion



was decided to approximate a usual clinical condition as closely as possible and to introduce an unusual procedure only in an attempt to avoid contamination of the data. (2) The sectional arch closing loop appliance constitues 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 weekly for eight consecutive weeks. The dimension measured was the distance between a notch cut into the molar buccal tube and the mesial surface of the distal cuspid bracket (Fig. 1). Readings were obtained to the nearest .01 mm with the aid of a pointed vernier caliper (Dental Corporation of America, Washington, D.C.) (Plate 6).

Study Casts

In addition to the direct intra-oral measurements, other methods of recording space closure were employed. Study casts were made at the begining and end

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consisted of two .045 inch round tubes soldered to the buccal and lingual surfaces of the posterior segments. The method of activation was elastic traction on both the buccal and lingual sides to control rotations. In spite of this rigid "rail" appliance they were unable to control tipping of all the teeth.

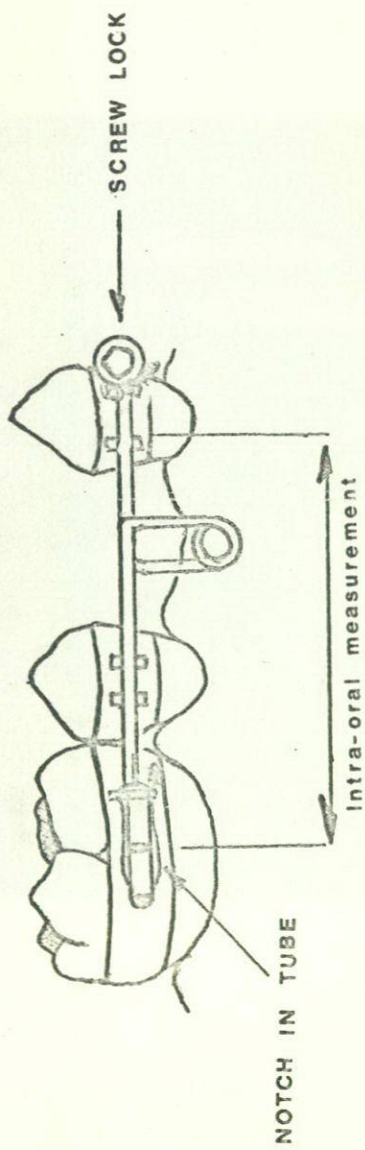
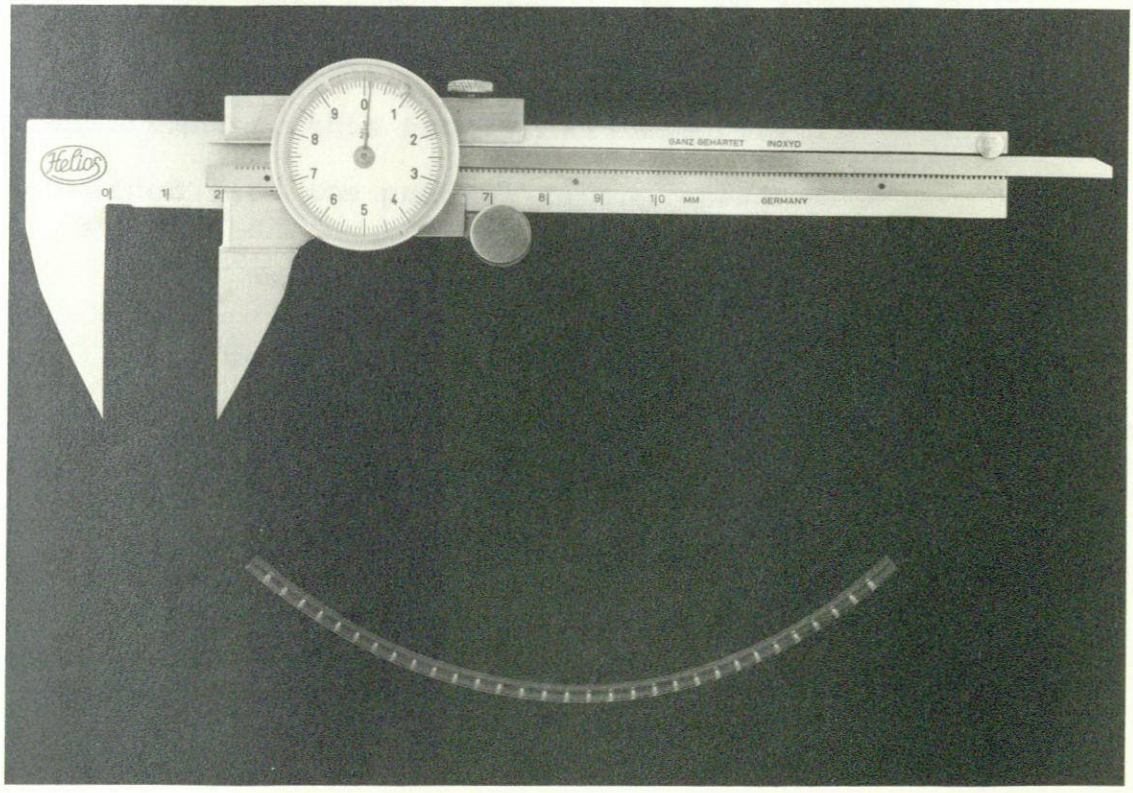


FIG.1 Intra-oral Recording Landmarks

PLATE 6

Vernier Caliper and Intra-Oral Grid


Helios
GANZ GEHÄRTET
INOXYD
MM
GERMANY

of the eight week experimental period. Anatomical reference points from the approximate centers of the cuspid and bicuspid were used to determine the amount of space closure. (Figure 2). Using these landmarks the rotational affects are, at least theoretically, eliminated. No attempt was made to determine whether the buccal segments moved mesially or the canines moved distally on either the study casts or the intra oral measurements; this problem was reserved for readings obtained from the panoral radiographs.

Panoral Radiographs

A cephlostat was used in an attempt to obtain reproducable head orientation (Conley, 1961; Hymer, 1965; Hauck, 1970) and an "intra-oral grid" (Digiulio, 1970) was used to quantitate distortions and magnifications.

The first panoral radiograph in each series was taken after all four first permanent bicuspids had been extracted but before any activation of the closing loop appliance had begun. A final radiograph was taken at the end of the experiment, eight weeks later. Originally an attempt was made to superimpose the panoral radiograph tracings on landmarks previously described in the literature (Hauck 1970), however, this author was unable to obtain reliable measurements. As a result, a different procedure was employed.

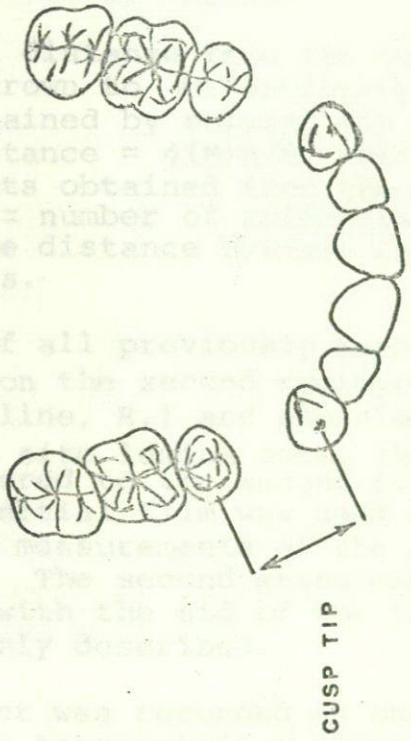


FIG. 2 Model Measurements

A tracing of the premolar, canine, extraction-site lamina dura, and other individual radiographic landmarks in the general vicinity of the extraction site were made for both initial and final radiographs. 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 bicuspid movements calculated by way of simple proportions. The procedure may be illustrated for bicuspids.

1. The actual distance from the center of the bicuspid crown to an arbitrary reference line, R, was obtained by solving the equation (Fig.3), Actual distance = 4(N)B/X, where B and X are measurements obtained from the panoral radiographs, N = number of intervals in dimension X, and 4 = the distance between intervals in millimeters.

2. Tracings of all previously described landmarks were made on the second radiograph (except the arbitrary line, R,) and superimposed on the extraction site lamina dura; the arbitrary line was transfered to the second film. This line from the initial film was used as the base line from which measurements of the second radiograph 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 (B - B'). Calculations for cuspids were executed in the same way (C - C'). The sum of the cuspid and bicuspid movement was taken as the total space closure, (B - B') + (C - C').

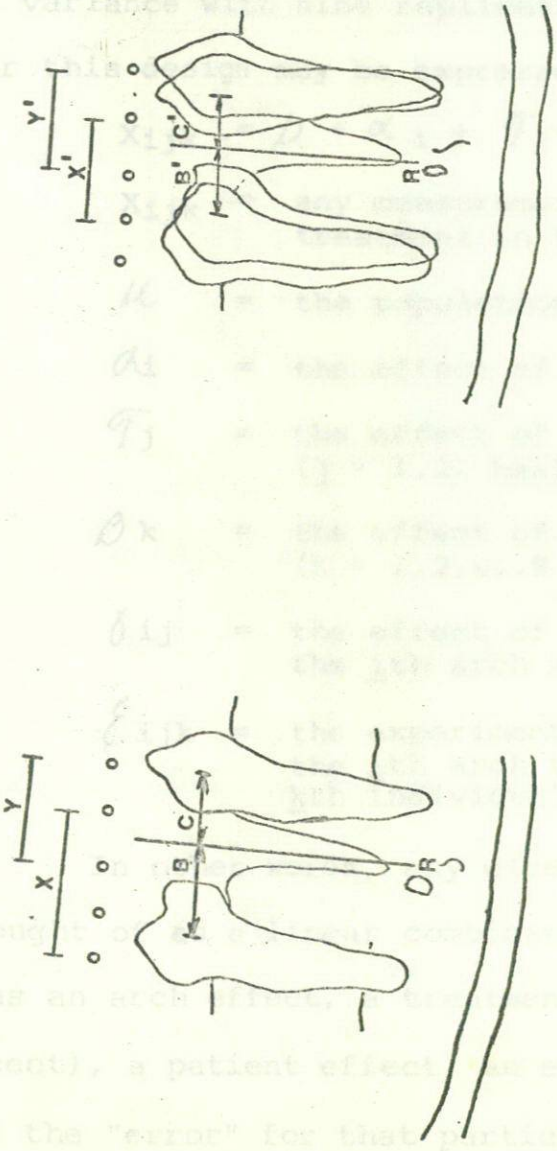


FIG. 3 Radiographic Method Procedure

Data Reduction

Calculations were performed on an electronic calculator (Model 9100A; Hewlett-Packard Co., Loveland, Col.) and its accompanying software. The statistical design employed was a randomized block, two way analysis of variance with nine replications. The linear model for this design may be expressed as

$$X_{ijk} = \mu + \alpha_i + \tau_j + \beta_k + \gamma_{ij} + \varepsilon_{ijk}$$ where,

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

μ = the population mean

α_i = the effect of the ith arch

τ_j = the effect of the jth treatment (j = 1,2- healed and recent

β_k = the effect of the kth block (k = 1,2,...9 - patients)

γ_{ij} = the effect of the interaction between the ith arch and jth treatment

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

In other words, any given measurement may be thought of as a linear combination of an overall mean plus an arch effect, a treatment effect (healed versus recent), a patient effect, an effect due to interaction, and the "error" for that particular determination.

Details of the experimental design and the calcul-

ations involved may be inferred from Tables 2,3.

TABLE 2

WORKSHEET FOR ANALYSIS OF VARIANCE

Patient	Arch			
	Maxillary		Mandibular	
	Healed	Recent	Healed	Recent
1	X_{121}	X_{111}	X_{221}	X_{211}
2	X_{122}	X_{112}	X_{222}	X_{212}
3	X_{123}	X_{113}	X_{223}	X_{213}
4	X_{124}	X_{114}	X_{224}	X_{214}
5	X_{125}	X_{115}	X_{225}	X_{215}
6	X_{126}	X_{116}	X_{226}	X_{216}
7	X_{127}	X_{117}	X_{227}	X_{217}
8	X_{128}	X_{118}	X_{228}	X_{218}
9	X_{129}	X_{119}	X_{229}	X_{219}

	Healed	Recent	Mean
Maxillary	$\bar{X}_{12.}$	$\bar{X}_{11.}$	$\bar{X}_{1..}$
Mandibular	$\bar{X}_{22.}$	$\bar{X}_{21.}$	$\bar{X}_{2..}$
Mean	$\bar{X}_{.2.}$	$\bar{X}_{.1.}$	$\bar{X}_{...}$ Grand Mean

$\bar{X}_{ij.}$ spans the Healed and Recent columns of the Maxillary and Mandibular rows; $\bar{X}_{i..}$ spans the Mean column of the Maxillary and Mandibular rows; $\bar{X}_{.j.}$ spans the Healed and Recent columns of the Mean row.

