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Molar distalization with a pendulum appliance K-loop combination

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SUMMARY The aim of this study was to evaluate the dentoalveolar effects of a pendulum appliance supported buccally by a K-loop, and to compare these with a cervical headgear (CHG) group. The records of 30 patients with skeletal Class I and dental Class II malocclusions were divided in to two groups: Patients in group 1 (seven females and eight males; mean age, 15.0 ± 3.4 years) were treated with a pendulum appliance supported with a K-loop buccally, while in group 2 (10 females and 5 males; mean age, 14.2 ± 2.9 years), the patients were treated with CHG. Standardized lateral cephalograms and study models were taken at the beginning of treatment (T0) and at the end of distal molar movement (T1). T0–T1 changes within the groups were analysed with a paired *t*-test, and between the groups with a *t*-test.

The mean amount of distalization was 4.53 ± 1.46 mm in group 1 and 2.23 ± 1.68 mm in group 2. The mean amount of distal tipping for group 1 was 5.13 ± 4.90 degrees; the mean amount of mesial tipping for group 2 was 0.80 ± 2.27 degrees. Intrusion and mesiobuccal rotation of the maxillary molars were achieved in both groups. In group 1, the amount of labial protrusion and tipping of the maxillary incisors was not statistically significant. In group 2, palatoversion and retrusion of the maxillary incisors was statistically significant ($P < 0.01$ and $P < 0.001$, respectively).

The two major disadvantages of intraoral appliances, which are distal tipping of molars and loss of anchorage at the anterior teeth, were significantly decreased with the use of a pendulum appliance K-loop combination.

Introduction

Treatment of Class II malocclusions, without extractions, frequently requires distalization of maxillary molars into a Class I relationship by means of extra or intraoral forces. Several methods and devices can be used to correct Class II malocclusions and to create space in the maxillary dental arch (Ghosh and Nanda, 1996; Gianelly, 1998; Gulati *et al.*, 1998; Runge *et al.*, 1999; Wong *et al.*, 1999; Bondemark, 2000; Bolla *et al.*, 2002; Keles *et al.*, 2003; Chiu *et al.*, 2005; Ferguson *et al.*, 2005).

Extraoral traction with headgear is one of the earliest methods used to move the maxilla and maxillary teeth distally. Although headgear is useful for correcting skeletal problems, they depend heavily on patient cooperation. To eliminate the dependency inherent in extraoral appliances, various fixed intraoral appliances for molar distalization have been introduced. However, these methods are not without their challenges, including patient compliance, aesthetics, comfort, loss of anterior anchorage, and tipping and rotation of the molars (Ghosh and Nanda, 1996; Gianelly, 1998; Gulati *et al.*, 1998; Runge *et al.*, 1999; Wong *et al.*, 1999; Bondemark, 2000).

Among the methods introduced, the Hilgers pendulum appliance seems to decrease the severity of most of these issues. However, even this device can produce undesirable tipping of the maxillary molars and loss of anterior anchorage during distalization (Hilgers, 1992).

According to Kalra (1995), molar tipping and anterior movement of the anchorage teeth are two areas of particular concern. To allow effective control and manipulation of the moment-to-force ratio, that author developed a K-loop molar distalizing appliance and suggested that by altering the moment-to-force ratio, bodily movement, and controlled tipping could be achieved.

Bodily movement and controlled tipping of molar teeth can be achieved with both the pendulum and the K-loop appliances (Hilgers, 1992; Jones and White, 1992; Hubbard *et al.*, 1994; Kalra, 1995).

The aims of this study were to evaluate the dentoalveolar and skeletal effects associated with the pendulum appliance, supported with a K-loop buccally, and to compare these changes with those in a group of patients treated using cervical headgear (CHG).

