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The Effect of Mandibular First Molar Tip Back on Mandibular Incisor Long-Term Stability

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THE EFFECT OF MANDIBULAR FIRST MOLAR TIP BACK ON MANDIBULAR INCISOR LONG-TERM STABILITY

by

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Each person whose signature appears below certifies that this thesis in their opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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ABSTRACT

THE EFFECT OF MANDIBULAR FIRST MOLAR

TIP BACK ON MANDIBULAR INCISOR

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The purpose of this study is to determine if mandibular first molar distal tip back during orthodontic treatment will result in improved long-term alignment of mandibular incisors. Our pre and posttreatment sample consisted of 57 Class I and Class II patients (40 female and 17 male). Incisor irregularity was recorded at T2 and T4 (average of 12.9 years postretention at T4). Molar tipback was evaluated T1 to T2 and T2 to T4. The sample was divided into 3 groups - molars tipped distally 1 degree or more during treatment, molars essentially not tipped, and molars tipped mesially 1 degree or more during treatment. A one-way ANOVA analysis of variance comparing mean change in incisor irregularity relapse total, T2 to T4, produced a significant difference in males. Males (n=17) demonstrated significantly less postretention incisor relapse (r=0.5, p=0.038) when first molars were tipped distally during treatment. Males (n=12) with bicuspid extraction exhibited even less incisor relapse (r=0.6, p=0.039). Females demonstrated variable unpredictable results.

I. INTRODUCTION

Orthodontic literature is replete with studies on suggested causes for postorthodontic treatment relapse.[1,2,3,4,5,6,7, 8,9,10,11,12,1314,15,16,17,18,20-22,31-34,36,48] All agree that relapse is multifactorial and at times, unpredictable. Overexpansion, violating intercanine width, unfavorable growth, parafunctional habits, significant arch form change, severity of initial crowding, shape of teeth and many other factors, have all been shown to be correlated with posttreatment relapse. In fact, the literature indicates that relapse is the norm. Careful attention to the details of finishing and overcorrection, as reported by Zachrisson[17-18] may help to minimize relapse.

Dr. Robert Little from the University of Washington has published extensively on the subject of relapse. At a meeting of the Pacific Coast Society of Orthodontists in 1996, he made the clinical observation that mandibular first molars tipped distally during treatment seemed to result in less long term incisor relapse. Could the degree of axial inclination of the mandibular first molar be used as a predictor of incisor relapse? To date, no study has addressed this relationship of molar inclination to incisor relapse.

The purpose of this study is to determine if a distally tipped mandibular first molar results in improved long term alignment of mandibular incisors.

II. LITERATURE REVIEW

Gardner et. al.[19] traced the history of occlusion and retention. They indicated four basic concepts which reflect the retention philosophy of the early orthodontic community: 1) establishment of good occlusion 2) Angle's theory of the lower arch as the guiding template for the upper arch 3) teeth centered over basal bone and 4) balance of the teeth within the intraoral and extraoral musculature. They also proposed maintenance of intermolar and intercuspid arch widths. Violation of the mandibular intercuspid width is now well recognized as the most predictable relapse factor of all. Sadowsky et. al.[20] and Paquette et. al.[21] document the necessity to maintain the 24-26 mm intercuspid width guideline. Artun et. al.,[22] later identified narrow pretreatment intercuspid width and high pretreatment incisor irregularity as significant predictors of relapse in their postretention study. The natural progression of crowding is documented by Hopkins et. al[23] who found increases of crowding of lower anterior teeth from age14 to 22, Barrow et al.[24] from 6 to 14 years of age, and Sinclair et. al.[25] from age 11 to 14 years with the level of incidence as high as 60%. In addition, Sinclair, et. al.[26] found that females demonstrated a greater degree of irregularity than males as adults, quantitatively.

Perhaps the most indicted cause for crowding of mandibular incisors is third molar pressure. Kaplan[27] described two schools of thought: 1) mandibular third molars become impacted due to lack of space behind the second molar, and 2) mandibular third molars crowd lower anterior teeth during their eruption.

Fastlicht[28] found no correlation between incisor crowding and molar impaction on treated vs. nontreated orthodontic patients. Lindqvist et. al.[29] compared extracted with nonextracted third molar sides and found no clinically significant data to predict whether patients of a specific facial pattern should have third molars removed or not. Ades et. al.[30] studied serial extraction, nonextraction with spacing, nonextraction and extraction cases 10 to 28 years postretention and concluded that erupted third molars in function do not contribute significantly to mandibular incisor crowding.

Other authors' results differ. Richardson et. al.,[31] found mesially directed force is the most important source of crowding in the early permanent dentition, although admitting the causes of crowding are multifactorial. Richardson et. al.[32] found superimpositions of serial lateral cephalograms of the mandible indicate that mandibular first molars moved forward, implying forward pressure, causing crowding anteriorly. Vego et. al.[33] found that patients with both mandibular third molars in place had a significantly greater decrease in arch perimeter than persons with agenesis of both third molars. Richardson et. al.[34] found that individuals developing third molar impaction had greater lower incisor crowding in the permanent dentition. There is no consensus in the literature.

