Original Article

Mandibular Growth Rotation Effects on Postretention Stability of Mandibular Incisor Alignment

Piotr Fudalej[a]; Jon Årtun[b]

ABSTRACT

Objective: To test the hypotheses that pronounced forward and backward mandibular growth rotation may be risk factors for postretention relapse of mandibular incisor alignment, and that morphologic parameters at adolescence may be predictive of the remaining type of mandibular growth.

Materials and Methods: Cephalograms and study models were made before (T1) and after (T2) active treatment and at a minimum of 10 years postretention (T3) of three groups of orthodontic patients with acceptable occlusion at the time of appliance removal. The groups were short facial height (n = 46), angle between the sella-nasion line and the mandibular plane (SN/MP) $\leq$ 28°; normal facial height (n = 42), SN/MP 29° through 37°; and long facial height (n = 35), SN/MP $\geq$ 38° at T2.

Results: The groups were similar regarding age at T2, gender ratio, incisor irregularity (IRI), intercanine (3-3) width at T1, change of 3-3 width from T1 to T2, and time from T2 to T3 ($P >$ .05). IRI increased in all groups from T2 to T3 ($P <$ .05), but there were not any intergroup differences in this increase ($P >$ .05). Minor differences were detected among the groups in mandibular growth rotation from T2 to T3. Males experienced more forward rotation than females ($P <$ .001) and more increase in IRI from T2 to T3 ($P <$ .01). Male gender, T1-T2 increase in 3-3 width, and T2-T3 reduction in 3-3 width were included in the model explaining T2-T3 increase in IRI.

Conclusion: High-angled and low-angled facial patterns at time of appliance removal are not associated with increased risk of postretention relapse of mandibular incisor malalignment, and in adolescent orthodontic patients are poor predictors of type of posttreatment growth.

KEY WORDS: Prediction; Stability; Mandibular incisor alignment; Mandibular growth rotation

INTRODUCTION

A high proportion of adolescent orthodontic patients demonstrate relapse of mandibular incisor alignment when examined at various periods after active treatment or at long-term postretention.[1–14] Despite attempts at identifying pretreatment occlusal parameters and dental treatment changes associated with such relapse,[1,3,8,9,12–15] few clinically useful predictors have been established. However, an evaluation of a large, representative group of well-treated adolescent patients presenting with Class II, division 1 malocclusion[14] suggests that increased incisor irregularity and reduced intercanine width prior to treatment as well as increased intercanine width during appliance therapy are significant risk factors. Routine fiberotomy of the mandibular incisors does not imply enhanced stability.[4]

The average changes in facial morphology caused by sutural and condylar growth from adolescence to adulthood include a reduction in facial convexity with a relative increase in mandibular prognathism and a flattening of the mandibular plane.[16,17] Studies utilizing metallic implants for accurate superimpositions[17,18] have shown that the changes are caused by a relative excess in vertical condylar growth, which causes a forward rotation of the mandible.

There are indications that pronounced forward

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growth rotation is a risk factor for development of mandibular incisor malalignment.[17,18] The mechanism offered is that the tendency for an increase in the interincisal angle as the mandibular incisors follow the rotation of the jaw may weaken or cause a complete loss of the fulcrum point at the incisors. This results in a deepening of the bite and progressive irregularity of the incisors, prohibiting compensatory proclination.[19] A small subgroup demonstrates posterior growth rotation because of limited vertical condylar growth.[17,18] The compensatory incisor retroclination with this type of growth[17,18] may also be associated with development of incisor irregularity. If morphologic parameters at adolescence are predictive of remaining mandibular growth rotation,[20] they may also be predictors of mandibular incisor relapse.

A cephalometric evaluation at ages 9–10, 12–13, and 19–20 of untreated normal subjects,[21] previously evaluated for mandibular incisor alignment,[22] confirmed that late mandibular growth is expressed as various amounts of forward rotation. However, the degree was not of clinical value as a predictor for mandibular incisor malalignment.[21] Similarly, attempts at establishing cephalometric parameters before and after active treatment as risk factors for mandibular incisor relapse have been unsuccessful.[3,8,9,14,15,23] One reason could be the inclusion of a few patients with extreme growth patterns in the different samples. The purpose of this study was to test the hypotheses that adolescent orthodontic patients with cephalometric indications of anterior and posterior growth rotation at the time of appliance removal are at risk of mandibular incisor relapse, as well as to test the association between posttreatment growth rotation and relapse.

