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Cephalometric evaluation of the effects of pendulum appliance on various vertical growth patterns and of the changes during short-term stabilization

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Abstract: The aim of this study was to evaluate the effects of the pendulum appliance in dental Class II patients with varying vertical growth patterns and to evaluate the changes during the short-term stabilization period of 3 months. The sample ($n = 30$) was divided into two groups based on their FMA°. The high-angle group consisted of 14 patients (10 girls and 4 boys) and had a mean age of 157.7 ± 8.0 months. The low-angle group consisted of 16 patients (8 girls and 8 boys) and had a mean age of 155.5 ± 18.6 months. Pretreatment, posttreatment and poststabilization cephalometric radiographs were obtained to measure the changes. Mann–Whitney U and Wilcoxon tests were used for statistical evaluation. The amount of upper molar distalization was 5.9 mm ($p < 0.001$) in the high-angle group and 1 mm ($p < 0.001$) in the low-angle group, showing no intergroup difference. The amount of anchorage loss at the second premolars was 4.8 mm ($p < 0.001$) in the high-angle group and 6.6 mm ($p < 0.001$) in the low-angle group. Upper incisors moved anteriorly for 2.1 mm ($p < 0.05$) in the high-angle group and 4.1 mm ($p < 0.001$) in the low-angle group. Intergroup difference was statistically significant ($p < 0.001$). During the stabilization period, 1.5 mm of anchorage loss was measured at the upper molar region in the high-angle group and 1.7 mm of anchorage loss was measured at the upper molar region in the low-angle group. During the stabilization period, upper second premolars and incisors tended to move back to their original places. The results of this study showed that pendulum appliance could move the upper molars distally in a short period of time without depending on the patient compliance. Care should be taken to prevent anchorage loss and to stabilize the upper molars for, at least, 3 months.

Key words: cooperation; intraoral mechanics; pendulum appliance; retention; upper molar distalization

Introduction

In the treatment of dental Class II malocclusion, a common aim is to move the upper molars distally into a correct functional relationship with the lower molars. It can be done either intraorally or extraorally depending upon the patient's dental and skeletal needs. Cephalometric evaluations revealed that extraoral appliances produce skeletal effects additional to their efficiency in upper molar distalization (1–4). This could be a major drawback when there is no need to guide the growth. Furthermore, extraoral appliances leave the clinician totally dependent on patient cooperation. There is a need for appliances that take the responsibility away from the patient and place the control of treatment mechanics in the hands of the orthodontist (5, 6). Such appliances should be simple, hygienic and must deliver light continuous forces. Based on these principles several intra-arch systems have been suggested that are less dependent on patient compliance and produce faster results while delivering optimal forces. Removable appliances with finger springs (7), repelling magnets (8), Class II intermaxillary elastics (9), Wilson arches (10), superelastic coils (11), Herbst appliance (12) and Jasper Jumper (13) have all been designed and used for upper molar distalization.

Unfortunately, removable appliances still need patient compliance and present hygiene and cleaning problems (14, 15), whereas, a significant problem with the repelling magnets is the discontinuity of their force application (8). As the magnets move away from each other, magnetic forces decay rapidly causing monthly reactivations. The size of the magnets generate considerable discomfort for the patient. Class II intermaxillary elastics move the lower molars mesially with their horizontal component of force and extrude the lower molars and maxillary incisors with the vertical component of force. Of course, such movements are undesirable when the anteroposterior and vertical positions of the lower dentition are in balance (16–18). Similar problems occur with the Herbst (12) and Jasper Jumper (13) appliances, and it has been concluded that both of the appliances have effects on mandibular skeletal structures.

The pendulum appliance is another intra-arch upper molar distalization appliance that is used, with increasing popularity, since 1992 (first introduced by Hilgers (19)). There are few clinical studies and case reports evaluating the effects of the pendulum appliance (20–23). Comparison of the effects of this appliance in patients with various vertical growth patterns have been discussed, but within a limited set of parameters. Moreover, evaluation of the changes during the stabilization period, which is recommended for at least 3 months, is missing. The aim of this study was, therefore, to cephalometrically evaluate the possible differences in the response of patients with varying vertical growth patterns to the pendulum appliance, and to extend these observations into the short-term stabilization period of 3 months.

Subjects and methods

Thirty patients were treated with the pendulum appliance until a Class I molar relationship was achieved. Patient selection was done based on the following criteria: acceptable oral hygiene, moderate space deficiency, skeletal Class I malocclusion and nonextraction treatment plan (Fig. 1A,B,C).

The sample was divided into two groups according to the FMA angle (Table 1). The first group had an FMA $\leq 24°$, and the second had an FMA $\geq 29°$. The low-angle group consisted of 16 patients (8 girls and 8 boys) and had a mean age of 155.5 ± 18.6 months. The high-angle group consisted of 14 patients (10 girls and 4 boys) and had a mean age of 157.7 ± 8.0 months. Eight of the patients in the high-angle group and 12 of the patients in the low-angle group had upper second molars erupted in complete occlusion.

According to initial cephalometric measurements (Table 1), the mandible was more retrusive in the high-angle group ($p < 0.01$). Although the ANB value was somewhat greater in the high-angle group, there were no statistically significant differences between the two groups. The inter-group difference for FMA angle, however, was significant ($p < 0.01$). Minimal differences could be distinguished in occlusal plane and upper facial height measurements. In the high-angle group, the upper second premolars and the lower molars were inclined more mesially compared to the low-angle group.