Leighton et. al.[35]evalutated the relationship between lower arch crowding and spacing and related these to height and depth of the face. They found shorter posterior face heights associated with severe crowding as well as shorter mandibular corpi with more posteriorly positioned symphasis and dentition.

Richardson et. al.[31] evaluated tooth shapes and stated that mesial-distally narrow teeth with wide contacts should be more stable than teeth with point contacts that are wide. This opinion agreed with Peck et. al.'s[36] results which found a correlation with shapes of teeth and incisor crowding. Smith et. al.,[37] however, found after studying casts of treated and nontreated patients, that incisor crowding, related to Pecks' tooth shape ratios, was clinically insignificant. Puneky et.al.[38], Glenn et. al.[39] and Gilmore,[40] agreed that Peck's analysis did not render clinically significant results.

Little et. al.[41] studied postretention cases. They found long-term (minimum 10 years) postretention first premolar extraction cases that were minimally crowded, worsened post retention, while severely crowded cases tended to moderate. Two-thirds of the cases had unacceptable levels of crowding postretention, while arch length and width decreased. In 10-20 year postretention cases Little et. al.[42] found that arch constriction and mandibular anterior crowding continued, although at a slower rate. Later Little et.al.[43] found that in cases with lower anterior spacing, it is normal for space to remain closed long-term following orthodontic treatment, and clinically unacceptable crowding occurs less, however, it does continue into middle age, mirroring the progression of non-spacing cases.

In another study Little et. al.[44] found that stability cannot be confirmed using serial extraction. Treatment time was decreased and ease of treatment was greater with serial extraction, but arch length and width decreased postretention, and alignment was no better than with late extraction treatment. McReynolds et. al.[45] found that cases with second premolars extracted serially prior to their eruption exhibited no difference in their long-term stability either. Reidel et. al.,[46] found somewhat better stability in incisor extraction cases with 71% of single incisor extraction cases and 46% of double incisor extraction cases exhibiting an acceptable level of alignment long-term. Richardson et. al.[47] evaluated cases where second molars were extracted versus cases where they were not extracted and found less lower anterior crowding when second molars were removed (short-term results only).

With regard to archform, De La Cruz et. al.[48] found rounding of arch form during orthodontic treatment in models they studied. This form relapsed posttreatment to a more tapered arch - closer to pretreatment shape - greater arch shape change during treatment correlating with more relapse long-term.

Boese[49,50] found that supracrestal fiberotomy in humans produced extremely stable results 4-9 years posttreatment with no active retention. However, long-term retention is often needed despite Boese's positive results. Little[53] prescribes permanent retention as the only sure means of maintaining ideal positions of teeth throughout life.

IV. MATERIALS AND METHODS

A. SAMPLE

Twenty-three orthodontic records from Loma Linda University, and thirty-four records from University of Washington (n = 57) were evaluated for post retention stability. The sample had a mean post retention time of 12.9 years, and ranged from 7.9 to 32.5 years and consisted of seventeen males and forty females. Thirty-three were bicuspid extraction cases, and twenty-four were non extraction cases. Serial extraction and mandibular incisor extraction cases were excluded. Race was not accounted for in this study.

Table 1 shows the distribution of the sample by Angle's classification.

Angle Classification	Frequency
Class I	17
Class II Division 1	30
Class II Division 1 subdivision right or left	6
Class II Division 2	3
Class II Division 2 subdivision right or left	1
Class III	0

Table 1. Five categories of Angle Classification used in study.

T1 (pretreatment), T2 (post treatment) and T4 (post retention) study models and lateral cephalograms were acquired from both universities.

Inclusion criteria:

1. Erupted permanent mandibular incisors and canines at T1
2. Models not damaged
3. No edentulous areas at T2 or T4

4. Lateral headfilms clear enough to readily identify mandibular symphasis and at least one mandibular first molar image
5. T2 mandibular models judged to have 1 mm or less incisor irregularity as defined by Little[51]

Descriptive statistics using one-way ANOVA analysis is contained in Appendix F. Frequency data for T1 to T2 and T2 to T4 molar angle change and T1 to T2 and T2 to T4 incisor irregularity total changes are listed in Appendix G for males and females combined. Frequency data for T1 to T2 and T2 to T4 molar angle change and T1 to T2 and T2 to T4 incisor irregularity total changes are listed in Appendix H, separated for males and females.

B. MEASUREMENTS ON MANDIBULAR STUDY MODELS

T1, T2 and T4 incisor irregularity was measured according to the parameters set out by Little et. al.[51] on mandibular casts using Miyomioto Digital Calipers (model 500-171). Measurements were made from left canine to right canine measuring the distance from all incisor mid-tooth contact points to mid-tooth contact point of each adjacent tooth for a total of 5 measurements, as described by Little - see Figure 1. These measurements were recorded in millimeters to the nearest 0.01 millimeter. In cases with no visible irregularity, the measurement was recorded as 0 mm.