MATERIALS AND METHODS

Sample

Cephalograms and study models made before (T1) and after (T2) orthodontic treatment and long-term postretention (T3) of all adolescent patients from the University of Washington sample were screened. Patients were selected who were judged subjectively to have successful occlusal results following one-phase comprehensive orthodontic treatment and who had not lost premolars or molars or undergone extensive prosthodontic treatment from T2 to T3. The angle between the sella-nasion line and the mandibular plane (SN/MP) was measured on the T2 cephalograms. Three groups were established: one group with short facial height (SFH, $n = 62$), defined as SN/MP $\leq 28°$; one with normal facial height (NFH, $n = 514$), defined as SN/MP 29° through 37°; and one with long facial height (LFH, $n = 47$), defined as SN/MP $\geq 38°$. The NFH group was then reduced to include only the 50 subjects with SN/MP closest to 33°.

Patients with extreme values were successively eliminated until the groups were similar regarding age at T2, irregularity index (IRI) and intercanine (3-3) width at T1 (see Measurements on Study Models), T1-T2 change of 3-3 width, T2-T3 time period, and gender ratio. The final sample consisted of 46 SFH patients (Figure 1), 42 NFH patients, and 35 LFH patients (Figure 2), allowing detection of IRI ≥ 1 mm at T3 for the SFH and LFH patients when comparing them to the NFH patients with a power of 62%. Table 1 shows balanced gender ratios, but some overrepresentation of Class I malocclusion and extraction therapy in the LFH group. Analysis of variance (ANOVA) did not demonstrate any intergroup differences in the variables chosen as matching criteria ($P > .05$, Table 2). However, the discriminating skeletal measurements were different ($P < .001$, Table 2), and pairwise comparisons using the Tukey multiple comparison procedure indicated that the differences between any two groups were significant ($P < .05$).

Measurements on Cephalograms

Following identification of nasion (N), sella (S), gonion (Go), and menton (Me), SN/MP, lower gonion angle (NGo/MP),[20] and facial height ratio (SGo/NMe $\times$ 100%) were calculated at T1, T2, and T3. For the 26 males in the SFH group, the cephalograms at T2 and T3 were superimposed on the mandibles, calculating the amount of mandibular matrix rotation as the angle between the SN lines at T2 and T3.[18] All measurements were made to the nearest half millimeter or degree.

Measurements on Study Models

The IRI was measured as the sum of the linear displacements of the anatomic contact points of each mandibular incisor from the adjacent tooth anatomic point[24] and 3-3 width as the distance between the cusp tips of the mandibular canines at T1, T2, and T3. The measurements were made to the nearest 0.01 mm using a digital caliper (Fred V. Fowler Co Inc, Newton, Mass).

Error of the Method

The measurement errors were calculated from the equation:

$$S_x = \sqrt{\frac{\sum D^2}{2n}}$$

with D representing the difference between corresponding first and second measurements on 16 (n)