Subjects and methods

Thirty adolescent patients participated in this prospective study. Written informed consent was obtained from all patients, parents or guardians, and the study protocol, was approved by the ethics committee of Başkent University. The selection criteria were a dental Class II malocclusion due to mesial migration of the upper first molars, no vertical or transverse skeletal or dental problems, and minor arch length discrepancies. The patients were randomly divided into two groups: group 1 (seven females and eight males; mean age 15.0 ± 3.4 years), were treated with a pendulum appliance supported with a K-loop buccally, while subjects in group 2 (10 females and 5 males; mean age 14.2 ± 2.9 years) were treated with CHG. Because of the short treatment time, gender differences were not considered.

Treatment protocol

The pendulum appliance described by Hilgers (1992) was used (Figure 1a). The beta titanium alloy (TMA) springs exerted a force of 230 g when the springs were activated 90 degrees. The K-loop was constructed according to the description of Kalra (1995). The K-loop was made from 0.017 × 0.025 inch TMA wire and was positioned between the upper first molar and first premolar. The K-loop was activated to produce a force of 200 g (Figure 1b).

After insertion of the appliances, the patients were monitored every 3 weeks and the K-loop was activated every 6 weeks. When a Class I molar occlusion was obtained, the appliance was replaced by a Nance button for retention. The patients were then instructed to wear the high-pull headgear at night to achieve molar uprighting.

In the CHG group, long outer bows were used, which were parallel to the occlusal plane, exerting a force of 400 g. The patients in group 2 were instructed to wear their appliances for 16–20 hours a day and were motivated at each visit. Patients in both groups were matched according to GoGnSN angle and length of treatment (Haydar, 1994).

Cephalometric measurements

Cephalometric head films were obtained before treatment (T0) and at the end of molar distalization (T1). The cephalograms were traced by one investigator (AGA) in a random order. For bilateral structures, a single average tracing was made. Two coordinate systems related to the cranial base and maxilla were established, a CT horizontal reference plane passing through point C (the most anterior point of cribriform plate at the junction with the nasal bone) and point T (the most superior point of the anterior wall of sella turcica, at the junction with tuberculum sella). A vertical reference plane (Vp) was constructed perpendicular to the CT horizontal reference line at point T, as recommended by Viazis (1991). The cephalometric profile analysis included 15 landmarks (eight skeletal and seven dentoalveolar, Figure 2) and 10 linear and 12 angular variables (Figure 3a–c). Descriptions of the measured parameters are given in Table 1.

For each patient, rotations of the maxillary first molars and premolars and changes in intermolar distance were measured on dental casts obtained at T0 and T2. Photocopies

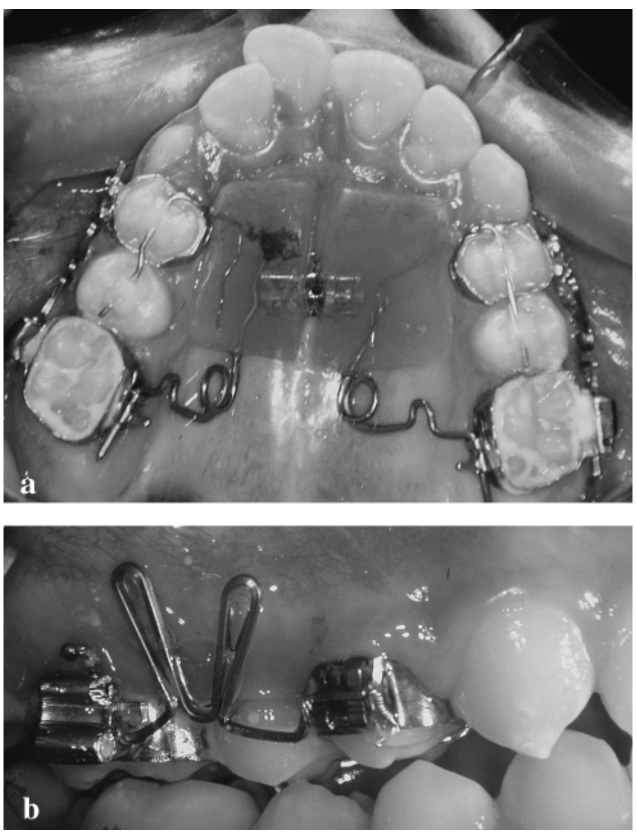

Figure 1 The pendulum (**a**) and K-loop (**b**) appliances *in situ*.