Changes in the amount of irregularity from T1 to T2 represent the changes induced by orthodontic treatment and growth, and changes from T2 to T4 represent the changes due to settling postretention plus any growth posttreatment and postretention.

C. MEASUREMENTS ON LATERAL CEPHALOGRAM HEADFILMS

T1 baseline molar angulation was derived from tracings of the T1 mandible which included a detailed tracing of the symphasis - particularly the inner cortical plate, the first molar(s), the mandibular canal (s), the inferior border of the mandible, the gonial angle to articulare, and the third molar crypts, when present. The T1 first molar was traced free hand - no template was used.

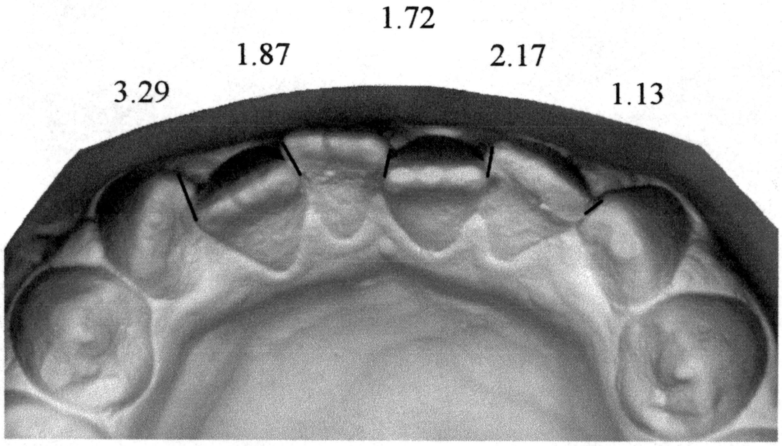

Figure 1. - Photograph of incisor irregularity measurement according to method described by Little.[51]

T1 cephalometric radiographs were hand traced in lead pencil (#3 hardness, frequently sharpened). T2 cephalometric radiographs were traced in red pencil (Sanford col-erase frequently sharpened) and T4 cephalometric radiographs were traced in blue pencil (same company and method as T2 cephs). See Figure 2.

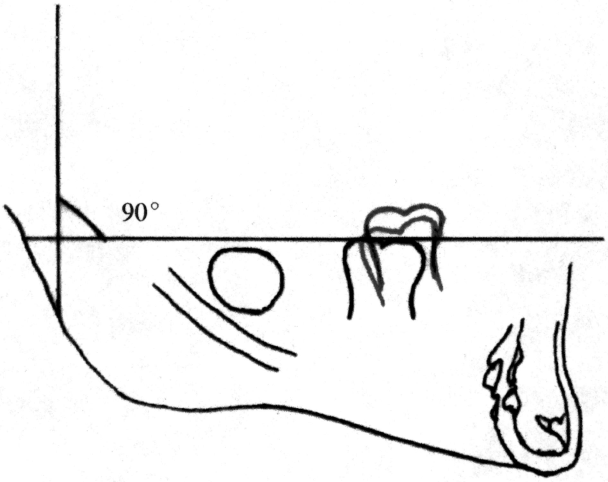

Figure 2. Tracing of mandible, mandibular first molar, occlusal plane and occlusal plane perpendicular. [T1 - in black, T2 - in red, T3 - in blue]

Using the method of mandibular superimposition described by Bjork et. al.,[52] the T2 and T4 tracings were superimposed with careful attention to anatomic detail. Order of priority used was as follows:

1) align the internal surface of the distal border of the cortical plate of the symphasis according to anatomical detail; secondarily the mesial border of the internal cortical plate; thirdly, the outer surface of the cortical plate
2) align the mandibular canal- using the symphasis as a point of rotation
3) align the inferior border of the mandible - use as a guide for vertical positioning - symphasis used as a point of rotation
4) align the third molar crypt - use as a guide for vertical positioning - symphasis used as a point of rotation (T2)

The first molar was located and the crown traced for T2 and T4. Mesial and distal contact points and surfaces were sometimes difficult to identify, as were root tips and furcations. Most easily identified were mesial and distal marginal ridges. Thus where cusp tips were not visible due to dual images or restorations, ascending marginal ridges were used to guide the location of cusp tips. Maxillary molar crown cusp tip anatomy was also used to help identify the mandibular molar cusp tips (crowns again traced by hand).

A line was drawn connecting the mesial and distal cusp tips of the molar crown to establish an occlusal plane at T1 - see Figure 2. In the case of two molar images on the lateral cephalometric radiograph, two occlusal planes were drawn and an average line was established. A perpendicular line to the occlusal plane of the T1 molar was drawn arbitrarily to the left of the traced molar - see Figure 2.

T2 and T4 molar occlusal planes were drawn along their respective molar cusp tips and extended until they intersected the occlusal plane perpendicular, thus forming the angles to be measured - see Figure 3.

