THE INFLUENCE OF
ORTHODONTIC TREATMENT ON THE
POSITIONING OF THE LOWER INCISOR

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INTRODUCTION

STOCK FOR SALE - "A recent survey was conducted regarding shoe size of the adult American male and it established that the average size was 9½C. On the basis of this information a new chain of shoe stores is opening nationwide offering only one size shoe - that being a 9½C. This has great benefit in that it eliminates large inventories thereby decreasing overhead and increasing profits."

At present a large percentage of orthodontic patients are being treated with a philosophy similar to that advocated above. Cephalometric studies have established averages (Frankfort mandibular incisor angle, the angle formed by the lower incisor to line NB, the distance in millimeters from the lower incisor to line A-Po, etc.) which have then been defined as an end point or goal of treatment for patients. Variation is usually considered as a deviation from such a mean figure that necessitates correction to the mean figure. Yet an orthodontist utilizing these so-called "norms" would not attempt to band all central incisors with only one sized band.

This simplistic interpertation of variation and normalicy persists in spite of a study by Brodie in 1944[1] which not only demonstrated similar means for the lower incisor mandibular plane angle for the various classes of malocclusion, but ranges for this angle as high as 42°. Brodie commented:

> "These studies exemplify once more the fallacy of employing a mean as a criterion for the individual. With such a large range in this angle

it would be impossible to employ it as a basis for clinical judgment. It would seem but logical to conclude that the axial inclination of the lower incisor, like any other anatomic feature, varies greatly and is probably just as much a part of the individual's pattern as are the other details of his physiognomy. That it changes very little during life is shown by Broadbent, who examined twenty-five white males at three stages between the third and eighteenth year. At three years of age the deciduous incisor stood 92 degrees, at sixteen years its successor stood at 96 degrees, and at eighteen years it had returned to 94 degrees. This feature is undoubtedly just as dependent on such factors as ethnic origins and genetic admixtures as is any other, and to insist that all lower incisors must stand upright to be considered normal is just as untenable as to insist that all foreheads be high or all noses of the Roman variety."

Variation exist in all aspect of nature; it is the genetically normal variation in appearance that results in no two individuals being identical. In this context one position is found in the statement:

"Most so-called malocclusions are biologically normal. What is labeled a malocclusion is merely inherited biologically normal variation in in size of facial and dental structures. The dental profession has transformed this concept into anatomic terms and speaks of "tooth relationships". (Overjet, Class I, Class II, and Class III describe certain anteroposterior incisor or molar relationships; cross-bites describe either lateral or anteroposterior relationships; while overbite describes tooth positions in a vertical plane.) A malocclusion is not a pathology; it is a cultural definition of deviation from socially defined esthetic standards. With few exceptions, the label malocclusion describes biologically normal variation."[2]

Cephalometric analyses are of two distinct types - those providing a subjective definition of an end point to treatment and those providing only objective descriptions of their sample.

An example of a treatment goal established via an analysis would be the IMPA (incisor mandibular plane angle) developed by Tweed[3] when he originally advocated that the lower incisor should be upright over "basal bone". In other words, all incisors should measure 90° to the mandibular plane. Because of certain geometric considerations, he then redefined the lower incisor position in relation to the Frankfort plane.[4] A constant FMIA (Frankfort mandibular incisor angle) of 65° was designated as the end point of treatment because this would upright the incisors and give an esthetically pleasing face.

Another example of such an approach is Steiner's analysis in which the upper incisor is positioned 4mm anterior to line NA and at an axial inclination of 22° to line N.A. Likewise, the lower incisor is positioned in relationship to line NB - 4mm anterior to line NB with an axial inclination of 25° to line NB.[5]

Downs[6] obtained a variety of facial measurements from headfilms from a sample of twenty excellent occlusions. Although he found a large variation to be present in all facial measurements, the averages he computed have since been taken by some orthodontists to represent treatment goals.

Hixon[7] compared a sample of malocclusions and good occlusions and found ranges and averages for size and growth comparable to each other as well as to the figures obtained by Downs. Such findings question the usefullness of cephalometric measurements to discriminate among occlusal classifications.

In a study dealing with esthetics, Riedel[8] obtained radiographs on beauty queen canditates and found that even though malocclusions were present, the ranges and averages again closely coincided with the figures obtained by Downs.

Lindquist[9] analyzed eight of his own treated cases with regard to several different analyses establishing lower incisor treatment goals (Tweed's FMIA, Down's lower incisor to A-Po plane, Holdaway's lower incisor and chin point relationship to the NB plane, and Steiner's lower incisor to NB plane, both angular and linear). He found that "the methods studied for positioning lower incisors very rarely indicated the same results for any individual case. A wide divergence of results and contradictions were apparent." He did find a great deal of consistency within each method. This raised the question that a concept of treatment and facial esthetics must lie behind the formulas and he questioned which came first, the concept or the formula. He concluded: "A perfect formula or guide for lower incisor position has never been devised and probably never will be."

Recently Weinstein[10] confirmed an old concept that teeth are in a state of stable equilibrium as a direct result of muscular balance. This provides an alternative hypothesis to the use of cephalometric numbers as an end point to treatment. Malocclusions are in a state of equilibrium and are therefore stable in their original position. If the results of treatment are to remain stable, it is then logical to "straighten teeth" within the form of the dental arch as presented. This has been a major premise in the Orthodontic Department of the University of Oregon Dental School. If teeth are moved to positions outside the original equilibrium position, one would expect relapse or return to their original position - aside from growth changes which include minor (1-2mm) retraction of the lower incisors.

The purpose of this paper is to assess the long term stability of the positions of lower incisors that have deliberately been moved outside this "stable" area.

REVIEW OF LITERATURE

Figure 1 summarizes several longitudinal studies with regard to the change in incisor mandibular plane angulation on orthodontically untreated samples. All changes of lower incisor angulation with age are similar (within 2^{o} of initial measurement) with the exception of Fletcher's findings. Fletcher recorded the change in angulation during the eruption of the lower permanent incisors which accounts for this difference. After occlusion was reached he stated that this angle changed very little. None of these studies, however, have provided a measurement of linear change with age of lower incisors from skeletal landmarks.

