THE EFFECTS OF BANDING AND VARIOUS METHODS OF LEVELING ON DENTAL ARCH LENGTH AND INCISOR INCLINATION

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

Orthodontic mechanotherapy has reached a level of sophistication well beyond the knowledge of changes in tooth position which arch wires effect. Appliances of varying designs are placed to accomplish specific objectives but quantitative knowledge of the changes occurring during each phase of treatment is often lacking. The information available on the changes brought about in each step of orthodontic therapy is often based upon clinical observation and empirical judgement.

Recent refinements in orthodontic therapy demand that information about tooth movements occurring while appliances are functional be based on scientific evidence, rather than empirical judgment. Only then can different appliances be evaluated rationally and the value of any step of a given procedure be determined. Such knowledge will make the transmission of ideas easier and will give the clinician greater confidence in selecting appliances. Therefore, studies of the specific changes occurring in various steps of treatment are indicated.

This study represents an attempt to evaluate the changes in tooth position and arch length which occur during band placement and leveling.

PURPOSE

The purpose of this paper is to evaluate from study models and lateral cephalometric roentgenograms the following:

1. The increment which the band material and cementing medium add to dental arch length in a full banding technic.
2. Angular and linear changes of the maxillary and mandibular incisor positions resulting from band placement.
3. The effect on the dental arch length of three varying leveling methods.
4. Changes in width of the dental arch following leveling.
5. Angular and linear changes in the maxillary and mandibular incisors following the various leveling methods.
6. Changes in extraction site width following leveling.

REVIEW OF THE LITERATURE

A review of the literature disclosed no studies confined specifically to this subject. There are many references to multiple banding techniques and placement of round leveling arch wires. These concern themselves primarily with the evolvement of procedures for banding and leveling. They describe at great length band construction, which teeth to band, how leveling arch wires are to be constructed and the sequence in which they are to be used.

Tweed (1), in discussing treatment of Class I malocclusions, suggests that if there is crowding of the anterior teeth they should not be banded until Class III mechanics have tipped the teeth in the buccal segments distally enough to loosen up the contacts of the incisor teeth.

He suggests the use of two types of leveling arch wires. In malocclusions with spacing of the anterior teeth the leveling arch wires should have stops 1/16" mesial to the molar tubes and should be tied back. This procedure will decrease dental arch length and will close the spaces. In malocclusions without spaces between the teeth the arch wires have no stops and are not tied back to the molar tube. He suggests placing of both arch wires in one appointment.

Strang and Thomson (2) suggest placing stops in contact with the mesial ends of the molar sheaths on all round arch wires. They state that this procedure will prevent the loss of denture space in the early stages of treatment. It is also stated that tooth movement produced by round arch wires is quite limited in degree and almost entirely confined to the vertical planes resulting in the alignment of all the brackets to a common level.

Shapiro (3), discussing treatment of Class II division 1 malocclusion, recommends starting the leveling phase with .018 round arch wires which have tie-back stops and tip-back bends. This procedure is said to maintain dental arch length and will begin uprighting the molar teeth.

Graber (4) states that .014, .016 and .018 leveling arch wires should be used. These are to be placed at three week intervals.

Holdaway (5), in discussing treatment of four-bicuspid extraction cases, recommends that leveling be started with an .015 round arch. The arch is left in place for two weeks and is then replaced with .018 arch wire which has sliding yokes for the application of a headgear force. In three weeks the .018 arch is replaced with .020 arch wire. In the mandibular arch a reverse curve of Spee is incorporated in the wire. The arch wire remains in the mouth for three weeks.

Herzberg (6), discussing the edgewise arch mechanism, states that he used .016, .018 and .020 leveling arch wires. Spaces in the arch are closed by cinching up on the arch wire. Tip-back bends are also incorporated in the arch wires.

As may be seen from the above comments, one of the primary concerns in mechanotherapy has been to evolve step by step treatment procedures by which malocclusions could be treated. These treatment procedures have been derived largely through clinical observations and trial and error. It would seem that well planned studies, designed to evaluate the effects of the individual steps in treatment, would be beneficial.

MATERIAL AND METHODS

For the purpose of clarity and material and methods and findings are presented under specific headings.

Material

The material consisted of patients who were to undergo treatment at the Orthodontic Department, Western Reserve University School of Dentistry. The sample included nine females and four males varying in age from ten and one half to fifteen years. All subjects were of the white race and in the permanent dentition stage. Ten were classified as having Angle Class II division I and three as Angle Class I malocclusions. Dental crowding was moderate to severe in most mandibular arches.

In twelve patients the dental crowding and the treatment objective of positioning dental units over basal bone necessitated the removal of dental units. In nine cases the four first bicuspids were removed. In one case the two maxillary first bicuspids and the two mandibular second bicuspids were removed. In one case two maxillary first bicuspids were removed. In the last case one mandibular and two maxillary first bicuspids were removed (Table 1).

Treatment Procedure

The treatment procedure and record collection in all cases was as follows:

1. Initial records.
   a) Study models.
   b) Photographs -- frontal, lateral, and intraoral views.
   c) Full mouth roentgenograms.
   d) Lateral and frontal cephalometric roentgenograms.
2. Band placement.

   Bands were formed and cemented on the following teeth: all of the first molars, second bicuspids, the first bicuspids not indicated for removal, cuspids, and all central and lateral incisors. The first molars were banded with .006 by .018 stainless steel band material. The remaining teeth were banded with .0035 by .0125 band material.
3. Second set of lateral and frontal cephalograms.

   These were made before extraction of teeth and were used to study changes in tooth positions and angulations due to the addition of the band material and cement.
4. Teeth indicated for extraction were removed.
5. Various leveling procedures were carried out.

6. The final records obtained included; study models, lateral and frontal cephalograms and photographs.

Leveling Procedures

For the leveling phase the subjects were divided into three groups according to the leveling procedure to be used. In all groups the leveling was carried out with a series of three round arch wires of .016, .018 and .020 diameters. Each .016 arch wire was allowed to remain in place for a minimum of three weeks. The .018 and .020 wires were in place for a minimum period of two weeks. In some cases the arch wires were left in place for four to six weeks.

The maxillary and mandibular arch wires were shaped to an ideal arch form. Lateral insteps and bayonet bends were included in the maxillary arches. A slight reverse curve of Spee and bayonet bands were incorporated in the mandibular wires. All arch wires were formed and placed by the same operator.

In Group I no stops were placed in the leveling arch wires. In Group II maxillary and mandibular closed loop tie-backs were incorporated into all the arch wires. The tie-backs were placed two millimeters mesial to the molar tubes and were tied back each time the arch wires were changed. In Group III closed loop stops were placed against the molar tubes and tied to the tubes.

All arch wires were ligated with .010 steel ligature wire by means of a ligature locking plier. An attempt was made to use a constant amount of force in tying the arch wire stops to the molar tubes.

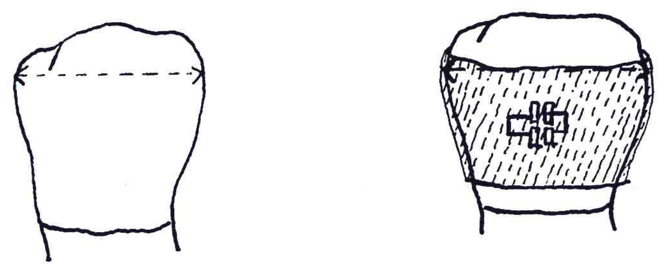
Measurements Relative to Band Placement

From Study Models

The mesio-distal width of each tooth was measured before and after band placement to determine the amount which is added to the width of each tooth by the band material and cementing medium. All measurements were made with a boley gauge to the nearest .1 of a millimeter. Measurements were made in the contact areas of each tooth as illustrated in Figure 1.