The T2 and T4 first molar angulations were measured to establish the degree of first molar distal tip back or mesial tip forward posttreatment and postretention. The angles were measured in the upper right quadrant of the cross formed by the occlusal plane and occlusal perpendicular - see Figure 3. Any molar tip back resulted in a negative, acute angle, and any mesial molar tip resulted in a positive, obtuse angle.

In order to evaluate the results, mandibular first molar change in angulation was divided into three groups: Group A molars distally tipped greater than 1 degree, Group B molars with little change in angulation - 1 degree distal tip back to 1 degree mesial tip forward and Group C molars with greater than 1 degree tip forward.

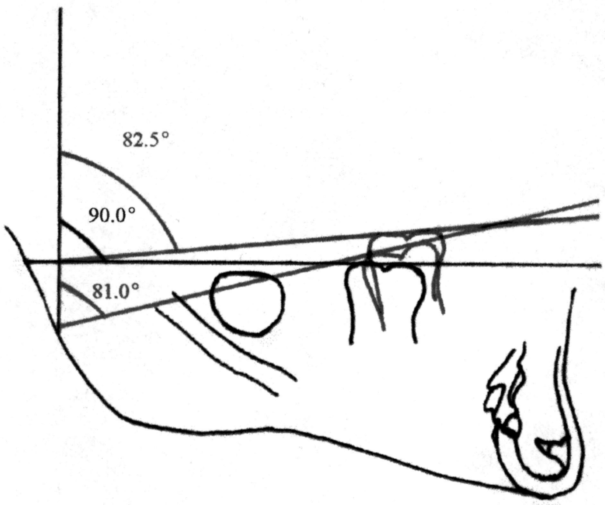

Figure 3. T2 and T4 occlusal planes drawn and angles measured. [T1 = 90.0 degrees, T2 = 81.0 degrees, T3 = 82.5 degrees]

D. ERROR OF THE METHOD

The reproducibility of the measurements was assessed by statistically analyzing the difference between two measurements, one month apart, of 15 models and 15 sets of lateral cephalometric headfilms. Models were randomly chosen from T1, T2 and T4 models in the sample. Repeat measurements were obtained by assigning each cast a number and randomly choosing 15 models from the entire group of 69 casts in the Loma Linda group. Paired t-test results on incisor irregularity revealed the mean difference in first and second readings was 0.12 mm (std. dev. = 0.80 mm, $p = 0.57$), with the maximum error being 2.1 mm. One tested case exceeded a 2.0 mm difference - an average of just over 0.40 mm error in measurement per contact point on that case.

Fifteen repeat molar angulation measurements were traced for T1, T2 and T4 lateral cephalograms. The mean difference between first and second readings for

T2 tracings was -1.48 degrees (std. dev. = 4.57 degrees, p = 0.23) and for T4 tracings the mean differences was -0.27 degrees (std. dev. 5.28 degrees, p = 0.85). However, there were 5 differences for T2 and 5 differences for T4 (33%) repeated tracings that exceeded 4 degrees indicating reproducibility was limited due to tracing error and poor clarity of the head films in some cases.

E. DATA ANALYSIS

One-way ANOVA analysis of variance was used to distinguish whether there was a significant difference between relapse for incisors with molar distal tip back angle change, minimal molar angle change and mesial tip forward angle change - see Appendix F. Pearson's Correlation, a 2-tailed significance test, was used to compare the changes in molar angulation from T1 to T2 and T2 to T4 to the changes in incisor irregularity to identify significant correlations found in the data - see Appendix J.

V. RESULTS

A complete listing of changes in molar angulation from T1 to T2 and the changes in incisor irregularity totals for mandibular casts from T2 to T4 are listed in Appendix K. The results indicate that, with orthodontic treatment, mean tip back in mandibular molars was 1.9 degrees with a standard deviation of 4.7 degrees. Mean posttreatment mandibular molar relapse was 0.6 degrees with a standard deviation of 3.2 degrees. Mean incisor irregularity increase due to relapse was 1.6 mm with a standard deviation of 2.1 mm.

Groups A, B and Cs' means, ranges and standard deviation differences for total incisor irregularity changes compared to their respective molar angulation changes are listed in Appendix A. Corresponding data separated by gender are found in the next two tables - males in Appendix B and females in Appendix C. Males with extractions are found in Appendix D and females with extractions are found in Appendix E.

A comparative summary of the significant differences in males vs. the population is listed in Table 2.

Three significant results were found. Table 2 shows that males, with distally tipped molars, showed the least incisor relapse, while those with mesial tipped molars showed the most relapse. This relationship was not true for females. In females, mesial tipped molars actually showed the least incisor relapse (0.883) but this was not significantly different than the distally tipped group - see Appendix C.

A positive correlation was also found for males between the T1 to T2 molar angulation change and the incisor irregularity change from T2 to T4, r = 0.506, (weak or moderate) with a p-value of 0.038, significance. This indicates that approximately

25% of the variability in incisor relapse can be explained by the change in molar angulation.

