Original Article

Long-term evaluation of the molar movements following Pendulum and fixed appliances

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ABSTRACT

Objective: To describe the molar movements and skeletal changes associated with Pendulum-fixed appliance treatment and the long-term postretention period.

Subjects and Methods: The treatment sample consisted of 76 Class II patients, 35 males and 41 females. Lateral cephalograms were obtained at the start of treatment (T1); the end of distalization (T2); the end of orthodontic fixed appliance therapy (T3); and long-term observation (7 years 2 months later; T4). Mean age was 12 years 11 months at T1, 13 years 8 months at T2, 15 years 4 months at T3, and 22 years 5 months at T4. The average amount of Class II molar relationship was 3.1 mm, with a mean overjet of 5.9 mm at the beginning of treatment. A paired *t*-test was used to identify significant between-group differences between T2–T4 and T3–T4.

Results: Distal molar movement was obtained during the distalization phase (T2), and more than half of the distalizing effect was maintained at the end of maxillary growth (T4). Most of the relapse occurred during fixed appliance therapy (T3), whereas no significant change was detected in the postretention period (T4). The molar relationship did not show any significant difference between T2 and T4. The vertical facial dimension increased during the distalization phase (T2) and fixed appliance therapy (T3) but returned to the initial values during the postretention period (T4).

Conclusions: The Pendulum appliance induces significant dentoalveolar effects, which can be partially maintained during the long-term period. The Class I molar relationship does not change during completion of individual growth. Increase in vertical facial dimension represents a temporary effect. (*Angle Orthod.* 2013;83:447–454.)

KEY WORDS: Class II malocclusion; Molar distalization; Pendulum appliance; Noncompliance; Long-term outcomes

INTRODUCTION

Among several intraoral distalizing devices, the Pendulum can be considered one of the most commonly used noncompliance appliances and one of the most effective in correcting a Class II molar relationship.[1] Similar to other distalizing appliances, the Pendulum appliance seems to correct the Class II molar relationship mainly by dentoalveolar changes rather than by maxillary growth restriction.[2] Once a Class I molar relationship is obtained, maxillary molars tend to move forward as a dentoalveolar compensation following the concomitant forward movement of the maxilla and the mandible.[3] This mesial movement tends to reduce the distalizing treatment effect, which seems to be lost over time.

Several investigations on the use of intraoral distalizing devices have been published; however, most reported data relative to treatment changes that occurred at the end of the distalization phase[4–6] or at the end of comprehensive fixed appliance therapy,[7–9] whereas data relative to long-term outcomes are lacking. A systematic review[10] revealed that most studies were short term in nature, had a small sample size, and provided no enough evidence on the stability of the changes after distalization therapy over time.[11] Therefore, the aim of this study was to describe the molar movements and skeletal changes associated with Pendulum-fixed appliance treatment and the long-term postretention period.

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Accepted: September 2012. Submitted: May 2012.
Published Online: October 18, 2012

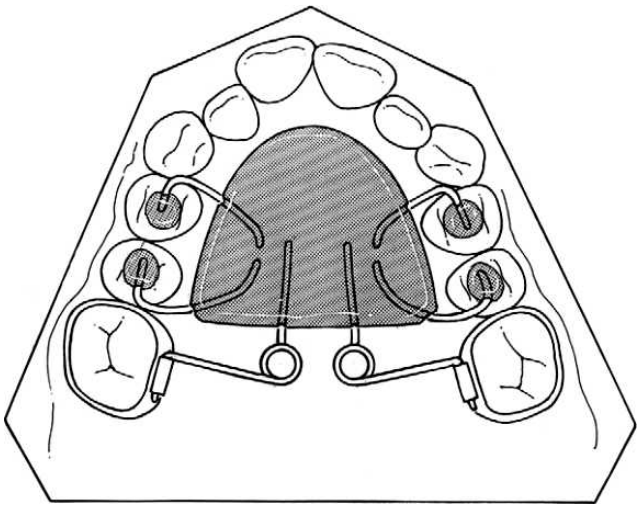

Figure 1. Pendulum appliance.