The difference between the first and second measurements for each tooth was recorded. The total increase in arch length was determined by adding the sums of the individual width increases. The bands were placed by four different operators as indicated in Table 2.

Fig. 1. Area of tooth width measurement.



Area of first measurement from initial study models

Same area with band Second measurement from final study models

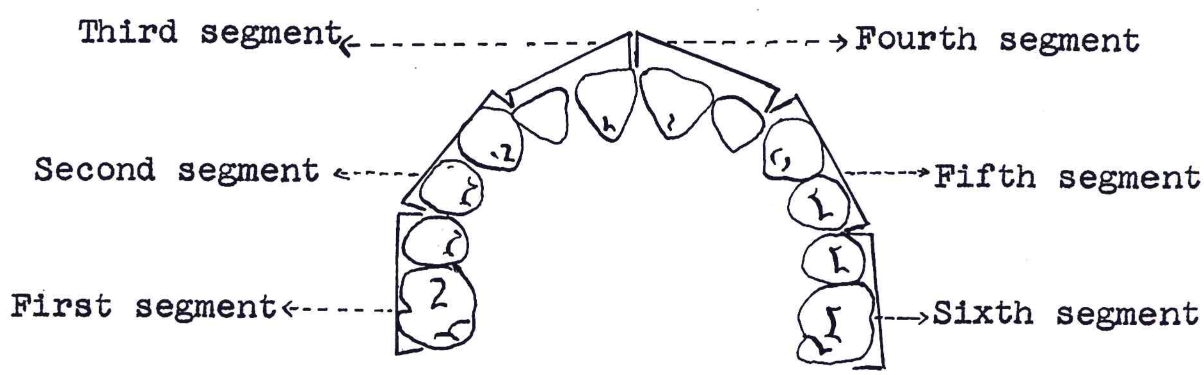
TABLE 1

CLASSIFICATION OF PATIENTS IN THE THREE GROUPS

Patient	Age	Sex	Angle Classification	Teeth Removed
			Group I	
1	15	F	Class II Div. 1	None
2	13	F	Class II Div. 1	Max. 2 First Bicuspids
3	14	M	Class II Div. 1	Four First Bicuspids
4	12	F	Class II Div. 1	Bicuspids Four First
5	12	F	Class I	Four First Bicuspids
			Group II	
6	10½	F	Class II Div. 1	Four First Bicuspids
7	13	M	Class II Div. 1	Max. 2 First Bi. Mand. 1 First Bicus.
8	12	M	Class II Div. 1	Four First Bicuspids
9	12	F	Class I	Four First Bicuspids
			Group III	
10	12	F	Class II Div. 1	Max. 2 First Bi. Mand. 2 Second Bi.
11	14	M	Class II Div. 1	Four First Bicuspids
12	13	F	Class II Div. 1	Four First Bicuspids
13	14	F	Class I	Four First Bicuspids

The tooth mass to dental arch length discrepancy was determined for each maxillary and mandibular arch. The tooth mass in each arch was determined by measuring the mesio-distal width of the first molars, second bicuspids, first bicuspids, cuspids, and lateral and central incisors. The dental arch length was determined by six segmental measurements of the perimeter of the dental arch as illustrated in Fig. 2. All measurements were made at the contact points with a boley gauge and recorded to the nearest .1 of a millimeter.

Fig. 2. Segmental measurements of the dental arch perimeter.



From Lateral Cephalometric Roentgenograms

Tracings of each cephalogram were made on frosted acetate. Fig. 3 indicates the structures traced. For bilateral structures, the right and left sides were traced separately and an average tracing made. The center of sella-turcica and nasion were transferred from the first tracing to tracings of the second and third cephalograms, taken after banding and leveling respectively, by orienting on the cranial outline, and palate, the orbit, sella-turcica and the outline of the pterygo-maxillary fissure.

Pogonion, menton and gonion were transferred serially by orienting on the mandibular outline and registering on the outline of the symphysis. The outlines of the maxillary and mandibular incisors were traced separately for each cephalogram. A long axis was established and the crown and root lengths transferred from the first tracing to the subsequent tracings by orienting on the outlines of the root and crown of the incisors and registering on the outline of the crown.

The following linear and angular measurements were made (Fig. 3);

1. Angle 3. The inferior posterior angle formed by the junction of the line through the long axis of the maxillary incisor and line SN. Used to determine angular changes in the maxillary central incisors.