With regards to treatment effects on the lower incisor, Jacobs[11] investigated the effect of serial extraction on the ultimate position of the lower incisor. He showed that in serial extraction cases the lower incisor mandibular plane angle decreased an average of 2.8^{o} while in his non-treated control groups the lower incisor mandibular plane angle increased an average of 0.6^{o}. He provided no information on the variation present in his sample but results indicate that all teeth did not respond to treatment in a similar manner.

Mills[12] compared several different treated groups of patients with a group of untreated controls. The untreated controls showed a proclination of the lower incisor mandibular plane angle of 2^{o} from age 9 to 19. (This sample he divided into two age ranges - from 9 - 14 years when the lower incisor proclined 1.5^{o}, and from 14 - 19 years when the lower incisor proclined an additional 0.5^{o}). Mills then compared the behavior of the

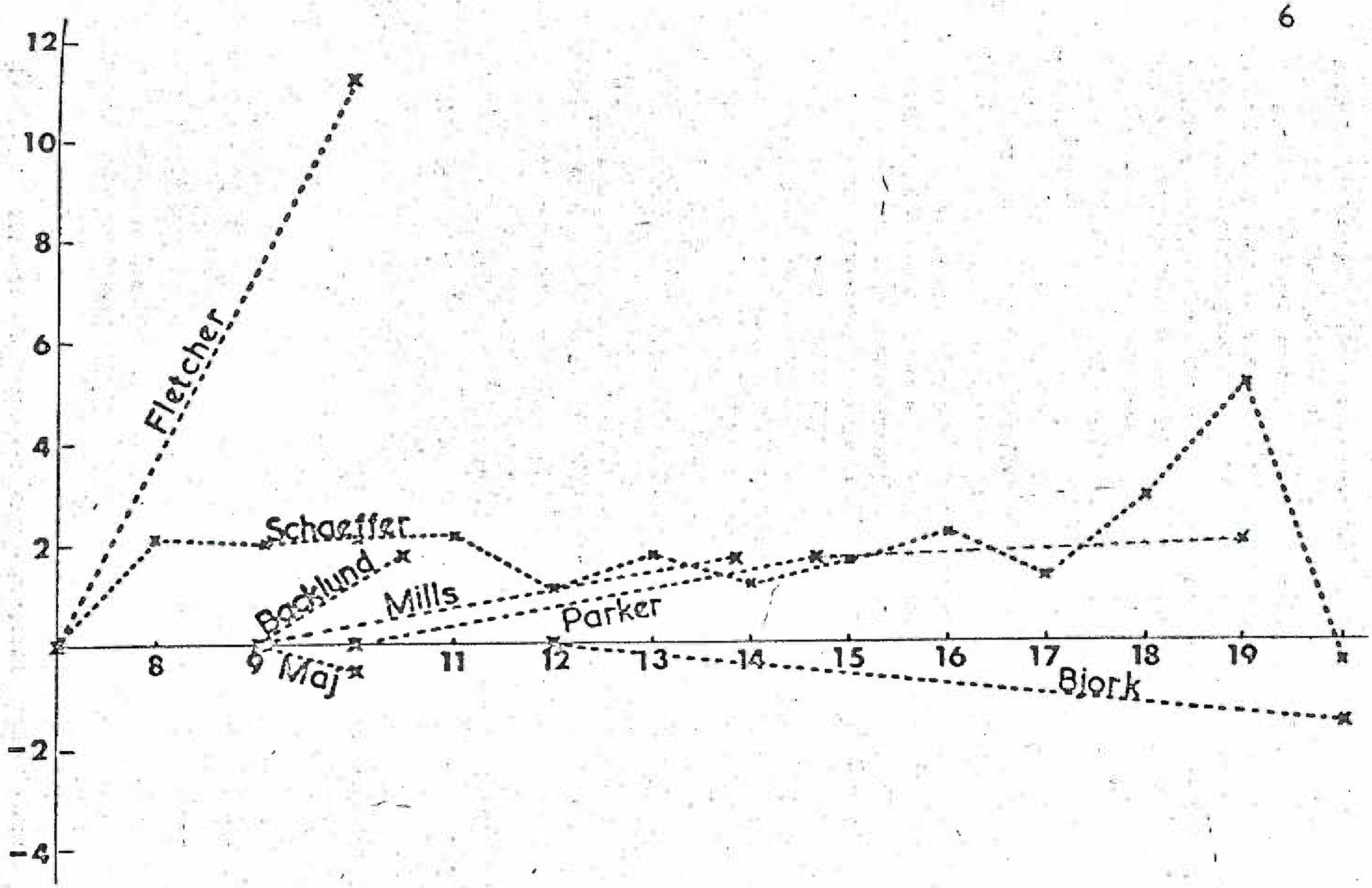


FIGURE I - Longitudinal change in lower incisor angulation in orthodontically non-treated samples reported by various investigators for various age spans.

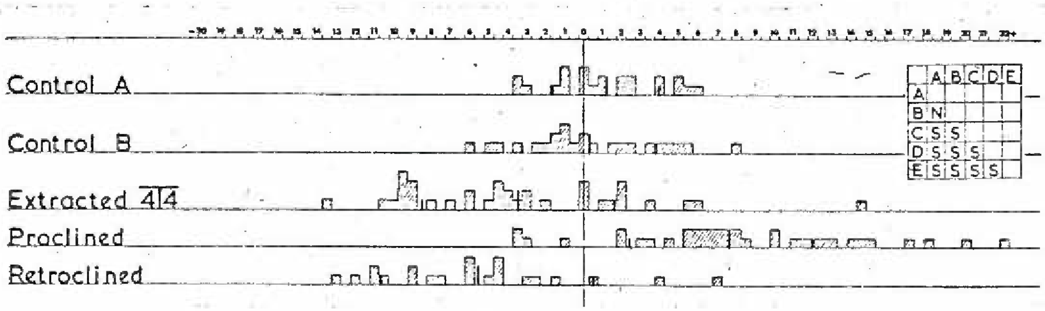


FIGURE 2 - A series of histograms showing the changes occurring in Mill's study to the lower incisor mandibular plane angle (treated cases at least one year with no retention). The longest black line in each group represents the mean, while each shorter line represents one S.D. from the mean. The inset shows significant differences between all groups except between the two controls (A = non-treated 9-14 year age control; B = non-treated 14-19 year age control) at the .95 level of confidence.