MATERIALS AND METHODS

A sample of 97 patients treated with Pendulum appliance followed by fixed appliance therapy was retrospectively obtained from a single orthodontic dental office. All patients were treated by a single operator and selected according to the following criteria:

- Skeletal Class I or mild Class II malocclusion and a bilateral full cusp or end-to end Class II molar relationship;
- Male or female at pubertal growth spurt (stage C3 or C4 according to the cervical vertebral maturation method)[12];
- SN/GoGn angle less than 37°;
- Nonextraction treatment;
- Use of the Pendulum appliance during the distalization phase (Figure 1);
- Use of a Nance button between distalization therapy and fixed appliance therapy; and
- Good-quality radiographs with adequate landmark visualization and minimal or no rotation of the head.

From the initial sample, 21 patients were excluded according to defined criteria, as summarized in Table 1.

The final sample consisted of 76 white patients (Figure 2), 35 males and 41 females with a mean age of 12 years 11 months ± 1 year 5 months (range, 11 years 4 months to 13 years 4 months). The average amount of Class II molar relationship was 3.1 mm, with a mean overjet of 5.9 mm at the beginning of treatment (Table 2). Four serial cephalograms for all patients were available at four observation times: before treatment (T1); after distalization (T2); after orthodontic fixed appliance therapy (T3); and in the postretention period (T4), after an average of 7 years 2 months ± 6 months to T3 (range, 6 years 5 months to 8 years 10 months). Demographics of observation periods and observation intervals are reported in Table 3.

Table 1. Sample Selection and Exclusion Criteria

Initial sample	97
Primary exclusion criteria	
1. Poor film quality	2
2. Lack of consensus	6
3. Incomplete records	7
Secondary exclusion criteria	
1. T1 to T2 >12 months	1
2. Mandibular inclination SN/GoGn >37°	3
3. Use of other molar distalizing mechanics between T1 and T2	2
Final sample	76

Clinical Management

All patients underwent maxillary molar distalization therapy with a Pendulum appliance similar to that described by Hilgers.[13] On average, intraoral reactivation of the distalizing springs was performed once or twice during the procedure. As recommended by Byloff and Darendeliler,[14] uprighting bends were added to the end of the TMA wire to prevent excessive molar tipping. The appliance was left in situ until a super Class I molar relationship was achieved. The mean treatment time for distalizing maxillary molars was 8 ± 2 months. After removal of the Pendulum appliance, a Nance button was placed and left passively for 4–5 months to retain the distalized first molars and allow a spontaneous premolar distal drifting. Subsequently, preadjusted fixed orthodontic appliances (Roth prescription 0.022″ × 0.028″) were placed. After conventional tooth leveling and aligning, the maxillary premolars and canine were individually retracted. The Nance button was removed and anterior teeth were retracted using sliding mechanics; quarter-inch intermaxillary elastics in conjunction with fixed appliances were used as support in anchorage during canine and incisor retraction. The mean total treatment time was 2 years 3 months ± 3 months.

Retention Protocol

At the end of the orthodontic treatment, all patients were instructed to wear a maxillary Hawley retainer at night for 2 years; a fixed canine-to-canine lingual retainer was used for retention in the lower arch. Thereafter, patients were left out of retention and reevaluated at least 5 years later.

Cephalometric Analysis

Lateral cephalograms for each patient at T1, T2, T3, and T4 in each treatment group were standardized as

