Original Article

Soft Tissue Profile after Distal Molar Movement with a Pendulum K-Loop Appliance Versus Cervical Headgear

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ABSTRACT

Objective: To evaluate the soft tissue changes associated with the pendulum appliance that was supported with a K-loop buccally and to compare these treatment changes with a cervical headgear group.

Materials and Methods: The records of 30 patients having skeletal Class I, dental Class II malocclusions were divided to two groups. Group 1 consisted of 7 girls, 8 boys (mean age, 15.0 ± 3.4 years), and Group 2 consisted of 10 girls, 5 boys (mean age 14.2 ± 2.9 years). The first group was treated with a pendulum appliance that was supported with a K-loop buccally, and the second group was treated with cervical headgear. Lateral cephalograms were taken at the beginning of treatment and at the end of distal molar movement. Treatment changes within the groups were analyzed using the paired *t*-test, and between group changes were analyzed with the independent *t*-test.

Results: The results showed that the pendulum/K-loop appliance had no significant effect on skeletal and dental variables and soft tissue A point, upper lip thickness, and sagittal upper lip position relative to the E plane. A significant difference for the change in Vp-Ls distance was found in patients in the pendulum/K-loop group ($P < .05$). Patients in the cervical headgear group showed significant retrusion in skeletal, dental, and soft tissue measurements ($P < .05$).

Conclusions: The pendulum/K-loop appliance produces distal molar movement without causing any significant changes in the sagittal or vertical positions of either the jaw or the soft tissue profile.

KEY WORDS: Pendulum appliance; K-loop; Distalization; Cervical headgear

INTRODUCTION

One of the primary concerns of the orthodontist in treatment planning must be the final esthetic appearance of the facial profile. A Class II patient usually shows either a protrusive upper jaw, retrusive lower jaw, or both.[1] Correction of the molar relationship is often required for the nonextraction treatment of Class II malocclusions. Headgear has been used for decades for upper molar distal movement, but growing concerns regarding compliance and esthetic impairment have arisen. Moreover, the headgear may have a negative effect on the facial profile since restriction of sagittal maxillary growth and retrusion of upper dentition have been shown to occur.[2]

These concerns have resulted in the development of intraoral distal molar movement appliances that offer noncompliance treatment and continuous forces. Among these are repelling magnets,[3,4] active transpalatal arches,[5] Nitinol coil springs,[6] Jones Jig,[7] pendulum,[8,9] distal jet,[10] superelastic wires,[11] and K-loop arches.[12] When a nonextraction treatment is planned, these appliances can move upper maxillary molars distally at a rate of 1–2 mm per month during the course of 4–5 months.[13]

An intermaxillary anchorage unit is needed to counteract the distal forces needed in intraoral appliances. Despite the increasing use of screws and implants for anchorage preservation of intraoral distal movement

