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A Comparative Analysis of Maxillary Tooth Movement Produced by Cervical Headgear and Pend-X Appliance

Tülin Uğur Taner, PhD;[a] Filiz Yukay, PhD;[b] Muge Pehlivanoglu, PhD;[c] Banu Çakırer, PhD[c]

ABSTRACT

The purpose of this study was to compare the effects of cervical headgear and pend-x on the maxillary first molar, second molar, first premolar, and upper incisors. Cephalometric radiographs were obtained at the start of treatment (T1) and after molar distalization was completed (T2) for 13 patients in a pend-x group and 13 patients in a cervical headgear group. The changes of the maxillary teeth were measured on maxillary superimpositions. Nonparametric Mann-Whitney *U*-test was used to compare the mean differences between the two groups. The mean amount of distalization for the headgear group was 3.15 ± 1.94 mm and that for the pend-x group was 3.81 ± 2.25 mm. The second molar teeth were also distalized to a mean amount of 2.27 ± 1.33 mm in the headgear group and 2.04 ± 2.15 mm in the pend-x group. The mean treatment time for distalization was 11.38 ± 3.18 months for the headgear group and 7.31 ± 4.09 months for the pend-x group. During distalization, the maxillary molars tipped distally in both groups, but intergroup differences were not significant. The anterior inclinations of the first premolar and upper incisor increased significantly in the pend-x group ($P < .01$). Maxillary molars showed no vertical movement in the pend-x group but extruded in the headgear group ($P < .01$). The anchorage loss of the pend-x appliance as well as the necessary patient compliance and greater treatment time with the cervical headgear should be taken into consideration.

KEY WORDS: Pendulum, Pend-x, Cervical headgear, Distalization.

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INTRODUCTION Return to TOC

Different treatment modalities have been suggested to distalize maxillary molar teeth to correct Class II malocclusion and to create space in the maxillary dental arch.[1–9] Conventional extraoral traction has been used successfully to correct Class II malocclusion by restraining the forward growth of the maxilla and to distalize the maxillary molars to correct dental discrepancies.[10,11] The effects of cervical headgear on the craniofacial complex have been evaluated by numerous experimental and clinical studies.[10–14] The force vector ideally should pass close to the center of resistance of the tooth for pure translatory movement to take place.[4] If the force vector passes far from the center of resistance, crown tipping is encountered. The center of resistance of a molar tooth lies at approximately the trifurcation of the root,[4] thus bodily molar distalization can be achieved if the outer bows of the cervical headgear are tilted 20° upward from the occlusal plane.[2,15,16] However, extraoral cervical traction requires considerable patient compliance,[17] and patient compliance is the key factor in obtaining successful results.

In recent years, methods of correcting Class II malocclusions without the need for strict patient compliance have been sought. These systems included palatal bars,[15] repelling magnets,[18,19] nitinol coil springs,[20,21] the K-loop,[22] superelastic wires,[23] Wilson arches,[24] Jones jig appliances,[7] distal jet appliance,[25] and intraoral bodily molar distalizer.[6] In 1992, Hilgers[26] introduced the pendulum appliance, an intraoral system to move molars distally. As the molar teeth are driven distally, they move on an arc toward crossbite. To counteract this tendency, Hilgers[27] updated his appliance design by adding an expansion screw. This new design was named the pend-x appliance.[27]

The dental and skeletal effects of the pendulum appliance have been previously evaluated.[28,29,30] However, until now, the literature comparing the dental changes brought about by the pend-x appliance and cervical headgear has been lacking. The purpose of this study was to determine the nature of maxillary molar, premolar, and maxillary incisor movement with the pend-x appliance and to compare it with an extraoral cervical traction method.