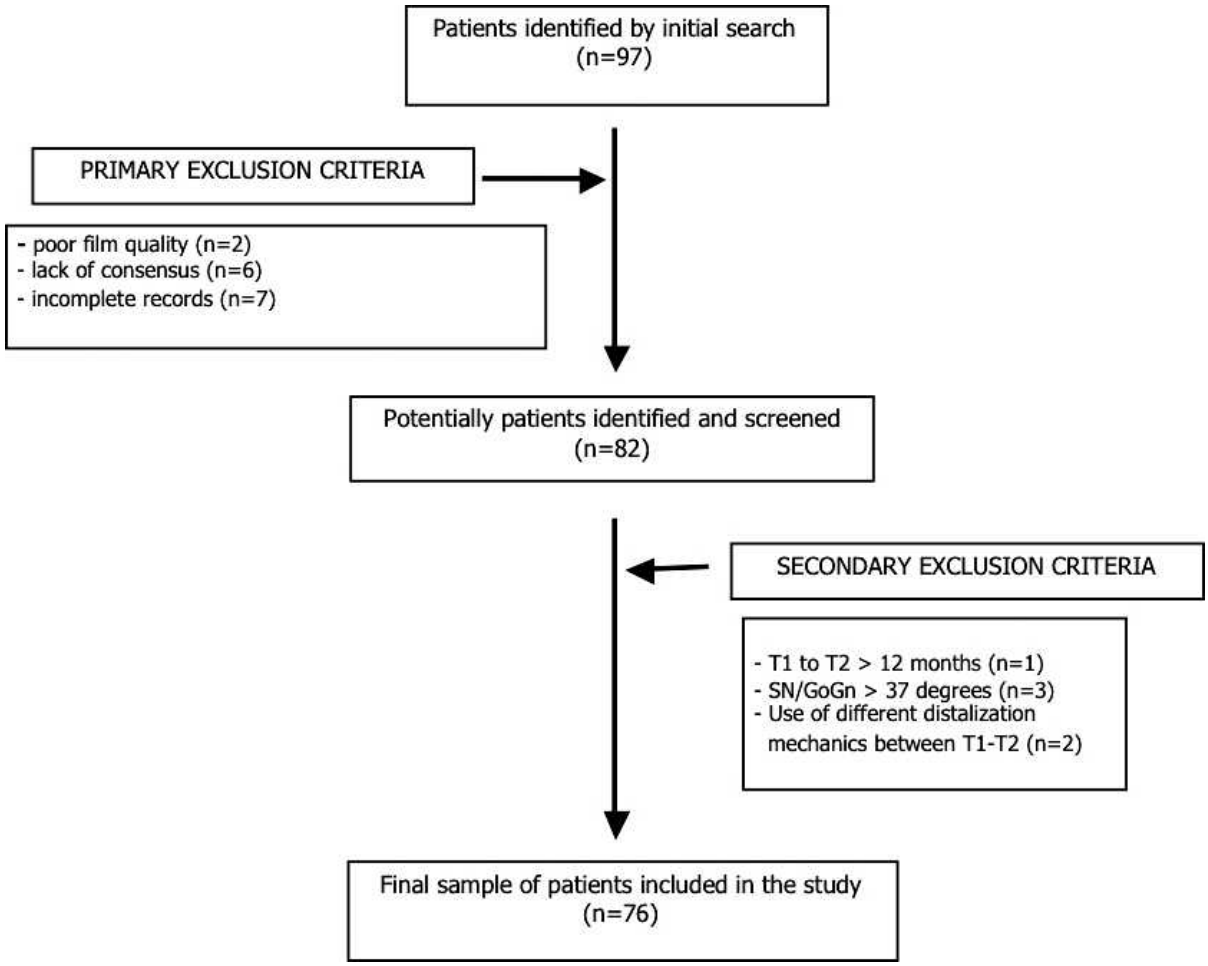

Figure 2. Flow diagram summarizing inclusion criteria for sample selection.

to magnification factor (6% enlargement). Cephalograms were hand traced by a single operator with verification of anatomic outlines and landmark position performed by a second investigator. In instances of disagreement, the structures in question were retraced to the mutual satisfaction of both. In instances of bilateral structures (eg, gonial angle, teeth), a single averaged tracing was made.

The cephalometric analysis consisted of 27 landmarks, six angular measurements, and seven linear measurements for each tracing; four fiducial markers were also placed in the maxilla and mandible[15] (Figure 3a,b). The 27 landmarks and four fiducial markers were used for superimposition.[8,16]

Statistical Analysis

Descriptive statistics was calculated for age, duration of treatment, and cephalometric measurements at T1 for all the subjects. Mean differences and standard deviations were also calculated for the treatment changes between T1–T2, T2–T3, and T3–T4.

A paired *t*-test was used to identify significant between-group differences for each cephalometric variable between T2–T4 and T3–T4 with a statistical software package (MedCalc Version 12.2.1, Mariakerke, Gent, Belgium). Normal distribution of the data was determined by exploratory tests (Shapiro-Wilk). Statistical significance was tested at $P < .05$, $P < .01$, and $P < .001$.

The power of the study was calculated on the basis of the difference in means and standard deviation of the changes in molar distalization (U6 horizontal) as reported in a previous longitudinal investigation.[8] The resulting power exceeded 0.90 at an α level of 0.05.

