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The effects of the Pendulum distalising appliance and cervical headgear on the dentofacial structures

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Background: Headgears are effective in distalising maxillary molars, but success depends on patient compliance and tolerance. Intra-oral distalising appliances are simple to construct and use and may be a better alternative for patients who are non-compliant or cannot tolerate headgear.
Aims: To compare the Pendulum (PEN) appliance and cervical headgear (CHG) on distal movement of maxillary first molars in patients requiring maxillary molar distalisation.
Methods: Thirty patients were randomly divided into two groups. Both groups had comparable occlusal and cephalometric characteristics before treatment. Fifteen patients (9 girls, 6 boys) with a mean age of 11.45 ± 1.54 years (Range: 8.58–13.50 years) were treated with Pendulum appliances and 15 patients (10 girls, 5 boys) with a mean age of 11.72 ± 1.24 years (Range: 9.58–13.33 years) were treated with a Ricketts-type CHG. A pilot study of four patients estimated that the time required to distalise the maxillary molars with the Pendulum appliance was five months. Therefore, the end of treatment records for the CHG group were taken after 4.96 ± 0.35 months. Lateral and postero-anterior cephalometric radiographs were taken of both groups at the start (T1) and end of distalisation/treatment (T2). Changes in cephalometric measurements in the two groups were compared with Wilcoxon and Mann-Whitney U tests.
Results: Measurements indicated that U6-ANS distance, overjet and U1-APo distance increased, U6-PP angle and U6-PTV distance reduced, and the molar relationship improved more in the PEN group compared with the CHG group. Statistically, significant right molar – left molar differences were found between the two groups. Distalisation produced significant side effects, resulting in distal tipping of the first molars and an increase in overjet, whereas the CHG reduced the overjet.
Conclusion: The Pendulum appliance was more effective than the CHG in distalising the maxillary first molars.
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Introduction

Dentoalveolar Class II malocclusions may be treated by the distal movement of the maxillary teeth. Treatment options range from extra-oral appliances, such as cervical headgear, to an ingenious collection of intra-oral devices designed to move the maxillary teeth distally. These appliances use magnets, wire springs, orthodontic screws and Class II intermaxillary traction to achieve their objectives.[1–11] The intra-oral treatment methods rely less on patient compliance for success compared with the extra-oral appliances, and in the absence of mini-screws, derive anchorage from the maxillary teeth and/or the hard palate. A frequent side effect of an intra-oral approach to molar distalisation is a loss of anterior anchorage.

Although the dental and skeletal effects of the Pendulum intra-oral appliance have been previously reported,[1,2,12–17] only one randomised trial has compared the skeletal and dental effects of intra- and extra-oral treatment approaches.[10,18,19] Therefore, the aim of the present study was to compare the effects of an intra-oral distalising appliance and cervical headgear on the dentofacial structures of adolescents.

Subjects and methods

The subjects comprised 30 consecutive patients, referred to the Department of Orthodontics, Hacettepe University, who fulfilled the following inclusion criteria:

Figure 1. The Pendulum appliance.

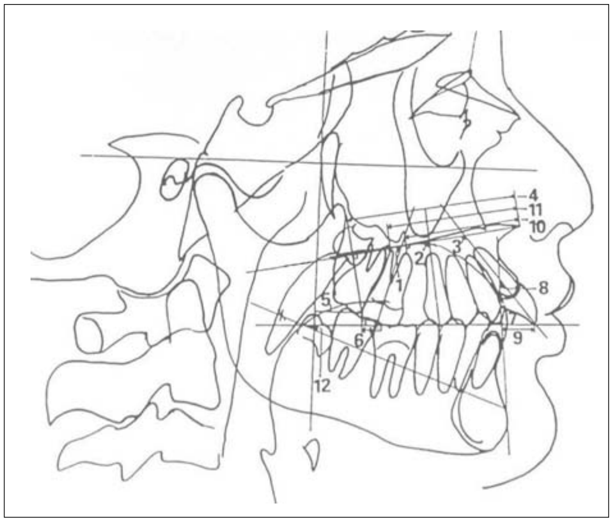

Figure 2. Lateral cephalometric measurements:
1. U6-PP: posterior angle between molar axis and the palatal plane (degrees)
2. U5-PP: posterior angle between premolar axis and palatal plane (degrees)
3. U1-PP: posterior angle between upper incisor axis and palatal plane (degrees)
4. U6-ANS: distance from the line constructed through the upper first molar to palatal plane to ANS (mm)
5. U6-PTV: distance from upper first molar distal surface to PTV (mm)
6. Molar relation: distance between mandibular first molar distal surface and maxillary first molar distal surface measured along the occlusal plane (mm)
7. Incisor overjet (mm)
8. U1-APo: angle between the axis of the upper incisor and APo line (degrees)
9. U1-APo: tip of the upper incisor to APo line (mm)
10. U6 mesial root-ANS (mm)
11: U6 distal root-ANS (mm)
12: Tilt of the occlusal plane: angle between occlusal plane and corpus axis (degrees)