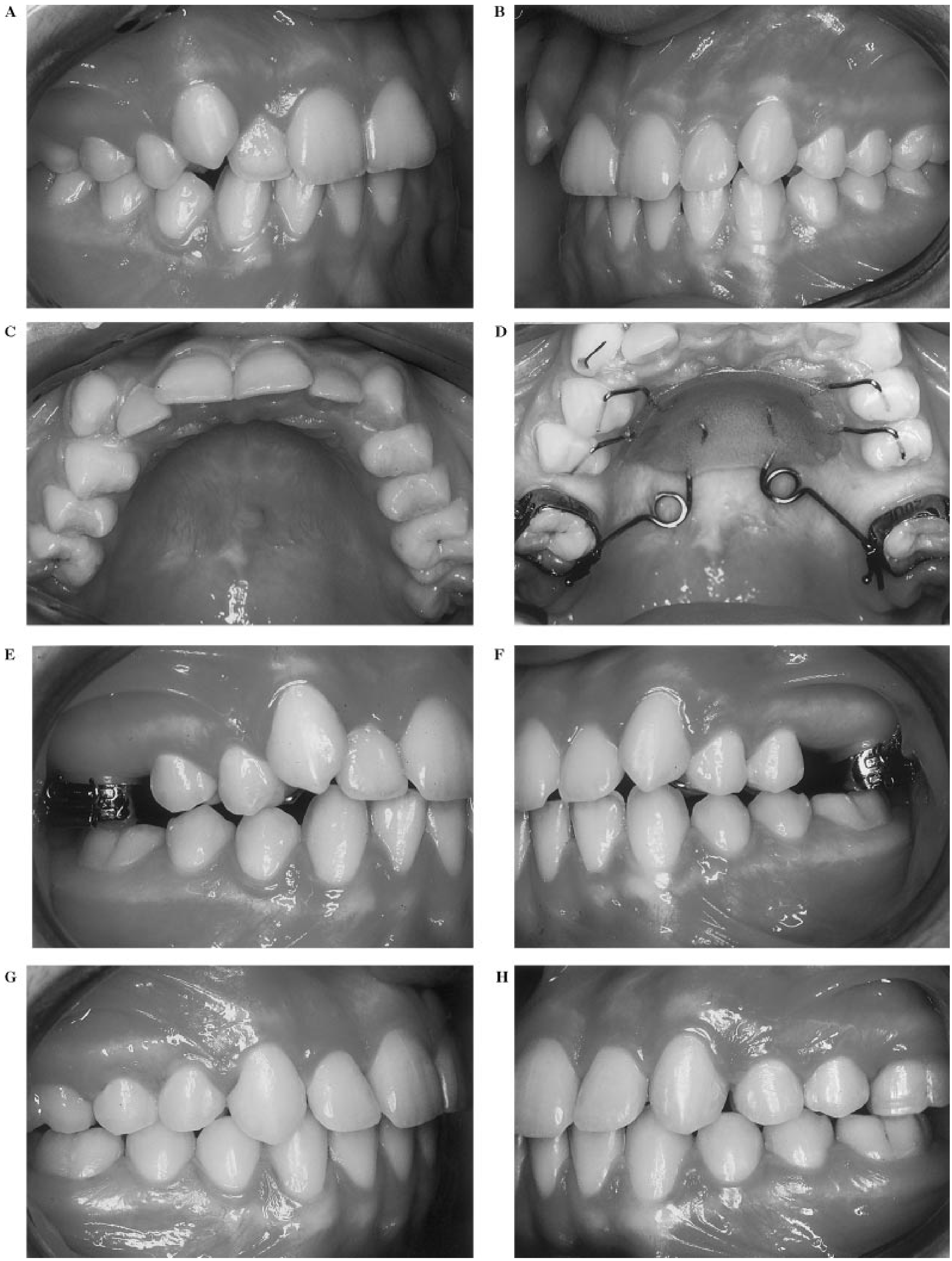

Fig. 1. A patient treated with pendulum appliance.

***Table 1.* Comparisons of initial measurements of the low-angle and high-angle groups**

Cephalometric measuremenrs	Low-angle	High-angle	significance
	mean ± SD	mean ± SD	
1. SNA°	78.4 ± 2.7	80.2 ± 3.7	
2. A-PTV(mm)	50.8 ± 2.5	50.4 ± 2.4	
3. SNB°	75.5 ± 3.2	76.1 ± 4.5	
4. B-PTV(mm)	49.9 ± 5.5	44.4 ± 4.3	**
5. Co-Pog(mm)	112.9 ± 9.9	113.6 ± 4.1	
6. ANB°	2.5 ± 1.3	3.2 ± 1.1	
7. FMA°	22.4 ± 1.3	31.1 ± 1.6	**
8. PP-FH°	−2.1 ± 2.5	−1.6 ± 3.0	
9. Na-ANS(mm)	55.7 ± 3.6	52.3 ± 3.7	*
10. ANS-Me(mm)	68.3 ± 3.5	70.5 ± 4.4	
11. U1-FH°	114.3 ± 4.7	108.6 ± 7.3	
12. U1-FH(mm)	52.0 ± 4.5	50.4 ± 7.0	
13. U1-PTV(mm)	56.0 ± 4.9	54.7 ± 4.2	
14. U5-FH°	87.4 ± 5.4	88.0 ± 4.9	
15. U5-FH(mm)	47.6 ± 2.7	50.1 ± 1.5	**
16. U5-PTV(mm)	32.1 ± 3.8	30.9 ± 3.7	
17. Overbite(mm)	3.6 ± 1.2	2.7 ± 1.7	
18. Overjet(mm)	1.1 ± 1.6	1.8 ± 2.4	
19. U6-FH°	81.4 ± 4.5	79.7 ± 5.8	
20. U6-FH(mm)	45.3 ± 2.5	46.7 ± 1.5	
21. U6-PTV(mm)	29.8 ± 2.6	27.8 ± 3.8	
22. L6-FH°	76.2 ± 8.0	70.4 ± 5.2	*
23. L6-FH(mm)	46.9 ± 3.0	49.6 ± 3.5	
24. L6-PTV(mm)	28.1 ± 3.8	26.1 ± 3.9	
25. Occ-FH°	7.7 ± 2.7	12.8 ± 4.4	**
26. Nasolabial°	107.4 ± 8.1	107.6 ± 8.9	
27. Mentolabial°	119.4 ± 19.8	112.2 ± 19.9	

* $p<0.05$.
** $p<0.01$.
U1, upper incisor; U5, upper second premolar; U6, upper molar; L6, lower molar.

Appliance design

The pendulum appliance was constructed and activated per Hilgers' recommendations (19). It consisted of three parts (Fig. 1D): a) large acrylic button placed anteriorly in the palate for anchorage, b) two TMA coil springs (0.032″) placed posteriorly on the acrylic button, c) auxiliary wires extending from the acrylic button to the first and second premolars and bonded on the occlusal surfaces. The springs were activated once, parallel to the midline of the palate (perpendicular to the large Nance button), and no other activation was done throughout the treatment. After the Class I molar relationship was achieved, a transpalatal bar carrying an acrylic button anteriorly, was inserted for stabilization.

Cephalometric evaluation

Cephalometric records were taken before the appliance insertion, after super Class I molar relationship was achieved and at the end of a stabilization period of 3 months. At the end of stabilization period, only 22 cephalograms (low-angle = 12, high-angle = 10) were available. The cephalograms of 8 patients were either not taken or had poor quality.

The head films were traced on an acetate paper with a 0.3 mm tip pencil, and 11 skeletal (6 angular and 5 linear), 14 dental (4 angular and 9 linear) and 4 soft tissue (2 angular) parameters (total 27) were used to assess the changes with the pendulum appliance treatment and also to asses the changes during the stabilization period of 3 months. PTV plane was used to measure the changes in sagittal direction and FH plane to measure the changes in vertical direction.