Method Error

Twenty-five randomly selected cephalograms were retraced by the same author after a period of 2 months. No significant mean differences between the two series of records were found by using paired *t*-tests. Dahlberg's[17] formula was used to establish the method error. A range from 0.5 to 0.8 mm for linear

Table 2. Mean Cephalometric Measures at the Beginning of Treatment

Cephalometric Measures	Mean	SD
Sagittal skeletal relations		
Maxillary position S-N-A	82.7°	3.1°
Mandibular position S-N-Pg	79.3°	3.0°
Sagittal jaw relation A-N-Pg	3.4°	1.4°
Vertical skeletal relations		
Maxillary inclination S-N/ANS-PNS	6.6°	1.4°
Mandibular inclination S-N/Go-Gn	29.8°	3.6°
Vertical jaw relation ANS-PNS/Go-Gn	23.2°	2.5°
Dento-basal relations		
Maxillary incisor inclination 1-ANS-PNS	117.2°	7.2°
Mandibular incisor inclination 1-Go-Gn	94.1°	5.3°
Mandibular incisor compensation 1-A-Pg (mm)	3.04	1.05
Dental relations		
Overjet (mm)	5.09	3.09
Overbite (mm)	3.01	3.04
Interincisal angle (1/1)	119.2°	7.5°
Molar relationship (mm)	−3.1	1.01

measurements and 0.6° to 0.9° for angular measurements was found. Reliability coefficient (r)[18] ranged from 0.94 to 0.98 and from 0.92 to 0.97, respectively.

RESULTS

The mean and standard deviation of the dento-skeletal changes relative to T1–T2, T2–T3, and T3–T4 are reported in Table 4. The mean, standard deviation, and statistical significance of the changes in skeletal and dental measurements relative to T2–T4 and T3–T4 are summarized in Table 5.

Skeletal Changes Between T2–T4 and T3–T4

Significant changes were detected in sagittal and vertical skeletal measurements. SNA and SNPg increased 0.7 ($P < .05$) and 2.4 mm ($P < .01$), respectively between the end of distalization-phase (T2) and the long-term observation (T4). In particular, SNA decreased 0.1 mm during fixed appliance therapy (T2–T3) and increased 0.8 mm in the postretention period (T3–T4). On the contrary, SNPg increased both between T2–T3 (0.7 mm) and T3–T4, but the major increase (1.7 mm) was noted after the completion of comprehensive orthodontic treatment (T3–T4).

SN/GoGn and SnaSnb/GoGn increased 1.2 and 0.7 mm, respectively, during fixed appliance therapy (T2–T3), and it decreased 0.9 mm ($P < .05$) and 1.5 mm ($P < .01$) in the postretention period (T3–T4).

Dental Changes Between T2–T4 and T3–T4

The maxillary first molar showed mesial movement of 2.2 mm ($P < .01$), mesial crown tipping of 4.5°, and extrusion of 1.3 mm ($P < .05$) between the end of distalization phase (T2) and the long-term observation (T4). In particular, 91% of the mesial molar movement and mesial crown tipping was observed during fixed appliance therapy (T2–T3), whereas no significant change was detected in the postretention period (T3–T4) (Figure 4). Accordingly, 69.2% of the molar extrusion occurred during fixed appliance therapy, but no significant change was detected after the completion of orthodontic treatment (T3–T4). The molar relationship did not show any significant difference between the end of distalization (T2) and the postretention period (T4).

DISCUSSION

Several investigations[14–19] evaluated the efficacy of the Pendulum appliance, reporting data relative to soft-tissue and dentoskeletal changes that occurred from the beginning (T1) to the end of the distalization phase (T2).[6,20,21] However, only few studies[2,8,9] showed findings at the end of fixed appliance therapy (T3), and data relative to long-term dentoskeletal effects (T4) are lacking. Angelieri et al.[9] stated that the results of his study should not be applied after the stage of craniofacial growth and development as further long-term investigations are needed. Therefore, our study aimed to investigate dento-skeletal effects of the Pendulum appliance during a 7-year postretention follow-up. In particular, long-term observation focused on two main topics: residual molar distalization rate and stability of the Class I molar relationship. It has