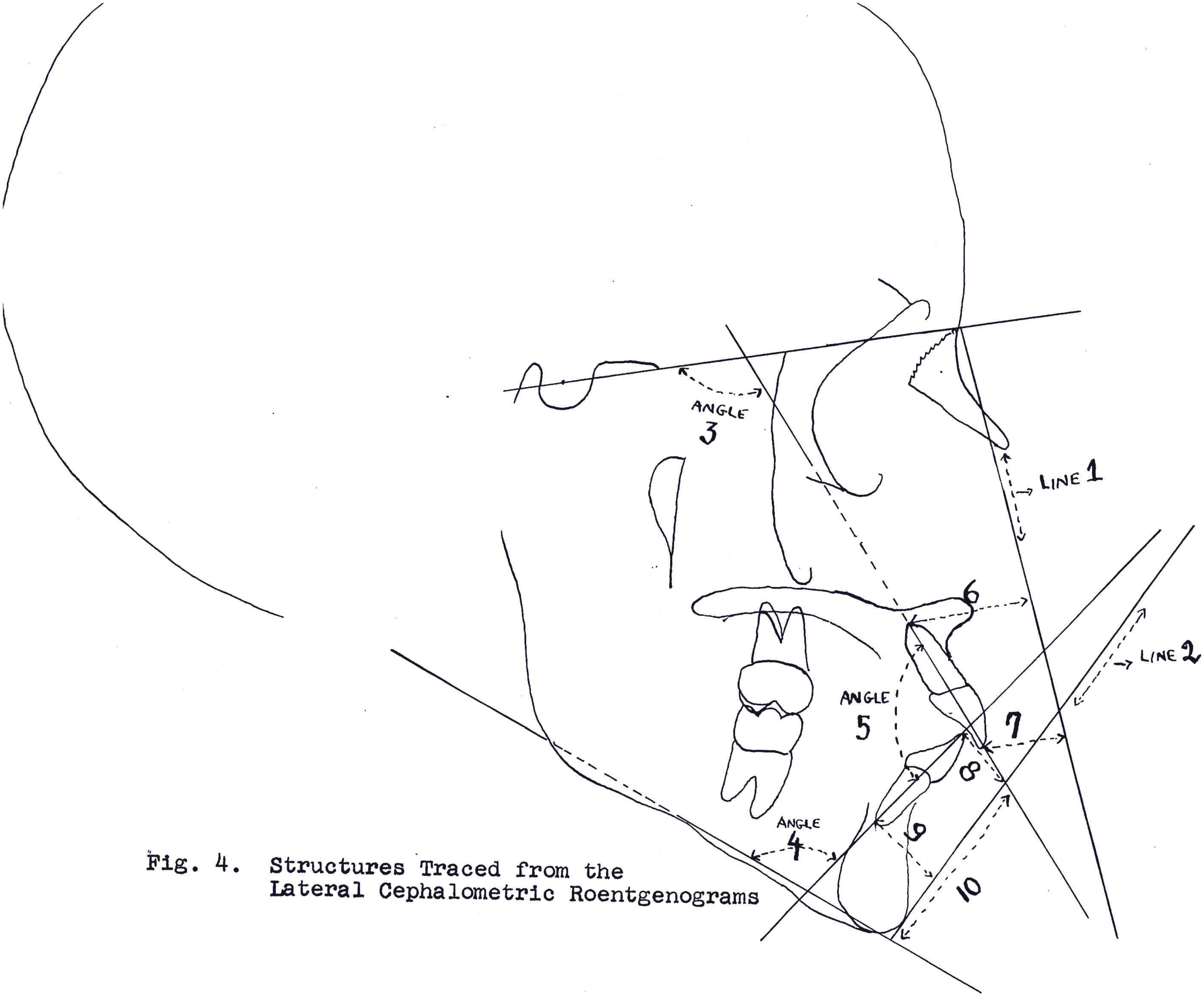


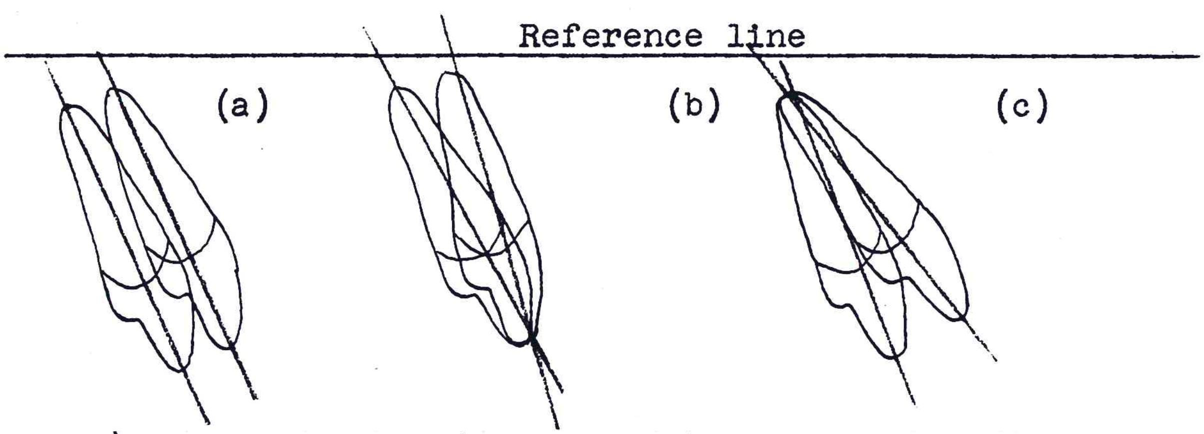
Fig. 4. Structures Traced from the Lateral Cephalometric Roentgenograms

2. Angle 4. The incisor mandibular plane angle. Used to determine angular changes in the mandibular central incisors.
3. Angle 5. The interincisal angle.
4. Measurement 6. The linear distance from the center of the apex of the root of the maxillary central incisor along a line perpendicular to line 1. Line 1 is a line erected perpendicular to SN from nasion and continuing inferiorly. Used as a measure of the labio-lingual root movement.
5. Measurement 7. A linear distance from the center of the incisal edge of the maxillary incisor along a line perpendicular to line 1. Used as a measure of labio-lingual crown movement.
6. Measurement 8. A linear distance from the center of the apex of the mandibular central incisor along a line perpendicular to line 2. Line 2 is a line through pogonion and perpendicular to the mandibular plane. Used to determine labial or lingual root movement.
7. Measurement 9. A linear distance from the center of the incisal edge of the mandibular incisors along a line perpendicular to line 2. Used to determine the labial or lingual movement of the crown.

8. Measurement 10. The linear distance along line 2 representing the vertical height of the mandibular incisor in relation to the mandibular plane. Used to measure changes in vertical height of the incisors.

Linear measurements 4, 5, 6 and 7 were felt to be necessary to augment the measurements of angular changes, since it is possible to have no angular changes and bodily tooth movement in either direction. It is also possible to have an angular change which may be the result of either crown movement, root movement or a combination of movements of the crown and root. These points are illustrated in Figure 4.

Fig. 4. Angular changes of the long axis of a tooth in relation to tooth movements



a) Change in position without a change in angulation.

b) Change in angulation due to root movement.

c) Change in angulation due to crown movement.

Measurements Relative to Leveling Changes

Study Model Measurements

The perimeter of each dental arch was measured on the initial models and models taken after leveling in the manner illustrated in Fig. 2. The difference between the two values was recorded as the gross change in dental arch length. Since the values for the band material and cement varied between dental arches, the actual or net change in dental arch length was calculated by subtracting the width of the band material and cement from the gross change in dental arch length. This value then represents the change which occurred in arch length while the leveling arches were in place.

Width changes in each arch were recorded by measuring the distance between the molars, second bicuspids and cuspids. The molar measurements were made between the central grooves. Second bicuspid and cuspid measurements were made from the tip of the buccal cusps and incisal edges respectively.

Changes in the extraction sites were recorded in millimeters and as a percentage change. The space gained by extractions was first measured from the initial models. The amount of remaining space after leveling was measured from the final models and the difference between the two measurements was recorded as the amount of space closure. The percentage change was determined by dividing the amount of space closure by the original amount of space.

Cephalometric Determinations

The tracing procedure and the angular and linear measurements have been described on pages 12 to 15. The changes recorded occurred between the second and third lateral cephalometric roentgenograms taken before and after the leveling procedures. To reduce the amount of error all cephalograms were traced and the measurements taken twice. Tables 4, 5, 9 and 10 represent the average values of the two determinations. The statistical evaluations are presented in the Appendix.

FINDINGS

Band Thickness

Table 2 presents the increase in width in the mesio-distal dimensions of the maxillary teeth due to the band material and cement. The average thickness of the band material and cement which is added to the dental arch length by banding ten teeth was 3.0 mm. To this total the individual bands contributed as follows:

1.	The first molar bands	.95 mm.
2.	The second bicuspid bands	.46 mm.
3.	The first bicuspid bands	.40 mm.
4.	The cuspid bands	.57 mm.
5.	The lateral incisor bands	.47 mm.
6.	The central incisor bands	.55 mm.

In twelve cases the band thickness ranged between 2.4 mm. and 3.4 mm. In one case the thickness of the band material was 4.7 mm.

In the mandibular arches (Table 3) the average thickness of the band material and cement from 10.2 bands was 2.8 mm. Individually the bands contributed as follows:

1.	The first molar bands	.77 mm.
2.	The second bicuspid bands	.58 mm.
3.	The first bicuspid bands	.45 mm.

TABLE 2

INCREASE IN MESIO DISTAL DIMENSION OF THE MAXILLARY TEETH DUE TO BAND THICKNESS AND CEMENTING MEDIUM

Patient No. Operator	1 A	2 B	3 A	4 A	5 A	6 A	7 A	8 DA	9 A	10 C	11 B	12 A	13 A	Average
Left side														
M	.4	.2	.5	.7	.4	.3	.5	.8	.3	.6	.5	.7	.4	.48
B	.2	.2	.1	.2	.2	.3	.3	.2	.3	.2	.2	.3	.2	.22
B	.2	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	.2
Cu	.3	.6	.2	.4	.3	.4	.3	.2	.3	.5	.4	.1	.4	.33
L	.3	.3	.4	.5	.2	.2	.2	.3	.3	.2	.1	.2	.3	.27
C	.3	.3	.3	.5	.4	.3	.6	.2	.2	.2	.2	.2	.2	.3
Right side														
C	.3	.2	.4	.6	.1	.3	.2	.3	.1	.2	.2	.1	.2	.25
L	.3	.2	.3	.3	.1	.2	.2	.3	.2	.1	.2	.1	.2	.2
Cu	.2	.2	.2	.4	.2	.2	NB	.2	.2	.3	.2	.2	NB	.24
B	.2	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	.2
B	.2	.3	.2	.5	.4	.1	.2	.2	.2	.2	.2	.3	.1	.24
M	.5	.3	.4	.6	.4	.4	.6	.6	.3	.8	.4	.4	.4	.47
No. Teeth banded	12	10	10	10	10	10	9	10	10	10	10	10	9	10
Total Arch Change MM.	3.4	2.8	3.0	4.7	2.7	2.7	3.1	3.3	2.4	3.3	2.6	2.6	2.4	3.0