Skeletal measurements (Fig. 2)

1. SNA (°): to determine the sagittal position of maxilla.
2. A-PTV (mm): perpendicular distance between point A and PTV plane.
3. SNB (°): determining the sagittal position of mandible.
4. B-PTV (mm): perpendicular distance between point B and PTV plane.
5. Co-Pog (mm): distance between condylion and Pog .
6. ANB (°): to determine the maxillo-mandibular difference.
7. FMA (°): the angle formed between the mandibular plane and FH plane.
8. PP-FH (°): angle formed between the palatal and FH planes.

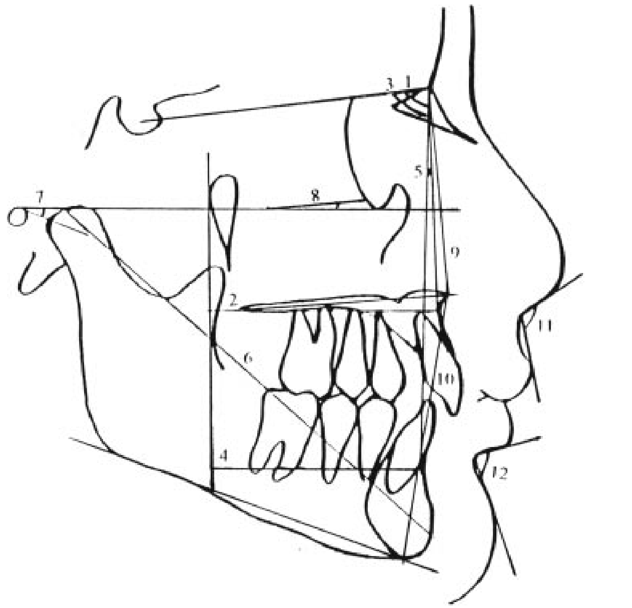

Fig. 2. Skeletal and soft tissue measurements: 1. SNA (°); 2. A-PTV (mm); 3. SNB (°); 4. B-PTV (mm); 5. ANB (°); 6. Co-Pog (mm); 7. FMA (°); 8. PP-FH(°); 9. Upper Facial Height (Na-ANS) (mm); 10. Lower Facial Height (ANS-Me) (mm); 11. Nasolabial (°); 12. Mentolabial (°).

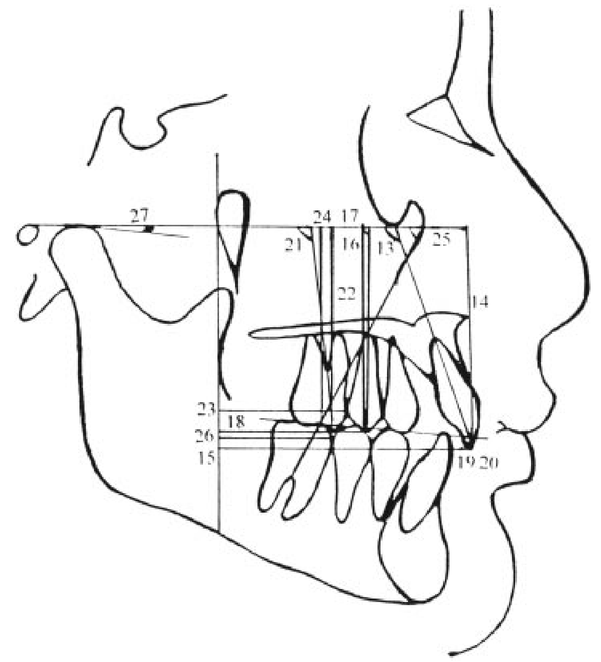

Fig. 3. Dental Measurements: 13. U1-FH (°); 14. U1-FH (mm); 15. U1-PTV (mm); 16. U5-FH (°); 17. U5-FH (mm); 18. U5-PTV (mm); 19. Overbite (mm); 20. Overjet (mm); 21. U6-FH (°); 22. U6-FH (mm); 23. U6-PTV (mm); 24. L6-FH (°); 25. L6-FH (mm); 26. L6-PTV (mm); 27. Occ-FH (°); angle between occlusal plane and FH plane.

9. Upper facial height (Na-ANS) (mm): distance between nasion and ANS.

10. Lower facial height (ANS-Me) (mm): distance between ANS and Me.

Soft tissue measurements

11. Nasolabial angle.

12. Mentolabial angle.

Dental measurements (Fig. 3)

13. U1-FH (°): angle formed between long axis of the upper incisor and FH plane.

14. U1-FH (mm): perpendicular distance from upper incisor tip to FH plane.

15. U1-PTV (mm): perpendicular distance from upper incisor tip to PTV plane

16. U5-FH (°): angle formed between upper second premolar long axis and FH plane.

17. U5-FH (mm): perpendicular distance from upper second premolar buccal cusp tip to FH plane.

18. U5-PTV (mm): perpendicular distance from upper second premolar buccal cusp tip to PTV plane.

19. Overbite (mm).

20. Overjet (mm).

21. U6-FH (°): angle formed between the line, connecting the mesio-buccal cusp tip of upper molar and trifurcation point, and FH plane.

22. U6-FH (mm): perpendicular distance between the mesio-buccal cusp tip of the upper molar and FH plane.

23. U6-PTV (mm): perpendicular distance between mesial contact point of the upper molar and PTV plane.

24. L6-FH (°): angle between the line, connecting mesio-buccal cusp tip of the lower molar and bifurcation point, and FH plane.

25. L6-FH (mm): perpendicular distance between the mesio-buccal cusp tip the of lower molar and FH plane.

26. L6-PTV (mm): perpendicular distance between mesial contact point of lower molar and PTV plane.

27. Occ-FH (°): angle between occlusal plane and FH plane.

Statistical evaluation

The statistical analyses were conducted using mainly two nonparametric hypothesis tests; the Mann–Whitney U for comparing results calculated for the two groups, and the Wilcoxon test for two matched pair comparisons. The software utilized for calculations was SPSS for Windows (version 8.0).

Results

In all patients a super Class I molar relationship was achieved at the end of the treatment (Fig. 1E,F). Mean treatment times were 150.9 ± 36.9 days (approximately 5.03 ± 1.0 months) for the low-angle group, and 170.6 ± 15 days (approximately 5.7 ± 0.5 months) for the high-angle. These differences were not statistically significant.

Significant changes are listed in Tables 1–4 for the treatment phase (T1-T2) and stabilization phase (T2-T3).