Third, a statistically significant correlation was found in males in extraction cases. Pearson's correlation test revealed an r = 0.6 (moderate), with p-value of 0.039. The results again indicate males demonstrate a weak clinical correlation between change in molar tipback from T1 to T2 with the amount of relapse of the incisors from T2 to T4. Removing the nonextraction cases increases the predictabiility of associating the variability of incisor relapse with molar angulation change during treatment - approximately 35% vs. 25 %.

Molar Angulation Change T1 to T2						
	Group A		Group B		Group C	
	$\bar{x}$ (mean)	s (std.dev.)	$\bar{x}$	s	$\bar{x}$	s
Total Group	-5.33 deg	3.21	-0.12	0.75	4.73	2.39
Males (♂)	-5.79	3.24	0.20	0.69	3.58	1.77
Extracted ♂	-4.70	3.16	0.12	0.78	3.75	2.48
Incisor Irregularity Relapse T2 to T4						
	Group A		Group B		Group C	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Total Group	1.35 mm	1.55	2.10	1.22	1.73	3.72
♂	1.36	1.88	2.75	1.29	3.97	1.91
Extracted ♂	1.28	0.72	2.92	1.42	3.05	1.48

Table 2. Comparative summary data for sample (n=57), males (n=17) and males with extractions (n=12) showing molar angulation mean changes T1 to T2 and standard deviations for Groups A, B and C vs. T2 to T4 incisor irregularity relapse means and standard deviations for Groups A, B and C. Figures in red indicate mean differences for Group A and Group B that are statistically significant.

VI. DISCUSSION

The most significant outcome of this study is the relationship that was found between mandibular first molar distal tip and the reduction of incisor irregularity relapse in males. The results indicate there is a statistically significant difference in the mean relapse for mandibular first molars in Group A that were tipped distally 1 degree or more vs. mandibular molars in Group C that were tipped mesially 1 degree or more in males. Thus, males in this study that have mandibular first molars distally tipped experience less incisor relapse than do males that do not have their molars distally tipped. The results, however, also indicate incisor irregularity relapse recurs in all cases despite the molar distal tip. There was no mean difference for females, or males and females as a combined group. In addition, these values, although statistically significant, are weak as a clinical predictor.

Molar tip back often occurs in bioprogressive mechanics due to use of utility arches. This can also occur with the use of reverse curve archwires in straightwire mechanics. In addition, with mesially welded attachment of the wire slots on bands (for distal rotation of the mandibular molars), more effective mesial seating of bands during cementation may tip molars during the leveling process in orthodontic treatment. Clinically, these resultant tip backs during treatment may promote less risk of incisor alignment relapse in male patients. Additional reasons may include extended growth for males (in some cases) and post orthodontic treatment settling occlusion, which may effect stability of the incisors.

Females were found to have no statistically significant predictor of greater or lessor amounts of irregularity based on molar angulation changes. Females in this study experienced incisor relapse independent of mesial or distal molar angulation. Relapse was inevitable.

Regarding correlations in the male and female combined data, no correlation was found between the T1 to T2 changes in mandibular first molar angulation and the changes in T2 to T4 incisor irregularity noted in the sample. However, when the 17 males were separated as a group and analyzed, the T1 to T2 angle change correlated with T2 to T4 incisor relapse. This correlation relates to the purpose of this study. An r value equal to 0.506 indicates that molar angle change explains approximately 25% of the variability in the data, ie.,molar tip back contributes 25% of the reduction in relapse. This, however, is a weak correlation at best. According to Little[53], at the University of Washington, the minimum literature standard for clinical significance has been the 0.600 to 0.650 significance level range, which explains 35 to 40% of the variability in the data. The result here falls short of the r value of 0.6 to 0.65 deemed necessary to merit clinical significance. In addition, the results must be tempered by the minimal number of males in the study, 17 out of 57, that produced these results. No relationship was established to distal tip back in nonextraction cases or tip forward in extraction cases.

The male extraction case correlations approached an r value of 0.60, 36% explanation of variability, a marginal clinical significance level. Although this correlation is stronger, it only approaches the minimal standards for clinical significance as a predictor of incisor relapse. With an even smaller sample of n = 12, the significance is dwarfed.

The method of molar angulation measurement was the most difficult measurement to reproduce in this study. Poor ceph images were the chief contributing factor to this error, in that the molar crown images were difficult to identify due to dual images, fillings, dual occlusal planes and obliterated roots in alveolar bone. Clarity of lateral cephs was directly related to the age of the films; the older the ceph, the less clairity that could be expected. In addition, the reproducability of superimposition was affected by the ability to match details in the tracing of the symphasis, visibility and clarity of the mandibular canal image, dual images in molars and thus mandibular planes and presence or absence of the third molar crypt. Despite the detailed step-by-step approach to attaining a superimposition, the final position was variable. Use of a template to establish crown outline once cusp tips are identified may be helpful in reproducing the angles more accurately when done in a future study.