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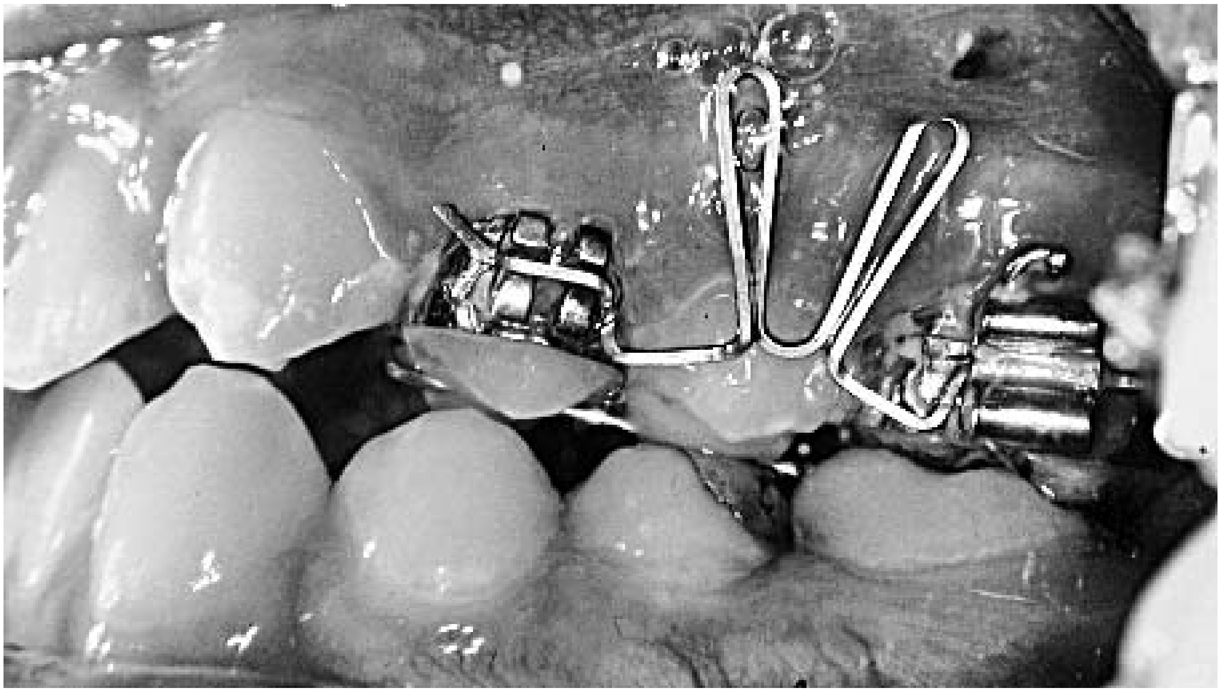

Figure 1. K-loop appliance in place.

appliances, the use of premolars and the palate as the anchorage unit continues. Although major advantages include the need for minimal patient cooperation and ease of use, distal molar movement with molar tipping and rotation of the crowns has been seen as well as anchorage loss in the premolars and incisors.[14] Greater protrusion of the upper and lower lips can be expected as a result of anchorage loss.

In recent years, many studies have been published on intraoral distal force appliances. In some of these studies, clinicians have tried to prevent anchorage loss by using uprighting bends,[15] occipital headgears,[17,18] or utility arches.[16,18] In 1995, Kalra[12] introduced an intraoral distal force loop that was fabricated from 0.017 inch × 0.025 inch titanium molybdenum alloy (TMA). In that study, use of the K-loop seemed to produce parallel distal molar movement.

Despite numerous studies investigating the dentofacial effects of the pendulum appliance, none of these studies have focused on soft tissue changes in detail. In most studies, the profile was evaluated only by using the esthetic line. Therefore, the aims of this study were (1) to evaluate the soft tissue changes associated with the pendulum appliance (which was supported with a K-loop buccally) and (2) to compare these changes with a cervical headgear group.

MATERIALS AND METHODS

Thirty adolescent patients participated in this prospective study. The selection criteria were:

—A dental Class II malocclusion due to mesial migration of the upper first molar;
—No vertical or transverse skeletal or dental problems;
—Minor arch length discrepancy problems.

The sample was randomly divided into two groups: Group 1 patients (7 girls, 8 boys; mean age 15.0 ± 3.4 years) were treated with a pendulum appliance supported buccally with a K-loop. Group 2 patients (10 girls, 5 boys; mean age 14.2 ± 2.9 years) were treated with a cervical headgear. Sex differences were not considered a factor due to the short duration of treatment.

Treatment Protocol

Pendulum appliances used were as described by Hilgers.[8] The TMA springs exerted 230 grams of force, as the springs were activated to 90°. The K-loop was constructed according to the description by Kalra.[12] The K-loop was made from 0.017 inch × 0.025 inch TMA wire and located between the upper first molar and the first premolar. The K-loop was activated to produce 200 grams of force (Figure 1).