lower incisor with his untreated sample in three forms of treatment. All treatment results were at least 1 year out of retention. With treatment by extracting the mandibular first bicuspid and no appliance therapy the lower incisors retroclined 3.5°. In using appliance therapy to procline the lower incisors a minimum of 7° (mean proclination 11.1°) the after-retention results showed an average increase from the start of treatment of 6.8° in the lower incisor mandibular plane angle. Using appliance therapy in another group to retrocline the lower incisors a minimum of 7° (mean retroclination 11.9°), the after-retention results showed an average decrease from the start of treatment of 5.5° in the lower incisor mandibular plane angle. A summary of Mill's findings are given in histogram form in figure 2. It can be seen from these histograms that treatment involving movement of the lower incisors has an effect on the resultant position of the lower incisor. After treatment, however, all teeth did not respond the same. Some teeth that were proclined continued to procline while others returned toward their original position or even beyond. The same response is noted for the retroclined teeth.

Mills used mostly removable appliances for his orthodontic treatment so a large percentage of the movement of the lower incisors was of a tipping nature. To establish crown movement of the lower incisor related to the facial complex, he measured the angle SNI (sella-nasion line to the incisal edge of the lower incisor) in his control groups as well as in the three treated groups. He found a significant change in this angle between his treated groups (although the difference in means between the retroclined and proclined groups was only 3°) and from this he concluded that crown movement was accomplished. No linear measurements for change in lower incisor position were made.

Mills' conclusion was that the more proclined or retroclined the lower incisors were angulated, the more they will tend to relapse because the lower incisors lie within a very narrow zone of stability. He states that the "first principle should be to leave the labiolingual position of the lower incisor unchanged, except in very rare cases."

Litowitz[13], in a study of twenty orthodontically treated cases at least one year out of retention, presented results of the treatment effect of both proclination and retroclination of the lower incisor. In his sample when the lower incisors were proclined, half tended to return toward their original position and half tended to become more procumbent. When they were retroclined the majority tended to continue in that direction after treatment. From the wide range of varying movements exhibited by the lower incisors following treatment and retention, no predictable pattern of lower incisor stability was present in Litowitz's sample.

The purpose of this paper is similar to that of Mills': to ascertain the changes in lower incisor position as a result of growth, and to then determine if mechanical repositioning of the lower incisors beyond that which could be attributed to growth remains stable.

The advantage of this study over previous studies is that post retention records of treated cases were obtained after a longer period of no retention (at least three years), orthodontic movement of the lower incisors was primarily bodily, and linear measurements have been made to ascertain the amount of lingual repositioning of the lower incisor within the mandible.

MATERIALS AND METHODS

To assess individual variation in growth or treatment requires longitudinal data. Untreated longitudinal cases were secured from the Child Study Clinic at the University of Oregon Dental School. Orthodontically treated cases were patients of private practitioners. All patients were from European-American stock in the middle socio-economic class. A total of twenty-seven children comprised the non-treated group. Criteria for selecting the non-treated group were: no orthodontic treatment, no missing teeth or accidental injuries, and availability of complete records. The initial age chosen was an age comparable to the desirable developmental age when orthodontic treatment is generally initiated (no more than 2-3 decidious teeth remaining in the mixed dentition). The mean initial age for this sample was 12 years, 1 month (12-1) with a range of 10-0 to 14-0. The latest age was established by the sample available as most records were discontinued at age 18. However, if an older age was available the oldest age was used. The latest age for this sample averaged 19-1 with a range of 18-0 to 22-1.

A group of orthodontically treated patients whose lower incisors were retracted were secured from private practitioners using the edgewise technique. The only requirements placed on these cases were that the lower incisors were positioned lingually during treatment at least 3mm and that the patient was without mechanical retention for a least 3 years prior to securing the post retention records. A total of nineteen patients comprised this group with a mean initial age of 12-0 (range of 10-2 to 15-10). The post retention records varied in age (a mean age of 22-4 with a range from 18-2 to 28-0) due to difficulty of locating patients (moving, attending school out of state, etc.) and the difficulty of finding patients that met the initial critiera established. Treatment was completed on these patients, on the average, at 15-10 (with a range from 1207 to 19-4).

The following measurements were recorded:

HEADFILMS:

Two types of measurements were performed on the headfilms.

1. Measurement of the lower incisor position. An acetate overlay was placed on the headfilms with a straight line touching nasion and pogonion. From this line the distance was recorded in mm to the most labial surface on the most prominent lower incisor (1-NPo measurement).

2. Tracings of each individual headfilm recording the following information:

a. SNA - The angle formed by a line passing from the center of sella tercica to nasion with a line from nasion to point A.

b. SNB - The angle formed by a line passing from the center of sella tercica to nasion with a line from nasion to point B.

c. ANB - The difference between angles SNA and SNB.

d. SNI - The angle formed by a line passing from the center of sella tercica to nasion with a line from nasion to the incisal edge of the lower incisor.

e. $\bar{1}$ to mandibular plane - The angle formed by passing a line through the incisal edge of the lower incisor and its apex to a line passing through the lower border of the symphysis and the lowest portion of the mandible near gonion.

f. Mandibular plane angle - The angle formed by a line passing through the lower border of the symphsis and the lowest portion of the mandible near gonion with a line passing through the top of porion and the inferior border of the orbit (Frankfort horizontal).

g. FMIA - Tweed's Frankfort mandibular incisal angle - the angle formed by the interception of the Frankfort horizontal line (explained in f.) and a line passing through the incisal edge and apex of the lower incisor.

h. $\overline{1}$ - NB in degrees - The angle formed by a line passing through the incisal edge of the lower incisor and its apex and the line NB (explained in b.).

i. $\overline{1}$ - NB in mm - The measurement in mm from the most labial surface of the lower incisor perpendicular to the line NB.

j. Po - NB - The perpendicular distance in mm from the line NB to pogonion (the furthest anterior point on the chin).

k. $\overline{1}$ to A-Po - The distance in mm from the most labial surface of a lower incisor to a line passing from point A to pogonion . A diagram of these measurements is shown in figure 3. All cephalometric landmarks referred to are located as described by Bjork[14].