Future studies with a larger male sample would be helpful in evaluating the significance of gender in relationship to distal tipped molars. In addition, larger numbers of males in the sample would allow the distally tipped molar group to be subdivided to evaluate the degree of distal tip most beneficial to resist incisor relapse. Introducing facial pattern categories (brachyfacial, dolichofacial and mesofacial) may also be beneficial in analyzing the reasons for differences in mean relapse. Arch length changes is also another factor that may have a relationship to the change in molar tip back

No statistically significant differences were noted in the data from University of Washington vs. Loma Linda University with regard to treatment mechanics when these variables were compared. Thus a greater prevalence of sectional mechanics in treatment at Loma Linda would appear to have minimal effect on the molar angulation and potentially, the incisor irregularity of patients post retention vs. that employed in straightwire edgewise mechanics or nonperscription brackets (also used in some cases from the University of Washington).

Other variables tested included Angle's classification, extraction vs. non extraction and number of years post retention. Due to the variability in the molar angulations measured, the extraction of premolars did not appear to affect this angulation variable. The same lack of correlation occurred with the Angle classification. Neither molar tip forward or backward could be predicted with the mechanics of treatment. Number of years post retention, although related to the irregularity of mandibular incisors, did not correlate to the molar angulation change in this study.

Data also analyzed on the Loma Linda sample included convexity, a millimeter measurement anterior or posterior to facial plane established from pogonion to nasion; overbite, established as a percentage of maxillary incisor overlap of the mandibular incisors; and overjet as a millimeter measurement of the tip of the maxillary incisor anterior to the mandibular incisor. None of these variables was found to correlate to any of the changes in incisor irregularity or molar angulation evaluated in this study.

VII. CONCLUSIONS

1) Males demonstrating distally tipped mandibular molars posttreatment experienced significantly less incisor relapse than those whose molars are mesially tipped.

2) Females demonstrated no predictability in incisor relapse.

3) The weak correlations found between mandibular first molar angulation change T1 to T2 and incisor irregularity T2 to T4 is not strong enough to be clinically significant.

4) A larger sample size and template tracing of the crowns may make the results more reliable and reproducible.

5) Evaluation of facial type may shed some new light on the information gathered in this study.

6) Evaluation of arch length as a variable may also be beneficial in relationship to molar angle change and incisor relapse.

7) Degree of molar tip back cannot be used to predict incisor relapse clinically.

VIII. APPENDIX

Group A		Group B		Group C	
Molar distal tip back > 1 degree (n=30)		Molar angle change + or - 1 degree (n=16)		Molar mesial tip forward > 1 degree (n=11)	
Mean	-5.330 deg	Mean	-0.125 deg	Mean	4.727 deg
Range	13.00 deg	Range	2.00 deg	Range	8.50 deg
S.D.	3.211 deg	S.D.	0.747 deg	S.D.	2.389 deg
Incisor Irregularity Relapse T2 to T4					
Mean	1.352 mm	Mean	2.104 mm	Mean	1.726 mm
Range	6.96 mm	Range	4.09 mm	Range	14.10 mm
S.D.	1.548 mm	S.D.	1.221 mm	S.D.	3.717 mm

Appendix A. Sample (n=57) total incisor irregularity means, ranges and standard deviations for Groups A, B and C molar angulation changes.

Group A		Group B		Group C	
Molar distal tip back > 1 degree (n=9)		Molar angle change + or - 1 degree (n=5)		Molar mesial tip forward > 1 degree (n=3)	
Mean	-5.792 deg	Mean	0.200 deg	Mean	3.583 deg
Range	8.88 deg	Range	1.75 deg	Range	3.50 deg
S.D.	3.245 deg	S.D.	0.694 deg	S.D.	1.774 deg
Incisor Irregularity Relapse T2 to T4					
Mean	1.361 mm	Mean	2.746 mm	Mean	3.973 mm
Range	6.58 mm	Range	3.35 mm	Range	3.82 mm
S.D.	1.877 mm	S.D.	1.290 mm	S.D.	1.913.mm

Appendix B. Males (n=17) total incisor irregularity means, ranges and standard deviations for Groups A, B and C molar angulation changes.

Group A		Group B		Group C	
Molar distal tip back > 1 degree (n=21)		Molar angle change + or - 1 degree (n=11)		Molar mesial tip forward > 1 degree (n=8)	
Mean	-5.131 deg	Mean	0.273 deg	Mean	5.156 deg
Range	13.00 deg	Range	2.00 deg	Range	8.25 deg
S.D.	3.256 deg	S.D.	0.754 deg	S.D.	2.546 deg
Incisor Irregularity Relapse T2 to T4					
Mean	1.349 mm	Mean	1.812 mm	Mean	0.883 mm
Range	6.73 mm	Range	3.96 mm	Range	14.10 mm
S.D.	1.438 mm	S.D.	1.128 mm	S.D.	3.965 mm

Appendix C. Females (n=40) total incisor irregularity means, ranges and standard deviations for Groups A, B and C molar angulation changes.