Table 3. Demographics of Observation Periods and Observation Intervals

Obsevation Period/Interval	Mean	SD	Minimum	Maximum
T1	12 y 11 mo	1 y 5 mo	11 y 4 mo	13 y 4 mo
T2	13 y 8 mo	1 y 4 mo	12 y 2 mo	15 y 1 mo
T3	15 y 4 mo	1 y 5 mo	13 y 9 mo	16 y 10 mo
End of retention	17 y 2 mo	1 y 2 mo	15 y 7 mo	19 y 09 mo
T4	22 y 5 mo	2 y 7 mo	19 y 4 mo	25 y 7 mo
T1–T2	8 mo	2 mo	6 mo	12 mo
T2–T3	1 y 7 mo	4 mo	1 y 4 mo	2 y 1 mo
T3–T4	7 y 2 mo	6 mo	6 y 5 mo	8 y 10 mo
T1–T3	2 y 4 mo	3 mo	1 y 9 mo	2 y 11 mo
T1–T4	9 y 5 mo	6 mo	7 y 9 mo	9 y 11 mo

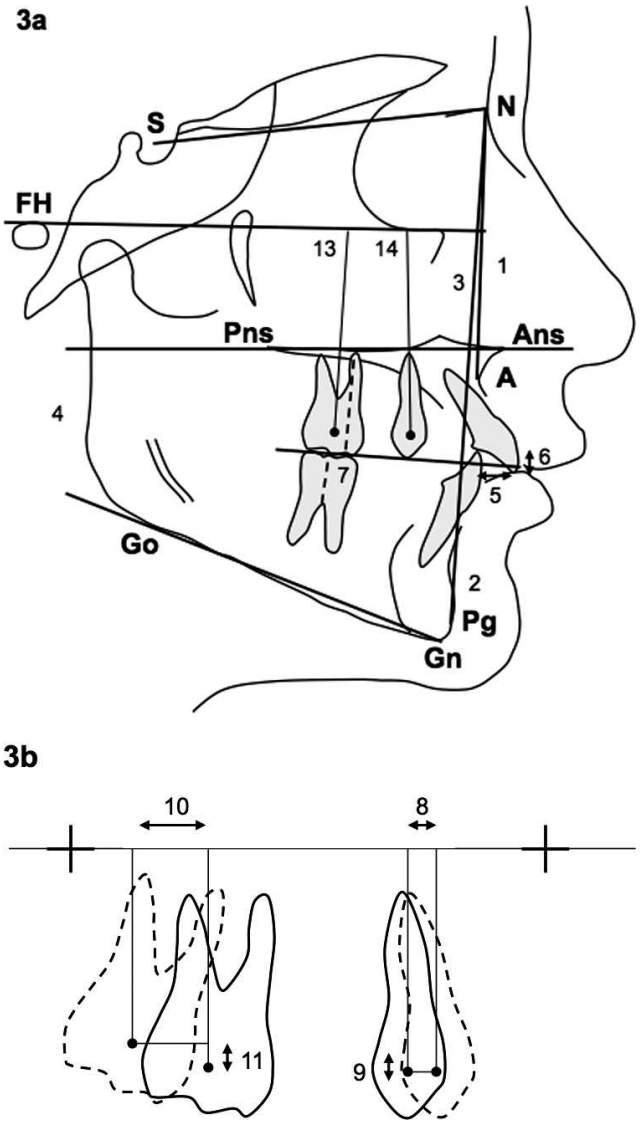

Figure 3a;3b. Cephalometric landmarks and measurements: (1) SNA; (2) SNPg; (3) ANPg; (4) AnsPns/GoGn; (5) Overjet; (6) Overbite; (7) molar relationship; (8) U4 horizontal; (9) U4 vertical (perpendicular to a line passing through maxillary fiducial markers); (10) U6 horizontal; (11) U6 vertical; (12) U4 to FH; (13) U6 to FH.

been widely demonstrated that maxillary molars show a distal movement during the distalization phase[8] (T1–T2), which partially or completely relapses at the end of orthodontic fixed appliance therapy (T2–T3)[2,8,9]; Burkhardt et al.[2] reported that after comprehensive treatment, the maxillary first molar was only 0.8 mm distal to its original position, and similar results were observed by Chiu et al.[8] This forward movement can be considered a normal process of dentoalveolar compensation during mandibular growth in order to maintain Class I molar relationship.[3]

Our study focused on changes that occurred between T2–T4 and T3–T4 in order to discern whether major modifications occurred during orthodontic treatment and whether minor modifications may also be observed in the postretention period during the completion of individual growth. The maxillary first molar showed distal movement and distal crown tipping during the distalization phase (T2) but mesial movement and mesial crown tipping during orthodontic fixed appliance therapy (T3) and the postretention period (T4). However, only 0.2 mm of mesial movement and 0.4° of mesial tipping were detected after completion of orthodontic treatment, suggesting that 91% of the relapse occurred during fixed appliance therapy, whereas no significant change was detected in the postretention period.