MODELS:

1. Estimation of initial lower anterior crowding, crowding at completion of treatment if any, and crowding recurring after retention. Estimation of crowding was used instead of a direct measurement because no satisfactory method of directly measuring crowding has yet been devised.

2. Direct measurements were made of molar width, cuspid width, and the distance from the mesial of the two mandibular first permanent molars

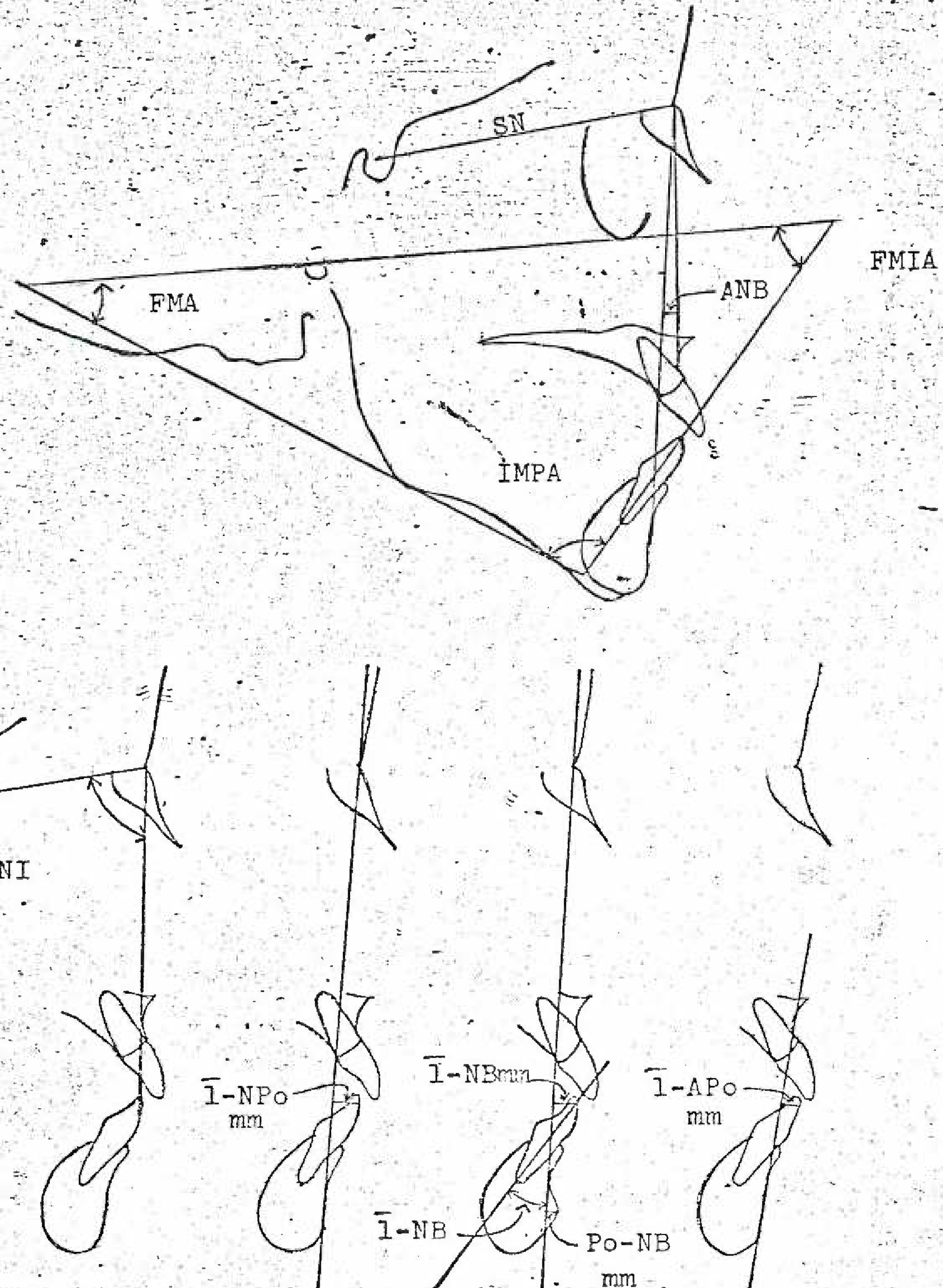


FIGURE 3 - Diagram of cephalometric measurements recorded

to the most labial edge of the lower central incisors. Measurements of molar width were made between the two mesial lingual cusp tips. Measurements of cuspid width were made between the cusp tips. If the cusp tips were abraded, the center of the abraded areas were used as a point from which to measure.

All measurements on the orthodontically treated group plus all $\bar{1}$ - NPo measurements on all individuals were made twice, independently, by the author. $\bar{1}$ - NPo measurements (only changes compared) that were not within one standard error of the measure ($SEM=\sqrt{\frac{\Sigma d^2}{2N}}$) were remeasured. If an obvious recording or measurement error was noted, the obvious erroneous measurement was discarded and the two closest measurements were then averaged. If no measurement was in obvious error, then all 3 measurements were averaged. Otherwise, when the measurements were within one standard error of the measure of each other they were averaged to represent the "true" measurement. The standard errors of measure are given in table 1.

After all data was analyzed, the two samples were found to be significantly different (only initial ages and the angle SNI were comparable). There are possibly several reasons for this difference - one of which, although small (5%), could be chance alone. The most likely would be the very decision of the orthodontic sample to undergo orthodontic treatment. With the wide range of variation present in all of nature, the treated sample as a whole probably came from one end of the range of normal variation with regard to dental features. Considering this fact, by their very nature the two samples cannot help but be from different populations.