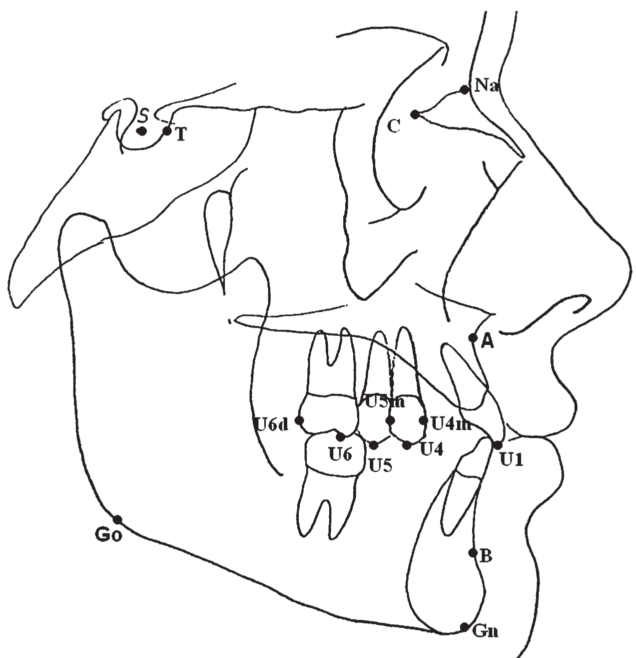

Figure 2 Cephalometric points used in this study.