The results from the 36 quadrants were also examined from the standpoint of binomial probability. Accordingly it was assumed that the results in each quadrant were independent and had an equal likelihood ($p = q = .5$).

TABLE 3

ANALYSIS OF VARIANCE TABLE

Source	Degrees[a] of Freedom d_f	Sum of Squares (SSQ)	Mean Squares (MSQ)
Treatments	J-1=1	$\sum_{ijk}^{229} (\bar{X}.j.-\bar{X}...)^2$	$SSQ_{tr.}/1$
Arches	I-1=1	$\sum_{ijk}^{229} (\bar{X}i..-\bar{X}...)^2$	$SSQ_{arches}/1$
Interaction	3-2=1	Subtotal(Tr. + arches)	$SSQ_{intr}/1$
Subtotal	I(J-1)=3	$\sum_{ijk}^{229} (\bar{X}ij.-\bar{X}...)^2$	* *
Patients	K - 1=8	$\sum_{ijk}^{229} (\bar{X}..j-\bar{X}...)^2$	* *
Error	35-11=24	Total - (Subttl + Patients)	$SSQ_{error}/24$
Total	IJK - 1= 35	$\sum_{ijk}^{229} (\bar{X}_{ijk}-\bar{X}...)^2$	

[a] Number of treatments =J=2; Number of Arches=I=2; Number of Patients =K=9

$F_{(1,24)}tr = MSQ_{tr.}/MSQ_{error}$

$F_{(1,24)}arches = MSQ_{arches}/MSQ_{error}$

$F_{(1,24)}intr = MSQ_{intr}/MSQ_{error}$

$F_{(1,24).95} = 4.26$

RESULTS

The results of the present investigation will be presented under three headings: (1) intra-oral measurements, (2) model measurements, (3) determinations from panoral radiographs.

Intra-Oral

General

All patients showed the same general pattern of tooth movement; the relationship between average movement and time is presented in Fig. 4 and Table 4.

TABLE 4

INTRA-ORAL MEASUREMENTS
AVERAGE SPACE CLOSURE

(millimeters/week)

Week	Arch			
	Maxillary		Mandibular	
	Healed	Recent	Healed	Recent
1	1.11	.79	1.09	.83
2	.53	.40	.33	.34
3	.42	.38	.35	.33
4	.60	.49	.53	.53
5	.69	.65	.61	.68
6	.92	.82	.73	.77
7	.89	.83	.85	.85
8	.90	.79	.73	.75

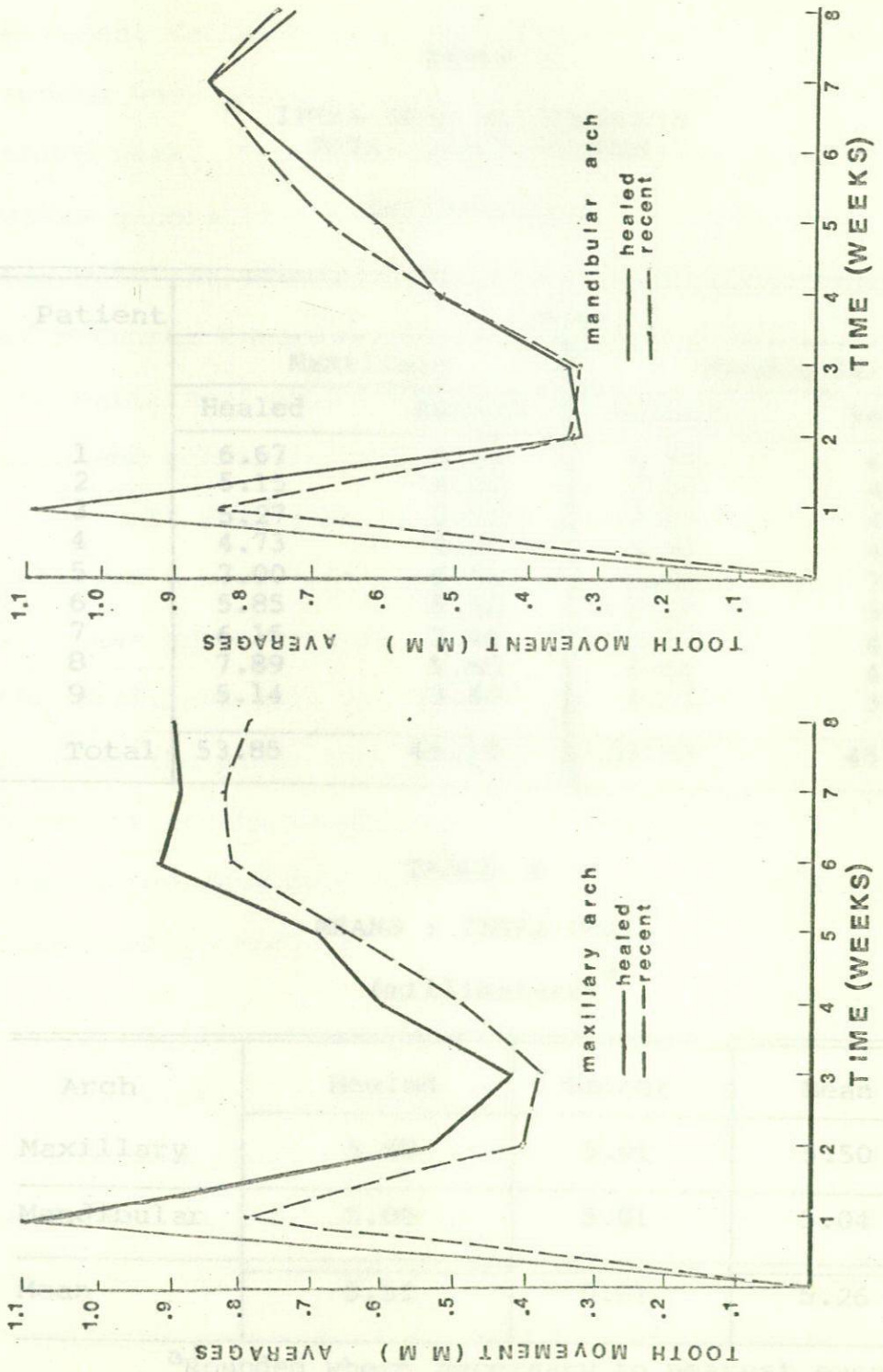


Fig. 4 Average Weekly Tooth Movement

Individual totals and means are shown in Tables 5,6.

TABLE 5

INTRA-ORAL MEASUREMENTS
TOTAL SPACE CLOSURE

(millimeters)

Patient	Arch			
	Maxillary		Mandibular	
	Healed	Recent	Healed	Recent
1	6.67	5.66	6.89	6.84
2	5.15	4.30	5.60	4.63
3	5.27	3.92	3.85	4.70
4	4.73	4.57	4.45	4.90
5	7.00	6.96	5.80	7.45
6	5.85	5.58	5.72	5.35
7	6.15	5.05	4.10	4.52
8	7.89	5.66	5.04	4.30
9	5.14	3.40	4.12	3.49
Total	53.85	45.10	45.57	45.18

TABLE 6

MEANS : INTRA-ORAL

(millimeters)[a]

Arch	Healed	Recent	Mean
Maxillary	5.98	5.01	5.50
Mandibular	5.06	5.01	5.04
Mean	5.52	5.01	5.26

[a]Rounded where necessary to nearest even hundredth

There was an initial phase of very rapid tooth movement followed by a "lag phase" begining with the second week and continuing until the begining of the third week. From the third through sixth week there was a generalized increase in rate of movement. Beginning with the seventh through the eight week, the rate of movement remained the same or decreased slightly. The pattern of movement was similar in both the mandibular and maxillary arches.

It should be noted that the maxillary arch followed a more definite pattern while the mandibular arch was more variable. The average weekly movement of the maxillary arch was greater on the healed side for each of the eight consecutive weeks. The average movement of the mandibular arch was greater during weeks one, three, and four but equal, or less in the remaining five week period.

Comparative Description

Figures 5-13 illustrate the individual weekly cummulative space closure in each quadrant, on each patient. Tables 7-10 summarize these results. Generally speaking, each patient tended to show a definite uniformity of movement, i.e. healed sites moved more than recent extraction sites. There was a greater total amount of movement on the healed side in all nine patients

TABLE 7

HEALED SITE SPACE CLOSURE
MAXILLARY ARCH

(millimeters)

Week	Patient								
	1	2	3	4	5	6	7	8	9
1	1.37	.90	.96	.87	1.15	.55	1.55	1.24	1.27
2	.60	.30	.73	.58	.50	.54	.55	.75	.45
3	.34	.15	.25	.50	.55	.41	.35	.66	.38
4	.59	.30	.55	.35	.95	.75	.65	.92	.31
5	.90	.45	.55	.20	.85	.65	.75	1.14	.59
6	.97	1.10	.73	.85	1.20	.75	.70	1.13	.65
7	.73	.80	.78	.78	.85	1.20	.95	.95	.85
8	1.17	1.15	.70	.60	.95	1.00	.65	1.10	.64
Total	6.67	5.15	5.27	4.73	7.00	5.85	6.15	7.89	5.14

TABLE 8

RECENT SITE SPACE CLOSURE
MAXILLARY ARCH
(millimeters)

Week	Patient								
	1	2	3	4	5	6	7	8	9
1	1.16	1.05	.72	.50	.66	.35	1.00	.79	.80
2	.45	.00	.30	.55	.60	.53	.25	.52	.31
3	.69	.45	.18	.15	.56	.42	.35	.41	.00
4	.59	.30	.17	.52	.79	.58	.30	.77	.04
5	.67	.41	.40	.68	.95	.77	.53	.79	.40
6	1.10	1.00	.53	.45	1.00	.73	.77	.88	.65
7	.70	.29	.92	.90	1.20	1.10	.75	.75	.95
8	.30	.80	.70	.82	1.20	1.10	1.10	.75	.25
Total	5.66	4.30	3.92	4.57	6.96	5.58	5.05	5.66	3.40

TABLE 9

HEALED SITE SPACE CLOSURE
MANDIBULAR ARCH

(millimeters)

Week	Patient								
	1	2	3	4	5	6	7	8	9
1	1.34	1.11	.74	.80	1.37	.92	1.45	1.04	.75
2	.25	.35	.26	.28	.36	.30	.00	.75	.40
3	.50	.74	.00	.37	.10	.41	.15	.40	.11
4	.51	.41	.45	.50	.62	.79	.35	.35	.77
5	.96	.47	.60	.50	1.00	.60	.65	.27	.22
6	1.08	.52	.70	.60	.55	.90	.30	.98	.90
7	1.10	.85	.50	.77	.90	1.10	.70	.80	.60
8	1.15	1.15	.60	.63	.90	.70	.50	.45	.37
Total	6.89	5.60	3.85	4.45	5.80	5.72	4.10	5.04	4.12

TABLE 10

RECENT SITE SPACE CLOSURE
MANDIBULAR ARCH

(millimeters)

Week	Patient								
	1	2	3	4	5	6	7	8	9
1	1.19	.93	.65	.45	1.00	1.07	1.01	.80	.19
2	.10	.25	.53	.45	.80	.14	.00	.44	.55
3	.80	.00	.72	.35	.51	.36	.04	.62	.20
4	.43	.71	.45	.80	.87	.34	.55	.36	.16
5	.82	.29	.43	.30	1.17	.69	.60	.43	.77
6	.90	.80	.72	.80	.85	.53	.82	.73	.70
7	1.20	.75	.70	.75	1.15	.62	.90	.60	.82
8	1.40	.90	.50	1.00	1.10	.60	.60	.32	.10
Total	6.84	4.63	4.70	4.90	7.45	4.35	4.52	4.30	3.49