1. Skeletal Class I malocclusion with a bilateral Class II molar relationship.

2. Radiographic confirmation that at least one third of the roots of the unerupted maxillary second molars had developed.

3. Nonextraction treatment plan.

4. Good oral hygiene.

5. No or minimal crowding in the mandibular dental arch.

6. No signs of a temporomandibular joint disorder.

The subjects were randomly allocated to either a group treated with an intra-oral Pendulum appliance with a midline expansion screw (PEN) or a group treated with a Ricketts-type cervical headgear (CHG).[20] The 15 subjects in the PEN group (9 girls, 6 boys) had a mean age of 11.45 ± 1.54 years (Range: 8.58–13.50 years) and the 15 subjects in the CHG group (10 girls, 5 boys) had a mean age of 11.72 ± 1.24 years (Range: 9.58–13.33 years). A pilot study on four subjects in the PEN group established that the Pendulum appliance distalised the maxillary molars in 5 months. Therefore progress records were taken as close as possible to 5 months after the appliances were fitted (4.96 ± 0.35 months).

The subjects in the PEN group received an appliance similar to that described by Hilgers.[2] A palatal acrylic button was anchored to the maxillary first and second premolars with bonded occlusal rests. A midline screw and bilateral 0.032 inch TMA cantilever springs (Ormco Corporation, Glendora, CA, USA) were inserted into lingual sheaths on the first molar bands (Figure 1). The springs were initially activated 90 degrees, and the subjects were monitored at three-week intervals. The appliance was left in situ until the molars were in a slightly overcorrected (Class III) position,[21] which, on average, took 4.83 ± 0.96 months (Range: 3.43–6.40 months). To prevent a posterior crossbite from developing, the subjects were instructed to turn the expansion screw a quarter turn, once a week.

The CHG group received an appliance described by Ricketts et al. to distalise the maxillary molars.[20] It was activated to deliver 500 g of force and the subjects were requested to wear the appliance for 12–14 hours per day, especially at night. Progress records were taken after 4.96 ± 0.35 months of treatment. The subjects were monitored at three-week intervals and the headgear was adjusted when clinically indicated.

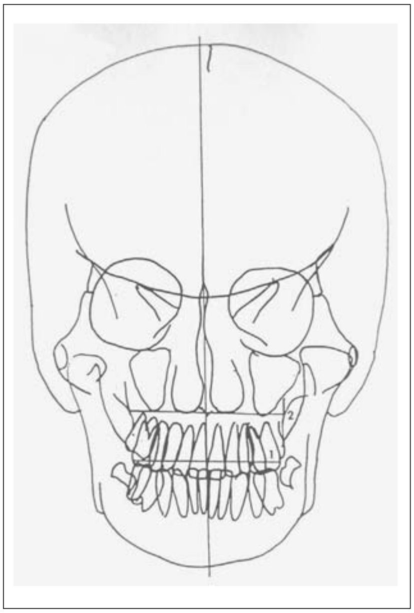

Figure 3. Postero-anterior measurements:
1. R6-L6 width: distance between the buccal surfaces of the right and left first molars (mm)
2. Maxillary width: distance between right and left jugular points (mm)