MATERIALS AND METHODS Return to TOC

Case selection

Cephalometric radiographs of 26 patients were obtained at the start of treatment (T1) and after molar distalization was completed (T2). Thirteen patients (10 girls, three boys) with a mean age of 10.64 ± 1.42 years were treated with the pend-x appliance for upper molar distalization, and 13 patients (eight girls, five boys) with a mean age of 10.5 ± 0.82 years used a cervical headgear to restrain the forward growth of the maxilla and to distalize the maxillary molars into a dental Class I relationship. The eruption pattern of the unerupted maxillary second molar teeth was also analyzed on the panoramic radiographs of each patient, which showed radiographically visible maxillary second molar teeth with crown formation and with one-third of the root formation completed.[31]

Appliance design and activation

In the headgear group, the outer bows were tilted 20° upward from the occlusal plane exerting 500 g of force with an average use of 14–16 hours per day until a Class I molar relationship was achieved.

In the pend-x group, all patients received a pend-x appliance similar to the one described by Hilgers.[27] It consisted of an acrylic Nance portion with an expansion screw and two posteriorly extending TMA coil springs that were inserted into the lingual sheaths on the first molar bands (0.032-inch TMA wire, Ormco Corp, Glendora, Calif). The appliance was anchored to the first and second premolar teeth with wires bonded to the occlusal surfaces. The pendulum springs were bent parallel to the midline of the palate with a force of 230–250 g. The appliance was left in the mouth until a super Class I molar relationship was achieved. The patients were instructed to turn the expansion screw depending on the amount of expansion needed to counteract the crossbite tendency.

Cephalometric analysis

Cephalometric radiographs of each patient were obtained at the start of treatment (T1) and after molar distalizations were completed (T2). One author traced the maxillary first molar, maxillary second molar, maxillary first premolar, maxillary incisor teeth, and palatal plane on the initial and final cephalometric radiograph of each patient on acetate paper with a 0.5-mm pencil. When a double image of the molars was present, all measurements were made from the distalmost molar band surface. The effects of the position of the second molar were measured and reflect the indirect effect of first molar distalization.

The maxillary superimposition was performed on the palatal plane registered at ANS as described by Ricketts[32] (Figure 1). The dental measurements were obtained through maxillary superimposition, thereby eliminating the orthopedic changes of the maxilla during the experimental period. The long axes of the maxillary first and second molar teeth were constructed by drawing a line through the mesiobuccal cusp tip and the mesiobuccal root apex, whereas the long axis of first premolar tooth was constructed through the buccal cusp tip and the apex. The long axis of the incisor tooth was constructed through the incisal edge and the apex. The angular differences in tooth position due to first molar distalization were then measured as the angles between the long axes of each maxillary tooth at T1 and T2. The distances between the most convex distal points on the crowns of first and second molar and first premolar teeth at T1 and T2, which were measured on a line parallel to palatal plane, were used to determine the amount of molar distalization. The amount of sagittal movement of incisor tooth was measured on a line parallel to the palatal plane as the difference between incisal edges at T1 and T2. The vertical movements of first molar, second molar, first premolar, and incisor teeth were determined by measuring the perpendicular distances between the mesiobuccal cusp tip of the molar teeth and incisal edge of the incisor teeth relative to the palatal plane (Figure 1).

Statistical analysis

The means and standard deviations of the sagittal, angular, and vertical dental changes were calculated. Nonparametric Mann-Whitney *U*-test was used to analyze the intergroup differences.

Error of the method

Operator precision was tested by random selection of 25% of the cephalometric radiographs, which were retraced and remeasured. The error of the method (ME) was calculated with Dahlberg's formula ($ME = \sqrt{d_2/2n}$), where d is the difference in measurements of cephalometric values on two different occasions and n is the number of double recordings. The measurement error for a single measurement of linear and angular variables ranged between 0.2 and 0.5 mm and between 0.7° and 1.0°, respectively.

RESULTS Return to TOC

Table 1 shows the means and standard deviations of the sagittal changes in the maxillary first molar, second molar, first premolar, and anterior teeth. Both the cervical headgear and pend-x appliance were able to distalize maxillary first molar teeth by similar amounts. The mean amount of distalization was 3.15 ± 1.94 mm for the headgear group and 3.81 ± 2.25 mm for the pend-x group. Because of the indirect effect of first molar distalization, second molar teeth were also distalized to a mean of 2.27 ± 1.33 mm in the headgear group and a mean of 2.04 ± 2.15 mm in the pend-x group. The mean treatment time was 11.38 ± 3.18 months for the headgear group and 7.31 ± 4.09 months for the pend-x group.