Moreover, considering that 5.1 mm molar distal movement was observed during the distalization phase and only 2.2 mm of relapse between T2–T4, it can be stated that 57% of the distalizing effect was maintained during maxillary growth. These data disagreed with those of Chiu et al.[8] and Burkhardt et al.,[2] who reported that about 90% and 87% of the molar distalization achieved by the Pendulum appliance during the first phase of treatment was lost during fixed orthodontic treatment. Therefore, use of anchorage reinforcement such as the Nance button or intermaxillary elastics is critical for retention of the distalized maxillary molars during retraction of the anterior teeth. Despite that, a marked tendency of the molars to return to the initial sagittal position was also detected by Melsen and Dalstra[3]; however, the mean age of their sample ranged from 8.0 to 10.4 years old, and retention protocols may not be effective at an early age. Moreover, the use of extraoral traction can be more indicated to restrain maxillary growth than to distalize maxillary molars, and orthopedic effects generated at an early age with functional or extraoral appliances are highly reversible.[22–24]

Maxillary cephalometric measurements were made on local superimposition and showed that at the completion of facial growth, maxillary molars were in a slight distal position and were more extruded than before treatment (Figure 4). The use of cranial base superimposition could have led to misleading results, as the forward movement of the maxilla during growth can underestimate the extent of residual molar distalization. However, although in our study maxillary fiducial markers were used for superimposition, exact modeling of the maxilla cannot be estimated, and measurements obtained using this method may be less accurate than those obtained using stable intraosseus implants.[3] In any event, maxillary local superimposition can better distinguish between skeletal and dentoalveolar effect, and it might be the best way to appropriately evaluate the dental effect of an intraoral distalizing device. Cranial base superimposition may be used for this purpose if adult patients are evaluated.[25]

Table 4. Dento-skeletal Changes at T1–T2, T2–T3, and T3–T4

	T1–T2		T2–T3		T3–T4	
Cephalometric Measures	Mean	SD	Mean	SD	Mean	SD
Sagittal skeletal relation						
Maxillary position SNA	0.2	0.4	−0.1	0.5	0.8	0.6
Mandibular position SNPg	0.2	1.1	0.7	1.2	1.7	1.2
Sagittal jaw relation ANPg	0.1	0.8	−0.6	0.6	−0.9	0.5
Vertical skeletal relation						
Vertical jaw relation	0.6	0.5	0.7	0.2	−1.5	0.4
Dental relations						
Overjet	3.5	0.7	−2.4	1.6	0.4	0.3
Overbite	−1.4	0.5	0.9	1.1	0.4	0.9
Maxillary dentoalveolar						
Molar relationship	−4.8	1.2	1.2	0.5	0.2	0.3
U4 horizontal	1.1	0.8	−2.2	0.9	0.2	0.3
U4 vertical	0.3	0.5	0.9	0.7	0.2	0.5
U6 horizontal	−5.1	0.9	2.0	0.8	0.2	0.5
U6 vertical	0.6	0.3	0.9	0.4	0.4	0.5
U4 to FH	1.2	1.4	−1.1	0.7	0.3	0.3
U6 to FH	−9.9	1.5	4.1	1.2	0.4	1.4

The Pendulum appliance yields a predominantly dentoalveolar effect, and mandibular growth can be crucial for correction of the Class II malocclusion in growing subjects.[2] Moreover, a residual skeletal growth can be detected after the completion of orthodontic treatment, both in the sagittal and vertical planes, and SNA and SNPg angles increased 0.8 mm and 1.7 mm between T3 and T4. Despite that, the molar relationship did not show any significant change during the postretention period. This finding can be explained by two main aspects. First, once a Class I molar relationship was obtained during orthodontic treatment, it was maintained by dentoalveolar compensation during maxillo-mandibular growth. A favorable growth pattern (skeletal) and a correct intercuspation (dentoalveolar) might be favorable factors in growing patients.[26,27] Second, only minimal changes were detected in the mandibular position between T3 and T4, as cephalometric measurements were not taken relative to B point but to Pogonion point. It can be suggested that growth of the nose and the chin continues downward and forward during facial development, even if growth of the maxilla and mandible is completed.[28] Therefore, residual growth of the Pogonion may not be accompanied by a concomitant growth of the basal bone.