Group A		Group B		Group C	
Molar distal tip back > 1 degree (n=6)		Molar angle change + or - 1 degree (n=4)		Molar mesial tip forward > 1 degree (n=2)	
Mean	-4.708 deg	Mean	0.125 deg	Mean	3.750 deg
Range	8.50 deg	Range	1.75 deg	Range	3.50 deg
S.D.	3.156 deg	S.D.	0.777 deg	S.D.	2.475 deg
Incisor Irregularity Relapse T2 to T4					
Mean	1.283 mm	Mean	2.920 mm	Mean	3.050 mm
Range	2.10 mm	Range	3.35 mm	Range	2.10 mm
S.D.	0.719 mm	S.D.	1.420 mm	S.D.	1.485 mm

Appendix D. Males with extractions (n=12) total incisor irregularity means, ranges and standard deviations for Groups A, B and C molar angulation changes.

Group A		Group B		Group C	
Molar distal tip back > 1 degree (n=11)		Molar angle change + or - 1 degree (n=6)		Molar mesial tip forward > 1 degree (n=4)	
Mean	-4.909 deg	Mean	-0.167 deg	Mean	4.438 deg
Range	7.75 deg	Range	2.00 deg	Range	4.25 deg
S.D.	2.944 deg	S.D.	0.753 deg	S.D.	2.045 deg
Incisor Irregularity Relapse T2 to T4					
Mean	0.954 mm	Mean	2.052 mm	Mean	2.468 mm
Range	4.59 mm	Range	3.32 mm	Range	6.52 mm
S.D.	1.303 mm	S.D.	1.184 mm	S.D.	2.831 mm

Appendix E. Females with extractions (n=21) total incisor irregularity means, ranges and standard deviations for Groups A, B and C molar angulation changes.

Gender			Group	N	Mean	Std. Deviation	Std. Error
Female	T2-T1 Change in Incisor Irregularity	Change in angle < -1	A	24	-4.1663	4.5855	.9360
		Change in angle between -1 and +1	B	8	-5.0638	2.7556	.9743
		Change in angle > +1	C	8	-5.36.13	3.4905	1.2341
		Total		40	-4.5848	4.0285	.6370
	T4-T2 Change in Incisor Irregularity	Change in angle < -1	A	24	1.3533	1.4015	.2861
		Change in angle between -1 and +1	B	8	1.9713	1.0789	.3815
		Change in angle > +1	C	8	.8825	3.9646	1.4017
		Total		40	1.3828	2.0764	.3283
Male	T2-T1 Change in Incisor Irregularity	Change in angle < -1	A	9	-3.2044	2.5647	.8549
		Change in angle between -1 and +1	B	5	-6.0860	3.9779	1.7790
		Change in angle > +1	C	3	-5.4333	2.0995	1.2122
		Total		17	-4.4453	3.1123	.7548
	T4-T2 Change in Incisor Irregularity	Change in angle < -1	A	9	1.3611	1.8766	.6255
		Change in angle between -1 and +1	B	5	2.7460	1.2899	.5769
		Change in angle > +1	C	3	3.9733	1.9131	1.1046
		Total		17	2.2294	1.9267	.4673

Appendix F. One way ANOVA analysis of variance to compare mean differences in incisor relapse by group.

		T2 angle - T1 angle	T4 angle - T2 angle	T2-T1 Change in Incisor Irregularity	T4-T2 Change in Incisor Irregularity
N	Valid	57	57	57	57
	Missing	0	0	0	0
Mean		-1.9279	.5563	-4.5432	1.6353
Median		-2.0000	.7500	-3.600	1.53.00
Std. Deviation		4.7262	3.1570	3.7515	2.0533

Appendix G. Frequency data for sample.

Gender			T2 angle - T1 angle	T3 angle - T2 angle	T2-T1 Incisor Irregularity Change	T4-T2 Incisor Irregularity Change
Female	N	Valid	40	40	40	40
		Missing	0	0	0	0
	Mean		-1.7377	.8908	-4.5848	1.3828
	Median		-2.1250	.7500	-3.5700	1.4500
	Std. Deviation		4.8272	3.3454	4.0285	2.0764
Male	N	Valid	17	17	17	17
		Missing	0	0	0	0
	Mean		-2.3753	-.2306	-4.4453	2.2294
	Median		-2.0000	.0000	-3.6000	1.9800
	Std. Deviation		4.5908	2.5821	3.1123	1.9267

Appendix H. Frequency data by gender.