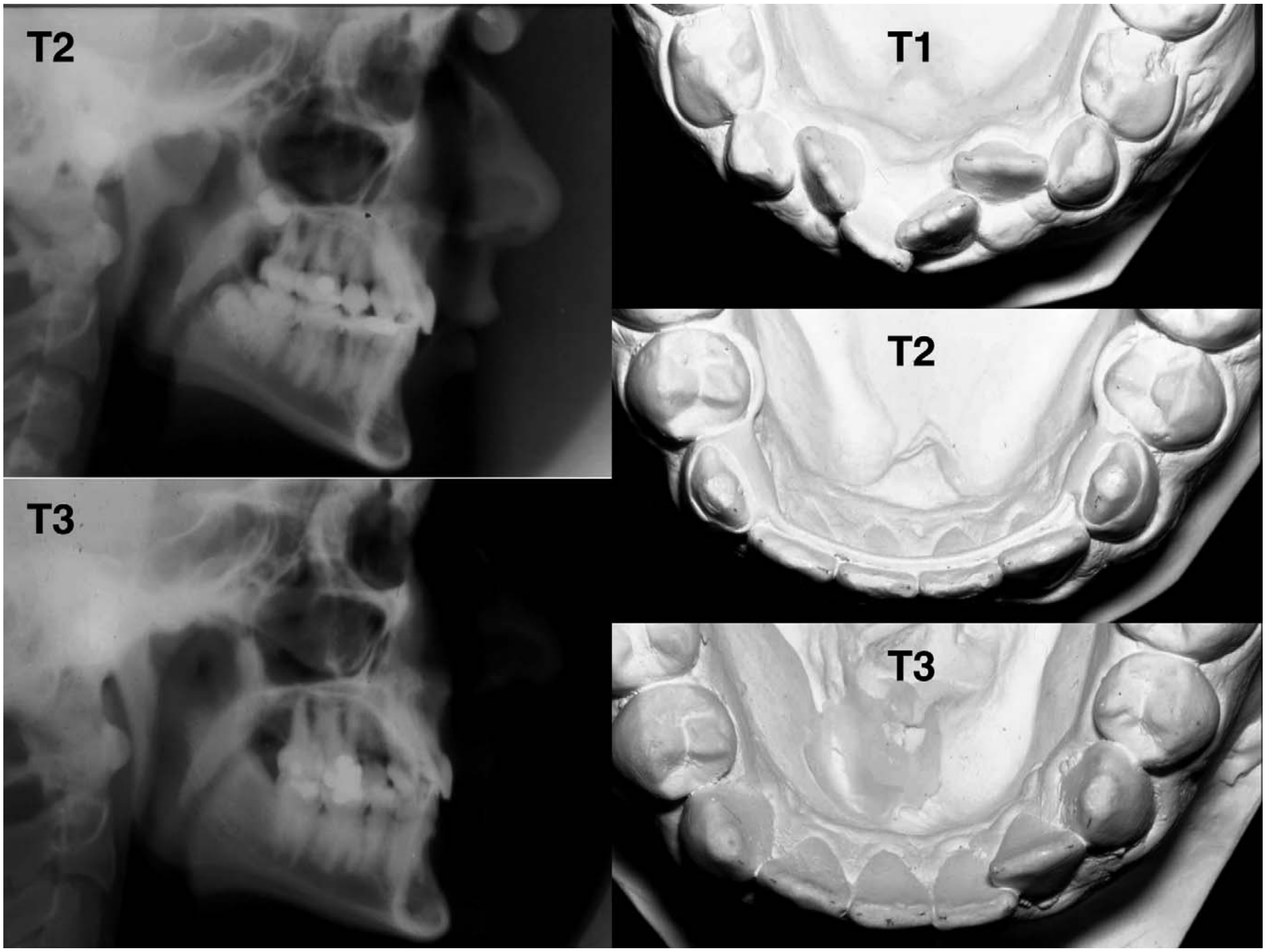

Figure 1. Mandibular models made before active treatment (T1) as well as mandibular models and lateral cephalograms made after active treatment (T2) and 11.3 years postretention (T3) of adolescent patient with SFH at T2 treated for Class II, division 1 malocclusion with extraction of four first premolars. IRI = 11.5 mm at T1, 1.1 mm at T2, and 2.4 mm at T3. 3-3 width = 24.9 mm at T1, 28.9 mm at T2, and 26.7 mm at T3. MP/SNL = 26.5° at T2 and 22.5° at T3.

randomly selected cephalograms and study models made 6 weeks apart.[25] The cephalometric measurement errors were 0.28% for the SGo/NMe ratio, 0.60° for SN/MP, 0.56° for NGo/MP, and 0.52° for the calculated angle of mandibular rotation. The model measurement errors were 0.19 mm for 3-3 change and 0.38 mm for IRI.

Statistical Analysis

For each group, descriptive statistics (means and standard deviations) were computed for each variable at T1, T2, and T3. Dependent *t*-tests were performed to test the differences over time within each group. A one-way ANOVA model was used to test the intergroup differences in measurements at T1, T2, and T3 as well as intergroup differences in changes from T1 to T2 and from T2 to T3 of the different measurements. When a difference was detected, pairwise comparisons were made using the Tukey multiple comparison procedure in order to control the type 1 error rate when conducting multiple comparisons. Chi-square analyses were used to test the difference in number of subjects with increase (SN/MP < 0), moderate reduction ($0 \leq$ SN/MP ≤ 1.5), and pronounced reduction (MP ≥ 2.0) of angle SN/MP from T2 to T3 among the subjects in each group. In addition, chi-square and independent *t*-tests were used to test the gender difference in number of subjects with increase, moderate reduction, and pronounced reduction and mean change of SN/MP from T2 to T3, respectively. Linear regression analyses were employed to test the associations between change in IRI from T2 to T3 and change in SN/MP from T2 to T3, SN/MP at T2, facial height category, IRI at T1, 3-3 width at T1, change in 3-3 width from T1 to T2, change in 3-3 width from T2 to T3, gender, age at T1, and time from T2 to T3. Pearson's product-