Table 5. Changes in Skeletal and Dental Measurements at T2–T4 and T3–T4[a]

	T2–T4			T3–T4		
Cephalometric Measurements	Mean	SD	*P* Value	Mean	SD	*P* Value
Sagittal skeletal relation						
Maxillary position SNA	0.7	0.8	.039*	0.8	0.6	.045*
Mandibular position SNPg	2.4	1.1	.007**	1.7	1.2	.009**
sagittal jaw relation ANPg	−1.5	0.5	.347	−0.9	0.5	.178
Vertical skeletal relation						
Certical jaw relation (degrees)	−0.8	0.4	.021*	−1.5	0.4	.006**
Dental relations						
Overjet	−2.0	0.4	.002**	0.4	0.3	.009**
Overbite	1.3	1.0	.389	0.4	0.9	.175
Maxillary dentoalveolar						
Molar relationship (mm)	1.4	0.3	.336	0.2	0.3	.098
U4 horizontal (mm)	−2.0	0.6	.132	0.2	0.3	.357
U4 vertical (mm)	1.1	0.6	.192	0.2	0.5	.479
U6 horizontal (mm)	2.2	0.7	.004**	0.2	0.5	.276
U6 vertical (mm)	1.3	0.5	.037*	0.4	0.5	.294
U4 to FH (degrees)	−0.8	0.5	.003**	0.3	0.3	.248
U6 to FH (degrees)	4.5	1.3	.059*	0.4	1.4	.526

[a] Paired *t*-test at significance levels * $P < .05$; *** $P < .01$.

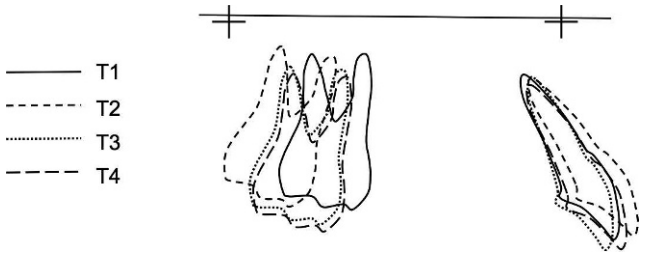

Figure 4. Average maxillary superimposition describing dentoalveolar changes during the overall observation period (T1–T4).

Most previous studies reported that distal molar movement is accompanied by an increase in vertical facial dimension and lower facial height.[14,19,20] This finding can be confirmed in our study, as SN/GoGn and SnaSnb/GoGn angles increased during the distalization phase and during orthodontic fixed appliance therapy, and this was exacerbated by a concomitant molar extrusion (1.5 mm); however, bite opening tended to decrease during the postretention period (-0.9°). Similar findings were recorded by Angelieri et al.[9] using Pendulum, by Chiu et al.[8] for the Pendulum and Distal Jet group, and by Ngantung et al.[29] for the Distal Jet used simultaneously with fixed appliances. Therefore, our findings support the hypothesis that increase in vertical facial dimension represents only a temporary effect after maxillary molar distalization, which can be partially or completely compensated by residual growth of the mandibular ramus after the completion of orthodontic treatment. This leads to the return to the initial sagittal and vertical mandibular positions and maintenance of the mesofacial growth pattern throughout treatment.[9]

The outcomes of this study are similar to those of other studies and suggest that the Pendulum appliance in combination with fixed appliances can be considered an effective protocol for treatment of Class II malocclusion in the absence of mandibular crowding and severe skeletal discrepancies. Maxillary molars can be moved distally along the maxilla, and relapse of this movement does not occur, even at the completion of maxillary growth. However, further long-term, prospective, controlled studies are needed to confirm our results; moreover, the use of the PAR index/Objective Grading System of the American Board of Orthodontic could be useful to provide more information about pretreatment and posttreatment long-term changes in the occlusion and tooth position over dental casts.

CONCLUSIONS

- Intramaxillary measurements indicated that maxillary molars were in a more distal position than before treatment at the end of growth.
- Maxillary molar distalization mostly relapsed during orthodontic fixed appliance therapy but did not show any significant change during the postretention period.
- Residual maxillo-mandibular growth continued after the completion of orthodontic treatment, but these changes did not affect the molar relationship.
- Increase in vertical facial dimension represents a temporary effect, which can be compensated during the postretention period.

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