TABLE 3

INCREASE IN MESIO DISTAL DIMENSION OF THE MANDIBULAR TEETH DUE TO BAND THICKNESS AND CEMENTING MEDIUM

Patient No. Operator	1 A	2 B	3 A	4 A	5 A	6 A	7 A	8 DA	9 A	10 C	11 B	12 A	13 A	Average
Left side														
M	.1	.2	.4	.5	.7	.4	.4	.3	.4	.4	.6	.4	.2	.38
B	.2	.2	.3	.5	.5	.2	.2	.3	.3	NB	.5	.2	.2	.3
B	.2	NB	NB	NB	NB	NB	NB	NB	NB	.2	NB	NB	NB	.2
Cu	.4	.2	.3	.2	.1	.4	.3	.3	.3	.3	.2	.2	NB	.27
L	.4	.3	.3	.4	.1	.2	.2	.2	.1	.2.	.1	.2	.3	.23
C	.2	.2	.2	.3	.3	.3	.3	.2	.3	.4	.1	.2	.2	.24
Right side														
C	.2	.3	.2	.2	.1	.2	.2	.2	.2	.2	.1	.2	.2	.19
L	.2	.2	.3	.3	.2	.2	.2	.2	.3	.3	.1	.2	.2	.22
Cu	.3	.3	.3	.2	.2	.4	.2	.2	.3	.2	.2	.1	.2	.24
B	.3	.2	NB	NB	NB	NB	.3	NB	NB	.2	NB	NB	NB	.25
B	.3	.2	.4	.3	.6	.1	.2	.3	.3	NB	.3	.2	.2	.28
M	.3	.4	.4	.6	.4	.6	.3	.3	.5	.3	.2	.4	.4	.39
No Teeth banded	12	11	10	10	10	10	11	10	10	10	10	10	9	2.8
Total Arch Change MM.	3.1	2.7	3.1	3.0	3.2	3.0	2.8	2.5	3.0	2.7	2.4	2.3	2.1	10.2

Note: NB indicates tooth not banded

4. The cuspid bands .51 mm.
5. The lateral incisor bands .47 mm.
6. The central incisor bands .41 mm.

In twelve cases the band thickness ranged between 2.3 mm. to 3.5 mm. In one case with nine bands, the band thickness was 2.1 mm.

Incisor Determinations

Table 4 presents the angular and linear changes of the maxillary central incisors. Six patients showed increases in incisor angulation; five patients showed decreases in incisor angulation; and two had no change in angulation of the central incisors. The average angular increase of the six patients was 1.2 degrees; while the average decrease for the five patients was .65 degrees. In patient number nine the 3.25 degree angulation increase resulted from a .7 mm lingual movement of the root and a .7 mm. labial movement of the crown.

In the mandibular arches (Table 5) the central incisor angulation increased in twelve patients. The average increase was 2.64 degrees with a range of .75 to 7.5 degrees. In patients 4, 6, and 11, with increases of 4.75, 3.5, and 7.5 degrees respectively, the crowns showed considerable labial movement. In patient number 11 the crown moved labially by 2.5 mm. and the root lingually .25 mm. In patient number 6 the crown moved labially by 1.9 mm. and the root lingually by .25 mm. In patient 4 the

TABLE 4

ANGULAR AND LINEAR CHANGES IN THE MAXILLARY CENTRAL INCISORS DUE TO BAND PLACEMENT

Patient No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Change in angulation	+.75	+.5	0	-1.25	-.25	-.75	+1	+1	+3.25	+.75	-.75	-.25	0
Root movement in mm. Labial					.7	1.1	0				.5		.4
Lingual	.1	.1	.1	.8				.4	.7	.9		.4	
Crown movement in mm. Labial	.15	.15	0						.7	.5			
Lingual			0	.8	.5	.1	.45	.35			.1	.5	.85
Arch length-rooth mass discrepancy in mm.	-1.9	-11.1	-3.5	+5.6	-1.9	-1.5	-1.6	+3.4	-6.8	+2.6	-1.3	+2.3	-1.7
Time interval between X-rays in days	17	24	14	24	14	17	37	39	13	68	52	24	39

Note: + Indicates increase in angulation
- Indicates decrease in angulation

TABLE 5

ANGULAR AND LINEAR CHANGES IN THE MANDIBULAR CENTRAL INCISORS DUE TO BAND PLACEMENT

Patient No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Change in angulation	+3.25	0	+1.25	+4.75	+2.25	+3.5	+1.25	+2.75	+2.5	+1.25	+7.5	+1.25	+.75
Root movement in mm.													
Labial	.15				.35		.2			0			.05
Lingual		.3	.2	.25		.25		.5	.7	0	.25	.5	
Crown movement in mm.													
Labial	.95			1.45	1.1	1.9	.45	.85	.1	.4	2.5	.5	.55
Lingual	.	.7	.15										
Arch length-tooth mass discrepancy in mm.	+2.2	+1.4	-7.3	-1.0	-4.9	-5.2	-5.5	0	-6.6	-4.2	-4.0	-.6	-9.8
Interincisal angulation	-.75	-1.5	.75	-4	-1.75	-4.25	-3.75	-4.5	-6	-1.25	-6.5	-.5	-1.5

Note: + Indicates increase in angulation
- Indicates decrease in angulation

crown moved labially by 1.45 mm. and the root lingually by .25 mm. Patient number 2 had no change in incisor angulation, a lingual movement of the root (.3 mm.), and a lingual movement of the crown (.7 mm). The probability that 12 of 13 patients would have increases in incisor angulation due to chance alone is one in 4098 a rather small probability (page 56 Appendix).

The average time interval between the first and second cephalograms was 29.4 days with a high of 68 days and a low of 13 days.

The interincisal angulation decreased in all cases. The average decrease was 2.34 degrees and a range of 6.5 to .5 degrees.

In the maxillary arches nine patients had a tooth mass to arch length discrepancy and four had excess space. In the mandibular arches eleven patients had a tooth mass to arch length discrepancy and two had excess space. In these two subjects the excess space was distal to the cuspids.

Findings Relative to Changes Following Leveling

Dental Arch Length

Table 6 presents the changes in dental arch length in the three groups.

In the maxillary arches the net change in dental arch length for Group I, (no stops on the leveling arch wires), showed an average decrease of 1.75 mm. However, there was a large individual variation in the five patients

TABLE 6

CHANGES IN THE DENTAL ARCH PERIMETER FOLLOWING LEVELING IN THE THREE GROUPS

	Group I					Group II				Group III			
Patient No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Maxillary arch Gross change in mm.	+5.8	+2.9	+.8	-2.4	+.8	-.3	-2.3	-1.5	+.3	+.9	+.2	+.2	-.3
Band thickness in mm.	3.4	2.8	3.0	4.7	2.7	2.7	3.1	3.3	2.4	3.3	2.6	2.6	2.7
Net change in arch length in mm.	+2.4	+.1	-2.2	-7.1	-1.9	-3.0	-5.4	-4.8	-2.1	-2.4	-2.4	-2.4	-2.7
Group average in mm.			-1.74 mm				-3.82 mm.				-2.40 mm.		
Mandibular arch Gross change in mm	+3.2	+3.0	+3.9	+2.6	+7.7	-2.7	+2.6	+.2	+4.1	+1.9	+.8	+.5	+2.7
Band thickness in mm	3.1	2.7	3.1	3.5	3.2	3.0	2.8	2.5	3.0	2.7	2.4	2.3	2.1
Net change in arch length in mm	+.1	+.3	+.8	-.9	+4.5	-5.7	-.2	-2.3	+1.1	-.8	-1.6	-1.8	+.6
Group average in mm.			+ .96 mm.				-1.77 mm.				- .9 mm.		

Note: + Indicates increase in dental arch length
- Indicates decrease in dental arch length

ranging from an increase of 2.4 mm. to a decrease of 7.1 mm.