An ideal control group would be one whose initial measurements did not significantly differ from the treated sample. A longitudinal sample of similar untreated malocclusions was unavailable. That the angle SNI was not significantly different in the two groups may be explained by the fact that

Table 1

Standard Error of the Measure of Change*

MEASUREMENT	S.E. MEASURE
Headfilms	
1-NPo	.2mm
Models	
molar width	.4mm
cuspid width	.4mm
arch length	.2mm
crowding	1.0mm

Standard Error of the Measure for Cephalometric Measurements

MEASUREMENT	S.E. MEASUREMENT
SNA	.7°
SNB	.4°
ANB	.6°
SNI	.3°
1-Mand. Plane	1.0°
Mand. Plane	.5°
FMIA	1.2°
1-NB (angle)	1.0°
1-NB (mm)	.2mm
Po-NB (mm)	.3mm
1-APo (mm)	.4mm

*This represents an estimate of total error - location of landmarks at both ages, their tracings and measurements as well as variation from patient positioning in the cephalstat for 1-NPo.

the lower incisors of the treated sample were initially more procumbent in the mandible (possibly one of the extremes in variation that prompted orthodontic treatment). Table 2 gives initial measurement comparisons between the two groups. Because of this difference in initial measurements, changes occurring within groups between initial and latest measurements will be the primary source of information. There is little reason to believe that differences could be found for the small amounts of growth remaining in the two samples. Even so, such differences are small in relation to the magnitude of treatment change and would detract little from the validity of the questions posed in this study.

Table 2

Initial Measurements for Non-Treated and Treated Samples

	1-NPo(mm)		SNI		$\bar{1}$-Mandibular Plane	
	Non-Treated	Treated	Non-Treated	Treated	Non-Treated	Treated
$\bar{X}$*	3.8	7.8	81.2	82.2	99.8	103.2
S.D.*	2.0	2.0	2.8	2.5	7.6	4.8
R*	0.0 7.7	3.2 10.0	78.0 91.5	77.0 86.5	82.0 110.0	96.0 112.8
N*	27	18	27	18	27	18
T*	5.59**		1.20**		1.70**	

	FMIA		$\bar{1}$-NB		$\bar{1}$-NB(mm)	
	Non-Treated	Treated	Non-Treated	Treated	Non-Treated	Treated
$\bar{X}$	56.1	49.6	28.0	33.6	5.0	7.2
S.D.	6.5	4.8	5.4	5.0	1.6	1.7
R	47.0 71.0	39.0 56.5	14.5 35.0	16.0 33.0	2.1 7.4	3.7 9.8
N	27	18	27	18	27	18
T	3.69**		3.44**		4.50**	

	$\bar{1}$-APo(mm)		Po - NB(mm)	
	Non-Treated	Treated	Non-Treated	Treated
$\bar{X}$	1.9	4.0	1.5	0.0
S.D.	1.3	1.8	1.1	1.1
R	0.0 5.2	0.8 8.8	-0.8 3.5	-2.7 1.4
N	27	18	27	18
T	4.41**		4.34**	

*$\bar{X}$=Mean, S.D.=Standard Deviation, R=Range, N=Number in Sample, T=Statistical T-Value computed from T test.
**A T-Value of 1.69 is necessary for statistical significance at the .95 level of confidence when comparing the non-treated with the treated sample. df=43 **following a T-Value indicates significance at the .95 level of confidence.

FINDINGS

Table 3 shows direct mm measurements of the position of the lower incisor measured to line N-Po as well as a graphic illustration of these measurements. Table 4 shows changes in position of the lower incisor related to line N-Po occurring between different ages in the non-treated and in the orthodontically treated samples. The total change occurring as a result of growth in the non-treated sample is a lingual movement of the lower incisor of 0.3 mm. Orthodontic treatment positioned the lower incisors lingually an average of 5.2 mm with an average "relapse" (minimum of 3 years out of retention) of 0.4 mm. The largest relapse of any treated case was 1.5 mm of anterior movement. One incisor that was retracted 6.2 mm actually continued lingual movement for an additional 0.9 mm amounting to over 7 mm of lingual repositioning from its original position. This compares to a maximum of 3.1 mm of lingual movement that occurred in one case in the non-treated sample. The T value of 10.79 calculated to compare the changes between the two groups shows the difference obtained by orthodontically repositioning the lower incisor. If that portion of lingual movement accounted for by growth (1/3 of a mm) were subtracted from the movement of the lower incisor in the orthodontically treated sample, the net lingual repositioning of the lower incisor due to orthodontic treatment alone would be 4.5 mm. It is apparent that orthodontic treatment can reposition the lower incisor in a lingual direction over and above that which could be accounted for by growth and have it assume a new equilibrium position.