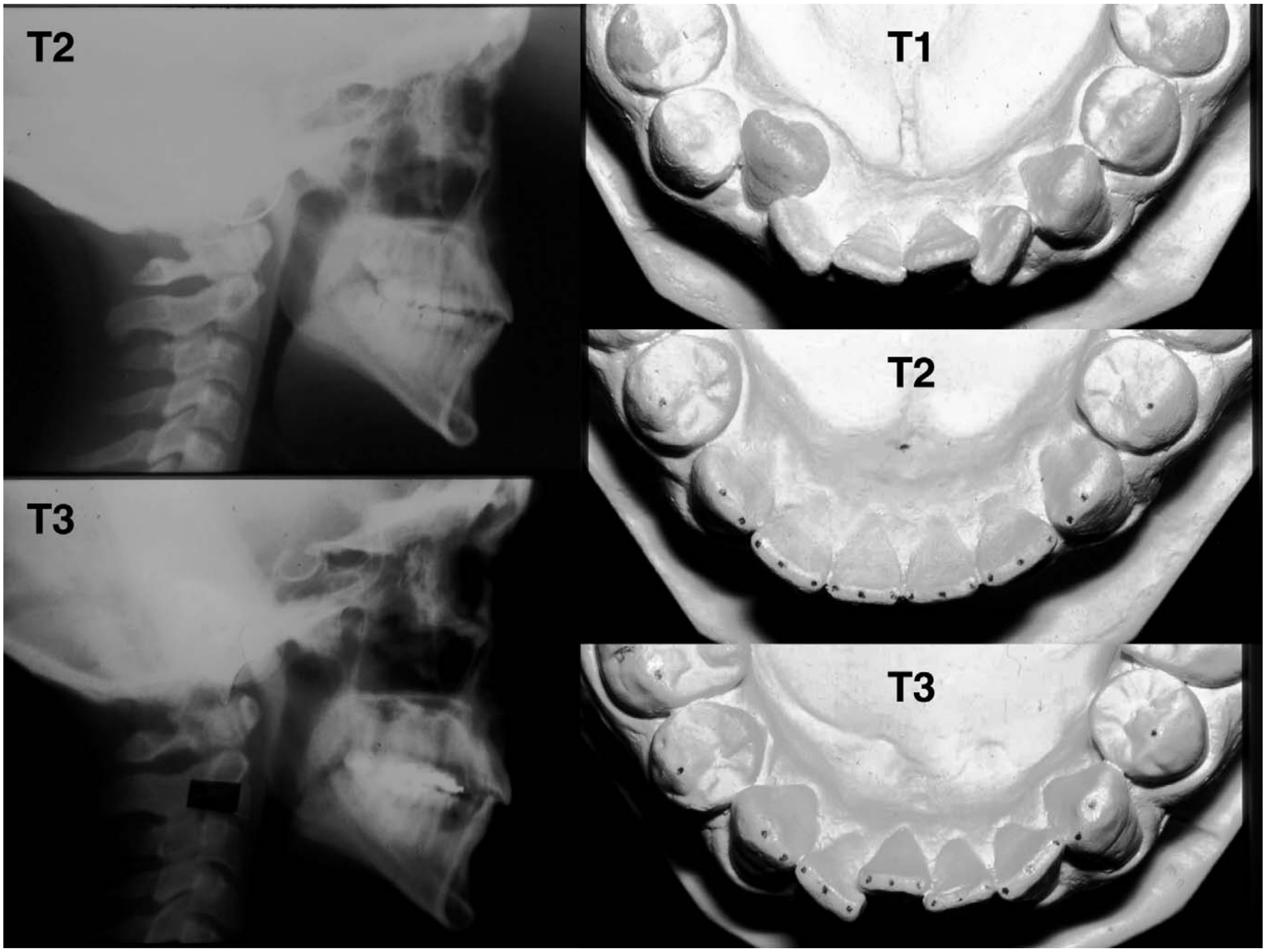

Figure 2. Mandibular models made before active treatment (T1) as well as mandibular models and lateral cephalograms made after active treatment (T2) and 11.4 years postretention (T3) of adolescent patient with LFH at T2 treated for Class II, division 1 malocclusion with extraction of four first premolars. IRI = 9.7 mm at T1, 0.0 mm at T2, and 6.0 mm at T3. 3-3 width = 20.0 mm at T1, 25.7 mm at T2, and 23.6 mm at T3. MP/SNL = 44.0° at T2 and at T3.

Table 1. Distribution of Angle Classification, Extraction Alternative, and Gender of 123 Adolescent Patients Selected According to Criteria for Short (SFH), Normal (NFH), and Long (LFH) Facial Height at End of Active Treatment

	SFH (n = 46)		NFH (n = 42)		LFH (n = 35)	
	n	%	n	%	n	%
Angle Class I	12	26.1	15	35.7	18	51.4
Angle Class II	34	73.9	27	64.3	16	45.7
Angle Class III	0	0.0	0	0.0	1	2.9
Nonextraction	14	30.4	17	40.5	5	14.3
Extraction	32	69.6	15	59.5	30	85.7
Males	26	56.5	19	45.2	18	51.4
Females	20	43.5	23	54.8	17	48.6

moment correlation coefficient was calculated between the measurement for mandibular matrix rotation and the change in SN/MP from T2 to T3 for the 26 males in the SFH group.

RESULTS

Dental Changes

The IRI and the 3-3 width were similar among the subjects in the SFH, NFH, and LFH groups at T1, T2, and T3 ($P > .05$). The IRI increased and the 3-3 width decreased in all three groups from T2 to T3 ($P < .05$, Table 