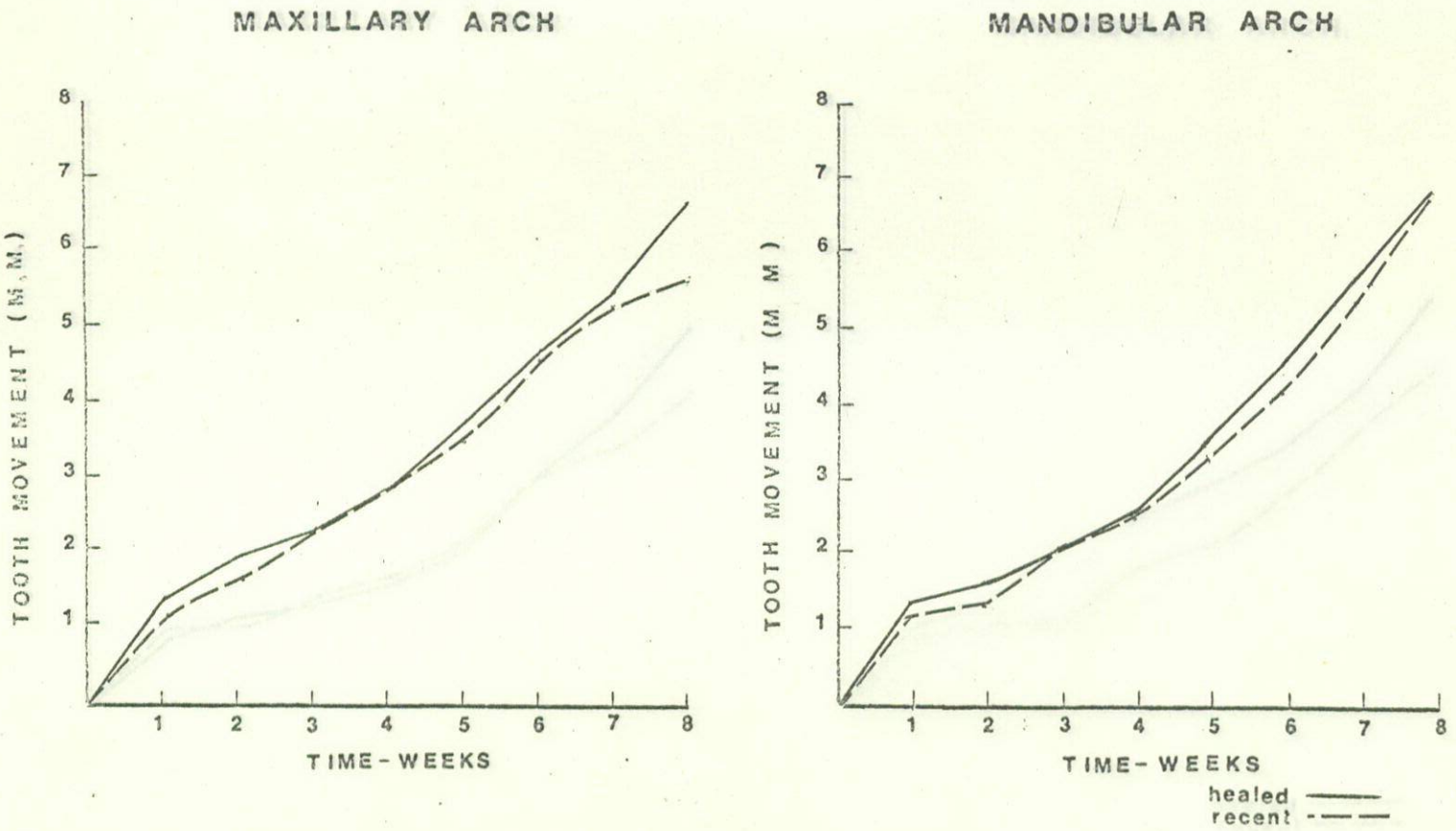


Figure 5. Weekly Cumulative Space Closure - Patient 1

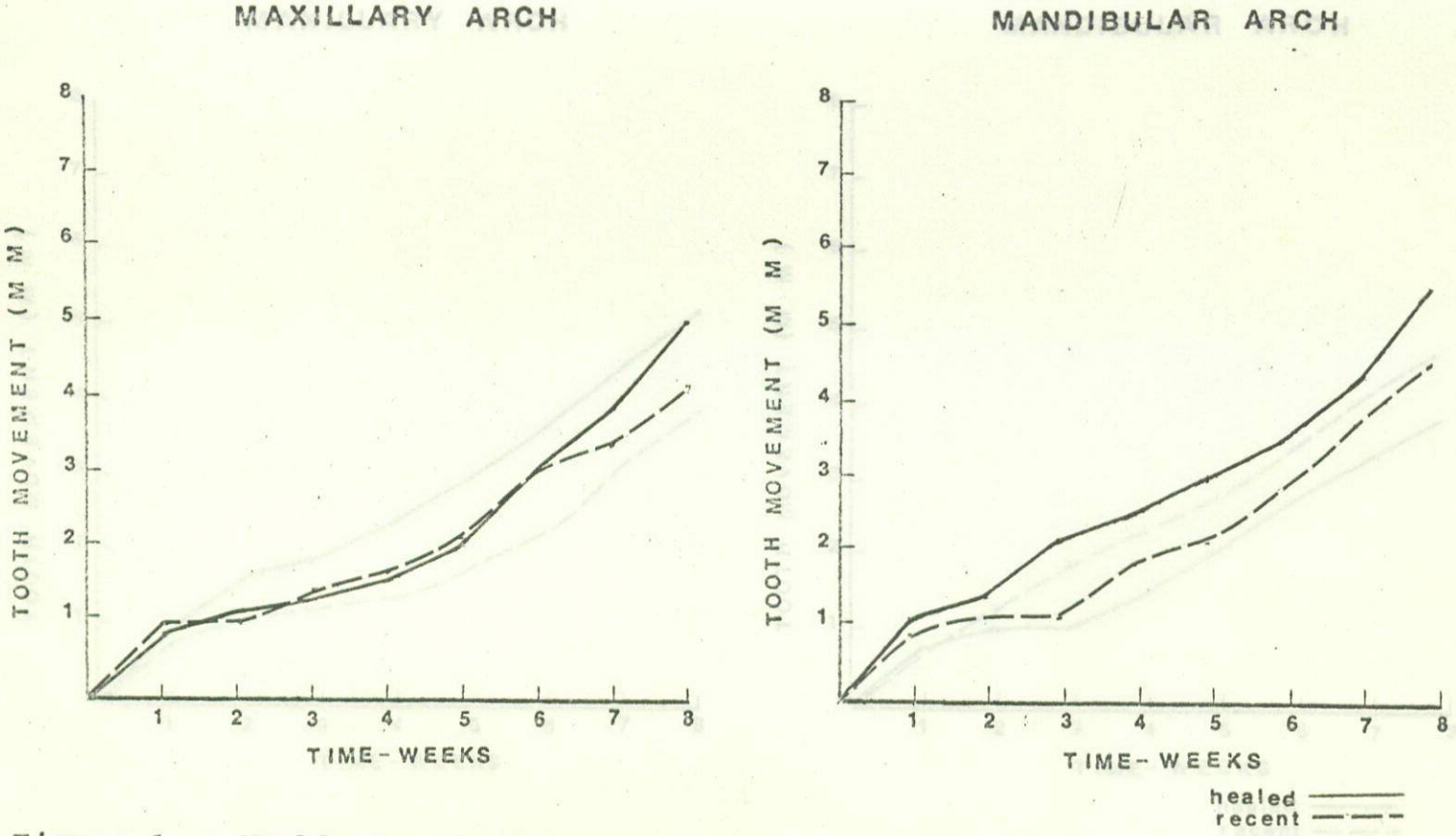


Figure 6. Weekly Cumulative Space Closure - Patient 2

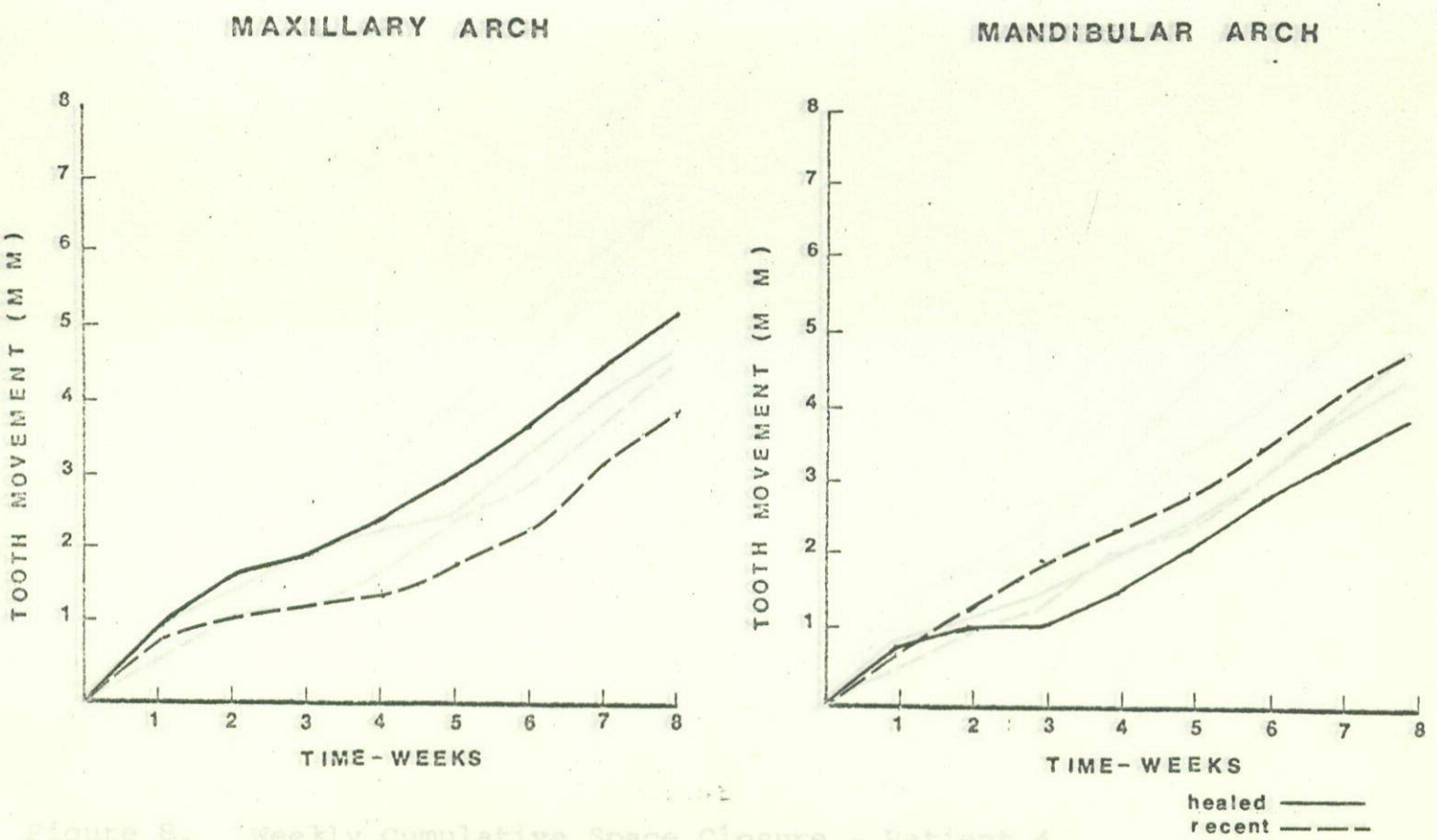


Figure 7. Weekly Cumulative Space Closure - Patient 3

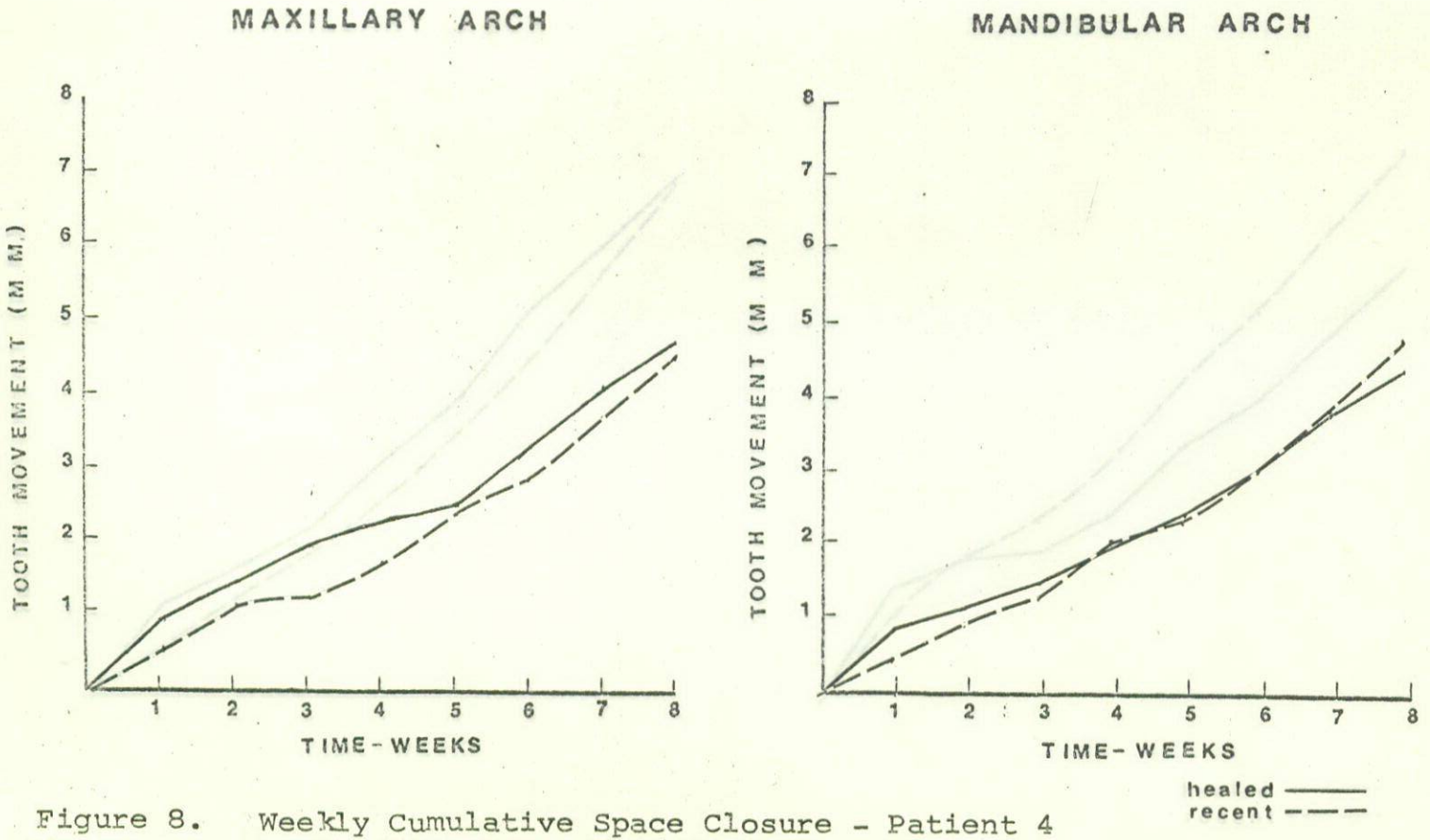


Figure 8. Weekly Cumulative Space Closure - Patient 4

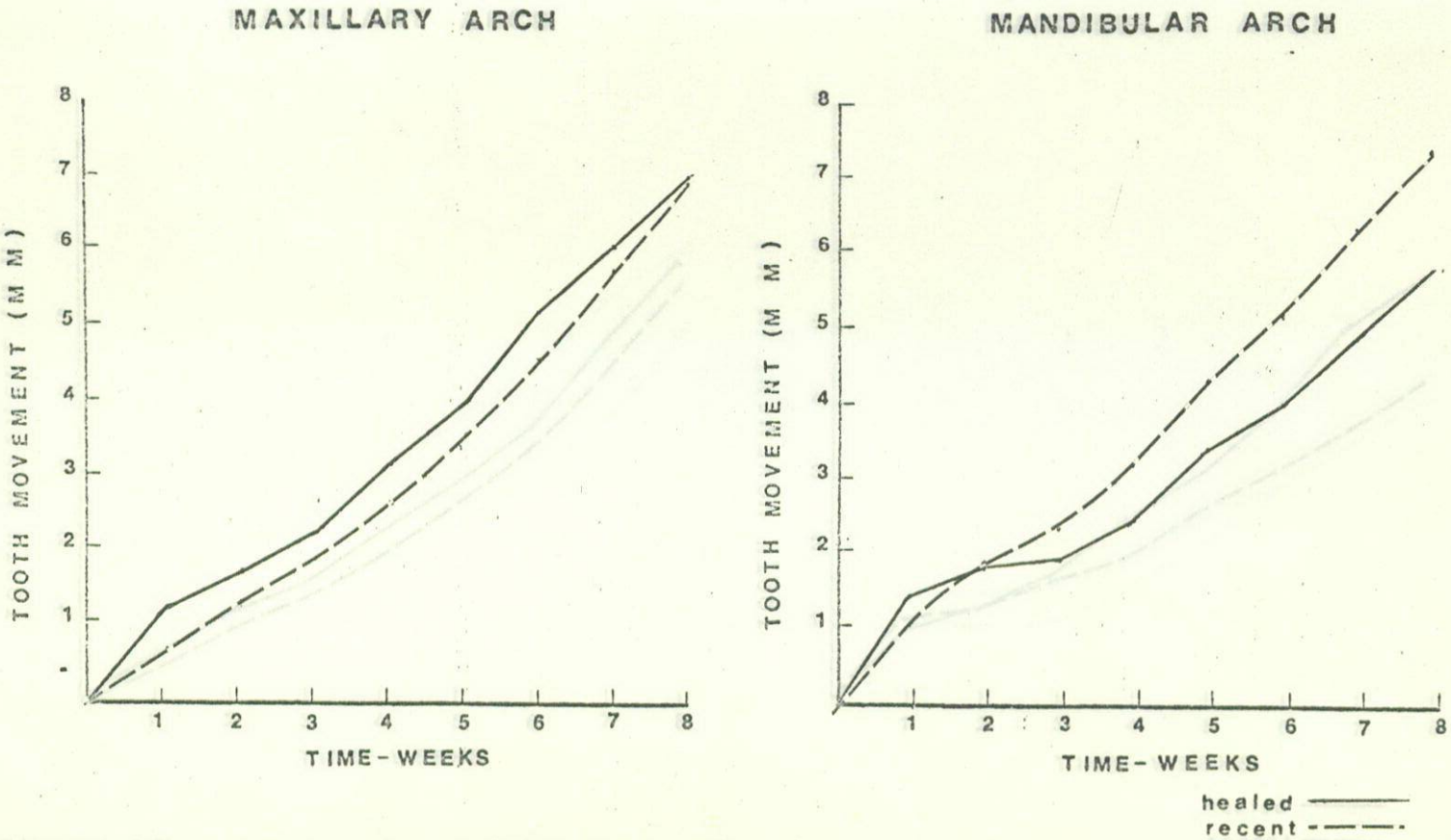


Figure 9. Weekly Cumulative Space Closure - Patient 5

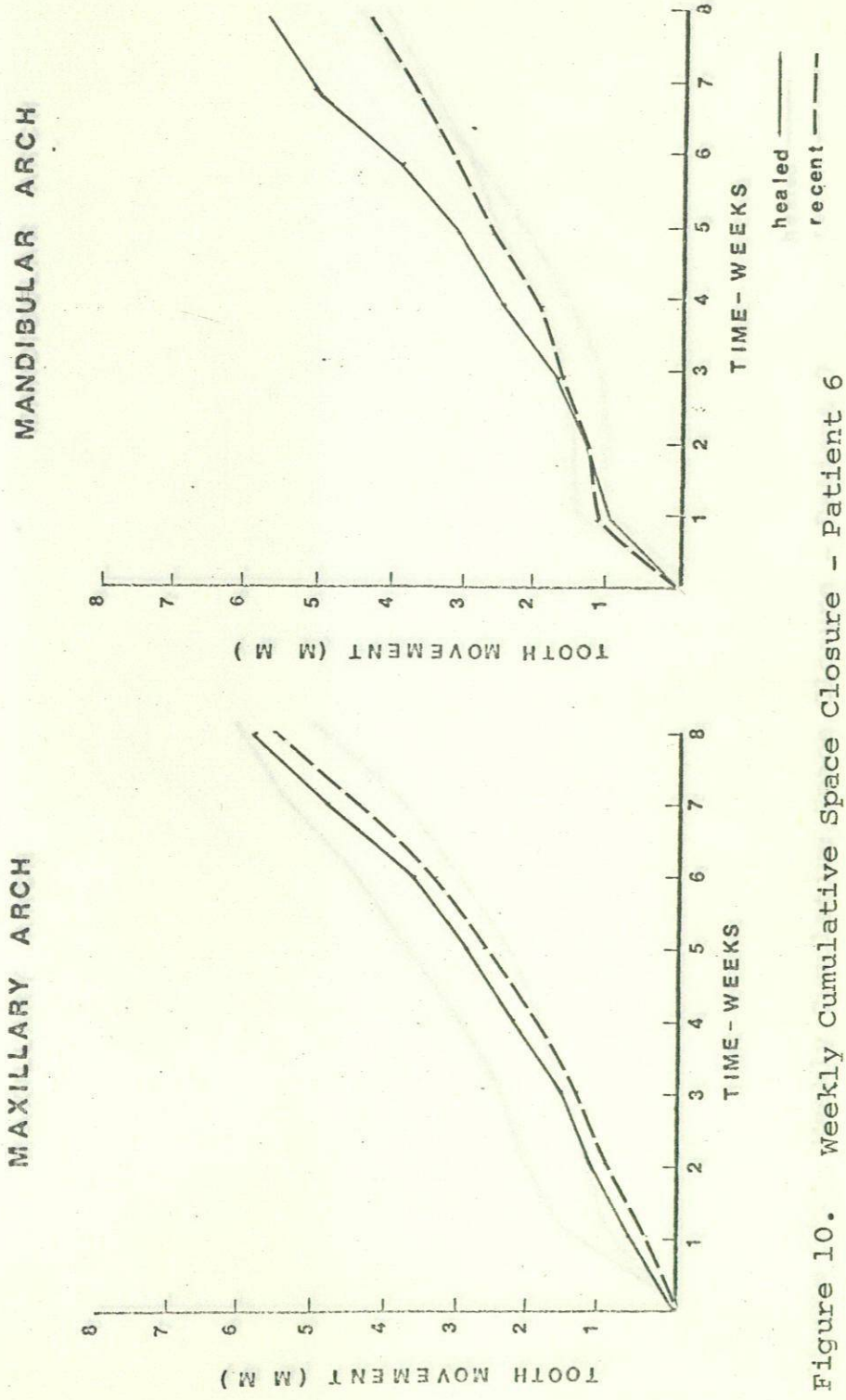