Discussion

Evaluation of the treatment phase (T1-T2)

The upper molars moved and tipped distally both in the high-angle group and in the low-angle group. The amount of distalization and tipping of the upper molars were significantly more in the high-angle group. This result contrasts Bussick and McNamara's (23) findings that reported that the amount of molar distalization among groups with various vertical growth patterns was similar. A close look at their results, however, revealed that the upper molars in the high-angle group moved more distally than that in the low-angle group.

In contrast, changes in the upper molar position were similar within various treatment time periods in our study (Table 4). These slight differences could be due to the amount of molar distalization needed to achieve a Class I molar relationship, the use of different reference points or differences in patient responses. Correction of the molar relationship by upper molar distal tipping rather than bodily movement is questionable. One way of overcoming the excessive distal tipping of the upper molars was to incorporate uprighting bends into the TMA springs, which resulted in increased treatment time and anchorage loss (22). In an observation period of 6 months, Firaouz et al. (1) demonstrated that 2.6 mm of molar distalization could be achieved by directing the force of the high-pull headgear through the center of resistance of the upper molars. This is a comparable study of headgear since the observation period was limited to 6 months, which was almost the same with pendulum appliance. The amount of molar distalization achieved was less when compared to the results of pendulum appliance. The literature suggests that treatment time with headgear differs from 4 to 16 months (1–4). This wide range of treatment time gives substantial support to the argument that effectiveness of headgear is entirely reliant on patient compliance.

Mesial movement of lower molars contributed to the treatment of the Class II molar relationship. With Wilson arches, it has been reported that 50.7% of the Class II correction results from upper molar distalization and 39.8% from the lower molar mesialization (10). Generally, lower molars move mesially because of full-time elastic wear. With the pendulum appliance treatment, almost 90% percent of Class II molar correction was due to the upper molar distalization in our hands.

Anchorage loss was evaluated by the mesial movements of the upper second premolars and of the upper incisors. The cause of anchorage loss is the mesially directed reciprocal forces in the system. The difference between the groups was significant, especially in the area of upper incisors ($p < 0.001$). The upper incisors and the upper second premolars in the low-angle group moved a significant distance mesially. It seems that as much as the upper molars are more resistant to the distally directed forces of the pendulum springs, there would be a reciprocal increase in the anterior anchorage loss. When the anchorage loss was compared to the recent articles, anterior movement of the second premolars and of the upper incisors was found to be greater in this study (Fig. 4) Ghosh and Nanda (20) and Bussick and McNamara (23) measured the anchorage loss at the first premolar region, which might provide an explanation for the amount of difference. Byloff and Darendeliler (21) used the centroid point of the teeth's crown as the reference point, whereas in this study buccal cusp tip was used as the reference point. The cusp tip of a tooth would move further mesially than the centroid point; keeping in mind that it was not a pure bodily movement whereas the tipping of teeth should be considered. Twenty out of the thirty patients had upper second molars in occlusion, which can be thought as the reason for

***Table 2*. Pretreatment and postdistalization (T1-T2) and postdistalization and poststabilization (T2-T3) comparisons within the low-angle group**

Cephalometric measurements	Low-angle group						
	T1 ($n = 16$) mean ± SD	T2 ($n = 16$) mean ± SD	T3 ($n = 12$) mean ± SD	T1-T2 mean ± SD	T2-T3 mean ± SD	T1-T2 Significance	T2-T3 Significance
1. SNA°	78.4 ± 2.7	79.9 ± 2.9	80.0 ± 3.5	−1.5 ± 2.0	−0.3 ± 1.3		
2. A-PTV(mm)	50.8 ± 2.5	52.0 ± 1.9	52.0 ± 3.1	−1.2 ± 1.8	0.1 ± 1.7	*	
3. SNB°	75.5 ± 3.2	77.0 ± 2.8	77.7 ± 4.0	−1.5 ± 2.3	−0.8 ± 1.6		
4. B-PTV(mm)	49.9 ± 5.5	50.6 ± 5.0	50.9 ± 6.5	−0.7 ± 1.9	−0.9 ± 3.2		
5. Co-Pog(mm)	112.9 ± 9.9	113.0 ± 5.0	113.1 ± 4.7	−0.1 ± 2.0	−0.4 ± 10.4	**	
6. ANB°	2.5 ± 1.3	2.3 ± 1.2	2.9 ± 1.6	0.2 ± 0.8	−0.6 ± 0.8		*
7. FMA°	22.4 ± 1.3	24.2 ± 2.0	23.8 ± 1.4	−1.8 ± 2.0	0.8 ± 1.9	**	
8. PP-FH°	−2.1 ± 2.5	−1.58 ± 3.0	−0.25 ± 3.7	0.52 ± 4.7	0.3 ± 1.6		
9. Na-ANS(mm)	55.7 ± 3.6	56.2 ± 4.3	57.5 ± 4.2	−0.5 ± 1.7	−0.3 ± 1.3		
10. ANS-Me(mm)	68.3 ± 3.5	70.4 ± 4.8	71.7 ± 4.6	−2.1 ± 2.0	−0.2 ± 2.8	**	
11. U1-FH°	108.6 ± 7.3	117.3 ± 4.8	117.2 ± 8.1	−8.7 ± 6.4	0.2 ± 7.3	***	
12. U1-FH(mm)	52.0 ± 4.5	52.8 ± 6.1	53.9 ± 2.2	−0.8 ± 5.6	0.3 ± 5.8		
13. U1-PTV(mm)	56.0 ± 4.9	60.1 ± 4.8	57.8 ± 2.9	−4.1 ± 1.6	2.3 ± 5.6	***	
14. U5-FH°	87.4 ± 5.4	93.3 ± 5.3	79.5 ± 7.0	−5.9 ± 5.1	12.5 ± 8.1	***	**
15. U5-FH(mm)	47.6 ± 2.7	49.2 ± 2.6	49.8 ± 2.1	−1.6 ± 2.2	0.1 ± 1.9	*	
16. U5-PTV(mm)	32.1 ± 3.8	38.7 ± 5.1	31.0 ± 2.7	−6.6 ± 3.1	7.8 ± 4.3	***	**
17. Overbite(mm)	3.6 ± 1.2	4.6 ± 2.2	3.9 ± 1.3	−0.9 ± 1.5	0.1 ± 1.7		
18. Overjet(mm)	1.1 ± 1.6	2.6 ± 1.0	1.7 ± 1.5	−1.4 ± 1.4	1.3 ± 1.7	**	*
19. U6-FH°	81.4 ± 4.5	68.1 ± 4.7	75.3 ± 8.5	13.4 ± 4.6	−5.9 ± 6.3	***	**
20. U6-FH(mm)	45.3 ± 2.5	45.6 ± 2.6	46.3 ± 3.0	−0.3 ± 2.2	−0.2 ± 1.8		
21. U6-PTV(mm)	29.8 ± 2.6	25.7 ± 2.6	27.6 ± 2.8	4.1 ± 0.8	−1.7 ± 1.2	***	
22. L6-FH°	76.2 ± 8.0	76.0 ± 7.9	75.8 ± 7.3	0.2 ± 1.8	1.3 ± 2.6		
23. L6-FH(mm)	46.1 ± 3.0	46.9 ± 3.0	46.4 ± 1.8	−0.8 ± 2.0	0.5 ± 1.6	**	
24. L6-PTV(mm)	28.1 ± 3.8	28.9 ± 3.8	28.8 ± 3.6	−0.8 ± 0.8	0.1 ± 1.7	**	
25. Occ-FH°	7.7 ± 2.7	7.1 ± 2.7	6.0 ± 1.6	0.6 ± 1.5	1.3 ± 1.5		*
26. Nasolabial°	107.4 ± 8.1	102.3 ± 11.7	110.0 ± 7.6	5.1 ± 6.4	−4.5 ± 6.2	*	*
27. Mentolabial°	119.4 ± 19.8	113.3 ± 16.3	123.8 ± 14.2	6.2 ± 14.6	−2.7 ± 10.4		