3; Figures 1 and 2), but ANOVA failed to detect any intergroup differences in these changes ($P > .05$). Only 13.6% of the subjects in the SFH group had IRI > 5.0 mm at T3, as opposed to 28.6% of those in the NFH group and 31.4% of those in the LFH group ($P < .05$). The increase in IRI from T2 to T3 was more

Table 2. Means of Age at End of Active Treatment (T2), Length of Posttreatment Observation Period (T2–T3), Irregularity Index (IRI) and Intercanine (3–3) Width Prior to Treatment (T1), Change in 3–3 Width During Treatment (T1–T2), and Means of the Discriminant Cephalometric Variables at T2 of 123 Adolescent Patients Selected According to Criteria for Short (SFH), Normal (NFH), and Long (LFH) Facial Height at End of Active Treatment[a]

	SFH (n = 46)		NFH (n = 42)		LFH (n = 35)		
	Mean	SD	Mean	SD	Mean	SD	*P*
Age at T2 (y)	15.88	1.68	15.72	0.97	15.74	1.38	>.05
Time T2–T3 (y)	16.80	5.40	16.06	5.46	15.27	4.55	>.05
IRI at T1 (mm)	4.87	2.81	5.62	3.49	5.35	3.13	>.05
3–3 at T1 (mm)	25.86	2.80	25.89	1.88	25.57	2.32	>.05
3–3 T1–T2 (mm)	0.96	2.26	0.89	1.66	0.98	1.73	>.05
SN/MP (°)	24.35	2.88	32.20	2.60	41.16	3.39	<.05
NGo/MP (°)	71.54	3.04	77.14	3.22	82.74	3.48	<.05
SGo/NMe (%)	75.18	2.81	69.15	2.37	62.42	2.78	<.05

[a] SN/MP indicates angle between the sella-nasion line and the mandibular plane; NGo/MP, lower gonion angle; and SGo/NMe, facial height ratio. *P* reflects intergroup differences according to analysis of variance.