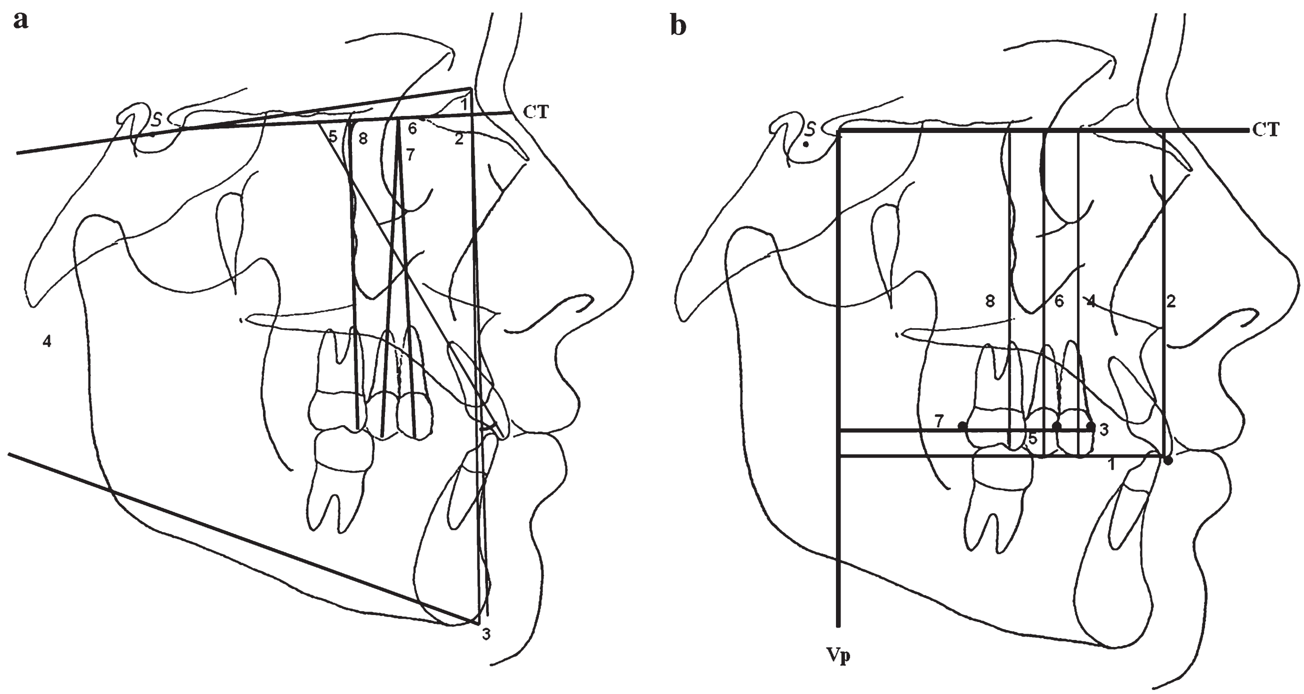

Figure 3 Angular (**a**) (1)SNA (°). (2)SNB (°). (3)ANB (°). (4)GoGnSN (°). (5)U1–CT (°). (6)U4–CT (°). (7)U5–CT (°). (8)U6–CT (°) and (**b**) Linear. (1) U1–Vp. (2)U1–CT. (3)U4m–Vp. (4)U4–CT. (5)U5m–Vp. (6)U5–CT. (7)U6d–Vp. (8)U6–CT cephalometric measurements used in this study.

of the models were obtained as described by Champagne (1992). The measurements analysed on the photocopies are shown in Figure 4.

Statistical analyses

Descriptive statistics (mean, standard deviation, and Spearman correlation coefficients) were calculated for each of the cephalometric measurements at T0 and T1. The data were analysed using the Statistical Package for Social Sciences (version 10.0; SPSS Inc., Chicago, Ilinois, USA).

Paired *t*-tests were used to analyse differences between the T0 and T1 cephalometric variables of the two groups, and a *t*-test to evaluate differences between the groups. Values of less than 0.05 were considered statistically significant.

The size of the combined method error (ME) in the changes in the different landmarks was calculated according to Dahlberg's formula. Ten randomly selected cephalograms from T0 to T1 were retraced and remeasured by the same investigator after a period of 2 weeks. The combined ME did not exceed 0.7 mm for any variable investigated.

Results

In group 1, a super Class I molar relationship was achieved in all patients. The mean treatment time for both groups was 12 ± 2.9 weeks. There were no significant age differences between the groups. Descriptive statistics, including mean and standard deviation for observations at T0 and T1 and changes during the treatment as measured on the cephalometric radiographs, are shown in Table 2.

Skeletal changes

The pendulum K-loop appliance caused insignificant changes in both the maxilla and mandible. There was no change in the mandibular plane angle. However, in group 2, the maxilla moved backward by 1 mm, and the mandible rotated posteriorly causing a decrease in SNB of 0.9 degrees and an increase in GoGnSN of 0.9 degrees. There was a statistically significant overall change in SNA during treatment between the groups ($P < 0.05$).

Dental changes

There was an increase in U1–CT angle and a decrease in U1–Vp distance in the headgear group, with statistically significant retrusion of the upper incisors ($P < 0.05$). The pendulum appliance K-loop combination seemed to have no significant effect on upper incisor position.

Although no changes were observed in group 1 U4–Vp or U5–Vp distance, a significant reduction in these distances was achieved in the CHG group. There was also a decrease in U5–CT angle in group 1, resulting in a statistically significant difference in the amount of mesial tipping of the upper second premolars. In both groups, there was a statistically significant reduction in U6–Vp distance, but this reduction was significantly greater in group 1 than in group 2 ($P < 0.001$). There was an increase

Table 1 Skeletal and dentoalveolar variables used in this study.