Figure 10. Weekly Cumulative Space Closure - Patient 6

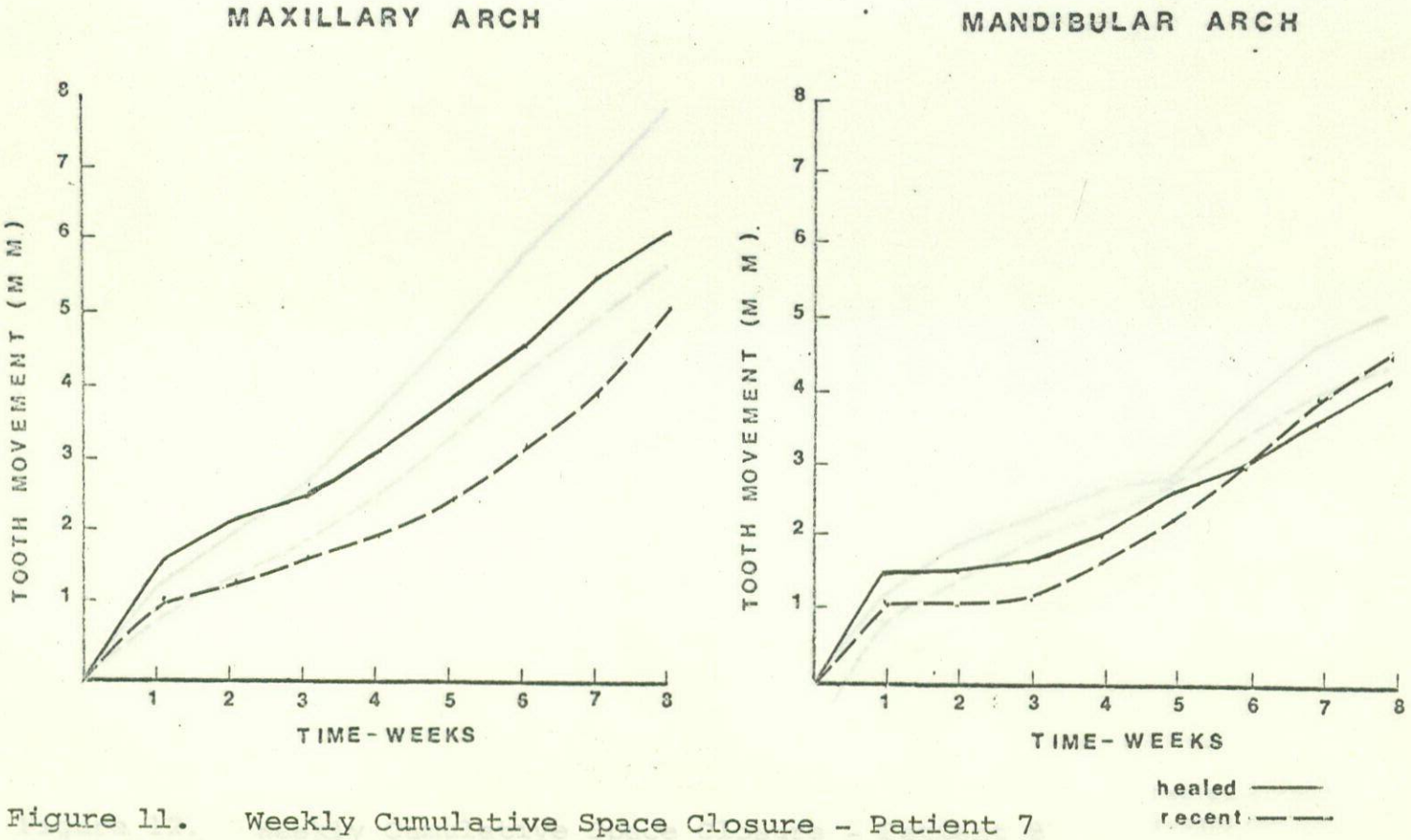


Figure 11. Weekly Cumulative Space Closure - Patient 7

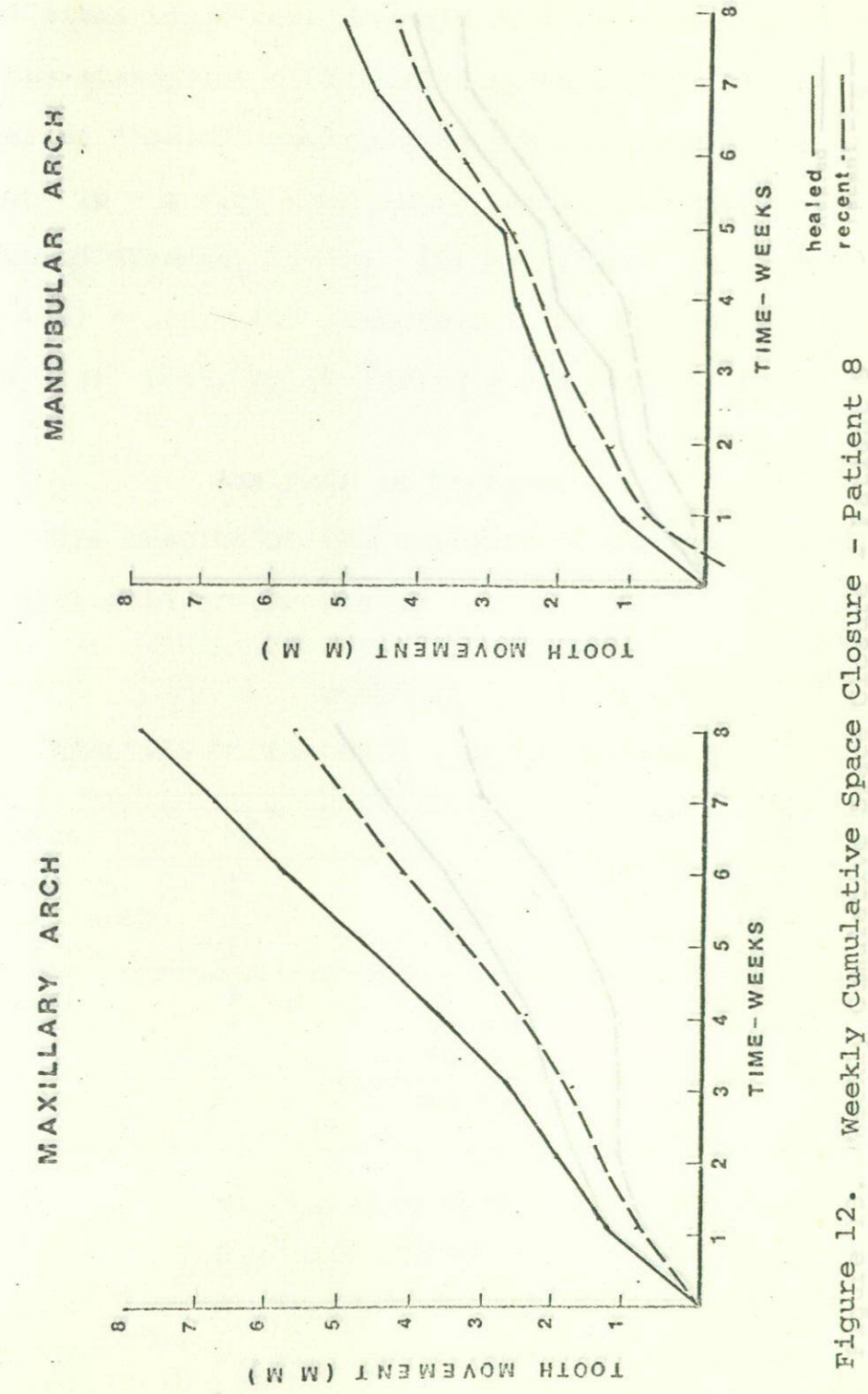


Figure 12. Weekly Cumulative Space Closure - Patient 8

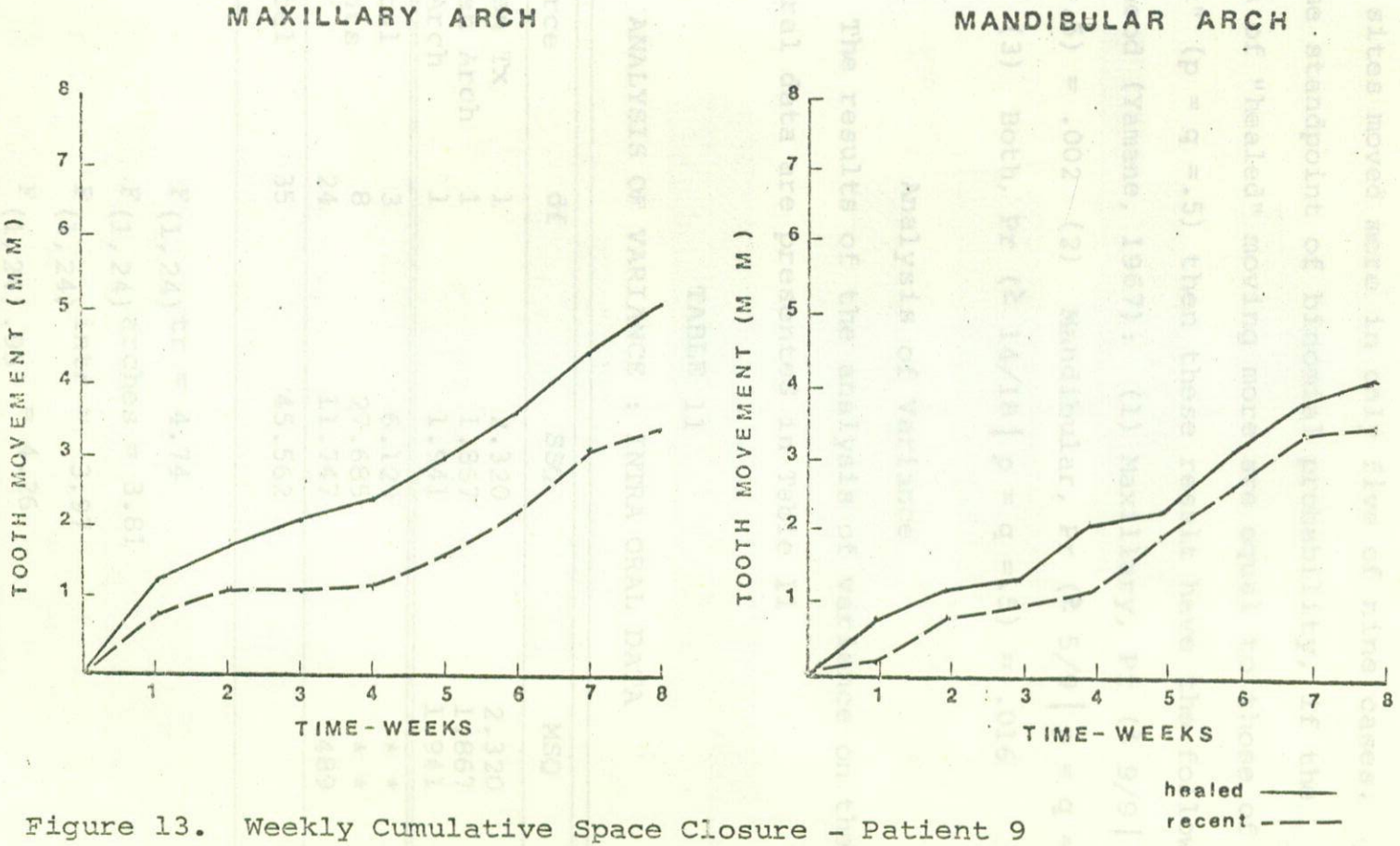


Figure 13. Weekly Cumulative Space Closure - Patient 9

in the maxillary arch but in the mandibular arch the healed sites moved more in only five of nine cases. From the standpoint of binomial probability, if the chances of "healed" moving more are equal to those of "recent" ($p = q = .5$) then these result have the following likelihood (Yamane, 1967): (1) Maxillary, $Pr(\geq 9/9 \mid p = q = .5) = .002$ (2) Mandibular, $Pr(\geq 5/9 \mid p = q = .5) = .500$ (3) Both, $Pr(\geq 14/18 \mid p = q = .5) = .016$

Analysis of Variance

The results of the analysis of variance on the intra-oral data are presented in Table 11

TABLE 11

ANALYSIS OF VARIANCE : INTRA ORAL DATA

Source	df	SSQ	MSQ
Between Tx	1	2.320	2.320
Between Arch	1	1.867	1.867
Tx X Arch	1	1.941	1.941
Subtotal	3	6.129	* *
Patients	8	27.685	* *
Error	24	11.747	.489
Total	35	45.562	