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.
U1, upper incisor; U5, upper second premolar; U6, upper molar; L6, lower molar.

increase in the anchorage loss, but the results of the recent articles have shown that there was no statistically significant difference in anchorage loss, as well as molar movement, between groups who had erupted upper second molars and who did not (20, 21, 23). The authors of the previous articles activated the TMA springs at 45° or 60° keeping the force level 200–250 gr. In this study the pendulum springs were activated,

***Table 3*. Pretreatment and postdistalization (T1-T2) and postdistalization and poststabilization (T2-T3) comparisons within the high-angle group**

Cephalometric measurements	High-angle group						
	T1 ($n=14$) mean ± SD	T2 ($n=14$) mean ± SD	T3 ($n=10$) mean ± SD	T1-T2 mean ± SD	T2-T3 mean ± SD	T1-T2 Significance	T2-T3 Significance
1. SNA°	80.2 ± 3.7	80.4 ± 3.4	80.5 ± 3.3	−0.2 ± 0.9	−0.1 ± 0.6		*
2. A-PTV(mm)	50.4 ± 2.4	51.4 ± 3.0	51.4 ± 2.3	−1.0 ± 2.1	−1.0 ± 1.0		*
3. SNB°	76.1 ± 4.5	76.7 ± 4.0	77.4 ± 3.5	−0.6 ± 2.0	−1.6 ± 0.7	*	**
4. B-PTV(mm)	44.4 ± 4.3	45.2 ± 5.2	46.1 ± 4.0	−0.8 ± 2.2	0.3 ± 2.3		
5. Co-Pog(mm)	113.6 ± 4.1	114.9 ± 5.1	115.1 ± 4.5	−1.3 ± 2.0	−1.6 ± 0.9	**	*
6. ANB°	3.2 ± 1.1	3.0 ± 0.9	3.5 ± 1.8	0.2 ± 0.9	−0.6 ± 0.9		
7. FMA°	31.1 ± 1.6	32.5 ± 2.3	31.7 ± 2.5	−1.4 ± 1.6	1.2 ± 3.2	*	
8. PP-FH°	−1.6 ± 3.0	−0.9 ± 4.1	−0.5 ± 3.7	0.6 ± 1.3	−0.9 ± 1.8	*	
9. Na-ANS(mm)	52.3 ± 3.7	52.2 ± 3.2	53.2 ± 2.1	0.1 ± 1.6	−1.1 ± 0.9		*
10. ANS-Me(mm)	70.5 ± 4.4	74.3 ± 6.0	73.6 ± 6.0	−3.8 ± 4.5	2.0 ± 1.8	*	*
11. U1-FH°	114.3 ± 4.7	117.9 ± 5.7	117.2 ± 5.7	−3.6 ± 3.5	1.2 ± 1.5	**	**
12. U1-FH(mm)	50.4 ± 7.0	52.8 ± 6.8	54.7 ± 3.6	−2.4 ± 3.4	−3.5 ± 7.0	*	
13. U1-PTV(mm)	54.7 ± 4.2	56.9 ± 4.9	56.7 ± 4.1	−2.1 ± 1.1	1.5 ± 3.9	**	
14. U5-FH°	88.0 ± 4.9	91.9 ± 6.0	81.4 ± 6.4	−3.9 ± 3.5	12.8 ± 8.2	**	**
15. U5-FH(mm)	50.1 ± 1.5	50.5 ± 7.4	50.8 ± 5.1	−0.4 ± 6.5	2.3 ± 1.4		*
16. U5-PTV(mm)	30.9 ± 3.7	35.7 ± 6.9	30.5 ± 4.6	−4.8 ± 3.7	8.1 ± 4.8	**	**
17. Overbite(mm)	2.7 ± 1.7	3.2 ± 2.2	3.0 ± 1.9	−0.5 ± 1.8	−0.4 ± 1.6		
18. Overjet(mm)	0.71 ± 2.1	1.8 ± 2.4	1.1 ± 2.7	−1.2 ± 1.3	1.3 ± 1.6	***	*
19. U6-FH°	79.7 ± 5.8	64.9 ± 6.4	74.6 ± 8.9	14.9 ± 5.3	−7.6 ± 10.3	***	*
20. U6-FH(mm)	46.7 ± 1.5	47.0 ± 4.0	47.7 ± 3.4	−0.3 ± 3.7	0.1 ± 2.3		
21. U6-PTV(mm)	27.8 ± 3.8	21.9 ± 4.9	25.8 ± 2.7	5.9 ± 2.3	−1.5 ± 1.5	***	
22. L6-FH°	70.4 ± 5.2	70.6 ± 4.5	71.7 ± 4.5	−0.3 ± 1.9	−1.1 ± 1.7		
23. L6-FH(mm)	49.6 ± 3.5	50.9 ± 3.5	49.7 ± 3.8	−1.3 ± 3.5	0.9 ± 3.4	**	
24. L6-PTV(mm)	26.1 ± 3.9	26.9 ± 3.8	26.2 ± 2.4	−0.8 ± 0.6	0.1 ± 1.7	**	
25. Occ-FH°	12.8 ± 4.4	13.1 ± 3.4	10.5 ± 3.3	−0.3 ± 1.2	1.6 ± 2.3		*
26. Nasolabial°	107.6 ± 8.9	112.0 ± 7.5	115.0 ± 5.0	−4.4 ± 7.4	−3.2 ± 7.0		
27. Mentolabial°	112.2 ± 19.9	124.9 ± 17.7	123.4 ± 18.1	−2.6 ± 7.7	−1.0 ± 11.0		

* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.
U1, upper incisor; U5, upper second premolar; U6, upper molar; L6, lower molar.

based on the recommendations of Hilgers (19), towards the midline of the palate, which might have increased the force magnitude (over activation) acting on both the upper molars and the anterior anchorage segment. It would be better to perform repeated activations in small increments. Also, the overjet increase was due to upper incisor proclination. The slight difference between the two groups was due to the greater

***Table 4.* Comparisons of differences between the high-angle and low-angle groups during the treatment phase (T1-T2) and during the stabilization phase(T2-T3)**

Cephalometric measurements	Low-angle	High-angle		Low-angle	High-angle	
	T1-T2 ± SD	T1-T2 ± SD	significance	T2-T3 ± SD	T2-T3 ± SD	significance
1. SNA°	−1.5 ± 2.0	−0.2 ± 0.9		−0.3 ± 1.3	−0.1 ± 0.6	
2. A-PTV(mm)	−1.2 ± 1.8	−1.0 ± 2.1		0.1 ± 1.7	−1.0 ± 1.0	**
3. SNB°	−1.5 ± 2.3	−0.6 ± 2.0		−0.8 ± 1.6	−1.6 ± 0.7	*
4. B-PTV(mm)	−0.7 ± 1.9	−0.8 ± 2.2		−0.9 ± 3.2	0.3 ± 2.3	
5. Co-Pog(mm)	−0.1 ± 2.0	−1.3 ± 2.0		−0.4 ± 10.4	−1.6 ± 0.9	
6. ANB°	0.2 ± 0.8	0.2 ± 0.9		−0.6 ± 0.8	−0.6 ± 0.9	
7. FMA°	−1.8 ± 2.0	−1.4 ± 1.6		0.8 ± 1.9	1.2 ± 3.2	
8. PP-FH°	0.52 ± 4.7	0.6 ± 1.3		0.3 ± 1.6	−0.9 ± 1.8	
9. Na-ANS(mm)	−0.5 ± 1.7	0.1 ± 1.6		−0.3 ± 1.3	−1.1 ± 0.9	
10. ANS-Me(mm)	−2.1 ± 2.0	−3.8 ± 4.5		−0.2 ± 2.8	2.0 ± 1.8	*
11. U1-FH°	−8.7 ± 6.4	−3.6 ± 3.5	*	1.2 ± 1.5	0.2 ± 7.3	
12. U1-FH(mm)	−0.8 ± 5.6	−2.4 ± 3.4		0.3 ± 5.8	−3.5 ± 7.0	
13. U1-PTV(mm)	−4.1 ± 1.6	−2.1 ± 1.1	***	2.3 ± 5.6	1.5 ± 3.9	
14. U5-FH°	−5.9 ± 5.1	−3.9 ± 3.5		12.5 ± 8.1	12.8 ± 8.2	
15. U5-FH(mm)	−1.6 ± 2.2	−0.4 ± 6.5		0.1 ± 1.9	2.3 ± 1.4	**
16. U5-PTV(mm)	−6.6 ± 3.1	−4.8 ± 3.7		7.8 ± 4.3	8.1 ± 4.8	
17. Overbite(mm)	−0.9 ± 1.5	−0.5 ± 1.8		0.1 ± 1.7	−0.4 ± 1.6	
18. Overjet(mm)	−1.4 ± 1.4	−1.2 ± 1.3	*	1.3 ± 1.7	1.3 ± 1.6	
19. U6-FH°	13.4 ± 4.6	14.9 ± 5.3		−5.9 ± 6.3	−7.6 ± 10.3	
20 .U6-FH(mm)	−0.3 ± 2.2	−0.3 ± 3.7		−0.2 ± 1.8	0.1 ± 2.3	
21. U6-PTV(mm)	4.1 ± 0.8	5.9 ± 2.3	*	−1.7 ± 1.2	−1.5 ± 1.5	
22. L6-FH°	0.2 ± 1.8	−0.3 ± 1.9		1.3 ± 2.6	−1.1 ± 1.7	*
23. L6-FH(mm)	0.8 ± 2.0	1.3 ± 3.5	*	0.5 ± 1.6	0.9 ± 3.4	
24. L6-PTV(mm)	−0.8 ± 0.8	−0.8 ± 0.6		0.1 ± 1.7	0.1 ± 1.7	
25. Occ-FH°	0.6 ± 1.5	−0.3 ± 1.2		1.3 ± 1.5	1.6 ± 2.3	
26. Nasolabial°	5.1 ± 6.4	−4.4 ± 7.4	**	−4.5 ± 6.2	−3.2 ± 7.0	
27. Mentolabial°	6.2 ± 14.6	−2.6 ± 7.7	*	−2.7 ± 10.4	−1.0 ± 11.0	

* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.
U1, upper incisor; U5, upper second premolar; U6, upper molar; L6, lower molar.

increase in the axial inclination in the low-angle group ($p < 0.05$). Negligible changes were measured for overbite.

Upper molars, second premolars and upper incisors have extruded insignificantly. Although there was no significant inter-group differences, the amount of incisor extrusion in the high-angle group was more than the low-angle group or of the recent reports (Figs. 4 and 5). The lower molars have erupted 1.3 mm in the high-angle group and 0.8 mm in the low-angle. In