Table 3. Mean Changes of Irregularity Index (IRI) and Intercanine (3–3) Width and Mean Changes of the Discriminant Cephalometric Variables From End of Active Treatment to Long-Term Follow-Up of 123 Adolescent Patients Selected According to Criteria for Short (SFH), Normal (NFH), and Long (LFH) Facial Height at End of Active Treatment[a]

	SFH (n = 46)		NFH (n = 42)		LFH (n = 35)		
	Mean	SD	Mean	SD	Mean	SD	*P*
IRI (mm)	2.13	1.83	2.55	1.80	2.49	2.11	>.05
3–3 width (mm)	−1.58	1.11	−1.62	1.09	−1.67	1.57	>.05
SN/MP (°)	−2.60	2.30	−1.65	2.09	−1.30	2.48	<.05
NGo/MP (°)	−1.21	1.28	−0.40	1.29	−0.14	1.51	<.001
SGo/NMe (%)	2.59	2.31	1.97	2.14	1.38	2.20	>.05

[a] SN/MP indicates angle between the sella-nasion line and the mandibular plane; NGo/MP, lower gonion angle; and SGo/NMe, facial height ratio. *P* reflects intergroup differences according to analysis of variance.

pronounced (*P* < 01) in males (mean 2.83 mm, SD 2.06) than in females (mean 1.89, SD 1.59).

Skeletal Changes

ANOVA showed that the angles SN/MP and NGo/MP as well as the ratio SGo/NMe were different among the subjects in the SFH, NFH, and LFH groups at T1, T2, and T3 (*P* < 0.001; Figures 1 and 2), and pairwise comparisons revealed that all groups differed from one another at each time period (*P* < .05). The angles SN/MP and NGo/MP decreased and the ratio SGo/NMe increased in all groups from T2 to T3 (*P* < .05, Table 3). However, ANOVA detected intergroup differences in changes only for SN/MP (*P* < .05) and NGo/MP (*P* < .001). Pairwise comparisons showed that only the SFH and LFH groups demonstrated differences in change in SN/MP (*P* < .05), whereas the SFH and NFH as well as the SFH and LFH groups demonstrated differences in change in NGo/MP (*P* < .05). No other differences were detected in changes from T2 to T3. Chi-square analysis did not detect intergroup differences in frequency of the three categorized changes in SN/MP from T2 to T3 (Table 4, *P* > .05). Maximum increases were 4.5°, 2.0°, and 3.0°, and maximum decreases were 8.0°, 6.5°, and 9.0° among the subjects with SFH, NFH, and LFH, respectively. However, increase was more frequent and pronounced reduction less frequent in females than in males (*P* < .001, Table 5). The mean change in SN/MP from T2 to T3 was 3.29 mm (SD 2.13) in males and 0.45 mm (SD 1.52) in females (*P* < .001).

Table 4. Number and Percentage of Subjects With Increase (SN/MP < 0), Minimal Reduction (0 ≤ SN/MP ≤ 1.5) and Pronounced Reduction (SN/MP ≥ 2.0) of SN/MP From End of Active Treatment to Long-Term Follow-Up of 123 Adolescent Patients Selected According to Criteria for Short (SFH), Normal (NFH), and Long (LFH) Facial Height at End of Active Treatment[a]

	SFH (n = 46)		NFH (n = 42)		LFH (n = 35)	
	n	%	n	%	n	%
SN/MP < 0	2	4.4	7	16.7	7	20
0 ≤ SN/MP ≤ 1.5	15	32.6	17	40.5	14	40
SN/MP ≥ 2.0	29	63	18	42.8	14	40

[a] SN/MP indicates angle between the sella-nasion line and the mandibular plan. *P* = .11 according to chi-square analysis.

Only the change in 3-3 width from T2 to T3 (effect −0.35, SE 0.13, *P* < .001), gender (effect −0.24, SE

Table 5. Number and Percentage of Males and Females With Increase (SN/MP < 0), Minimal Reduction ($0 \leq$ SN/MP ≤ 1.5) and Pronounced Reduction (SN/MP ≥ 2.0) of SN/MP From End of Active Treatment to Long-Term Follow-Up of 123 Adolescent Patients Selected According to Criteria for Short, Normal, and Long Facial Height at End of Active Treatment[a]

	Males (n = 63)		Females (n = 60)	
	n	%	n	%
SN/MP < 0	2	3.2	14	23.3
$0 \leq$ SN/MP $\leq$ 1.5	10	15.9	36	60.0
SN/MP ≥ 2.0	51	81.0	10	16.7

[a] SN/MP indicates angle between the sella-nasion line and the mandibular plane. $P < .001$ according to chi-square analysis.