The first premolars moved mesially in the pend-x group (mean −0.73 ± 3.53 mm) and distally in the headgear group (mean 1.88 ± 1.12 mm). These differences in sagittal premolar position were significant between the groups ($P < .01$). The mean sagittal change in incisor position was −0.42 ± 1.59 mm for the headgear group and 2 ± 1.54 mm for the pend-x group. The mean difference in sagittal incisor position was not statistically significant between the groups.

The means and standard deviations of angular dental changes are shown in Table 2. The first and second molar teeth were tipped distally with the pend-x group (first molar 11.77 ± 11.14° and second molar 11.04 ± 12.94°) and the headgear group (first molar 6.96 ± 6.05° and second molar 4.30 ± 6.81°). The mean amount of tipping was not statistically significant between the groups. The first premolars were tipped mesially in the pend-x group and distally in the headgear group to a mean amount of −4.07 ± 8.63° and 3.46 ± 7.52°, respectively. The differences in the mean angulation of the first premolars were statistically significant ($P < .05$). The incisors were proclined a mean of 6.08 ± 3.67° in the pend-x group and 1.73 ± 3.12° in the cervical headgear group. The mean difference in the angulation of the incisor position was statistically significant ($P < .01$).

The means and standard deviations of vertical dental changes are shown in Table 3. The amount of maxillary first and second molar extrusion was significantly different between groups ($P < .01$). Maxillary first and second molar teeth were extruded significantly in the cervical headgear group compared with the pend-x group. The mean values of the first and second molar extrusions in the cervical headgear group were 1.42 ± 0.98 and 1.72 ± 1.18 mm, respectively, whereas the same values for the pend-x group were 0.00 ± 0.96 and 0.23 ± 2.71 mm, respectively.

The mean vertical changes in first premolar position were 2.12 ± 1.76 mm in the cervical headgear group and 1.77 ± 0.90 mm in the pend-x group. The mean vertical changes in incisor position were 0.12 ± 0.92 mm in the cervical headgear group and 0.19 ± 0.78 mm in the pend-x group. The differences in the mean values of the vertical position of the first premolar and the incisor were not statistically different between the groups.

DISCUSSION Return to TOC

The availability of several methods to correct different Class II malocclusions is very valuable for the clinician. Extraoral traction with the headgear has been one of the earliest methods used to distalize the maxilla and maxillary teeth.[2,7,10–16] Despite its success in tooth movement, it has the major disadvantage of heavy dependence on the patient's complying and following of directions. Keeping this shortcoming in mind, Hilgers[26] introduced a new mechanism, the pend-x appliance, for maxillary molar distalization in the treatment of noncompliant patients with Class II malocclusions.

The purpose of this study was to compare the maxillary dental effects of cervical headgear traction with those of the pendulum appliance. In the cervical headgear group, the appliance was worn 14–16 hours per day with 500 g of force. The average treatment time to achieve Class I molar relationship was 11.38 months.

In the pend-x group, a one-time initial activation of 90° delivered 230–250 g of force, and the appliance was left in place for approximately 7.31 months until a super Class I molar relationship was achieved.

In this study, the dental measurements were obtained through maxillary superimposition which was performed on the palatal plane registered at ANS as described by Ricketts.[32] Therefore, orthopedic teeth displacements due to the growth and remodeling changes of the maxilla during treatment could be eliminated.