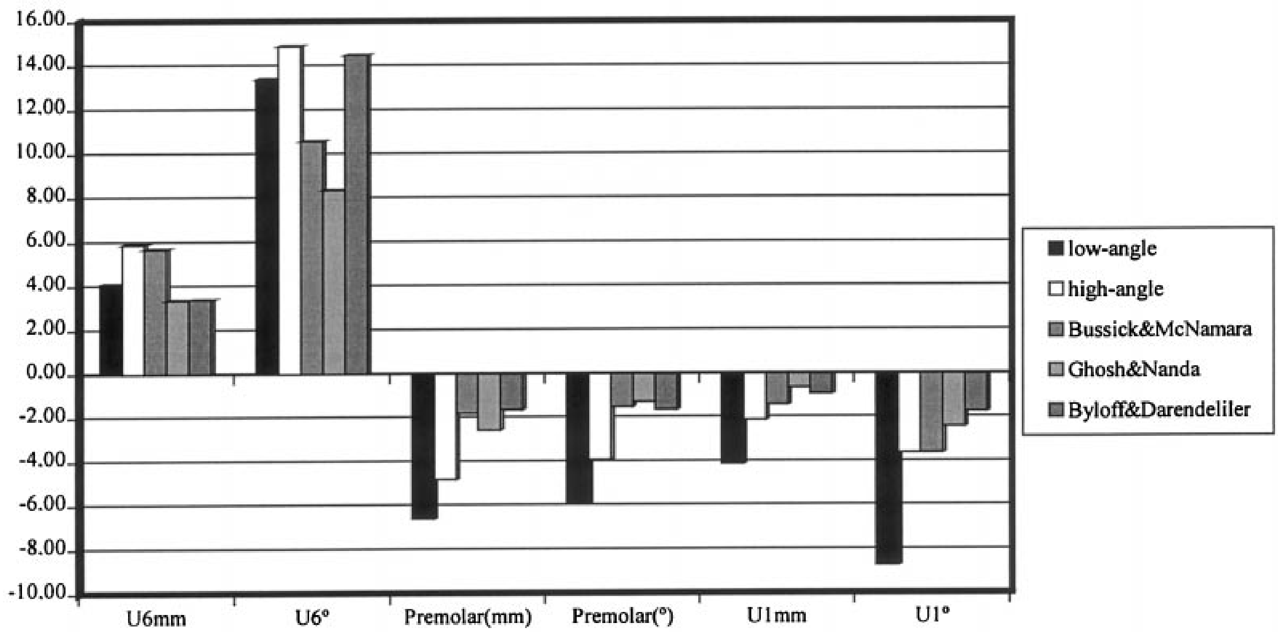

Fig. 4. Comparisions of the mean changes along the sagital plane between low-angle group and the high-angle group and also between the previously published articles in the literature. Positive (+) values indicate distal direction; negative (−) values indicate mesial direction

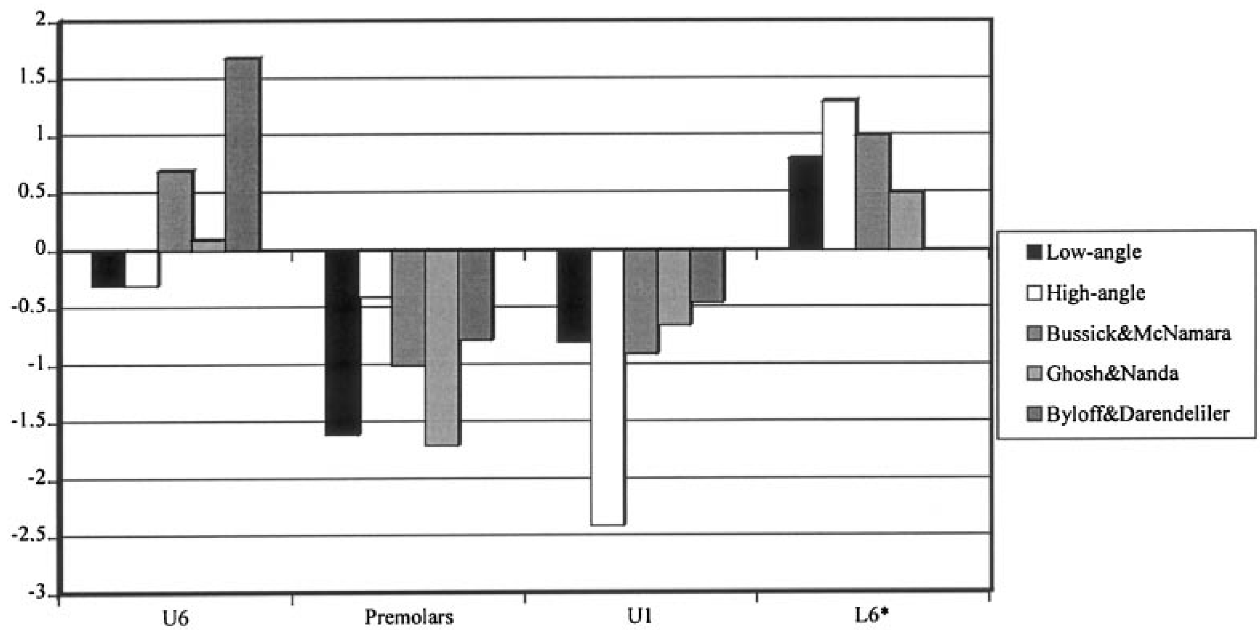

Fig. 5. Comparisions of the mean changes along the vertical plane space between the low-angle group and the high-angle group and also between the previously published articles in the literature. *Byloff and Darendeliler did not measure the movement of the lower molar in vertical plane.

growth studies, maxillary dental arch was found to erupt down and forward about 0.2 mm to 0.3 mm per year and the lower molars tend to erupt straight up about 0.8 mm per year (24). Changes greater than these values should be considered as treatment effects. Since the treatment time with pendulum appliance was 5–6 months, changes were mainly dentoalveolar. Auxiliary wires that were bonded on the occlusal surfaces of the premolars create an interocclusal space, which induce over eruption (25). Extruded teeth force the mandible to a posterior rotation, which increases the facial height in both groups. No inter-group differences were found. This finding was in agreement with Bussick and McNamara (23) and Byloff and Darendeliler (21), but was in contrast with Ghosh and Nanda (20). Ghosh and Nanda stated that patients, who had higher mandibular plane angles, showed significant increase in the lower facial height at the end of treatment. Bussick and McNamara related the increase in the lower facial height with the presence of upper second molars in occlusion rather than the growth pattern. Although there was no inter-group difference for the change in the value of FMA, the increase in the low-angle group was slightly more. Twelve out of sixteen patients (75%) in the low-angle group had upper second molars in occlusion, whereas 8 out of 14 patients (57%) in the high-angle group had upper second molars in occlusion. This might explain the slight between-group difference.

Evaluations of the skeletal structures in the sagittal plane showed that both the maxilla and mandible were positioned forward compared to initial values. However, their relationship with each other (ANB angle) did not change. Mandibular length was increased in both groups. Upper lips and lower lips protruded as a result of incisor proclination (20).

Evaluation of the stabilization period (T2-T3)

After achieving a Class I molar relationship, the pendulum appliance was replaced with a palatal bar, incorporating a Nance button. After 3 months, cephalometric records were repeated. A strong intercuspation prevents teeth from moving back to their initial positions. During the treatment phase with the pendulum appliance, upper molars and the anchorage segment were forced to an unstable occlusal relationship (26). A combination of this and the stretched transseptal fibers (27, 28) force the teeth to their pretreatment positions (Fig. 6). Over correction of the upper molars aided in the uprighting of upper molars during the stabilization period. In this period the upper molars tip mesially to a Class I relationship (11).