After placement of the appliances, patients were monitored every 3 weeks, and the K-loop was activated every 6 weeks. When the molars achieved a Class I occlusion, the appliance was replaced with a Nance button for retention. Patients were instructed to wear

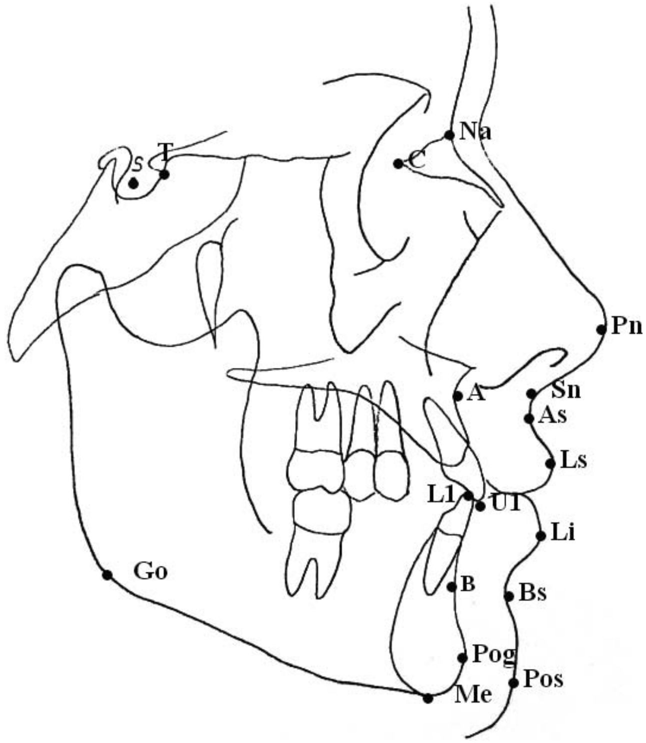

Figure 2. Cephalometric points used in this study.

high-pull headgear at night to achieve molar uprighting.

In the headgear group, long outer bows were used and these bows were parallel to the occlusal plane, exerting a force of 400 grams. The patients in the headgear group were instructed to wear their appliances 16–20 hours a day and were motivated at each visit to wear the appliance for corporation. Patients in both groups were matched according to the GOGnSN angle and length of treatment.

Cephalometric Measurements

Cephalometric head films were obtained pretreatment (T0) and at the end of distal molar movement (T1). The cephalograms were traced by one investigator in random order. In instances of 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 the C point (the most anterior point of the cribriform plate at the junction with the nasal bone) and point T (the most superior point of the anterior wall of the sella turcica at the junction with the tuberculum sella). A vertical reference plane (Vp) was constructed perpendicular to the CT horizontal reference line at the T point as recommended by Viazis.[19] The cephalometric profile analysis included 18 landmarks (11 dentoskeletal and 9 soft tissue, Figure 1) and 24 linear