The current clinical evaluation suggested that both the cervical headgear and the pend-x appliance are capable of distalizing molar teeth similar amounts. The correction of the Class II relationship was achieved by a maxillary first molar distalization of 3.15 mm with the cervical headgear and 3.81 mm with the pend-x appliance. These findings were in agreement with those of Cook et al,[2] Ghosh and Nanda,[3] Byloff and Darendeliler,[29] O'Reilly et al,[11] and Mills et al.[13] Bussick and McNamara[30] measured a mean of 5.7 mm of first molar distalization with the pendulum appliance. This difference between studies may be due to different cephalometric methods used to measure the amount of maxillary first molar distalization.

The second molar teeth were also distalized to a mean of 2.27 mm in the cervical headgear group and 2.04 mm in the pend-x group. The rate of second molar distal movement in these two groups was comparable with that reported by Taner et al,[33] who found second molar teeth were constantly following first molar distalization. Ghosh and Nanda[3] also found similar amount of maxillary second molar distalization after treatment with the pendulum appliance.

Maxillary first molars were tipped distally both in the cervical headgear and the pend-x groups. Molar tipping in the cervical headgear group was in accordance with previous findings.[34–37] For the pendulum appliance, Ghosh and Nanda[3] found 3.37 mm of maxillary molar distalization with 8.36° of distal tipping. Byloff and Darendeliler[28] reported 14.5° of tipping, and Bussick and McNamara[30] found 10.6° of distal tipping of maxillary first molar during distalization with the pendulum appliance. In this study, even though 11.04° of distal tipping was accomplished rapidly in the pend-x group, it was not statistically different from the 6.96° of distal tipping achieved in the cervical headgear group. However, the broad range of the standard deviation of angular changes in maxillary first and second molar positions suggest that the amount of distal tipping cannot be predicted for either appliance.

There was distal tipping of the maxillary second molar teeth in both groups similar to the angular changes in maxillary first molar tooth positions. This shows that the maxillary second molar teeth follow the angular change of the maxillary first molars during distalization. Similarly, Taner et al[33] also found a moderate correlation between the amounts of distal crown tipping of maxillary first and second molar teeth after distalization with a combination headgear.

Maxillary first molar teeth were extruded significantly in the cervical headgear group compared with the pend-x group. The mean extrusion of 1.42 mm in first molar position with the cervical headgear was in accordance with the findings of Cook et al[2] and O'Reilly et al.[11] A vertically stable position of the same teeth with the pend-x appliance was obtained in this study in agreement with Ghosh and Nanda.[3] Maxillary first molar teeth were intruded by 0.7° in Bussick and McNamara's[30] study. Byloff and Darendeliler[28] found even more maxillary molar intrusion during molar distalization with the pendulum appliance and related this finding to prevention of dentoalveoler vertical growth by the rigid bonded appliance or by intrusive force exerted by the tongue. Maxillary second molar eruption was also significantly greater in the cervical headgear group than in the pend-x group in this study. The difference in treatment time between the two groups could have an effect on first and second molar vertical position. It took four months more with the cervical headgear than with the pend-x appliance to achieve a Class I molar relationship.

Maxillary first premolars came forward in the pend-x group and moved distally in the headgear group during this study. Spontaneous distalization of premolar teeth due to molar distalization with headgear was an expected outcome in most instances.[38] After molar distalization with the pend-x appliance, the anchorage loss due to first premolar mesial movement was 0.73 mm with 4° of mesial tipping in this study. Ghosh and Nanda[3] found 2.6 mm of mesial movement of the first premolar with 1.23° of mesial tipping, whereas Bussick and McNamara[30] reported values of 1.8 mm and 1.5° for mesial movement and tipping of first premolar teeth, respectively, after molar distalization with the pendulum appliance.

In this study, incisors showed significant amount of proclination due to molar distalization with the pend-x appliance. Different authors[3,6,8,19,34] have also reported proclination of anterior teeth during molar distalization with intraoral mechanics. On the contrary, Toy and Enacar[39] did not report any significant incisor proclination with the pend-x appliance.

Several methods exist for the correction of Class II malocclusion, none of which work for all patients in all situations. The availability of several methods to correct different Class II malocclusions is valuable.[24]

The conventional cervical headgear has been frequently used to correct Class II malocclusion by restraining the forward growth of maxilla and by distalizing the maxillary molars into Class I dental relationship. However, the success of an extraoral method depends on the patient's complying and following directions.