It has been reported that with the use of cervical headgear, upper second premolars move and tip distally during a treatment period of 10.7 months (29). This is an advantageous effect of the headgear as it reduces the total treatment time after the Class I molar relationship is achieved. With our pendulum appliance the second premolars moved anteriorly during the 5–6 month treatment time. Then in the stabilization period they reverted back to their original positions (even far

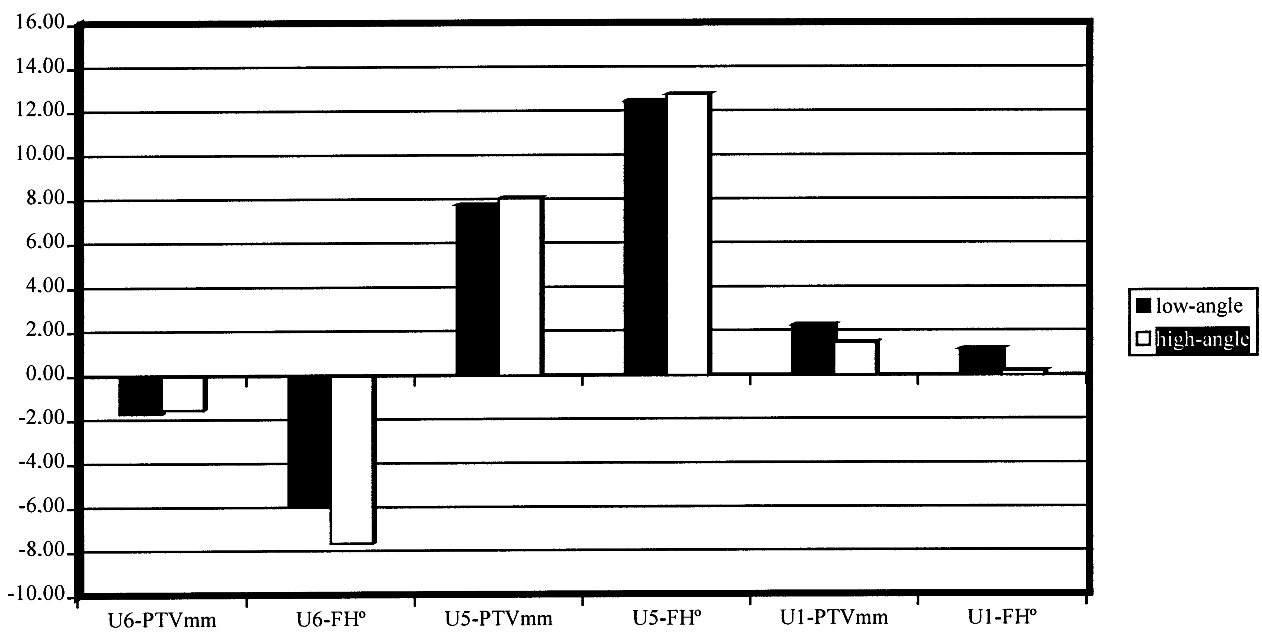

Fig. 6. Comparisions of the mean changes between the low-angle group and the high-angle group during the stabilization period.

back to Class I relationship). Eighty-four percent of the space, between second premolar and molar, was closed by the distal movements of the premolars in the high-angle group and in the low-angle this ratio was 82%. Thus, the total treatment time was almost 8–9 months, which is acceptable since no additional effort was performed to bring back the premolars and there was a minimum need of patient compliance. Additionally, the overjet was significantly decreased in both of the groups due to distal tipping of the incisors (1.3 mm for both of the groups).

Conclusions

The pendulum appliance is an effective alternative in the treatment of Class II molar relationships. In 5–6 months, upper molars can be distalized with reduced need for patient compliance. Appliance effects are limited to the dentoalveolar structures. As in other orthodontic treatment modalities negative side effects can be seen. Care should be taken to minimize the protrusion and mesial movement of the anterior segment. The main difference between the groups is that in the high-angle group molars have moved distally more than their counterparts in the low-angle group. Because the treatment time was the same in both groups, this resulted in lesser anchorage loss.

Moving the upper molars distally into Class I relationship doesn't solve the problem entirely. Instead, keeping the molars in this position without drifting back to their original place is a major challenge. Palatal bar (with a Nance button) and nighttime wear of headgear should be instructed to the patients. While this strategy might be effective, it defeats the purpose – patient cooperation is required. Relapse could be reduced by overcorrecting the molars into a super Class I molar relationship. During the stabilization period, drifting of the upper second premolars into Class I relationship reduces the total treatment time.

Structured Abstract

Authors – Toroğlu MS, Uzel İ, Çam OY, Hancioğlu ZB.
Objective – To evaluate the effects of the pendulum appliance in dental Class II patients with varying vertical growth patterns and to evaluate the changes during the short-term stabilization period of 3 months.
Design – A retrospective clinical cephalometric study on consecutively treated patients.
Settings and Sample Population – The Department of Orthodontics at Çukurova University. Thirty consecutively started patients requiring treatment for dental Class II malocclusion.
Experimental Variable – The sample was divided into two groups depending on their FMA. The high-angle group consisted of 14 patients (10 girls and 4 boys) and had a mean age of 157.7 ± 8.0 months. The low-angle group consisted of 16 patients (8 girls and 8 boys) and had a mean age of 155.5 ± 18.6 months. The pendulum springs were activated once parallel to the midline of the palate and no other activation was done through the treatment. After Class I molar relationship was achieved, a transpalatal bar in combination with an acrylic button against the palatal mucosa was inserted for stabilization.
Outcome Measure – Pretreatment, posttreatment and poststabilization cephalometric radiographs were obtained to measure the changes. Mann–Whitney U and Wilcoxon tests were used for statistical evaluation.
Results – The amount of upper molar distalization was 5.9 mm ($p < 0.001$) in the high-angle group and 4.1 mm ($p < 0.001$) in the low-angle group, showing no inter-group difference. The amount of anchorage loss at the second premolars was 4.8 mm ($p < 0.001$) in the high-angle group and 6.6 mm ($p < 0.001$) in the low-angle group. Upper incisors moved anteriorly for 2.1 mm ($p < 0.05$) in the high-angle group and 4.1 mm ($p < 0.001$) in the low-angle group. Inter-group difference was statistically significant ($p < 0.001$). During the stabilization period, 1.5 mm of anchorage loss at the upper molar region was measured for the high-angle group and 1.7 mm of anchorage loss at the upper molar region was measured for the low-angle group. During the stabilization period, upper second premolars and incisors tended to move back to their original places.
Conclusion – The results of this study showed that pendulum appliance could move the upper molars distally in a short period of time without depending on the patient compliance. Care should be taken for anchorage loss and also upper molars should be stabilized for at least 3 months. Greater amount of distal molar movement and lesser amount of anchorage loss was observed in the high-angle group.

Clinical Orthodontics and Research **4**, 2001; 15–27

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