		T2 angle - T1 angle	T4 angle - T2 angle	T2-T1 Incisor Irregularity	T4-T2 Incisor Irregularity
T2 angle - T1 angle	Pearson Correlation Sig. (2-tailed) N	1.000 . 57	-.200 .135 57	-.128 .342 57	.099 .464 57
T4 angle - T2 angle	Pearson Correlation Sig. (2-tailed) N	-.200 .135 57	1.000 . 57	.116 .390 57	.033 .809 57
T2-T1 Incisor Irregularity	Pearson Correlation Sig. (2-tailed) N	-.128 .342 57	.116 .390 57	1.000 . 57	-.066 .627 57
T4-T2 Incisor Irregularity	Pearson Correlation Sig. (2-tailed) N	.099 .464 57	.033 .809 57	-.066 .627 57	1.000 . 57

Appendix I. Pearson's Correlation - 2-tailed significance test.

Gender			T2 angle - T1 angle	T4 angle - T2 angle	T2-T1 Incisor Irregularity	T4-T2 Incisor Irregularity
Female	T2 angle - T1 angle	Pearson Correlation Sig. (2-tailed) N	1.000 . 40	-.236 .142 40	-.017 .916 40	-.029 .858 40
	T4 angle - T2 angle	Pearson Correlation Sig. (2-tailed) N	-.236 .142 40	1.000 . 40	.138 .395 40	.070 .670 40
	T2-T1 Incisor Irregularity	Pearson Correlation Sig. (2-tailed) N	-.017 .916 40	.138 .395 40	1.000 . 40	-.001 .998 40
	T4-T2 Incisor Irregularity	Pearson Correlation Sig. (2-tailed) N	-.029 .858 40	.070 .670 40	-.001 .998 40	1.000 . 40
Male	T2 angle - T1 angle	Pearson Correlation Sig. (2-tailed) N	1.000 . 17	-.142 .586 17	-.494* .044 17	.506* .038 17
	T4 angle - T2 angle	Pearson Correlation Sig. (2-tailed) N	-.142 .586 17	1.000 . 17	.048 .856 17	.054 .836 17
	T2-T1 Incisor Irregularity	Pearson Correlation Sig. (2-tailed) N	-.494* .044 17	.048 .856 17	1.000 . 17	-.309 .228 17
	T4-T2 Incisor Irregularity	Pearson Correlation Sig. (2-tailed) N	.506* .038 17	.054 .836 17	-.309 .228 17	1.000 . 17

Appendix J. Pearsons Correlation broken down by gender. * Correlation is significant at the 0.05 level (2-tailed).

		T2 angle - T1 angle	T4 angle - T2 angle	T2-T1 Incisor Irregularity	T4-T2 Incisor Irregularity
T2 angle - T1 angle	Pearson Correlation Sig. (2-tailed) N	1.000 . 33	.048 .790 33	-.060 .739 33	.427* .013 33
T4 angle - T2 angle	Pearson Correlation Sig. (2-tailed) N	.048 .790 33	1.000 . 33	.043 .810 33	.015 .934 33
T2-T1 Incisor Irregularity	Pearson Correlation Sig. (2-tailed) N	-.060 .739 33	.043 .810 33	1.000 . 33	-.129 .473 33
T4-T2 Incisor Irregularity	Pearson Correlation Sig. (2-tailed) N	.427* .013 33	.015 .934 33	-.129 .437 33	1.000 . 33

Appendix K. Subpopulation with extractions. * Correlation is significant at the .0.5 level (2-tailed).

Gender			T2 angle - T1 angle	T4 angle - T2 angle	T2-T1 Incisor Irregularity	T4-T2 Incisor Irregularity
Female	T2 angle - T1 angle	Pearson Correlation	1.000	.057	.093	.306
		Sig. (2-tailed)	.	.807	.687	.109
		N	21	21	21	21
	T4 angle - T2 angle	Pearson Correlation	.057	1.000	.069	.096
		Sig. (2-tailed)	.807	.	.766	.678
		N	21	21	21	21
	T2-T1 Incisor Irregularity	Pearson Correlation	.093	.069	1.000	-.037
		Sig. (2-tailed)	.687	.766	.	.874
		N	21	21	21	21
	T4-T2 Incisor Irregularity	Pearson Correlation	.360	.096	-.037	1.000
		Sig. (2-tailed)	.109	.678	.874	.
		N	21	21	21	21
Male	T2 angle - T1 angle	Pearson Correlation	1.000	.048	-.524	.600*
		Sig. (2-tailed)	.	.882	.081	.039
		N	12	12	12	12
	T4 angle - T2 angle	Pearson Correlation	.048	1.000	.011	-.006
		Sig. (2-tailed)	.882	.	.973	.985
		N	12	12	12	12
	T2-T1 Incisor Irregularity	Pearson Correlation	-.524	.011	1.000	-4.72
		Sig. (2-tailed)	.081	.973	.	.1221
		N	12	12	12	12
	T4-T2 Incisor Irregularity	Pearson Correlation	.600*	-.006	-.472	1.000
		Sig. (2-tailed)	.039	.985	.121	.
		N	12	12	12	12

Appendix L. By gender with extractions. *Correlation is significant at the 0.05 level (2-tailed).

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