Pend-x is a fixed appliance, which does not rely on patient compliance and is doctor-controlled. Initial activation of its springs is enough to distalize molar teeth successfully. Although the treatment time for the same amount of distal molar movement is shorter with the pend-x appliance, it causes mesial movement of first premolars and more proclination on anterior teeth.

CONCLUSIONS Return to TOC

Both the pend-x and cervical headgear are very effective in distalizing maxillary molar teeth. The indirect effect of first molar distalization on unerupted maxillary second molar teeth is also the same with both appliances. When selecting the appropriate method for maxillary molar distalization, anchorage loss by mesial movement of first premolar teeth and incisor proclination caused by the pend-x appliance as well as patient compliance and greater treatment time with the cervical traction method should be taken into consideration.

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TABLES Return to TOC

TABLE 1. The Means and Standard Deviations of Sagittal Changes in the Maxillary First, Second Molar, First Premolar, and Anterior Teeth

Variables	Cervical Headgear Mean	Cervical Headgear SD	Pend-X Mean	Pend-X SD	*P* value
First molar distalization	3.15	1.94	3.81	2.25	NS
Second molar distalization	2.27	1.33	2.04	2.15	NS
First premolar distalization	1.88	1.12	−0.73	3.53	**
Incisor distalization	−0.42	1.59	2.00	1.54	NS

* $P < .05$, ** $P < .01$.

TABLE 2. The Means and Standard Deviations of Angular Changes in the Maxillary First, Second Molar, First Premolar, and Anterior Teeth

Variables	Cervical Headgear Mean	Cervical Headgear SD	Pend-X Mean	Pend-X SD	*P* value
First molar angular change	6.96	6.05	11.77	11.14	NS
Second molar angular change	4.30	6.81	11.04	12.94	NS
First premolar angular change	3.46	7.52	−4.08	8.63	*
Incisor angular change	1.73	3.12	6.08	3.67	**

* $P < .05$, ** $P < .01$.

TABLE 3. The Means and Standard Deviations of Vertical Changes in the Maxillary First, Second Molar, First Premolar, and Anterior Teeth

Variables	Cervical Headgear Mean	Cervical Headgear SD	Pend-X Mean	Pend-X SD	*P* value
First molar vertical change	1.42	0.98	0.00	0.96	**
Second molar vertical change	1.77	1.18	0.23	2.71	**
First premolar vertical change	2.12	1.76	1.77	0.90	NS
Incisal edge vertical change	0.12	0.92	0.19	0.78	NS

* $P < .05$, ** $P < .01$.

FIGURES Return to TOC

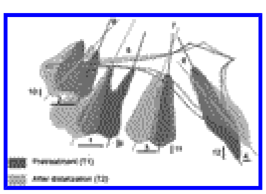

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FIGURE 1. The sagittal, angular, and vertical changes in maxillary teeth. 1 indicates First molar distalization; 2, Second molar distalization; 3, Premolar distalization; 4, Incisor distalization; 5, First molar angulation; 6, Second molar angulation; 7, First premolar angulation; 8, Incisor angulation; 9, First molar vertical movement; 10, Second molar vertical movement; 11, First premolar vertical movement; 12, and Incisor vertical movement.

[a]Associate Professor, Department of Orthodontics, Hacettepe University Faculty of Dentistry, Ankara, Turkey

[b]Professor, Department of Orthodontics, Hacettepe University, Faculty of Dentistry, Ankara, Turkey

[c]Assistant Professor, Department of Orthodontics, Hacettepe University, Faculty of Dentistry, Ankara, Turkey

Corresponding author: Tülin Uğur Taner, PhD, Associate Professor, Department of Orthodontics, Hacettepe University Faculty of Dentistry, Hacettepe University, Ankara 06100, Turkey (E-mail: tulinortho@hotmail.com)