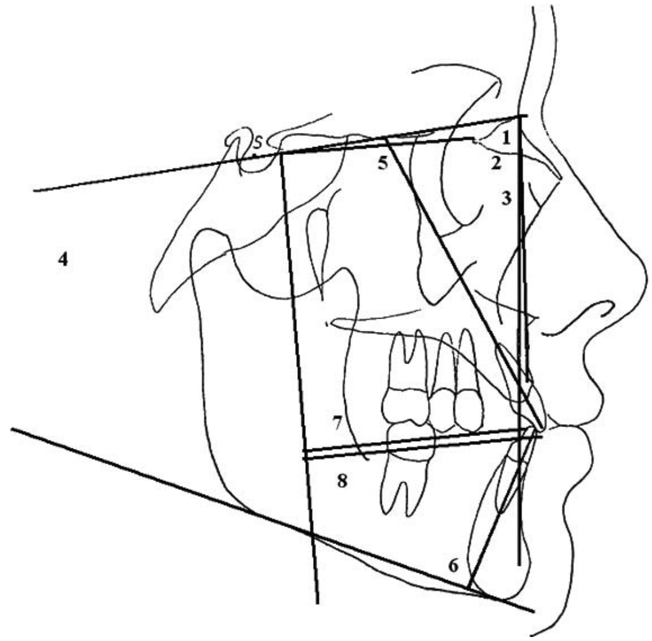

Figure 3. Skeletal and dental measurements used in this study. (1) SNA. (2) SNB. (3) ANB. (4) GoGnSN. (5) U1-SN. (6) L1-MP. (7) Vp-U1. (8) Vp-L1.

and angular variables (Figures 2–4). Descriptions of the measured parameters are given in Table 1.

Statistical Analyses

Descriptive statistics (mean, standard deviation, and ranges) were calculated for each of the cephalometric measurements at T0 and T1. The data were analyzed using SPSS software (Statistical Package for the Social Sciences, version 10.0, SSPS Inc, Chicago, Ill).

Paired *t*-tests were used to analyze differences between the pretreatment and post distal molar movement cephalometric variables from Groups 1 and 2. To compare differences in soft tissue profiles between Groups 1 and 2, independent *t*-tests were done. Values of $P < .05$ 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. Before and after treatment, cephalograms from 10 randomly chosen subjects were traced and superimposed with measurements recorded on two different occasions. The combined ME did not exceed 0.7 mm for any variable investigated.

RESULTS

In the pendulum/K-loop group, a super Class I molar relationship was achieved in all of the patients. The mean treatment time was 12 $\pm$ 2.9 weeks for both groups. There were no significant age differences between the groups. Descriptive statistics, including

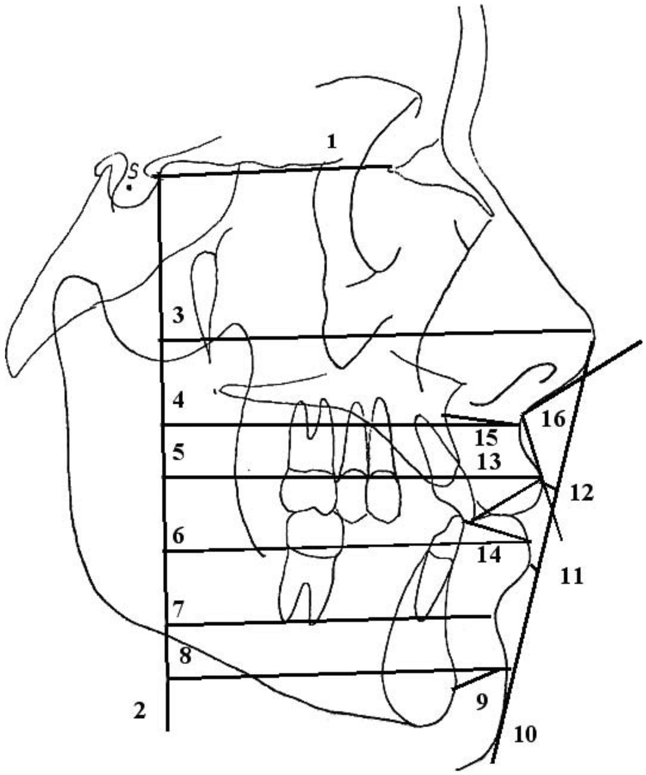

Figure 4. Soft tissue measurement used in this study. (1) CT Horizontal reference plane. (2) Vertical reference plane. (3) Vp-Pn. (4) Vp-As. (5) Vp-Ls. (6) Vp-Li. (7) Vp-Bs. (8) Vp-Pos. (9) Pog-Pos. (10) E-plane. (11) Li-E plane. (12) Ls- E plane. (13) Ls-U1. (14) Li-L1. (15) Sn-A. (16) NLA.

mean and standard deviation for observations T1, T2, and changes during treatment as measured from cephalometric radiographs, are shown in Table 2.