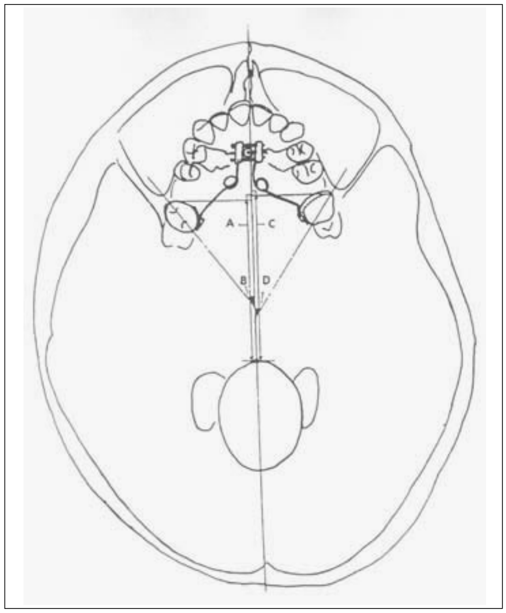

Figure 4. Basilar measurements:
A. R6 distance: distance from the perpendicular to the maxillary right first molar and the anterior margin of the foramen occipitale, measured along the midsagittal plane (mm)
B. R6 rotation: anterior angle between axis of the maxillary right first molar and midsagittal plane (degrees)
C. L6 distance (mm)
D. L6 rotation (degrees)

Cephalometric analysis

Lateral, basilar and postero-anterior cephalometric radiographs were taken at the start of treatment (T1) and after completion of molar distalisation (T2) or, in the case of the CHG group, after 4.96 ± 0.35 months of treatment. The basilar cephalometric radiographs were taken with the mouth fully open.

The cephalometric radiographs were traced and measured using Jiffy Orthodontic Evaluation (JOE) digitising software (Rocky Mountain Orthodontics, Denver, CO, USA). Conventional lateral and postero-anterior cephalometric measurements were applied (Figures 2 and 3). The distalising and rotational effects of both appliances were measured on the basilar cephalometric radiographs (Figure 4).

Statistical analysis

Shapiro-Wilks and Levene's variance homogeneity tests were used to test the normality of the data. As the data were not normally distributed and there was no homogeneity of variance between the groups, the intra-group comparisons were performed with the non-parametric Wilcoxon test and intergroup changes were analysed with the Mann-Whitney U test. All statistical analyses were performed using the Statistical Package for the Social Sciences, version 13.0 for Windows (SPSS Inc., Chicago, IL, USA).

Error of the method

Two weeks after the first measurements, 45 films (15 postero-anterior, 15 lateral and 15 basilar radiographs) were selected at random and remeasured by the same investigator and a paired *t*-test was applied to the first and second measurements. There were no statistically significant differences between the first and second measurements. Pearson correlation analyses were applied to the same measurements, the highest r value was .997 for U6-PTV and the lowest r value was .930 for the lower lip to aesthetic plane distance.

Results

The results are presented in Table I.

Pendulum group

The lower anterior face height (LAFH) angle (p = 0.001), maxillary depth angle (p = 0.041), lower lip-E plane (p = 0.007) and upper lip length (p = 0.021)

Table I. Dentofacial changes after distalisation with Pendulum (PEN) and cervical headgear (CHG) appliances.

Variables	PEN group		CHG group		
	Mean difference (T2-T1)	p*	Mean difference (T2-T1)	p*	p† PEN vs CHG
Skeletal and soft tissue measurements					
Total facial height (degrees)	0.79	0.140	-0.14	0.995	0.436
Lower anterior face height (degrees)	1.63	**0.001**	0.28	0.460	0.267
Mandibular arch (degrees)	0.62	0.590	0.12	0.865	0.567
Mandibular plane angle (degrees)	0.65	0.164	0.15	0.887	0.389
Facial axis (degrees)	-0.60	0.061	0.23	0.650	0.056
Maxillary depth angle (degrees)	0.66	**0.041**	0.00	0.944	0.250
Lower lip-E plane (mm)	0.65	**0.007**	0.75	0.221	0.713
Upper lip length (mm)	0.79	**0.021**	0.00	0.910	0.217
Nasolabial angle (degrees)	0.17	0.977	-3.83	0.281	0.412
Dentoalveolar measurements					
U6 -PP (degrees)	-15.10	**0.001**	0.90	0.616	0.000
U5-PP (degrees)	0.93	0.496	1.80	0.092	0.870
U1-PP (degrees)	1.67	0.112	-0.53	0.529	0.116
U6-ANS (mm)	4.07	**0.001**	1.73	**0.001**	**0.001**
U6–PTV (mm)	-3.69	**0.001**	-0.77	**0.038**	**0.000**
Molar relation (mm)	-3.55	**0.001**	1.08	**0.025**	**0.001**
Incisor overjet (mm)	0.54	**0.024**	-0.82	**0.005**	**0.000**
U1-APo (degrees)	2.10	0.052	-1.67	**0.016**	0.001
U1-APo (mm)	1.05	**0.001**	-0.62	**0.006**	**0.000**
U6-Mesial root-ANS (mm)	0.47	0.427	2.10	**0.003**	0.037
U6-Distal root-ANS (mm)	-0.17	0.691	1.80	**0.003**	0.007
Occlusal plane (degrees)	0.75	0.514	2.58	**0.005**	0.161
Upper molars measurements					
R6-L6 width (mm)	3.17	**0.001**	0.93	0.213	0.015
Maxillary width (mm)	1.43	**0.006**	2.10	**0.002**	0.455
R6 Distance (mm)	-3.87	**0.001**	-2.10	**0.002**	**0.008**
R6 Rotation (degrees)	4.43	0.100	10.06	**0.001**	0.081
L6 Distance (mm)	-4.00	**0.001**	-1.87	**0.002**	**0.000**
L6 Rotation (degrees)	6.87	**0.029**	8.36	**0.001**	0.575