0.30, $P < .01$), and the change in 3-3 width from T1 to T2 (effect 0.19, SE 0.09, $P < .05$) were included in the final model explaining increase in IRI from T2 to T3. The amount of mandibular matrix rotation according to Björk[18] was $-5.1°$ for the 26 males in the SFH group, with a concomitant reduction in SN/MP of only 3.9 deg. The correlation coefficient between the two angular changes was 0.57 ($P < .05$).

DISCUSSION

Our findings do not support the hypothesis that high-angled[17,18] and low-angled[17–19] facial patterns at the time of appliance removal are risk factors for postretention relapse of mandibular incisor malalignment in adolescent orthodontic patients. The large variability in amount of relapse among the subjects in each of the three experimental groups combined with the lack of intergroup differences may be interpreted as a confirmation of the multifactorial nature of mandibular incisor relapse.[1,3,8,9,12–15] However, it should be stressed that we were limited to a 62% chance of detecting a true difference of 1 mm in incisor irregularity when comparing each of the extreme facial types to the control group of subjects with normal vertical relationships.

Our research question may therefore merit reinvestigation, provided that a larger and equally representative sample can be identified. It should also be emphasized that our sample selection was based on facial morphology at the end of active treatment. Any increase in mandibular plane angle during active treatment because of the extrusive nature of the orthodontic appliances was not accounted for. We cannot therefore rule out bias caused by occasional erroneous inclusion of subjects in the group with increased lower facial height. However, any appliance-induced posterior rotation of the mandible during active treatment may contribute to an increase in confidence regarding representation of the subjects selected for short lower facial height.

In keeping with inferences from previous studies,[18,20,21,26] our findings suggest that posterior mandibular growth rotation is rare in adolescent patients following appliance removal. Despite our rather strict criteria for including subjects in the group with long facial height, only 13% demonstrated an increase in inclination of the mandibular plane during the follow-up period. For that reason, our sample does not allow conclusions regarding the effect of such growth pattern on relapse. Our results support recent findings[26] that facial morphology at adolescence may be less clinically useful in predicting remaining growth rotation than previously suggested.[18,20] Also, the rather small differences in anterior mandibular rotation during the posttreatment growth period among the patients in the different facial height categories (Table 3) may not be considered clinically significant. The lack of differences in postretention incisor irregularity between the patients with short and long facial heights and those with normal facial height may therefore not automatically be interpreted to conclude lack of effect of anterior mandibular rotation on relapse of incisor alignment.

The adolescent patients in our sample demonstrated a gender difference in relapse of mandibular incisor irregularity as well as in prevalence and amount of anterior growth rotation after appliance removal. Our study was not designed to test the effect of gender on the different study model and cephalometric measurements. However, the linear regression analyses we elected to employ suggest that males are at increased risk of relapse. The differences in type of posttreatment growth between males and females suggest that the reason may be a larger number of subjects with forward rotation in males. Change in MP/SN angle was not included in the final prediction model because of colinearity of that variable with gender. Our results may suggest that a study designed to test these issues may have merit. We could confirm previous findings that increase in 3-3 width during active treatment and postretention reduction in 3-3 width are risk factors for relapse.[14]

Our results confirm that remodeling apposition and resorption along the lower border of the mandibular corpus will mask part of the anterior mandibular growth rotation.[18] Among the male subjects of our sample selected for short facial height, this compensatory remodeling masked about one fourth of the total amount of rotation. Provided that the alveolar process that houses the dentition rotates according to the mandibular corpus, the potential effect of anterior growth rotation on relapse of incisor alignment is therefore likely to be larger than the follow-up changes of the cephalometric parameters may indicate, increasing the confidence in our negative finding regarding difference in relapse between adolescent patients with normal and short facial height at the end of active treatment. The potential for remodeling compensation for posterior growth rotation is unclear.[18] However, we cannot rule out that some apposition at the posterior aspect of the lower border of the mandible may have underestimated the amount of posterior growth rotation among the subjects with long facial height.[18]

CONCLUSIONS

- High-angled and low-angled facial patterns at the time of appliance removal are not associated with increased risk of postretention relapse of mandibular incisor malalignment in adolescent orthodontic patients, and are poor predictors of type of postretention growth.
- However, adolescent males experience significantly more forward mandibular growth rotation than adolescent females following appliance removal, which may explain why the male patients in our sample experienced more relapse than the females.
- About one fourth of the anterior rotation is masked by remodeling apposition and resorption along the lower border of the mandible.

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