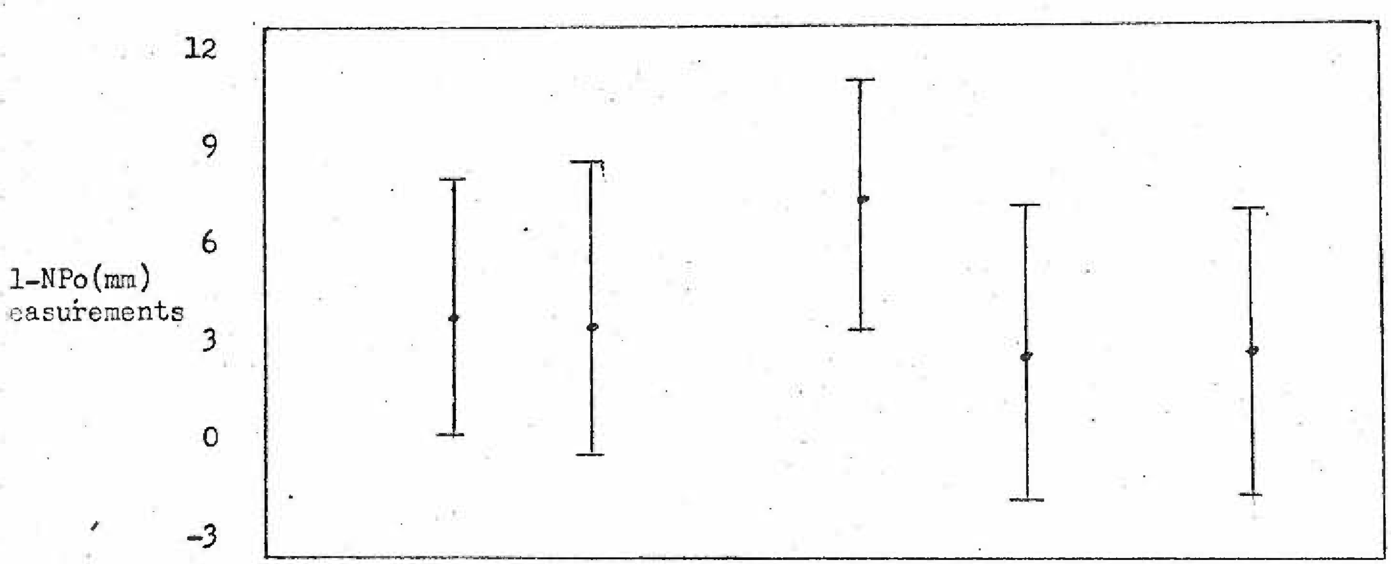
Table 3

Measurements of Lower Incisor Position to Line N-Po in mm (1-NPo)

	NON-TREATED		TREATED		
	Initial	Last	Initial	Treatment Completed	Post Retention
$\overline{X}$	3.8	3.4	7.4	2.3	2.6
S.D.	2.0	2.6	2.0	2.5	2.7
R	0.0 7.7	-0.8 8.5	3.2 10.8	-2.2 6.9	-2.0 6.7
T	5.59**			1.04	

Measurements of Lower Incisor Position to Line N-Po in mm (1-NPo)

	NON-TREATED		TREATED		
	Initial	Last	Initial	Treatment Completed	Post Retention
Ages	12-0	19-1	12-1	15-10	22-4



The vertical lines represent the range of measurements for 1-NPo for the various ages measured in the two samples. The center dot in each line represents the mean for that sample.

Table 4

Change of Incisor Position in mm Calculated from 1-NPo mm Measurements

	NON-TREATED	TREATED		
	Change Initial-Last	Change Initial-Completion of Treatment	Change Completion of Treatment-Post Retention	Change Initial-Post Retention
$\bar{X}$	-0.3	-5.2	0.4	-4.8
S.D.	1.3	1.3	0.8	1.6
R	-9.3 1.4	-7.1 -3.1	-0.9 1.6	-7.3 -2.4
T	10.79** (Change Initial-Last vs. Change Initial-Post Retention)			

Table 5

Angle SNI

	NON-TREATED			TREATED			
	Initial	Late	Change Initial Late	Initial	Treatment Completed	Post Retention	Change Initial Post Retention
$\bar{X}$	81.2	82.6	1.4	82.2	79.6	80.1	-2.0
S.D.	2.8	3.0	1.3	2.5	2.1	2.2	1.7
R	78.0 91.5	78.0 92.5	-1.5 4.0	77.0 86.5	76.0 83.5	76.5 84.0	-5.0 1.5
T	7.84** (Change Initial Late vs. Change Initial Post Retention); 3.02** (Late vs. Post Retention)						

Table 6

Incisor Mandibular Plane Angle

	NON-TREATED			TREATED			
	Initial	Last	Change Initial-Last	Initial	Treatment Completed	Post Retention	Change Initial-Post Retention
$\bar{X}$	99.8	100.4	-0.6	103.2	95.5	97.8	-5.5
S.D.	7.6	8.8	3.7	4.8	5.5	4.8	3.8
R	82.0 110.0	80.0 114.0	-6.0 7.5	96.0 113.0	86.0 107.5	89.0 109.0	- 13.0 1.5
T	5.33** (Change Initial-Last vs. Change Initial-Post Retention); 1.17 (Last vs. Post Retention)						

The angle SNI shows no statistical difference between the two groups initially. There is, however, a significant difference between the two latest groups as the angle SNI in the treated group decreases by 2° while the angle SNI in the non-treated sample increases by 1.4°. The angle SNI only represents a change in positioning of the lower incisor in relation to the upper face. As can be seen in table 5 there is a statistical significance in the measurements for angle SNI between the two groups at their latest ages. Even though this angle is a less valid form of measuring positional changes than the direct measurement of lower incisor position to line N-Po, it reinforces the findings of lingual positioning of the lower incisors as a result of orthodontic treatment that was found by direct measurement.

The incisor mandibular plane angle is a measurement commonly used by some orthodontists to denote incisor movement. The variability associated with this measurement (Mills reported a S.E. Measure of 2.5°) affects its reliability as even a descriptive measurement. Parallel bodily movement of a lower incisor could be accomplished with no change in this angle.

On the average the untreated group's incisor mandibular plane angle increased by 0.6° while the orthodontically treated sample's incisor mandibular plane angle decreased by 5.5°. Statistically this difference tests to be significant. The measurement figures for the lower incisor mandibular plane angle are given in table 6.

Correlations were computed on the change from initial to latest ages for positions of the lower incisors related to line N-Po and the change in incisor mandibular plane angle. The correlation for the non-treated sample was r =.56 while the correlation for the treated sample was r =.08. There is a part-whole phenomena associated with this correlation that accounts for the relatively large correlation for the non-treated sample. Even so, the correlation of r =.08 for the treated sample illustrates why the incisor mandibular plane angle measurement is of no value in describing bodily movement of lower incisors accomplished by orthodontic treatment. For this reason the statistical significance found between the two samples for the incisor mandibular angle is not clinically meaningful.

The behavior of the lower incisor is thought by some orthodontists to be related to the steepness of the mandibular plane. To test this supposition the mandibular plane angle for the non-treated sample was divided at the mean and the movement of the lower incisor (1-NPo) was compared for the two halves of the sample (high and low mandibular plane angles). The difference in means of 0.1 mm in lower incisor movement (1-NPo) was not significant.

The FMIA angle of Tweed, 1-NB angle and mm measurement of Steiner, 1-APo measurement of Down's, and Po-NB measurement of Holdaway's were computed for the two groups regarding change, but since they revealed no information that was significantly different from that already contained in table 1, 2, or 3, the data is presented in Appendix I.