In Group II, (tie-backs mesial to the molar tubes), all patients showed a decrease in net arch length. The group average decrease was 3.81 mm. with a range of 2.1 to 5.4 mm.

In Group III, (stops against the molar tubes), all patients showed a decrease in net dental arch length. For the group the average decrease in net arch length was 2.4 mm. with a rather uniform decrease in all the arches.

Statistically, there is no significant difference between the net average change in the three groups. However, there is a highly significant difference in the variability among the three groups. Group I is significantly more variable than Group III ($P<.005$), and Group II is significantly more variable than Group III ($P<.005$). There is no significant difference in the variability between Group I and Group II.

In the mandibular arches Group I had an average increase in net dental arch length of .96 mm. The range of change in dental arch length was from a decrease of .9 mm. to an increase of 4.5 mm.

In Group II there was a decrease in the average net arch length of 1.77 mm. with a range between an increase of 1.1 mm. and a decrease of 5.7 mm.

In Group III there was an average decrease in the net dental arch length of .9 mm. with a range between an increase of .6 mm. and a decrease of 1.8 mm. Statistically, due to the smallness of the groups and the large individual variability there is no significant difference between the averages of the mandibular arches in the three groups (page 55 Appendix).

Arch Width

Table 7 presents the changes in dental arch width between the molars, second bicuspids and cuspids.

In the maxillary arches the average amount of movement of the molars was .47 mm. with a range of movement between 1.1 mm. lingually and 1.4 mm. buccally. The second bicuspids showed an average amount of movement of 1.1 mm. with a range of movement between 5.9 mm. buccally and 1.5 mm. lingually. There was an average increase in intercuspid width of 1.48 mm. ranging from 0 to 4.00 mm. Eleven patients had an increase in the intercuspal width.

In the mandibular arches the average amount of movement in either direction of the molars was .66 mm. and in the second bicuspids region it was 1.68 mm. The cuspid region had an average increase of 1.70 mm.

The relative amount of movement of the three teeth in each arch was as follows:

Maxillary molars showed
53% less movement than the maxillary bicuspids
and 68% less movement than the maxillary cuspids.

Mandibular molars showed
61% less movement than the mandibular bicuspids
and 62% less movement than the mandibular cuspids.

TABLE 7

CHANGES IN WIDTH OF THE DENTAL ARCHES IN THE THREE GROUPS

	Group I					Group II				Group III				
Patient No.	1	2	3	4	5	6	7	8	9	10	11	12	13	AVERAGE
Maxillary arch Intermolar width	-1.1	0	-.9	-1.1	0	0	+1.4	0	+.4	0	-1	-.1	+.2	.47
Inter-Bicuspid Width	+1.2	+5.9	-.2	-1.5	-.6	+.3	-1.4	+.1	0	NB	+2.1	+.1	+1.1	1.10
Inter-Cuspid Width	0	+1.3	+4	+1	+.9	+2.1	+2.6	+3.1	0	+.3	+1	+2.3	+.7	1.48
Mandibular arch Intermolar width	0	0	0	-.4	-2.2	-.7	+.3	-1.4	-.5	+1	-1	0	+1.2	.66
Inter-Bicuspid Width	+1.6	+.8	-6	-1.9	-1.3	-1.7	+2.5	+.2	+1.3	+.6	-2.1	-1.4	+.5	1.68
Inter-Cuspid Width	+1	+.5	+2.9	+.9	+1.7	+2.6	0	+.5	+2.7	+2.6	+1.8	+1.3	+3.2	1.70

Note: + Indicates increase in width or labial and buccal movement
- Indicates decrease in width or lingual movement

The maxillary bicuspids showed 24% less movement on average than the cuspids and only slightly less movement than the cuspids in the mandibular arch. All three pairs of teeth in the maxillary arch showed more change in width than the mandibular teeth. The maxillary molars showed on the average 29% less movement than the mandibular molars. The maxillary second bicuspids region had 35% less change in cross arch width on the average than the mandibular second bicuspid region. The maxillary cuspids had 13% less movement than the mandibular cuspids. The changes in cross arch width of the molars and bicuspids were in either buccal or lingual direction with large individual variation; whereas, the cuspid region showed increases in width in both arches in almost all cases. The probability of 23 out of 26 intercuspid widths increasing due to chance alone is very small (page 56 Appendix).

Extraction Sites

The extent of space closure in the extraction sites is presented in Table 8.

The combined average of all the extraction sites in Group I show a space closure of 42% for the maxillary sites and a 25% space closure in the mandibular sites. In Group II 30% of the maxillary and 40% of the mandibular extraction spaces closed during leveling. In Group III 22.5% of the maxillary and 24% of the mandibular extraction spaces closed. Individual areas showed a very wide variation in the amount of space closure from a high of

TABLE 8

AMOUNT OF SPACE CLOSURE IN THE EXTRACTION SITE FOLLOWING LEVELING IN THE THREE GROUPS

Patient No.		Group I					Group II				Group III		
	1	2	3	4	5	6	7	8	9	10	11	12	13
Maxillary arch													
Right side space closure	NE (MM)	3.6	3.7	2.3	3.0	1.0	2.5	1.5	4.3	.8	2.1	1.3	2.6
% of space closure	NE	52	48	33	40	14	33	21	58	9	29	20	26
Left side space closure	NE (MM)	3.9	3.9	1.2	2.9	3.0	2.8	.7	3.6	1.9	2.8	.8	1.7
% of space closure	NE	58	51	16	39	41	37	10	47	22	38	12	24
Mandibular arch													
Right side space closure	NE	NE	1.2	1.8	2.6	4.4	NE	.5	3.0	1.3	3.0	.9	3.2
% of space closure	NE	NE	16	25	33	60		7	40	12	40	14	44
Left side space closure	NE	NE	2.7	1.4	1.9	2.7	5.1	1.4	4.1	1.5	2.1	1.1	2.4
% of space closure	NE	NE	35	19	24	36	64	21	53	14	30	17	30

Note: NE = indicates teeth not extracted

64% to a low of 9%. The variations are large in all the three groups.

Incisor Determinations Following Leveling

The results of the maxillary incisor determinations are presented in Table 9.

In Group I the angular changes of the maxillary incisors varied from an increase of 5.75 degrees to a decrease of 6.75 degrees. Three patients had a decrease in incisor angulation and two patients showed an increase in incisor angulation. The average change in either direction for the group was 3.8 degrees.

In Group II three patients showed large decreases in incisor angulation and one had an increase in incisor angulation. The largest angular decrease in Group II was 11.25 degrees and the one increase was 3.5 degrees. The average angular change of the maxillary incisors in either direction for the group was 6.06 degrees.

In Group III the magnitude and individual variation of change in maxillary incisor angulation was much smaller than in either Group I or Group II. Three patients showed increases in incisor angulation and one had a decrease in angulation. The largest angular increase in Group III was 1.17 degrees. The group average angular change in either direction was 1.1 degrees.

The individual linear root and crown movements which combined to produce the above angular changes can be seen

TABLE 9

CHANGES IN THE MAXILLARY CENTRAL INCISOR AND INTERINCISAL ANGULATION FOLLOWING LEVELING IN THE THREE GROUPS

Patient No.	Group I				Group II					Group III			
	1	2	3	4	5	6	7	8	9	10	11	12	13
Change in angulation	+5.75	+2.25	-6.75	-2	-2.25	-5.5	-11.25	-4	+3.5	-.75	+1.75	+1	+1
Root movement in mm. Labial			0	.45			1.0		.15	.2			
Lingual	.65	1.75	0		.3	.2		.9			.2	.3	.1
Crown movement in mm. Labial	1.45								1.0				
Lingual		.4	2.15	.55	1.6	1.6	4.25	1.95		.15	.1	.4	.25
Interincisal angulation	-2.75	-9.25	+1.75	-.5	-7.5	+6.25	+9.25	+.75	-12.25	+.5	-2.5	-2	-2.5

Note: + Indicates an increase in angulation
- Indicates a decrease in angulation

in Table 9. In comparing the relative amounts of linear movement of the roots and crowns for angular changes of 2 degrees or more of all the maxillary incisors, on the average 27.5% was due to root movement and 72.5% was due to crown movement.