$F_{(1,24)}tr = 4.74$

$F_{(1,24)}arches = 3.81$

$F_{(1,24)}intr = 3.97$

$F_{(1,24).95} = 4.26$

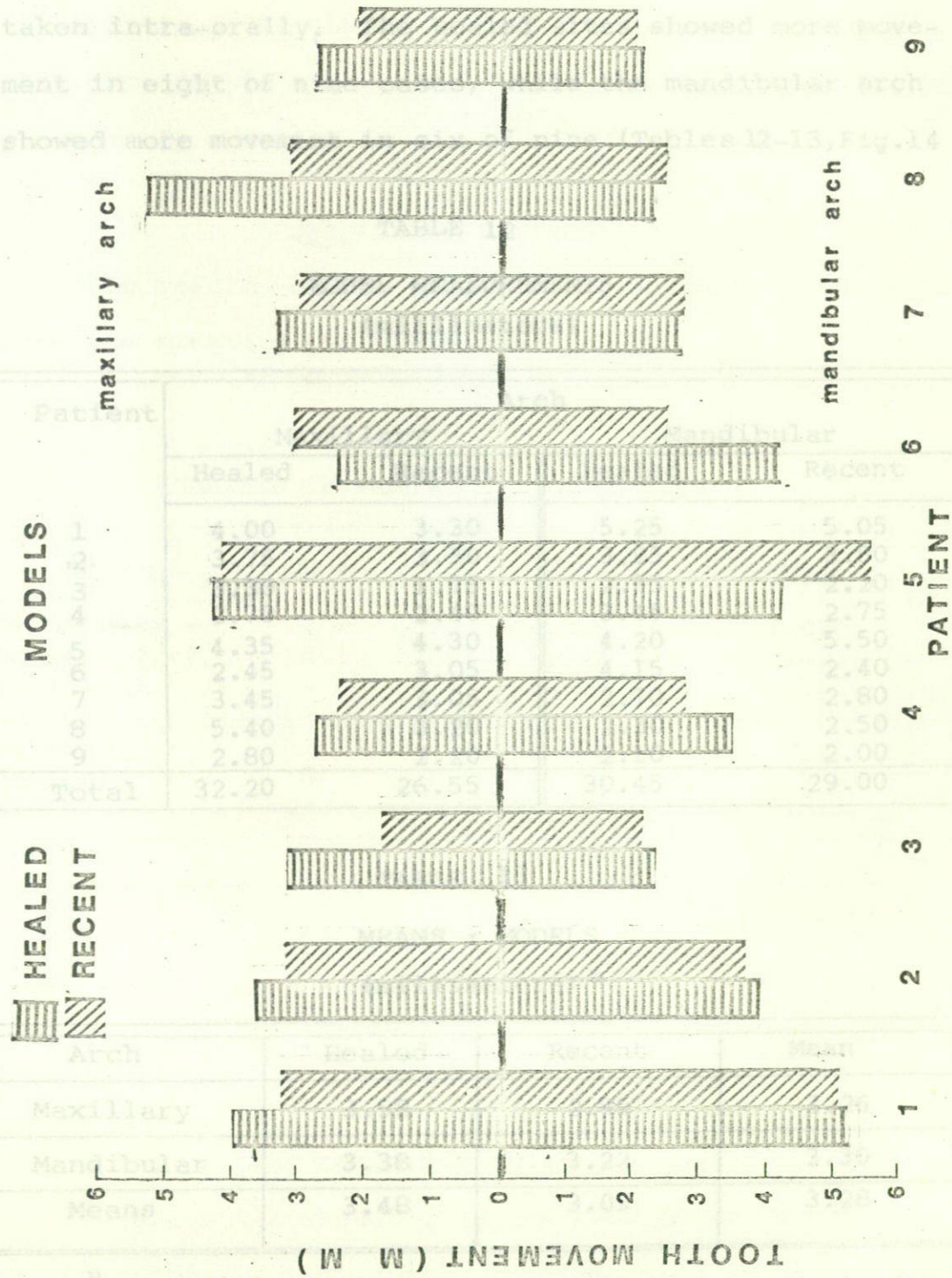


Figure 14. Total Movement : Models

Model Measurements

The model measurements closely parallel those taken intra-orally. The healed sites showed more movement in eight of nine cases, while the mandibular arch showed more movement in six of nine (Tables 12-13, Fig. 14

TABLE 12

MODEL MEASUREMENTS
(millimeters)

Patient	Arch			
	Maxillary		Mandibular	
	Healed	Recent	Healed	Recent
1	4.00	3.30	5.25	5.05
2	3.75	3.30	3.95	3.80
3	3.30	1.75	2.35	2.20
4	2.70	2.40	3.45	2.75
5	4.35	4.30	4.20	5.50
6	2.45	3.05	4.15	2.40
7	3.45	3.05	2.70	2.80
8	5.40	3.20	2.30	2.50
9	2.80	2.20	2.10	2.00
Total	32.20	26.55	30.45	29.00

TABLE 13

MEANS : MODELS
(millimeters) [a]

Arch	Healed	Recent	Mean
Maxillary	3.58	2.95	3.26
Mandibular	3.38	3.22	3.30
Means	3.48	3.09	3.28

[a] Rounded where necessary to nearest even hundredth

Given the assumption of equal likelihood, these results have the following probability (Yamane, 1967): (1) Maxillary, Pr ($\geq 8/9 \mid p = q = .5$) = .020, (2) Mandibular, Pr ($\geq 6/9 \mid p = q = .5$) = .254, (3) Both, Pr ($\geq 14/18 \mid p = q = .5$) = .016.

Analysis of Variance

The results of the analysis of variance on the model data are presented in Table 14.

TABLE 14

ANALYSIS OF VARIANCE : MODEL DATA

Source	df	SSQ	MSQ
Between Tx	1	1.016	1.016
Between Arch	1	.001	.001
Tx X Arch	1	.765	.765
Subtotal	3	1.784	* *
Patients	8	22.418	* *
Error	24	12.307	.512
Total	35	36.510	

$F_{(1,24)}tr = 1.98$

$F_{(1,24)}arches = .002$

$F_{(1,24)}intr = 1.49$

$F_{(1,24).95} = 4.26$

Panoramic Radiographs

The total amount of space closure as recorded on the panoramic radiographs is summarized in Tables 15,16.

TABLE 15

PANORAMIC RADIOGRAPHS MEASUREMENTS

(millimeters)

Patient	Arch			
	Maxillary		Mandibular	
	Healed	Recent	Healed	Recent
1	4.09	4.13	6.12	4.99
2	1.97	3.56	4.90	3.06
3	3.44	1.63	2.80	2.74
4	3.66	3.39	5.43	3.57
5	5.56	4.33	3.87	7.32
6	1.45	4.12	4.34	3.29
7	2.96	3.26	2.30	2.64
8	5.25	2.82	2.50	3.20
9	3.38	3.55	4.39	2.53
Total	31.76	30.79	36.65	33.34

TABLE 16

MEANS : PANORAMIC RADIOGRAPHS

(millimeters)[a]

Arch	Healed	Recent	Mean
Maxillary	3.53	3.42	3.48
Mandibular	4.07	3.70	3.84
Means	3.80	3.56	3.68

[a]Rounded where necessary to nearest even hundredth

The pattern that emerges is as follows (Fig. 1 (1) the maxillary healed site showed more movement in four of nine situations, (2) the mandibular healed site showed more movement in six of nine.

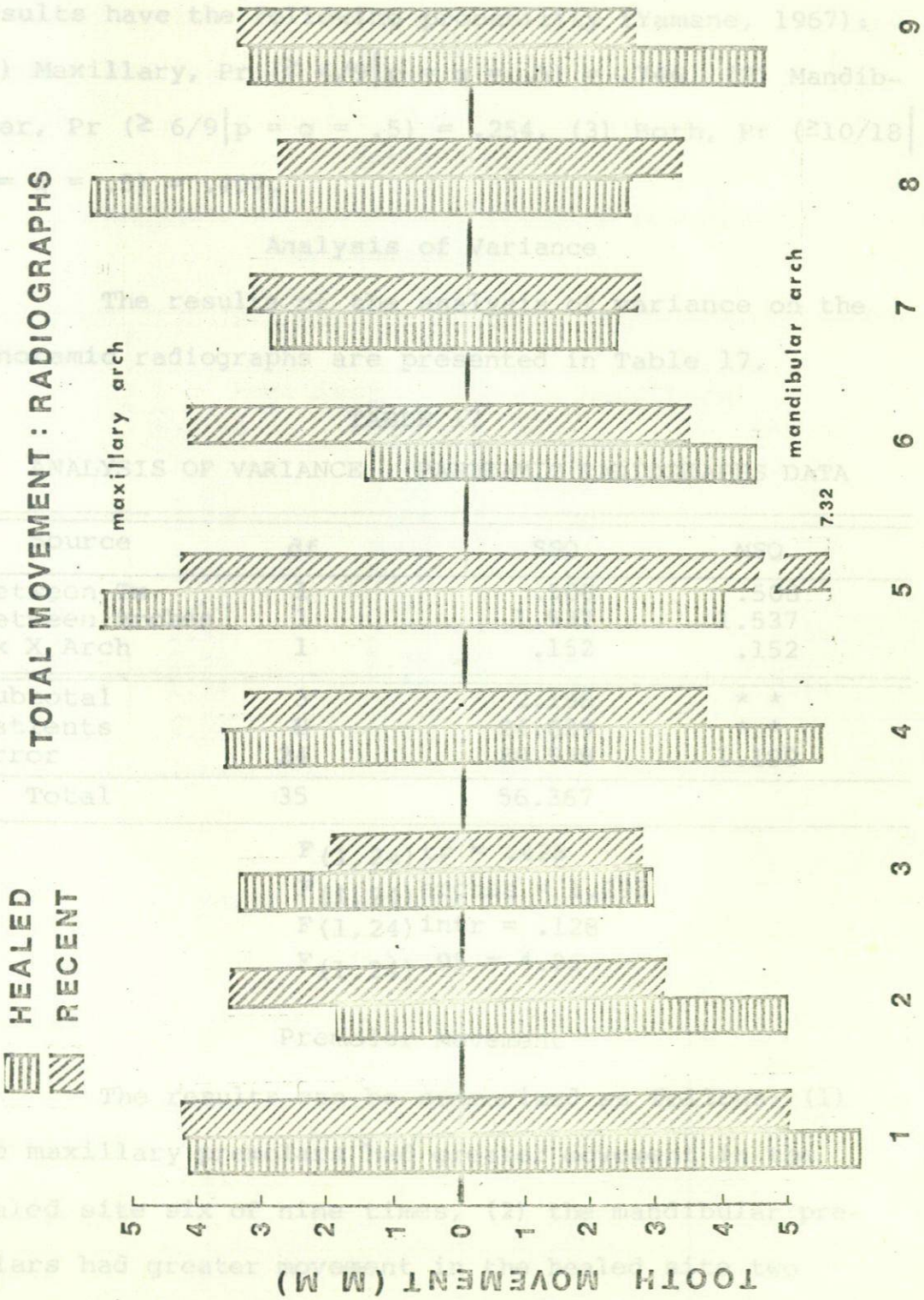


Figure 15. Total Movement : Radiographs

Given the assumption of equal likelihood, these results have the following probability (Yamane, 1967): (1) Maxillary, Pr ($\geq$ 4/9$|$ p = q = .5) = .746, (2) Mandibular, Pr ($\geq$ 6/9$|$p = q = .5) = .254, (3) Both, Pr ($\geq$10/18$|$ p = q = .5) = .407.

Analysis of Variance

The results of the analysis of variance on the panoramic radiographs are presented in Table 17.

TABLE 17

ANALYSIS OF VARIANCE : PANORAMIC RADIOGRAPHS DATA

Source	df	SSQ	MSQ
Between Tx	1	.508	.508
Between Arches	1	1.537	1.537
Tx X Arch	1	.152	.152
Subtotal	3	2.198	* *
Patients	8	24.629	* *
Error	24	28.538	1.189
Total	35	56.367	

$F_{(1,24)}$tr = .428
$F_{(1,24)}$arches = 1.293
$F_{(1,24)}$intr = .128
$F_{(1,24)}$.95 = 4.26

Premolar Movement

The results can be summarized as follows: (1) the maxillary premolars had greater movement in the healed site six of nine times, (2) the mandibular premolars had greater movement in the healed site two

of nine cases. In summary there was greater premolar movement in the healed side eight of a possible eighteen times. The results are presented in Tables 18,19, Fig. 16.