	Skeletal measurements
SNA (°)	Anterior position of the maxilla
SNB (°)	Anterior position of the mandible
ANB (°)	Difference between SNA and SNB
GoGnSN (°)	Angle formed between the anterior cranial base (cephalometric reference line connecting the centre of the sella turcica with nasion) and the mandibular plane (cephalometric reference line connecting gnathion and gonion)
	Dentoalveolar measurements
U1-CT (°)	Angle formed between the upper incisor axis and the CT horizontal plane
U1–Vp	Distance from the vertical plane to the upper incisor crown tip
U1–CT	Distance from the CT horizontal plane to the upper incisor crown tip
U4–CT (°)	Angle formed between the upper first premolar axis and the CT horizontal plane
U4m–Vp	Distance from the vertical plane to the upper first premolar mesial point
U4–CT	Distance from the CT horizontal plane to the upper first premolar crown tip
U5–CT (°)	Angle formed between the upper second premolar axis and the CT horizontal plane
U5m–Vp	Distance from the vertical plane to the upper second premolar mesial point
U5–CT	Distance from the CT horizontal plane to the upper second premolar crown tip
U6–CT (°)	Angle formed between the upper first molar axis and the CT horizontal plane
U6d–Vp	Distance from the vertical plane to the upper first molar distal point
U6–CT	Distance from the CT horizontal plane to the upper first molar mesiobuccal crown tip
UR6m–UL6m	Distance between the mesiobuccal cusp tips of the right and the left upper first molars
UR6d–UL6d	Distance between the distopalatal cusp tips of the right and the left upper first molars
UL6axis (°)	Angle formed between the midline and a line passing through the mesiobuccal cusp tip and the distopalatal cusp tip of the upper left first molar
UR6axis (°)	Angle formed between the midline and a line passing through the mesiobuccal cusp tip and the distopalatal cusp tip of the upper right first molar
UL4axis (°)	Angle formed between the midline and a line passing through the mesiobuccal cusp tip and the distopalatal cusp tip of the upper left first premolar
UR4axis (°)	Angle formed between the midline and a line passing through the mesiobuccal cusp tip and the distopalatal cusp tip of the the upper right first premolar

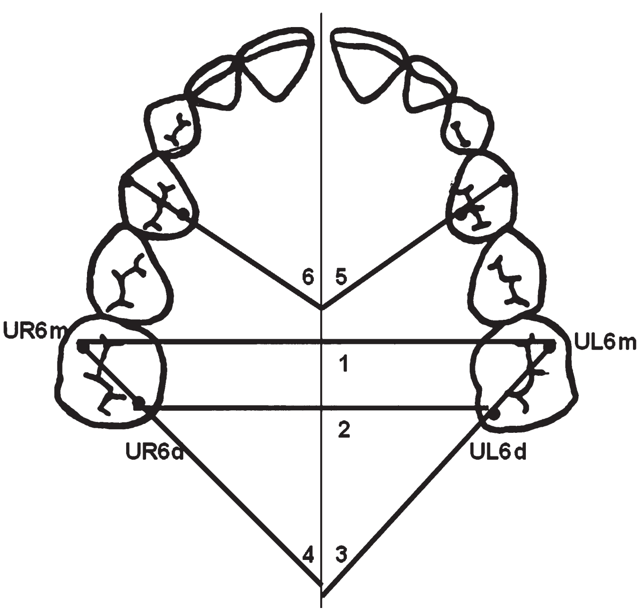

Figure 4 Measurements on the model photocopies. (1)UR6m–UL6m. (2) UR6d–UL6d. (3)UL6axis (°). (4)UR6axis (°). (5)UL4axis (°). (6)UR4axis (°).