Table 10 presents the results of the mandibular incisor determinations.

In Group I the angular changes of the mandibular incisors varied from an increase of 9.75 degrees to a decrease of 5.25 degrees. Four patients had increases in incisor angulation and one showed a decrease in incisor angulation. The average change in either direction for the group was 5.85 degrees.

In Group II three patients showed increases in incisor angulation and one had a decrease in angulation of the mandibular incisors. The largest angular increase was 6.75 degrees and the greatest decrease was .75 degrees. The average angular change in either direction for the group was 3 degrees.

In Group III the magnitude and individual variation of change in incisor angulation was much smaller than in either Group I or Group II. All four patients showed increases in incisor angulation. The largest angular increase was 2.25 degrees and the smallest 1 degree. The group average angular change in either direction was 1.43 degrees.

In comparing the relative amounts of linear movement of the roots and crowns of all the mandibular incisors

TABLE 10

CHANGES IN THE MANDIBULAR CENTRAL INCISORS FOLLOWING LEVELING IN THE THREE GROUPS

Patient No.	Group I					Group II				Group III			
	1	2	3	4	5	6	7	8	9	10	11	12	13
Change in angulation	-5.25	+7.25	+5.5	+1.5	+9.75	-.75	+1	+3.5	+6.75	+1	+1	+1.5	+2.25
Root movement in mm.													
Labial	.7					.1	0						.55
Lingual		.3	.8	.4	1.5		0	1	.5	.6	.1	.05	
Crown movement in mm.													
Labial		2.8	1.25	0	2.35			.35	2.5		.45	.4	1.45
Lingual	1.15			0		.8	1.15			.45			
Treatment intervals*	105	76	85	76	83	79	92	84	86	84	61	83	73

Note: + Indicates an increase in angulation
- Indicates a decrease in angulation
* The time in days between the second and third cephalogram.

for angular changes of 2 degrees or more, on the average, 32.9% was due to root movement and 67.1% was due to crown movement.

DISCUSSION

The actual thickness of the size of band material that was used in banding ten teeth was 2.032 mm. This 2 mm. would be added to dental arch length if the bands were perfectly adapted and the cement layer were of microscopic thickness. In this study the mandibular bands were more closely adapted than the maxillary bands. The average total thickness of the mandibular bands and cement was 2.74 mm. for ten bands; whereas, for the maxillary bands and cement the average was 3.0 mm. Individually the teeth compare as follows:

	Mandibular	Maxillary
Molars	.38 mm.	.48 mm.
Second bicuspids	.29 mm.	.23 mm.
First bicuspids	.22 mm.	.20 mm.
Cuspids	.26 mm.	.28 mm.
Laterals	.24 mm.	.24 mm.
Centrals	.20 mm.	.28 mm.

The maxillary molar bands were less well adapted than the mandibular molar bands. The mandibular bicuspid bands were less well adapted than the maxillary bicuspid bands. The maxillary cuspid bands were less well adapted than the mandibular cuspid bands. There were no differences in the lateral incisor bands. The maxillary central incisor bands were less well adapted than the mandibular central incisor bands.

The inclination of the maxillary incisor teeth showed little effect from the addition of the band material. Twelve patients had changes in the magnitude of 1 degree in either direction. Some of these could certainly be attributed to tracing errors (Table 11 Appen). There was no apparent relation between the tooth mass to dental arch length discrepancy and the angular changes in the inclination of the maxillary central incisors, although the only case to show an angular increase of any magnitude had a 6.8 mm. tooth size-arch length discrepancy.

All but one of the mandibular incisors showed angulation increases. In seven patients these increases were in excess of 2 degrees. In six of these patients the angulation increase was translated into approximately 1 or more mm. of labial movement of the crowns. Here, as in the maxillary arches, there was no obvious correlation between the tooth mass-arch length discrepancy and the angular increases. The probability of getting increases in incisor angulation of 12 out of 13 patients due to chance alone is 1 in 4098 which is a small probability. These changes were recorded after complete banding and before teeth were removed from each dental arch.

A partial explanation for the difference in response between the maxillary and mandibular central incisors may be found in the difference in configuration of the anterior segments. The reason that the maxillary incisors did not show angular changes while the mandibular incisors had increases in the angulation may well be due to the anatomical difference in the size of the teeth. Also the relative distance between cuspids may play a part. In the maxillary arch the distance between cuspids is greater than in the mandibular arch. The short time interval between cephalograms would seem to preclude any significant growth changes.

<u>Changes Relative to Leveling</u>

There were differences in the resulting dental arch length between the three leveling methods.

Group II showed a larger average decrease in arch length than either Group I or Group III. This is as expected; since in this group the teeth were being pulled together actively by tying the tie-back to the molar tubes. In this group, as in the other groups, the maxillary arches showed larger average decreases in arch length than did the mandibular arches. A partial explanation of this may be the response of the central incisors. In the maxillary arches the central incisors showed considerable lingual movement of the crowns. However, in the mandibular arches the crowns of the central incisors tended to move labially.

In Group III the dental arch length decreased in a uniform manner for all patients. There was little individual variation in change compared to the other groups. Statistically, the maxillary arches were significantly less variable than either Group I or Group II ($P < .005$). The implication here is that the treatment applied to this group tended to effect a more uniform result throughout the group. A larger patient sample in each group would have allowed better statistical evaluations.

Group I reacted on an individual basis with large individual variation in results. Patients number 1 who had no extractions showed a 2.4 mm. increase in arch length in the maxillary arch. In the others, since there were extraction spaces, muscle pressure anteriorly and mesial drift of buccal segments, may have contributed to the decrease in arch length.

The measurements of dental arch width showed no distinct differences among the three groups. However, differences were distinct between the molar, bicuspid and cuspid cross arch widths.

In all patients the inter-molar width, on average, tended to show less positional change in width than the inter-bicuspid or inter-cuspid width in both arches. One reason for this may be that the molar is a larger tooth. The inter-molar and inter-second bicuspid width showed no directional trend in either the maxillary or mandibular arches. The inter-cuspid width tended to increase in both maxillary and mandibular arches.

In the maxillary arches Group I showed more average space closure of the extraction sites than Group II and Group III. Group II showed more average space closure than Group III. In the mandibular arches Group II had more space closure in the extraction sites than either Group I or Group III. Group I had more space closure than Group III.

An interesting finding was that in Group I, of the 14 extraction sites, 9 or 64% had space closures of 1/3 or more. In Group II, 10 of the 15 extraction sites, or 66%, had space closures of 1/3 or more. In Group III only 3 of the 16 extraction sites, or 18%, showed space closures of 1/3 or more. This difference in the extraction space closure is statistically significant.

An attempt was made to determine the extent of space closure which occurred due to mesial movement of the second bicuspids and molars. However, due to the difficulty in tracing accurately the position of the first molars, no definite results were obtained. It would seem, from subjective observations, that in some cases a good deal of this space closure occurs due to movement of the molars mesially. Further study in this area is suggested.

The inclination of the maxillary and mandibular central incisors in Group III showed less angular and linear changes than in Group I and Group II. The average for both arches in this group was 1.26 degrees. Seven of the eight arches, four mandibular and four maxillary arches, showed increases in angulation of the incisors between 1 degree, 5 patients, and 2.25 degrees, in patient No. 13. Only one linear measurement for the entire group, patient 13, labial movement of the mandibular incisor crown, had a change greater than .7 mm.