TABLE 18

PANORAMIC RADIOGRAPHS : PREMOLAR MOVEMENT
(millimeters)

Patient	Arch			
	Maxillary		Mandibular	
	Healed	Recent	Healed	Recent
1	2.65	.76	1.58	2.28
2	1.o7	2.95	2.75	1.86
3	2.13	.66	.90	1.80
4	1.16	2.09	1.64	1.71
5	3.72	3.35	2.89	2.10
6	.69	1.80	1.55	1.67
7	2.59	2.09	.71	2.34
8	2.86	1.38	2.07	2.23
9	1.94	1.55	1.74	2.14
Total	19.24	16.63	15.82	18.13

TABLE 19

MEANS : PREMOLAR MOVEMENT

(millimeters)[a]

Arch	Healed	Recent	Mean
Maxillary	2.14	1.85	1.95
Mandibular	1.76	2.01	1.89
Means	1.95	1.93	1.92

[a]Rounded where necessary to nearest even hundredth

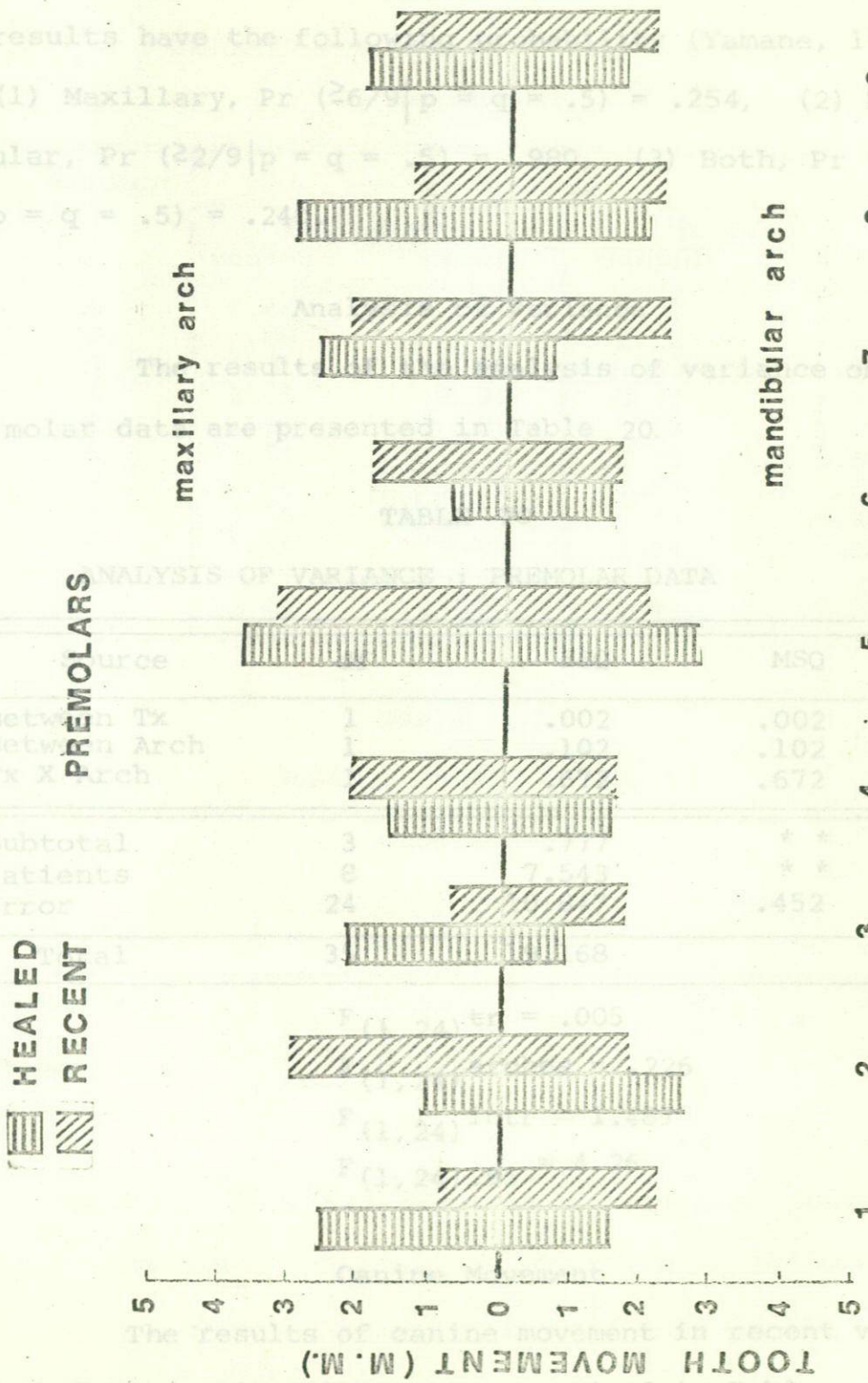


Figure 16. Total Movement - Premolars

Given the assumption of equal likelihood, these results have the following probability (Yamane, 1967): (1) Maxillary, Pr ($\geq 6/9 \mid p = q = .5$) = .254, (2) Mandibular, Pr ($\geq 2/9 \mid p = q = .5$) = .980, (3) Both, Pr ($\geq 8/18 \mid p = q = .5$) = .240.

Analysis of Variance

The results of the analysis of variance on the premolar data are presented in Table 20.

TABLE 20

ANALYSIS OF VARIANCE : PREMOLAR DATA

Source	df	SSQ	MSQ
Between Tx	1	.002	.002
Between Arch	1	.102	.102
Tx X Arch	1	.672	.672
Subtotal	3	.777	* *
Patients	8	7.543	* *
Error	24	10.847	.452
Total	35	19.168	

$F_{(1,24)}tr = .005$

$F_{(1,24)}arches = .226$

$F_{(1,24)}intr = 1.487$

$F_{(1,24).95} = 4.26$

Canine Movement

The results of canine movement in recent versus healed extraction sites are summarized in Tables 21-22 Fig. 17.

TABLE 21

PANORAMIC RADIOGRAPHS : CANINE MOVEMENT

(millimeters)

Patient	Arch			
	Maxillary		Mandibular	
	Healed	Recent	Healed	Recent
1	1.44	3.38	4.54	2.71
2	.89	.61	2.16	1.20
3	1.31	.97	1.90	.94
4	2.05	1.29	3.79	1.87
5	1.84	.99	.98	5.22
6	.78	2.32	2.79	1.61
7	.36	1.17	1.60	.31
8	2.38	1.44	.43	.96
9	1.44	2.00	2.64	.42
Total	12.49	14.18	20.84	15.25

TABLE 22

MEANS : CANINE MOVEMENT

(millimeters)[a]

Arch	Healed	Recent	Mean
Maxillary	1.39	1.58	1.48
Mandibular	2.32	1.69	2.00
Means	1.85	1.63	1.74

[a]Rounded where necessary to nearest even hundredth

There were fewer instances in which the healed site moved more than the recent: four of nine in the maxilla, six of nine in the mandible.

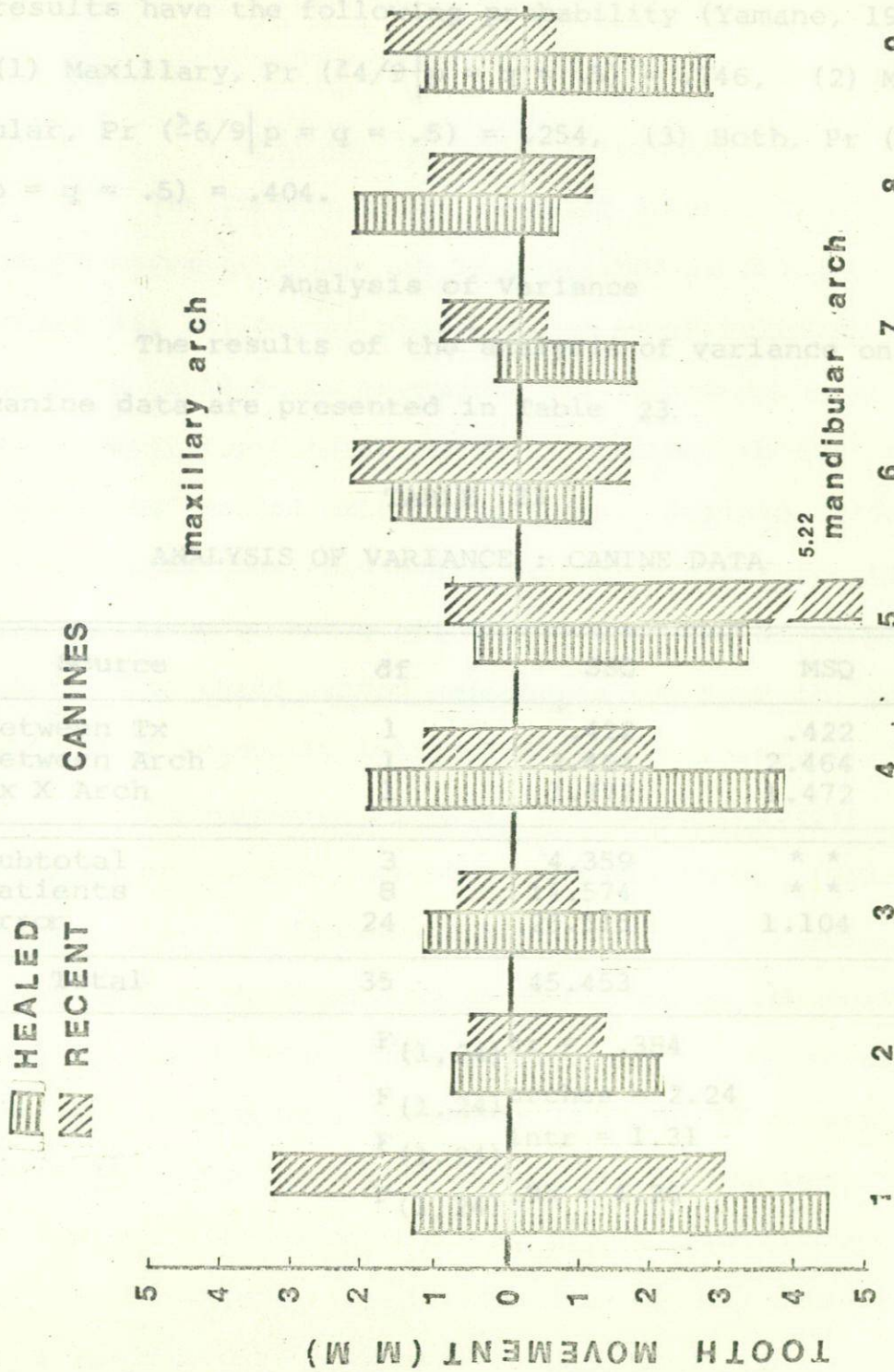


Figure 17. Total Movement - Canines

Given the assumption of equal likelihood, these results have the following probability (Yamane, 1967): (1) Maxillary, Pr ($\geq 4/9 \mid p = q = .5$) = .746, (2) Mandibular, Pr ($\geq 6/9 \mid p = q = .5$) = .254, (3) Both, Pr ($\geq 10/18 \mid p = q = .5$) = .404.

Analysis of Variance

The results of the analysis of variance on the canine data are presented in Table 23.

TABLE 23

ANALYSIS OF VARIANCE : CANINE DATA

Source	df	SSQ	MSQ
Between Tx	1	.422	.422
Between Arch	1	2.464	2.464
Tx X Arch	1	1.472	1.472
Subtotal	3	4.359	* *
Patients	8	14.574	* *
Error	24	26.515	1.104
Total	35	45.453	

$F_{(1,24)}$ tr = .384

$F_{(1,24)}$ arches = 2.24

$F_{(1,24)}$ intr = 1.31

$F_{(1,24)}$ .95 = 4.26

DISCUSSION

Pattern of Tooth Movement

The present study revealed a general pattern of tooth movement which can be described as follows: There was an initial phase (first week), characterized by very rapid tooth movement. It should be noted that this early rapid tooth movement occurred in both the recent and healed extraction sites. Begining with the second week there was a "lag period" in which the teeth did not move or had a relatively low rate of displacement. The third period represents the time the teeth undergo a gradually increasing rate of movement.

This pattern of tooth movement parallels the studies of previous investigators (Burstone, 1962; Reitan, 1969). Burstone has proposed (1962) that such a pattern of movement can be explained on the following basis: The initial phase corresponds to compression of the periodontal membrane as is to expected in any tooth movement. The lag period occurs due to the hyalinization of the periodontal membrane as a result of the pressure of tooth movement. Localized areas of necrosis occur and, as a result, direct frontal resorption is temporarily arrested. The resumption of tooth movement begins as

the area of hyalinization is resolved and undermining resorption begins. The rate of movement increases as the last remanents of hyalinization are resolved and a more normal mechanism of bone resorption asserts itself.

Space Closure

The intra-oral measurements reveal that in both arches the average decrease in distance between measurement landmarks was 5.26 mm (Table 6). In contrast, the model measurements show 3.28 mm of space closure (Table 13). The panoral radiographic measurements of 3.68 mm corresponds closely to the model measurements (Table 16).

As discussed in Methods, the intra-oral measurements are more affected by rotations than are the model and radiographic measurements. Therefore, the absolute amount of space closure is obtained from the model measurements and totals approximately 3.28 mm/8 week period for this sample. It can be concluded that rotations accounted for a considerable part of the intra-oral measurements.

Reliability of Measurements

A summary of the pertinent statistics of the three measurement methods is presented in Table 24.