Significant differences are in bold
p^* Wilcoxon test
$p^\dagger$ Mann-Whitney U test

increased significantly during treatment. Of the dentoalveolar measurements, the U6-PP angle (p = 0.001) and the U6-PTV distance (p = 0.001) reduced, the molar relationship (p = 0.001) improved, and the U6-ANS distance (p < 0.001), incisor overjet (p = 0.024) and U1-APo distance (p = 0.001) increased.

The R6 distance (p = 0.001) and L6 distances (p = 0.001) reduced and R6-L6 width (p = 0.001), maxillary width (p = 0.006) and L6 rotation (p = 0.029) increased significantly. The maxillary right first molar rotated approximately 4.5 degrees.

CHG group

There were no statistically significant skeletal or soft tissue changes. Of the dentoalveolar measurements, only the U6-PP angle, U5-PP angle and U1-PP angle did not change significantly.

All maxillary molar measurements, except the R6-L6 width, changed significantly during treatment.

Intergroup comparisons

There were no statistically significant skeletal or soft tissue changes. There were six statistically significant dentoalveolar differences: U6-ANS distance (p = 0.001), U6-PTV distance (p < 0.001), molar relationship (p = 0.001), incisor overjet (p < 0.001) and U1-APo distance (p < 0.001). In all cases the changes in the PEN group were greater than the changes in the CHG group. Importantly, both right and left molars distalised approximately 2 mm more in the PEN group compared with the CHG group.

Discussion

Many intra-oral molar distalisation appliances have been designed to minimise or eliminate the need for patient cooperation. In the present comparative study of different appliances, postero-anterior and basilar cephalometric radiographs were added to standard records to assess transverse, rotational and distalising effects on maxillary molars.

As an example of a non-compliant device, the Pendulum appliance efficiently distalised the maxillary molar teeth to a Class I relationship without the need for patient cooperation. Furthermore, only one activation period was required. These are distinct advantages of the appliance when compared with other mechanistic approaches requiring patient compliance, such as CHG and Class II elastics.

Studies of the effects of the Pendulum appliance usually do not use a control group because the observation period is invariably short (4.83 ± 0.96 months for the Pendulum and 4.96 ± 0.35 months for the CHG, in the current study) for normal growth changes to play a significant role in the treatment result.[4,7,14–16,18,22] Previous studies describing the appliance have revealed that approximately 4–5 months of treatment time has been adequate.[3,23] Joseph and Butchart[3] reported that Pendulum appliance treatment time ranged from 1.5 to 5 months. Angelieri et al.[23] found that the mean time for distalisation of the maxillary molars was 5.85 months. While accepting these published time periods, the present study required confirmation of the effective time period to take second records and apply the result to gathering progress records of the CHG group. At the end of the pilot study, it was confirmed that a five-month treatment period was adequate.

The amount of distal movement of the maxillary first molars was higher and more rapid with the Pendulum appliance compared with the CHG and was a significant finding of the current study.[24] As seen on the lateral cephalograms measured by U6-ANS, the correction of the Class II relationship was achieved by maxillary first molar distalisation of 4.07 mm in the Pendulum appliance group and 1.73 mm in the CHG group. The amount of molar distalisation was statistically greater in the Pendulum group than in the CHG for each subject. Overcorrection is desirable because it has been noted that molar anchorage loss invariably occurs during retraction of the premolars, the canines and especially the incisors.[25] The distalisation values generated by the Pendulum appliance agree with those previously reported by Ghosh and Nanda,[14] Byloff and Darendeliler,[15] Bolla et al.[8] and Gelgor et al.[24] However, the mean molar distalisation value of 1.73 mm for the CHG group was less than the data of Hubbard et al.,[26] who found 2.4 mm of Kloehn type CHG movement in four months.