Group II showed the largest angular and linear changes in both maxillary and mandibular arches. The average angular change for the eight arches was 4.5 degrees. The maxillary arch showed large angular decreases in 3 patients and one increase with a group average change of 6.06 degrees. In the mandibular arch, contrary to expectations, most patients (3 out of 4) showed increases in the incisor angulation. Tying back the arch wires should have resulted in decreases in the incisor angulations. The mandibular group average angular change being 3 degrees. The crowns of the central incisors had large linear changes (Table 9 and 10).

Group I had an average angular change in the inclination of the central incisors of 3.78 degrees for both maxillary and mandibular arches. The extent of the average angular change was equal in magnitude between the maxillary and mandibular arches. In the maxillary arches the tendency was towards a decrease in angulation (3 out of five patients). In the mandibular arches the tendency was towards an increase in angulation of the central incisors (4 out of five patients). The comparisons between the results of the first and second determinations are presented in Table 12 of the Appendix.

The implication of the difference in response of the central incisors to the three varying leveling methods would seem to be dependent on what the objectives of the leveling phase are. If one wishes to confine the leveling phase to an alignment of brackets on a common plane with as little change in the incisor inclination as possible, with less closure of the extraction spaces, and a uniform change in dental arch length, then the treatment outlined for Group III may be followed. On the other hand, if one wishes the leveling phase to align the brackets on a common plane, close the extraction sites, decrease the incisor angulation in the maxillary arch, increase the incisor angulation in the mandibular arch and decrease arch length, then either the treatment of Group II or Group I may be followed.

Using the leveling arch wires in the manner of Group II apparently does not assure a decrease in the central incisor angulation, especially in the mandibular arch. The configuration of the teeth in the anterior segment probably influences the angular changes. A lingually positioned incisor will move labially when tied to an arch wire whether the arch wire is tied back to the molar tubes or not.

The linear measurements of the crowns and roots of the incisors for angular changes in excess of 2 degrees, would seem to suggest that the movement produced by round leveling arch wires is primarily of a tipping nature. The roots of the mandibular incisors moved in one direction an average of 32.9% of the total linear root and crown movement and the crowns moved in the opposite direction by 67.1%. In the maxillary arch the roots of the incisors moved in one direction by 27.5% of the total linear root and crown movement and the crowns moved 72.5% in the opposite direction. The findings suggest that the fulcrum of this tipping movement is in about the apical third of the total root and crown length. From the data in this study the fulcrum would be lacated slightly more incisally in the mandibular teeth than in the maxillary teeth.

Due to the short time interval between cephalograms and models, growth should not have been a major factor. Further studies along this or similar lines are indicated.

Selection of orthodontic appliances should not be based upon how well an appliance works in someone's hands. A knowledge of the kind of tooth movement that an appliance effects is essential to the intelligent practice of orthodontics and should provide the basis of selection of appliances. The appliance must do the most good and the least harm.

SUMMARY

The effect of banding and three methods of leveling were investigated on thirteen white children. Measurements were made from study models and tracings of lateral cephalometric roentgenograms. Angular changes were recorded to the nearest .5 degree and linear changes were recorded to the nearest .1 mm. The entire tracing procedure was repeated twice and the averages reported.

The band material and cement were found to add 3.00 mm. to dental arch length for the maxillary teeth and 2.74 mm. for the mandibular teeth. The maxillary bands were less well adapted than the mandibular bands. No significant angular changes in the maxillary incisors were observed following banding. The mandibular incisors showed an average increase in angulation of 2.64 degrees.

For the various leveling methods the patients were divided into three groups. Group I had no stops or tie-backs on the leveling arch wires. In Group II tie-backs were bend in the leveling arch wires two millimeters mesial to the molar tubes and tied back with each arch wire change. In Group III stops were placed on the arch at the molar tubes and tied with steel ligature to the molar tubes.

The maxillary dental arch length decreased in all three groups. In Group III the maxillary dental arch length decrease was statistically significantly less variable than Group I and Group II ($P < .005$). This group had constancy of change between individual patient. In the mandibular arch Group I showed an average arch length increase while Group II and Group III had average arch length decreases. In Group III the mandibular dental arch length decrease was less variable between individual patient than in the other groups.

The changes in width between the molars, second bicuspids and cuspids were recorded. There were no group trend in the changes in width between the three groups. Almost all maxillary and mandibular cuspids showed increases in width. The molars showed the fewest changes in width. The molars showed the fewest changes in width. The molars and second bicuspids had both lingual and buccal movements. The mandibular teeth showed larger changes in width than the corresponding maxillary teeth.

The changes in the extraction sites were recorded. In Group I and Group II the extraction sites showed space closure of large magnitude. In some instances 60% of the space closed during leveling. Group III had the least amount of space closure in the extraction sites. An evaluation of space closure in the extraction sites larger than 30% showed a significant difference between Group III and the other two groups.

The angular and linear changes in the maxillary and mandibular incisor inclinations were recorded. Group III, where the arch wires had stops at the molar tubes, showed the least amount of angular changes in the inclination of the maxillary and mandibular central incisors. In Group II the mandibular incisors moved labially,although, the arch wires had tie-backs two millimeters mesially to the molar tubes and were tied back with each arch wire change.

CONCLUSION

On the basis of this study it was concluded that:

1. The band material and cement thickness did not influence significantly the inclinations of the maxillary central incisors.
2. The mandibular central incisors are flared labially by the band material and cement in a full banding technic and Dr. Tweeds' suggestion of moving mandibular buccal segments distally before banding the incisors is well taken.
3. Tying back the leveling arch wires, Group II, tended to decrease dental arch length in the maxillary and mandibular arches more than with the other two leveling methods. However, it did not prevent the mandibular central incisors from flaring labially.
4. Stops on the leveling arch wires at the molar tubes tend to decrease dental arch length in a uniform manner.
5. With the three leveling methods the inter-molar width showed the least change. Most inter-cuspid widths showed increases.

6. The leveling arch wires with stops at the molar tubes produced less labio-lingual movement of the maxillary and mandibular central incisors than the other two leveling methods. This leveling procedure tended to close less of the extraction sites than the other leveling methods. It would appear to be the leveling procedure of choice.
7. The movement produced by round arch wires is of a tipping nature with the fulcrum between the apical third and central third of the total tooth length. The fulcrum of the mandibular incisors is located more incisally than that of the maxillary incisor teeth.

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APPENDIX

TABLE 11

COMPARISON OF RESULTS BETWEEN THE FIRST AND SECOND TRACING FOR CHANGES DUE TO BANDING

Patient	Tracing	1 Ang.	1 Rt.	1 Cn.	Ī Ang.	Ī Cn.	Ī Rt.	1 to Ī
1	1	+.5	+.6	+.2	+3.5	-1.1	-.1	-.15
	2	+.5	-.4	-.5	+3	- .8	-.2	-1.5
2	1	+5	+4	+2	-5	+1.0	+.6	- .5
	2	+5	-.2	-.5	+5	+ .3	0	- .10
3	1	+0	-0	-.1	+1.5	- .3	-1	- .5
	2	-0	+2	+.1	+1.0	+ .6	+.5	-1
4	1	-1	+.4	+.3	+5	-1.4	+.4	-4.0
	2	-1.5	+1.1	+1.4	+4.5	-1.5	-.1	-4.
5	1	-5	-.9	+.4	+2.5	-1.1	-.4	-2
	2	-0	-.5	+.6	+2.0	-1.1	-.3	-1.5
6	1	+1	-1.6	-.3	+2.5	-1.8	+.3	-4
	2	+.5	-.5	+.5	+4.5	-2.0	+.2	-4.5
7	1	+1	-.2	+.9	+.5	- .6	-.7	-3.5
	2	+1	+.2	-0	+2	- .3	+.3	-4
8	1	+1	-.4	-.2	+2.5	- .8	+.7	-4.5
	2	+1	+1.2	+.9	+3.0	- .9	+.3	-4.5
9	1	+3	-.2	-1	+2.5	+ .1	+.6	-6
	2	+3.5	+1.5	-.3	+2.5	- .2	+ 8	-6
10	1	+.5	+1.1	+.1	+1	- .5	+.1	-1
	2	+1	+ .7	-1.1	+1.5	- .3	- 1	-1.5
11	1	-.5	- .3	+.1	+8	-2.6	+ .3	-7
	2	-1	- .7	+.1	+7	-2.4	+ .2	-6
12	1	-5	+ .8	+.6	+1	- .5	+ .5	-.5
	2	0	+ .1	+.4	+1.5	- .5	+ .6	-.5
13	1	0	- .2	-.7	+.5	- .4	+ .3	-1.5
	2	0	- .6	-1.0	+ 1	- .7	-4	-1.5