in the U6/CT angle in group 1, showing a statistically significant difference in the amount of distal tipping of the upper first molar ($P < 0.001$). U1–CT distance was decreased but only in group 2 ($P < 0.05$); the difference between the groups was not significant. There was a decrease in U6–CT distance in both groups, but the amount of intrusion was statistically significant only in group 1 ($P < 0.01$). The differences between the two groups were also significant ($P < 0.01$). UR6m–UL6m and UR6d–UL6d distances increased in both groups, and for UR6m–UL6m, they were statistically significant in both groups. The increases in UR6d–UL6d were statistically significant only in group 2. There was an increase in UL6axis and UR6axis angles in both groups, with a statistically significant rotation of the maxillary first molars ($P < 0.05$, $P < 0.01$, $P < 0.001$). The amount of rotation of the maxillary right and left premolars was statistically significant but only in group 1 ($P < 0.05$). There was a statistically significant difference in the amount of change in UL4-axis angle during treatment between the two groups ($P < 0.05$). A statistically significant difference was also found for the amount of change in the U5/CT and U6/CT angles between the groups ($P < 0.01$ and $P < 0.001$, respectively; Table 2).

Discussion

A common strategy to correct Class II malocclusions using a non-extraction protocol is to move the maxillary molars distally during the initial stage of treatment to convert the Class II molar relationship to a Class I molar relationship. An efficient force system to move molars distally is a

Table 2 Treatment changes with a pendulum appliance K-loop combination (group 1) and cervical headgear (group 2).

Variable	Group 1			Group 2			ΔTO–T1		
	Pre-treatment (T0) mean	Post-treatment (T1) mean	Significance	Pre-treatment (T0) mean	Post-treatment (T1) mean	Significance	Group 1 mean	Group 2 mean	Significance
Skeletal									
SNA (°)	81.2 ± 2.48	80.86 ± 2.79	NS	82.73 ± 3.05	81.73 ± 3.39	*	−1.53 ± 1.01	−0.86 ± 1.13	**
SNB (°)	77.33 ± 3.01	76.73 ± 3.05	NS	78.03 ± 3.06	81.74 ± 3.41	*	−1.54 ± 1.02	−0.87 ± 1.14	NS
ANB (°)	3.86 ± 1.24	4.00 ± 1.06	NS	4.76 ± 3.07	81.75 ± 2.43	*	−1.55 ± 1.03	−0.88 ± 1.15	NS
GoGnSn (°)	31.33 ± 4.18	31.66 ± 3.97	NS	29.93 ± 3.08	81.76 ± 5.08	*	−1.56 ± 1.04	−0.89 ± 1.16	NS
Dentoalveoler									
U1–CT	77.67 ± 9.74	76.60 ± 10.41	NS	72.70 ± 7.57	74.00 ± 6.99	**	−1.07 ± 2.96	1.33 ± 1.59	*
U1–Vp	65.46 ± 5.14	65.80 ±5.04	NS	65.33 ± 7.00	63.77 ± 6.58	***	0.33 ± 1.63	−1.57 ± 1.37	**
U1–CT	81.47 ± 3.89	80.97 ± 3.53	NS	79.70 ± 6.07	78.57 ± 4.61	*	−0.50 ± 1.64	−1.13 ± 2.09	NS
U4–CT (°)	91.60 ± 7.79	89.93 ± 5.87	NS	95.53 ± 4.51	95.80 ± 4.65	NS	−1.67 ± 3.44	0.27 ± 1.98	NS
U4–Vp	52.83 ± 4.49	53.07 ± 4.8	NS	49.60 ± 5.06	48.40 ± 5.10	**	0.23 ± 1.86	−1.20 ± 1.51	*
U4–CT	75.40 ± 4.50	74.97 ± 4.14	NS	71.50 ± 6.02	71.67 ± 4.06	NS	−0.43 ± 1.50	0.17 ± 2.83	
U5–CT (°)	97.53 ± 8.15	95.33 ± 7.60	**	102.8 ± 4.36	103.00 ± 5.17	NS	−2.20 ± 2.51	0.20 ± 1.74	**
U5–Vp	45.27 ± 4.07	45.53 ± 4.39	NS	42.37 ± 4.71	40.90 ± 4.67	**	0.27 ± 1.62	−1.47 ± 1.56	*
U5–CT	74.00 ± 4.26	73.73 ± 3.78	NS	68.47 ± 7.26	68.80 ± 5.75	NS	−0.27 ± 1.11	0.33 ± 2.50	NS
U6–CT (°)	102.87 ± 10.78	108.00 ± 10.64	***	110.4 ± 6.00	109.6 ± 6.01	**	5.13 ± 4.90	−0.80 ± 2.27	***
U6–Vp	27.30 ± 4.49	22.47 ± 4.50	***	23.10 ± 4.70	20.87 ± 4.27	***	−4.53 ± 1.46	−2.23 ± 1.68	***
U6–CT	71.53 ± 4.70	70.63 ± 4.19	**	68.73 ± 5.24	68.53 ± 4.19	NS	−0.90 ± 1.04	−0.20 ± 1.48	**
UR6m–UL6m	52.07 ± 2.02	54.37 ± 2.41	***	51.07 ± 1.43	52.33 ± 1.80	**	2.30 ± 1.03	1.27 ± 1.39	*
UR6d–UL6d	43.13 ± 1.81	44.00 ± 2.51	NS	42.60 ± 2.69	43.33 ± 2.92	*	0.87 ± 1.77	0.73 ± 1.33	NS
UR6axis (°)	28.67 ± 7.00	30.67 ± 7.40	***	27.20 ± 5.53	29.00 ± 5.99	**	2.00 ± 1.77	1.80 ± 2.40	NS
UL6axis (°)	30.93 ± 5.42	33.13 ± 5.78	***	27.67 ± 7.12	28.47 ± 7.21	*	2.20 ± 1.52	0.80 ± 1.15	**
UR4axis (°)	74.06 ± 5.84	73.27 ± 5.65	*	74.00 ±7 .59	74.20 ± 7.46	NS	−0.80 ± 1.15	0.20 ± 0.68	NS
UL4axis (°)	78.27 ± 9.74	77.33 ± 4.79	*	76.73 ± 6.56	77.00 ± 6.35	NS	−0.93 ± 1.62	0.27 ± 0.80	*