Skeletal Changes

The pendulum/K-loop appliance caused insignificant changes in both the maxilla and the mandible. Also, there was no change in the mandibular plane angle. However, in the headgear group, the maxilla moved backward by 1 mm, and the mandible rotated posteriorly causing a decrease in SNB of 0.9 mm and an increase in GoGnSN of 0.9 mm. The overall change in treatment between the two groups in SNA was statistically significant ($P < .05$).

Dental Changes

There was a decrease in U1-SN angle and Vp-U1 distance in the headgear group, showing a statistically significant retrusion of the upper incisor ($P < .05$). The pendulum/K-loop appliance seemed to have no significant effect on upper incisor position. Lower incisors were retruded in both the pendulum/K-loop and headgear groups, but there was no significant difference between the groups ($P > .05$).

Soft Tissue Changes

Sagittal measurements. Vp-Pn, Vp-Ls, Vp-Bs, and Vp-Pos distances showed a statistically significant re-

Table 1. Skeletal, Dental, and Soft Tissue Variables Used in This Study

Skeletal and dental measurements	
SNA	Anterior position of maxilla
SNB	Anterior position of mandible
ANB	Difference between SNA and SNB
GoGnSN	Angle formed between anterior cranial base and mandibular plane
U1-SN	Angle formed between anterior cranial base and upper incisor axis
L1-MP	Angle formed between mandibular plane and lower incisor axis
Vp-U1	Distance from vertical plane to upper incisor crown tip
Vp-L1	Distance from vertical plane to lower incisor crown tip
Soft tissue measurements	
CT	Horizontal reference line drawn from tuberculum sella to most anterior point in cribriform plate
Vp	Vertical reference line perpendicular to CT horizontal reference, drawn from tuberculum sella
Vp-Pn	Distance from vertical plane to nose prominence
Vp-As	Distance from vertical plane to soft tissue A point
Vp-Ls	Distance from vertical plane to most anterior point of the upper lip
Vp-Li	Distance from vertical plane to most anterior point of the lower lip
Vp-Bs	Distance from vertical plane to soft tissue B point
Vp-Pos	Distance from vertical plane to soft tissue pogonion
Pog-Pos	Distance from pogonion to soft tissue pogonion
E Line	Line tangent to nose prominence and most anterior point of the chin
Ls-E plane	Distance from Ricketts' line to the most anterior point of upper lip
Li-E plane	Distance from Ricketts' line to the most anterior point of lower lip
Ls-U1	Distance from upper incisor crown tip to most anterior point of the upper lip
Li-L1	Distance from lower incisor crown tip to most anterior point of the lower lip
Sn-A	Distance from subnasale to A point
NLA	Nasolabial angle