Note: Rt indicates Root
Cn indicates Crown
1 indicates Maxillary Incisor
Ī indicates Mandibular Incisor

TABLE 12

COMPARISON OF RESULTS BETWEEN THE FIRST AND SECOND TRACING FOR CHANGES FOLLOWING LEVELING

Patient	Tracing	1 Ang.	1 Rt.	1 Cn.	1 Ang.	1 Cn.	1 Rt.	1-1	1 to Hi
1	1	+6.0	+ .4	-2.2	-5.5	+1.3	- .5	+ .9	-2.5
	2	+5.5	+ .9	- .7	-5.0	+1.0	-9	+5	-3.0
2	1	+2.5	+1.6	+ .1	+8.0	-3.3	+ .4	+ .6	-9.5
	2	+2.0	+1.9	+ .7	+6.5	-2.3	+ .2	+ .6	-9.0
3	1	-7	+ .8	+2.8	+5	- .5	+1	+ .4	+ .5
	2	-6.5	- .8	+1.5	+6	-2	+ .6	+ .1	+1
4	1	-2.0	- .2	+ .9	+1.5	- .6	0	-1	- .5
	2	-2.0	- .7	+ .2	+1.5	+5	+8	+ .1	- .5
5	1	-20	+1	+1.8	+9.5	-1.9	+1.7	- .9	-7
	2	-2.5	+ .5	+1.4	+10.0	-2.8	+1.3	- .6	-8
6	1	-6	+ .8	+2.5	0	+ .6	-2	+ .2	+5.5
	2	-5	- .4	+ .7	-1.5	+1	0	-1	+7
7	1	-11	- .6	+5.5	+1.5	+2.4	0	-1.3	+9
	2	-11.5	-1.4	+4.0	+ .5	-1	0	+ .1	+9.5
8	1	-4	+ 1.9	+2.6	+3.	- .2	+1	- .9	+ .5
	2	-4	- .1	+1.3	+4	- .5	+1	+ .1	+1
9	1	+3.5	+2	- .6	+7	-2.9	+ .5	-1.1	12
	2	+3.5	-5	-1.4	+6.5	-2.1	+ .5	0	12.5
10	1	-1	- .3	+ .4	+ .5	+ .6	+ .7	- .4	+ .5
	2	- .5	-1	- .7	+ 1.5	+3	+ .5	+16	+ .5
11	1	+ .2	+5	+ .5	+1	- .7	- .2	+ .2	-2.5
	2	+1.5	0	- .7	+1	- .2	+ .4	-1.2	-2.5
12	1	+ .5	+ .2	+ .1	+1.5	- .3	+ .2	+ .3	-2.0
	2	+1.5	+ .4	+ .7	+1.5	- .5	- .1	- .1	-2.0
	1	+1	0	- .3	+2	-1.6	- .9	+1	-2.5
	2	+1	+ .2	- .2	+2.5	-1.3	- .2	- .1	-2.5

ANALYSIS OF VARIANCE FOR ANGULAR CHANGES IN TABLE 12

Treatment: means in Group I or Group II or Group III.

Group:	Group I*				Group II				Group III			
Tooth	1	2	3	4	1	2	3	4	1	2	3	4
Determination												
1	+2.5	-7	-2.0	-2.0	-6	-11	-4	+3.5	-1	+.2	+.5	+1.0
2	+2.0	-6.5	-2.0	-2.5	-5	-11.5	-4	+3.5	-.5	+1.5	+1.5	+1.0
Total	+4.5	-13.5	-4.0	-4.5	-11	-22.5	-8	+7.0	-1.5	+1.7	+2.0	+2.0
Mean	+2.25	-6.75	-2.0	-2.5	-5.5	-11.25	-4	+3.5	-.75	+.85	+1.0	+1.0
Treatment Totals:		-17.5				-34.5				4.2		
Treatment Means:		- 2.19				- 4.31				.52		

Average Total -47.5

* Patient No. one was eliminated from Group I to even groups

$$C = \frac{(-47.5)^2}{24} = 95.20 \qquad \frac{(\text{Overall total})^2}{\text{Total number of observations.}}$$

A SS Total = Sum Squares of each observation - C

$= (+2.5)^2 + (+2.0)^2 + (-7)^2 + \ldots\ldots+(1.0)^2 - C$

$= 498.54 - 95.20 = 403.34$

B SS Treatments =

$$\frac{\text{Sum of squares of treatment totals}}{\text{Number of observations in treatment total}} - C$$

$$= \frac{(-17.5)^2 + (-34.5)^2 + (+4.2)^2}{8} - 95.20$$

$$= \frac{1514.14}{8} - 95.20 = 189.25 - 95.20 = 84.07$$

C SS among teeth =

$$\frac{\text{Sums of squares of totals for each tooth}}{\text{Number of determinations (Number going into total)}} - C$$

$$= \frac{(+4.5)^2 + (-13.5)^2 + \ldots+(+2.0)^2}{}$$

$$= \frac{992.14}{2} - 95.20 = 496.07 - 95.20 = 400.87$$

D SS Among teeth within treatment = C- B 400.87 - 8407
316.80

E SS Among determinations within teeth A - C 2.47

Analysis of Variance Table

Source of Variation	Degrees of freedom	Sums of squares	Mean Square	F ratios
Among teeth	11	400.87	36.44	
Between treatments	2	84.07	42.04	1.19
Among teeth within treatments	9	316.80	35.20	
Among determinations	12	2.47	.21	
Total	23	403.34		

Conclusions

1. Very small variance due to error in making determinations.
2. Much larger variance due to difference between teeth.
3. Differences due to treatment effects not significantly greater than teeth differences.

$$u\ F = \frac{42.04}{35.20} = 1.19$$

smaller than actual $F_{(2,\ 9),\ 10} = 3.01$

Treatments not significant at the 10 per cent level.

Statistical conclusions relative to net change in dental arch length:*

Maxillary Arch

1. Group II not significantly greater -ve average than III. (Group averages I, II and III not significantly different).
2. Group I highly significantly more variable than III ($P < .005$).
3. Group II Highly significantly more variable than Group III ($P < .005$).
4. Group I not significantly more variable than Group II.

Mandibular Arch

1. No significant differences between averages of Groups I, II and III.
2. Group II not significantly more variable than Group III.
3. Groups I, II and III are not significantly different in variability.

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* By means of F tests

Evaluation Relative to Cuspid Width Increases

The probability of getting a positive sign by chance = $\frac{1}{2}$.
The probability of getting a negative sign by change = $\frac{1}{2}$.
Out of an observed sample of 12 observations, all of these were positive, (one observation was 0 to the accuracy of measurement and therefore, neither positive nor negative).
If the chance in angulation were determined by a chance mechanism the probability of obtaining all 12 of the observations by chance would be = $(\frac{1}{2})^{12} = \frac{1}{4098}$.
This is such a small probability that it is inferred that a chance mechanism is not operating.
The same process is assumed for the increase in incisor angulation discussed on page 24.