NS, not significant. $*P < 0.05$ $**P < 0.01$ $***P < 0.001$.

continuously acting force with little or no patient cooperation. Although there are many intraoral appliances available to move molars distally, none can control molar movement in all three directions (Gianelly *et al.*, 1988, 1989; Bondemark and Kurol, 1992; Kalra, 1995; Bondemark, 2000). Therefore, a combination of two intraoral appliances (the pendulum and the K-loop appliance) were used, and the results compared with a conventional method, CHG, in dental Class II subjects.

It has been stated that continuous forces move teeth faster than intermittent forces and that faster movement occurs when the molar is tipped distally (Daskalogiannakis and McLachlan, 1996). Similar to previous studies, the molars moved distally to a greater degree with a combination pendulum and K-loop appliance than with CHG during the same period of time. The amount of distalization achieved with the pendulum appliance K-loop combination and CHG was 4.53 ± 1.46 mm and 2.23 ± 1.68 mm, respectively, in 12 weeks. Additionally, the degree of molar tipping was greater with the pendulum appliance K-loop combination (Table 2).

In the current study, mesial tipping of the maxillary molars was observed in the CHG group. Cangialosi *et al.* (1988) also found mesial tipping of the maxillary molars during headgear therapy and attributed it to several factors, such as lack of patient cooperation, duration of wear and force of the headgear, and the plane on which superimposition was based.

Many authors have reported distalization and distal tipping of the maxillary first molars with other intraoral appliances (Bondemark and Kurol, 1992; Ghosh and Nanda, 1996; Gianelly *et al.*, 1988, 1989; Gulati *et al.*, 1998; Bussick and McNamara, 2000; Ferguson *et al.*, 2005; Schütze *et al.*, 2007). Distal tipping of the maxillary molars in the current study was a consistent finding in both groups (Table 2). Therefore, high-pull headgear was used for uprighting roots and maintenance of molar position during the retention period.