Table 2. Changes in Facial Profile

	Group 1 (Pendulum/K-loop)			Group 2 (Headgear)			ΔT0–T1		
Variable	T0 Mean	T1 Mean	Significance	T0 Mean	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 ± 3.47	77.4 ± 3.41	*	−0.7 ± 1.18	−0.66 ± 1.18	NS
ANB	3.86 ± 1.24	4 ± 1.06	NS	4.76 ± 2.22	4.26 ± 2.43	*	−0.90 ± 0.65	−0.26 ± 0.68	NS
GoGnSn	31.33 ± 4.18	31.66 ± 3.97	NS	29.93 ± 4.86	30.8 ± 5.08	*	1.40 ± 1.65	0.86 ± 1.66	NS
Dental									
U1-SN	105.28 ± 9.43	104.18 ± 8.76	NS	106.33 ± 7.36	105.93 ± 7.01	*	−1.05 ± 3.09	−1.75 ± 2.89	NS
L1-MP	100.29 ± 9.68	96.71 ± 5.74	*	97.86 ± 6.68	98.26 ± 7.86	*	2.42 ± 3.03	−1.55 ± 2.51	NS
Vp-U1	64.67 ± 5.7	64.82 ± 5.5	NS	63.96 ± 7.71	62.31 ± 6.11	*	0.70 ± 2.47	2.51 ± 2.12	NS
Vp-L1	61.17 ± 5.82	60.22 ± 5.41	*	58.74 ± 6.47	57.56 ± 4.81	*	2.43 ± 2.25	2.65 ± 1.87	NS
Soft tissue									
Vp-Pn	95.76 ± 5.13	93.88 ± 5.29	*	92.15 ± 5.85	90.63 ± 4.65	*	3.61 ± 2.01	3.24 ± 1.82	NS
Vp-As	78.24 ± 4.84	77.18 ± 5.04	NS	76.57 ± 5.95	7.446 ± 4.49	*	1.66 ± 1.98	2.72 ± 1.74	NS
Vp-Ls	80.19 ± 4.71	79.01 ± 5.02	*	77.41 ± 6.93	75.99 ± 5.23	*	2.77 ± 2.16	3.02 ± 1.7	NS
Vp-Li	75.29 ± 5.17	74.7 ± 5.32	NS	73.03 ± 7.34	70.45 ± 5.12	NS	2.26 ± 2.31	4.24 ± 1.90	**
Vp-Bs	66.12 ± 5.99	64.91 ± 5.71	*	62.44 ± 7.89	60.67 ± 5.38	*	3.68 ± 2.55	4.24 ± 2.02	**
Vp-Pos	67.3 ± 6.66	65.26 ± 6.3	*	63.61 ± 8.66	62.41 ± 6.70	*	3.68 ± 2.82	2.85 ± 2.37	NS
SnA	16.25 ± 1.76	15.75 ± 2.39	NS	14.91 ± 2.26	14.56 ± 2.14	*	1.33 ± 0.74	1.19 ± 0.83	NS
Ls-U1	13.08 ± 1.75	12.65 ± 2.26	NS	11.76 ± 1.30	12.03 ± 1.35	*	1.31 ± 5.56	0.62 ± 5.42	NS
Ls-L1	14.83 ± 1.62	14.89 ± 2.15	NS	15.71 ± 1.66	15.01 ± 1.73	NS	−0.88 ± 0.59	−0.12 ± 0.71	NS
Pog-Pos	12.91 ± 2.34	12.76 ± 2.22	NS	15.01 ± 2.99	12.45 ± 3.06	*	−0.41 ± 0.98	0.31 ± 4.24	NS
Ls-E plane	−2.02 ± 3.78	−1.52 ± 3.07	NS	1.62 ± 2.00	−0.27 ± 2.45	*	−2.01 ± 1.10	−1.24 ± 1.01	NS
Li-E plane	−1.75 ± 3.48	−0.89 ± 2.79	*	1.11 ± 2.19	0.52 ± 1.60	NS	−2.86 ± 1.06	−1.42 ± 0.83	NS
NLA	109.84 ± 10.6	109.45 ± 10.27	NS	113.4 ± 6.45	110.73 ± 8.15	NS	−3.55 ± 3.20	−1.28 ± 3.38	NS

[a] NS indicates not significant.
* $P < .05$, paired *t*-test; ** $P < .05$, independent *t*-test.

duction in both groups. Although no changes were observed in Vp-As measurements in Group 1, a significant reduction in this distance was achieved in Group 2. Reduction of Vp-Li distance was significantly greater in the headgear group than it was in the pendulum/K-loop group ($P < .05$). The upper lip showed a retrusion relative to the E plane in the headgear group ($P < .05$). The lower lip E plane distance decreased in the pendulum/K-loop group ($P < .05$).

Soft tissue thickness. SnA, Ls-U1, and Pog-Pos distances decreased in the headgear group only ($P < .05$), but the differences between the two groups were insignificant ($P > .05$). There were no statistically significant changes in the nasolabial angle (NLA) in either group.