What was of interest, however, were the ranges and standard deviations associated with these measurements for the treated sample. Each of these measurements constitute an average or ideal end point of treatment as defined by Tweed, Steiner or Holdaway. The ranges and standard deviations for the latest ages of the two samples are almost identical with no differences apparent that would separate the treated group from the non-treated group. This single fact, that the standard deviations associated with these measurements for the treated group at completion of treatment are as large as the standard deviations for the non-treated group, illustrates the uselessness of such "norms" as treatment goals.

Model measurements were done primarily to determine if crowding in the lower anterior region could be directly related to any measurements or changes. The changes in arch dimensions recorded are presented in table 7.

Table 8 shows correlations coefficients computed relating change in crowding to various arch dimensional changes as well as to change in lower incisor position (1-NPo) obtained by headfilm measurements.

Molar width and arch length changes between the two groups cannot be directly compared because extraction in the treated sample significantly affects both. Cuspid width changes from initial to last decrease in both samples with the non-treated cuspid width decreasing on the average 0.6 mm while the orthodontically treated cases on the average show a decrease in cuspid width of 1.3 mm. This exceeds measurement error and is of interest because both samples do show a decrease in cuspid width with age.

On the average crowding increased in the non-treated sample by 1.9 mm. Initial crowding in the treated sample was decreased on the average 2.3 mm by treatment with 2.1 mm of crowding returning after retention. The most meaningful correlation is probably that correlating change in crowding from end of treatment to post retention with change of incisor position accomplished during treatment (r =.12). In effect orthodontic treatment by retraction of the lower incisors did not after a period of no retention significantly reduce the amount of crowding initially present, although it appears to have prevented the average increase of 1.9 mm of additional crowding that might have appeared due to growth change. From the correlations calculated, the variable which most affected the return of crowding is the decrease in cuspid width with age (r =.55).

Table 7

Changes in Arch Dimensions

NON-TREATED

	Change Molar Width	Change Cuspid Width	Change Arch Length	Change In Crowding
$\bar{X}$	-0.3	-0.6	-1.3	1.9
S.D.	1.1	0.9	1.0	1.7
R	-2.1 2.0	-2.4 1.2	-3.1 0.8	-1.0 -7.0

TREATED

	Change Molar Width		Change Cuspid Width		Change Arch Length		Change Crowding	
	Initial to Treatment Completed	Treatment Completed to Post Retention	Initial to Treatment Completed	Treatment Completed to Post Retention	Initial to Treatment Completed	Treatment Completed to Post Retention	Initial to Treatment Completed	Treatment Completed to Post Retention
$\bar{X}$	-2.6	-0.6	-0.0	-1.3	-8.3	-0.1	-2.3	2.1
S.D.	2.2	0.9	1.4	1.0	2.1	0.6	2.9	1.5
R	-7.4 1.4	-2.8 0.3	-2.2 3.1	-2.7 0.9	-11.2 - 4.6	-1.3 1.0	2.0 -10.0	0.0 6.0

Table 8

Correlation Coefficients Relating Changes in Crowding with Changes in Arch Dimensions

NON-TREATED	r
Change in Crowding, and Change in Arch Length	.32
Change in Crowding, and Change in Cuspid Width	.11
Change in Crowding, and Change in incisor Position (1-NPo change)	.08
TREATED	
Change in Crowding, Treatment Completed to Post Retention, and Change in Incisor Position, (1-NPo change) Initial-Treatment Complete	.12
Change in Crowding, Treatment Completed to Post Retention, and Change in Incisor Position, (1-NPo change) Treatment Complete - Post Retention	.35
Change in Crowding, Treatment Completed to Post Retention, and Change Cuspid Width, Initial - Treatment Complete	.39
Change in Crowding, Treatment Completed to Post Retention, and Change Cuspid Width, Treatment Completed - Post Retention	.55
Change in Crowding, Treatment Completed to Post Retention, and Change Arch Length, Treatment Completed - Post Retention	.23
Change in Crowding, Treatment Completed to Post Retention, and Change in Crowding, Initial - Treatment Complete	.29

DISCUSSION

The primary purpose in undertaking this study was to ascertain if mechanical retraction of lower incisors yielded "stable" results following removal of all forms of retention. This was done by calculating change in position of the lower incisor in relation to line N-Po. The results obtained show that it is usually possible, on the average, to move the lower incisor a few millimeters from its original position to a "new" position of equilibrium and have it remain stable.

The untreated group exhibited a lingual movement of the lower incisor of 0.3 mm while orthodontic treatment produced an average lingual change in lower incisor position of 4.8 mm. The mandible continues to grow after growth of the remaining portions of the head has ceased. When this occurs, the lower incisors are advanced into the perioral musculature surrounding the dentition and as a direct result the teeth are repositioned lingually to some extent. This is probably what occurred in the untreated sample. The treated sample shows that the tongue is able to be encroached upon to a greater extent than previously believed possible.

At the orther extreme, three orthodontically treated cases were found that were proclined at least 2mm. (Initially this study was to include an equal sample of orthodontically treated cases with labially advanced incisors in order to compare labial placement of incisors with retraction of incisors. At least 300 records were examined in trying to locate a suitable sample of this form of treatment with the net result of only finding three cases which met the criteria established.) All three of these relapsed after treatment by advancement of the lower anteriors to very near their original position. Measurements of the lower incisor ($\bar{1}$-NPo) for these three cases are as follows:

Case#	Lower incisor advanced from initial position	Lower incisor relapsed	Net gain in labial direction
1	2.2 mm	3.2 mm	-1.6 mm
2	2.7 mm	2.3 mm	+ .4 mm
3	2.8 mm	2.6 mm	+ .2 mm

Three cases do not supply enough information upon which to base conclusions, but due to the lack of orthodontic treatment by advancement of the lower incisors in this area and the trend set by these three cases, advancement of lower incisors would appear to place them in an unstable position.