A potentially undesirable effect of Pendulum appliance treatment is excessive distal tipping of the upper first molars. According to the U6-PP measurement, the maxillary first molars were tipped distally 15.1 degrees in the Pendulum and 0.9 degrees in the CHG group. Gosh and Nanda,[14] and Byloff and Darendeliler[15] found tipping, as a result of the Pendulum appliance treatment, to range from 8.3 and 14.5 degrees. The value of 15.1 degrees of tipping of the first molar was similar to the 14.5 degrees of distal tipping described by Byloff and Darendeliler,[15] when the original Pendulum design was evaluated. The small amount of molar tipping in the CHG group was contrary to the findings of Ringenberg and Butts,[27] who reported substantial tipping. Byloff and Darendeliler[15] attempted to correct molar tipping by incorporating an uprighting bend in the Pendulum spring after distalisation of the molar had been completed. The uprighting bend appeared to be successful in uprighting the roots of the tipped molars, but has the potential to increase anchorage loss.

The Pendulum appliance group suffered mild anchorage loss as defined by maxillary incisor protrusion (U1-APo mm) (mean differences 1.05 mm) and increased overjet (mean differences 0.54 mm).

No clinical importance was attributed to the changes because of their minor nature. U5-ANS, U1-PP and U1-APo angles showed no statistically significant changes during treatment. Anchorage loss, as defined by the significant maxillary incisor proclination and concomitant increase in overjet has been clearly shown previously.[15] The present study determined a comparatively smaller increase in overjet.

The possible bite-opening effect of CHG is well known, and so any appliance that is capable of distalising molar teeth without adversely altering the vertical dimension is advantageous in the treatment of high-angle Class II and/or dentally crowded patients. Distalisation and tipping of the upper first molars can result in molar extrusion relative to the palatal plane and therefore affect face height. In the present study and in agreement with previous reports, the Pendulum appliance produced clockwise mandibular rotation, demonstrated by statistically significant increases (1.63 degrees) in LAFH.[1,17] In addition, a statistically significant increase (0.66 mm) in maxillary depth was seen in the same group. However, over the short time frame of treatment, no statistically significant skeletal differences were observed in the CHG group. According to Ghosh and Nanda,[14] a small backward rotation of the mandible (Mean 1.09 °) was reported following CHG use. While there was a trend toward an increase in the mandibular plane angle observed after treatment, it was not statistically significant. In the opinion of Ngantung et al.,[28] the increase in LAFH during treatment was a result of normal vertical craniofacial growth. Burkhardt et al.[29] explained the change as an increase in inclination of the mandibular plane as a result of Pendulum appliance effects.

An advantage of CHG is that as molar distalisation occurs, distal movement of the maxillary incisors also takes place. This implies a decrease in overjet, which is a desired aim in the treatment of Class II division 1 malocclusions. However, when the maxillary molars are distalized by an intra-oral appliance, anchorage loss or forward movement of the anterior teeth is likely.[14,15,30–33] The maxillary incisors were proclined by 2.1 degrees and protruded by 1.05 mm by the Pendulum appliance and retroclined by 1.67 degrees and retruded by 0.62 mm in the CHG group. A similar amount of mesial and distal movement of maxillary incisors was observed by Bondemark and Karlsson[19] for intra-oral and extra-oral appliances. Escobar et al.[34] and Önçağ et al.[35] described distal incisor movement in their implant-supported Pendulum appliance groups. In contradistinction, Taner et al.[18] found that incisors showed a significant amount of proclination due to molar distalisation following Pendulum appliance treatment. In support of Taner et al.,[18] additional authors[9,14,30,36] have reported proclination of anterior teeth during molar distalisation with intra-oral mechanics.

Conclusion

The findings demonstrated that the Pendulum appliance was more effective than CHG in producing distal movement of the maxillary first molars. The distalisation time and rate of movement were significantly shorter with the Pendulum appliance compared with CHG. However, this gain in molar distalisation was at the expense of significant side effects, including molar tipping and anchorage loss at the incisors. CHG treatment produced more upright molar distalisation and a decrease in overjet. Molar distalisation occurred without any significant changes to the mandibular plane angle. To achieve successful results, the effects of each treatment modality on dentofacial structures need to be taken into individual patient consideration.

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