Similar to the findings of other authors, the upper incisors were intruded and palatally tipped in the CHG group (Droschl, 1973; Hershcopf, 1990; Wieslander, 1974). Several studies have shown protrusion of the upper incisors during distalization with intraoral appliances due to a loss of anchorage (Hilgers, 1992; Jones and White, 1992; Carano and Testa, 1996; Runge *et al.*, 1999; Brickman *et al.*, 2000; Haydar and Uner, 2000; Keles and Sayinsu, 2000); however, in the current study, there was slight retrusion of the upper incisors in group 1. This finding may be attributed to the reinforced anchorage obtained with the K-loop (Kalra, 1995). The buccal support of this appliance seemed to reduce anchorage loss and provide more effective distalization. Thus, the major advantage of this appliance, when compared with other intraoral appliances, is its maintenance of anchorage on the anterior teeth (Bondemark and Kurol, 1992; Ghosh and Nanda, 1996; Gulati *et al.*, 1998). This effect is similar to that of extraoral appliances on the anterior dentition (Wieslander, 1974; Godt *et al.*, 2006). In group 1, mesial tipping and mesial movement of the first premolars were insignificant. Mesial tipping was statistically significant only on the second premolar teeth in group 1 ($P < 0.01$; Table 2). Mesial tipping of the second premolars during distalization of the molar teeth improved spontaneously during fixed appliance treatment after distalization had been completed.

In group 2, the premolars drifted distally as a consequence of molar distalization, resulting in a statistically significant difference between the groups due to premolar movement in the opposite direction (Table 2).

Study model and photocopy analysis did not show a significant expansion in the intermolar region in group 1; however, mesiobuccal rotation of the maxillary first molars was observed. In group 2, mesiobuccal rotation of the first molars was accompanied by intermolar expansion (Table 2). Several studies have also shown mesiobuccal rotation of the first molars during distalization with intraoral appliances and cervical traction (Ghosh and Nanda, 1996; Elekdağ-Türk, 1999; Kinzinger *et al.*, 2005). Mesiobuccal rotation of the first molars is desirable since it results in improved molar occlusion (Ghosh and Nanda, 1996).

When vertical movement of the maxillary first molar was analysed, significant intrusion was found in group 1. The first molar was also intruded in the CHG group; however, this movement was not statistically significant (Table 2). Byloff and Darendeliler (1997) and Byloff *et al.* (1997) demonstrated the intrusive force from a pendulum appliance on the maxillary molars. However, when compared with the findings of those authors, the amount of intrusion in the present study was relatively less. Thus, the intrusion effect of the pendulum appliance was inhibited when combined with a K-loop.

In group 2, statistically significant decreases in SNA, SNB, and ANB were found, which is similar to the results of other studies (Barton, 1972; Uner *et al.*, 1994; Ghafari *et al.*, 1998; Haydar and Uner, 2000). Other orthopaedic effects of extraoral traction that have been reported include reduced forward movement of pogonion, an increase in overall face height and mandibular plane angle, and tipping of the palatal plane downward and anteriorly (Poulton, 1967; Barton, 1972; Wieslander, 1974, 1975; Odom, 1983; O'Reilly *et al.*, 1993; Hubbard *et al.*, 1994). In agreement with previous studies, a significant increase in the GoGnSN angle (Table 2) was also found but no orthopaedic effects were observed in group 1 (Table 2).

Conclusions

The mean amounts of distalization achieved with the pendulum appliance K-loop combination and CHG were 4.53 ± 1.46 mm and 2.23 ± 1.68 mm, respectively. The major advantages of the pendulum appliance K-loop combination were prevention of anchorage loss on the anterior teeth and significantly less distal tipping at the maxillary molars. However, the amount of distal tipping of the molar teeth was still greater than with CHG. The mesiobuccal rotation of the molars observed might be controlled by changing the amounts of buccal and palatal force.

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