The reason for this difference in behavior of the lower incisor is possibly due to a degree of imbalance between the muscles of the tongue and lips. The tongue exerts a strong influence as the eruption of teeth is occurring, thereby positioning these erupting teeth into the largest perimeter possible, the boundry of which is established by the perioral musculature. After the lower incisors are initially positioned, to advance them any further into the perimeter established by the perioral musculature (with hopes of stability) is not generally possible because lengthening or stretching of muscles (other than by surgical reattachment) does not produce stable results.

When overbites are reduced only by increasing vertical dimension and allowing over eruption of posterior teeth, the muscles of mastication become over extended and in time return to their original position. As a consequence the overbite returns. Rapid maxillary palatal expansion encroaches into the perioral musculature also. It appears that, after retention is removed, rapid maxillary palatal expansion cases tend to return to their original width.

Muscles are able to readapt at shorter lengths. An example of this is available when a broken long bone of the body heals at a shorter length than its original length. Muscles associated with these bones are able to compensate and still perform their functions. The perioral musculature is unopposed by other antagonists and consequently is able to readapt to lingually positioned teeth. This would necessitate that the tongue not exert as great an influence as the perioral musculature and/or be capable of readapting to a shortened position.

It was hoped that by analyzing various measurements of arch dimensional changes and correlating these with change in lower incisor position, some significant relationships could be established regarding the cause of crowding. Because so many variables affect crowding, no useful correlations were apparent. The largest correlation in the non-treated sample was $r = .32$ reflecting change in crowding with arch length change. In the treated sample the largest correlation was $r = .55$ reflecting change in crowding with change in cuspid width from completion of treatment to post retention.

A coefficient of determination was calculated for the correlation of return of crowding with cuspid width change in the treated sample ($r = .55$). It reveals that of all the variables contributing to crowding calculated in this sample, the variable of decrease in cuspid width only accounts for about 30% of all variation contributing to crowding. Crowding becomes a very complex issue when one realizes that it is possible for two teeth to be overlapped or considered crowded yet distal to them sufficient space may exist in the arch to accomodate them.

Probably the most significant but unmeasured variable affecting crowding and least possible to study is the connective tissue blanket (the soft tissue surrounding the teeth and overlying the bone). Supracrestal fibers connecting the teeth in some manner affect the ultimate positioning of teeth. An illustration of this is the degree of rotational relapse lessened by performing a quiltectomy after rotational corrections by orthodontic treatment have been accomplished. Clinically it appears that this procedure decreases the affect of these fibers on the ultimate positioning of teeth after orthodontic treatment.

CONCLUSIONS

A study was conducted to ascertain whether the lower incisor position presented in a malocclusion is "the" position of stability for these teeth.

It was found that the lower incisors of a non-treated sample moved lingually on the average 0.3 mm from age 12 to 19 while the incisors of an orthodontically treated sample were placed on the average 5.2 mm lingual from their original location and "rebounded" on the average only 0.4 mm.

The ranges and standard deviations for the treated and non-treated samples were similar when comparing latest measurements. Because of the large standard deviations present for these measurements at the end of treatment it is apparent that the use of "norms" or averages to define treatment goals or the end point of treatment are without merit.

In spite of lingually positioning lower incisors by orthodontic treatment which provides more than enough space to accomodate these teeth, the average lower anterior crowding returning after treatment was over 2 mm.

APPENDIX I

FMIA

	Non-Treated			Treated			
	Initial	Late	Change Initial - Late	Initial	Treatment Completed	Post Retention	Change Initial- Post Retention
$\bar{X}$	56.1	58.3	2.6	49.6	59.5	58.5	8.9
S.D.	6.5	8.2	3.6	4.8	6.3	6.2	4.4
R	47.0 71.0	45.5 75.0	-5.5 8.5	39.3 56.5	46.5 69.3	47.5 67.3	1.0 16.8
T	5.38** (Change Initial - Late vs. Change Initial-Post Retention) 0.06 (Late vs. Post Retention)						

$\bar{1}$ - NB Angle

	Non-Treated			Treated			
	Initial	Late	Change Initial - Late	Initial	Treatment Completed	Post Retention	Change Initial-Post Retention
$\bar{X}$	28.1	27.8	0.3	33.6	23.9	24.8	-8.8
S.D.	5.4	5.9	3.4	5.0	5.4	6.0	3.8
R	14.5 35.0	14.0 38.0	-6.5 7.0	24.3 44.8	16.0 32.8	13.8 35.0	-16.0 - 1.0
T	7.86** (Change Initial - Late vs. Change Initial-Post Retention) 1.66 (Late vs. Post Retention)						

$\bar{1}$ - NBmm

	Non-Treated			Treated			
	Initial	Late	Change Initial - Late	Initial	Treatment Completed	Post Retention	Change Initial-Post Retention
$\bar{X}$	5.0	5.4	0.4	7.2	4.0	4.7	-2.6
S.D.	1.6	2.1	1.0	1.7	1.4	3.1	1.1
R	2.1 7.4	1.5 9.6	-1.3 2.4	3.7 9.8	1.3 7.0	1.7 7.6	-4.9 0.3
T	9.48** (Change Initial - Late vs. Change Initial-Post Retention) 1.13 (Late vs. Post Retention)						

APPENDIX I

$\overline{I}$ - APomm

	Non-Treated			Treated			
	Initial	Late	Change Initial - Late	Initial	Treatment Completed	Post Retention	Change Initial-Post Retention
$\overline{X}$	1.9	2.3	0.3	4.0	1.1	1.4	-.2.5
S.D.	1.3	1.7	0.8	1.8	1.7	1.9	1.1
R	0.0 5.2	-0.2 6.5	-1.7 1.7	0.8 8.8	- 1.6 5.4	- 2.5 5.6	- 4.8 - 0.9
T				1.50		9.93**	

$\overline{Po}$ - NBmm

	Non-Treated			Treated			
	Initial	Late	Change Initial - Late	Initial	Treatment Completed	Post Retention	Change Initial-Post Retention
$\overline{X}$	1.5	2.7	1.2	0.0	2.5	3.0	3.0
S.D.	1.1	1.4	0.7	1.1	1.7	1.8	1.5
R	-0.8 3.5	0.0 4.7	-0.2 2.9	-2.7 1.4	0.0 5.3	-0.55 6.5	0.3 5.3
T				.69		5.30**	