TABLE 24

SUMMARY OF RELATIVE STATISTICS

Source of Data	Analysis of Variance Summary				Binomial Probability		
	Tx MSQ	Error MSQ	F	Prob	Max.	Mand.	Both
Intra-oral	2.320	.489	4.74*	.04*	.002*	.50	.20*
Model	1.016	.512	1.98	.20	.020*	.25	.02*
Panoramic Radiograph	.508	1.189	.482	.50	.75	.25	.41

Intra-oral measurements were assumed to be much more reliable than either panoramic radiographs or model measurements due to the distinct landmarks as described in Methods. This clinical conviction is substantiated by comparing the estimates of error variance (Error MSQ) obtained from the three classes of measurements. It should be noted that the intra-oral measurement has the lowest value for mean squares due to error (Error MSQ). The error inherent in the model method is only slightly greater than the intra-oral method, but the panoramic radiographic method is three times greater than the intra-oral. Perhaps as a result, only for intra-oral determinations was there a significant difference between healed and recent sites ($F = 4.74$). A non-parametric treatment of the data, however, showed a

significant difference, not only for intra-oral measurements but also for those obtained from models. In neither analysis, parametric nor non-parametric could any significant differences be gleaned from the panoramic radiographic determinations. From the standpoint of determining absolute space closure the panoramic radiograph measurements are of questionable value, but they provide the only method available in the present study of determining relative individual tooth movement.[1]

Anchorage and Differential Force

With the advent of extractions as an acceptable orthodontic procedure, the problem of anchorage became an area of special interest to many investigators. As Brodie has stated (1944, p.448), "anchorage has always been the orthodontist's hardhearted master. . . ." An intregal part of the "Tweed Treatment" is the preparation of anchorage to conserve the extraction space. According to the proponents of the "Tweed Philosophy," it is generally assumed that approximately two-thirds of the extraction site can be preserved for canine retraction.

The present clinical study showed that 61% of the space closure was accounted for by the movement of the premolar on the healed side (Tables 15,18) in the

[1]Perhaps an intra-oral grid with a 45° cephlometric radiograph and metallic implants would be more reliable.

maxillary arch. The maxillary arch recent side showed 51% of the movement was that of the premolar. The mandibular arch showed 41% of the movement on the healed side was premolar movement while the recent side had 51% of the space closure.

Although the above percentages were derived from the central tendencies of total space closure and total premolar movement, they do lend support to the belief that an unprepared arch is subject to greater anchorage loss and gave some justification for the preparation of anchorage as demanded by the"Tweed Method" (Tweed, 1966). It seems reasonable that the variance in individual patient response is probably related to the amount of tipping of the posterior segments, the mandibular plane angle, the original position of the molar (Lindquist, Stoner, 1969), and the individual biological constituion of each patient.

With respect to the theory of differential force (Storey & Smith, 1952)[1] only two patients showed

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[1]The theory of differential force was formulated from the following data: In each of five patients (four patients had the lower cuspids and the fifth an upper cuspid) who required distal movement of the cuspid a light spring was connected to onle side of the dental arch and a heavy spring to the other side. From a total of 70 measurements only 7 were taken at force values over 350 grams. One patient had an equal amount of anterior and posterior movement (.03 mm) and one had no recorded movement.

any evidence that there may have been a differential response to the magnitude of forces employed here. Both lower canines in patient eight moved 0.43 mm and 0.96 mm, while the molars moved 2.7 mm and 2.3 mm respectively. In patient five, the maxillary canines moved 1.84 mm and 0.99 mm versus 3.72 mm and 3.35 mm respectively. All other patients displayed such a wide degree of variability that any attempt to attach clinical significance to these data would be misleading. The preceeding data suggest that, although there may be a differential rate of tooth movement, the between-patient variation is of such a magnitude as to preclude the formulation of any quantitative estimations of this optimum force.

Healed Sites Versus Recent Sites

In general, the data from the intra-oral, model, and panoramic radiographs indicated that there was greater total tooth movement on the healed extraction side than on the fresh extraction side. The differences in the amount of space closure can be attributed to the different methods of recording the data. The radiographic and model measurements showed less linear movement than did the intra-oral because these measurements were recorded from the approximate rotational centers of the cuspid and bicuspid teeth. The intra-oral recordings

were made from a notch in the buccal tube on the molar and the mesial surface of the distal bracket on the cuspid. An analogous situation would be measuring the linear distance wheels are moving toward each other by choosing points on the outer rim rather than the center of the wheel. For this reason the model method was deemed the most useful for this determination.

An examination of the means of total space closure in the model measurements offers some interesting speculations. The means for the mandibular arch healed site and recent site are 3.22 mm and 3.38 mm respectively. The mean for the maxillary arch recent side is 2.95 mm and the healed side 3.58 mm. There was a remarkable consistency of pattern which showed that there was greater tooth movement on the healed side than on the fresh side. The results of this study do not support the theory that movement in the recent side had any mechanical or physiological advantages as has been suggested by other investigators (Tweed, 1950; Revell, 1964). In fact, the data from the present clinical investigation concur with the recent microscopic (Murphey, 1969) and radiographic (Bauer, 1969) studies on monkies which indicated that teeth may move faster in a healed site.

Hypothetical Model

If it be assumed that pressure yields resorption and that an excess of negative charges results in deposition, then the following model may be advanced as a possible explanation for the results of the present investigation:

1. Recent Sites.--retraction of canines results in a distortion of the unsupported distal alveolar septum and, at the same time, subjects it to increased pressure (Fig. 17). As a result of the piezoelectric effect (Bassett, 1964; Frost, 1964; Gillooly, 1968; DeAngelis, 1969; Giannelly, 1969), such a distortion should elicit a deposition of bone (or at least a tendency toward deposition) such that frontal resorption would be markedly decreased.

2. Healed Sites.-- Inasmuch as the extraction site may be assumed to be partially filled in by new bone (Boyne, 1966) one might expect a marked decrease in alveolar distortion. As a result, pressure resorption would not be countered by as great a tendency toward deposition. According to this model, healed sites would be expected to show a greater space closure due to the lesser alveolar distortion. Moreover, it might be expected that a greater experimental difference would be seen in the maxillary arch where the bone is less dense and presumably more amenable to pressure deformation and its untoward side affects. In the present study both of these somewhat a posteriori predictions were realized.

The evidence from the present study suggests that further research aimed specifically at testing the hypothesis generated by this model is required to further elucidate the mechanism of tooth movement.

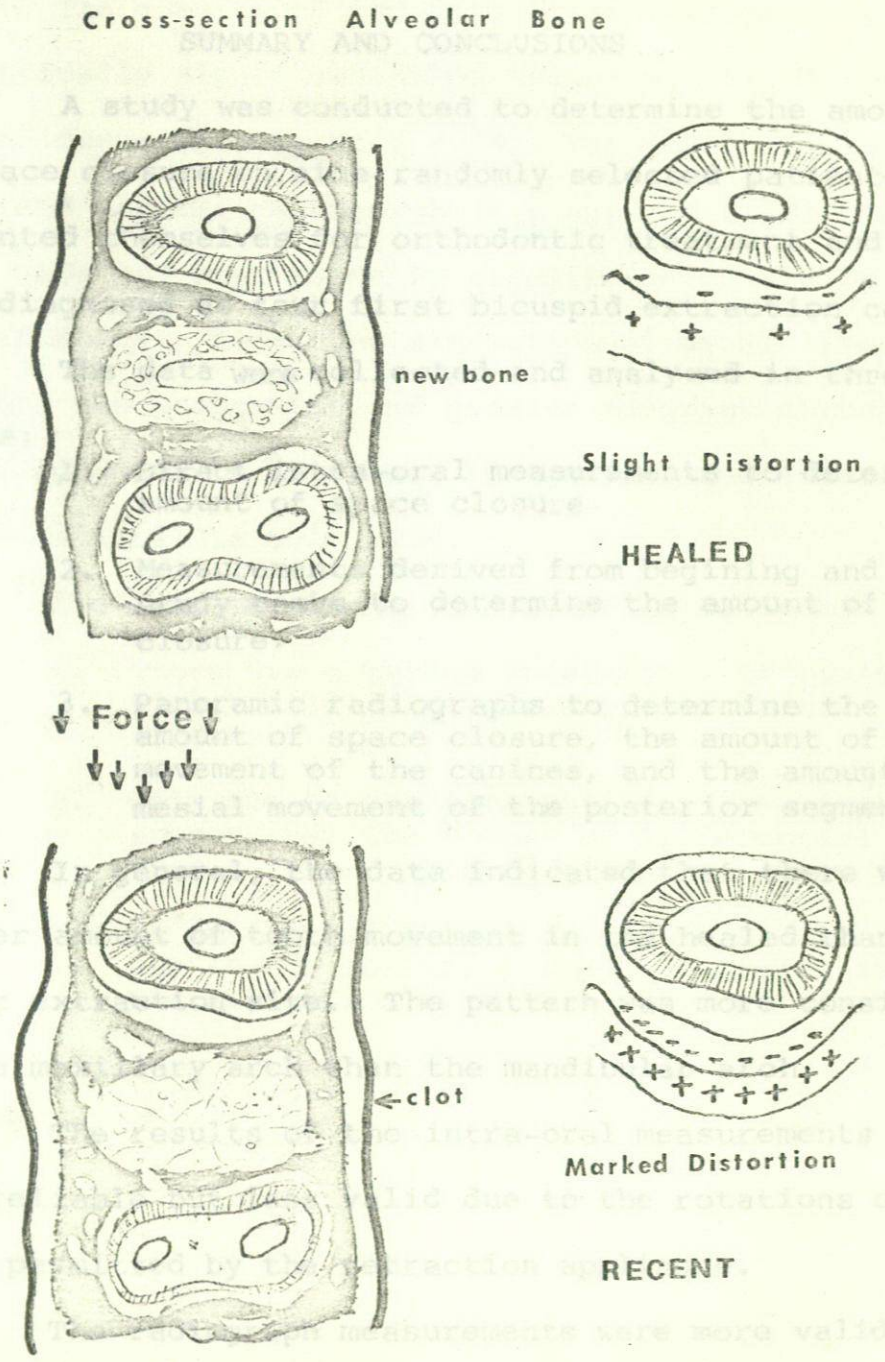


Figure 18. Hypothetical Model of Recent and Healed extraction sites.

SUMMARY AND CONCLUSIONS

A study was conducted to determine the amount of space closure on nine randomly selected patients who presented themselves for orthodontic treatment and who were diagnosed as four first bicuspid extraction cases.

The data were collected and analyzed in three groups:

1. Direct intra-oral measurements to determine the amount of space closure
2. Measurements derived from begining and final study casts to determine the amount of space closure.
3. Panoramic radiographs to determine the amount of space closure, the amount of distal movement of the canines, and the amount of mesial movement of the posterior segments.

In general, the data indicated that there was a greater amount of tooth movement in the healed than the recent extraction site. The pattern was more consistent in the maxillary arch than the mandibular arch.

The results of the intra-oral measurements were more reliable but less valid due to the rotations of teeth permitted by the retraction appliance.

The radiograph measurements were more valid but not as reliable due to the inaccuracy in the method of measuring space closure. These measurements were most useful for assessing relative individual tooth movements on

either side of the extraction site.

The results of the intra-oral measurements were statistically significant when tested at the 5% level of confidence ($F_{(1,24)}tr = 4.74$). The model ($F_{(1,24)}tr = 1.98$) and panoral radiograph ($F_{(1,24)}tr = .428$) measurements were not statistically significant at the 5% level of confidence. Given the assumption of equal likelihood, however, the probability of greater movement through healed sites in 14/18 arches (intra-oral and model determinations) is only .016.

The results can be summarized as follows:

1. There was a marked consistency of pattern with healed sites showing more space closure.

2. Only two of the nine patients gave any support for the theory of differential force when a force value of 360 grams was used.

3. An average of 50% of the space closure was due to the posterior segments moving into the extraction site in an unprepared arch.

APPENDIX I

Patient Consent Form

CASE WESTERN RESERVE UNIVERSITY

SCHOOL OF DENTISTRY

PATIENT CONSENT FOR STUDIES

Title of Project: RATE OF MOVEMENT IN RECENT AND HEALED EXTRACTION SITES.

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 feel 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 rate of movement in recent and healed extraction sites.

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

3. Candidates for the experiment to be selected would be patients whose treatment plan arrived at by standard diagnostic procedures and approved by the Orthodontic Staff calls for the extraction of four first bicuspids in order to achieve the most optimal orthodontic result.

4. A special appliance will be constructed for each patient and placed in the appropriate site at the time of extraction.

5. The candidate is assured that it is the consensus of the Orthodintic Staff that the experiment 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 experiment each candidate will be treated to completion as they normally would have been if they had, or had not, participated in this experiment.

7. You will receive a reduction in the total fee to cover the cost of the extractions performed at the School of Dentistry, Case Western Reserve University.

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 C.W.R.U 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_____

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