DISCUSSION

In its early years, the objective of orthodontic treatment was to achieve ideal occlusion. Angle[20] suggested that if the teeth were placed in optimal occlusion, good facial harmony would be accomplished. With the introduction of soft tissue measurements in cephalometrics, several authors underscored the importance of the soft tissue as well as the hard tissues.

Quantifying and predicting soft tissue responses to various orthodontic treatment mechanics could provide information to advise patients about treatment alternatives. Detailed studies have reported profile changes resulting from extraction and nonextraction protocols,[21] face mask,[22] surgery,[23] and rapid maxillary surgery.[24] However, only limited data exist regarding the profile changes associated with intraoral distal force appliances. Therefore, the purposes of this study were (1) to evaluate the soft tissue changes associated with the pendulum appliance (which was supported with a K-loop buccally) and (2) to compare these changes with a cervical headgear group.

Skeletal Changes

With regard to skeletal changes of the maxilla, the SNA angle showed no statistical differences in the intraoral distal molar movement group. However, significant differences between the groups were found for changes in the SNA angle, confirming previous findings.[9,25] A significantly greater retraction of A point relative to the anterior cranial base was found in the headgear group. The changes in the vertical plane in the pendulum/K-loop group were insignificant (as has been demonstrated by other studies), but an increase was observed in the headgear group. SNB also was affected in the headgear group due to posterior mandibular rotation, which agrees with previous findings.[9,25]

Dental Changes

Surprisingly, the results of the present study demonstrated no upper incisor protrusion and a slight retrusion was statistically insignificant. This finding can be attributed to the reinforced anchorage obtained with the K-loop. Ghosh and Nanda[9] found an incisor proclination of 2.4° relative to the SN line. Likewise, a mean of 1.71° of labial tipping was measured by Byloff and Darendeliler,[26] and an average of 1.8 mm of anterior movement of the incisor edge and 6° of anterior tipping of the same teeth was measured by Bondemark et al.[27] Kalra[12] claimed that the K-loop produced bodily distal molar movement relative to the 20° bend. Buccal support seemed to reduce anchorage loss and provide a more effective distal molar movement in this study.

Soft Tissue Changes

Prediction of soft tissue changes is difficult because of the vast number of variables to consider. Differences in soft tissue thickness and tension between individuals produce a complex variation in profiles as demonstrated by hard tissue changes. However, changes in the positions of the incisors do have a direct impact on the supporting soft tissues.[22]

Most of the previous studies on variations of the pendulum appliance have focused on soft tissue changes relative to the E plane.[28,29] In one of the earliest studies, Byloff and Darendeliler[26] analyzed the effects of the pendulum appliance on distal movement of the maxillary molars. However, they only studied changes in the hard tissues. Ghosh and Nanda[9] evaluated the soft tissue changes relative to the E plane and reported a 0.31-mm protrusion in the upper lip and a 0.95-mm protrusion in the lower lip due to upper incisor protrusion. Bussick and McNamara[25] evaluated four soft-tissue variables: upper incisor and lower incisor position relative to the E plane, nasolabial angle, and cant of the upper lip. Their results also showed protrusion in both the upper and lower lips and a 2.5° decrease in the nasolabial angle and 2.0° decrease in the cant of the upper lip, reflecting a slight protrusion of upper lip contour.

The only significant change in upper lip position in the pendulum/K-loop group was seen in the upper lip-vertical plane (Vp-Ls) distance. However, in contrast to other published data, this variable showed a decrease.

There exists only one study that showed a 0.4-mm retrusion of the upper lip relative to the E plane, and the results of that study were found insignificant.[30] Increased lip prominence after pendulum treatment is related to a loss of anchorage and labial incisor tipping. The dentoskeletal effects of the pendulum/K-loop appliance will be discussed elsewhere in detail, but it may be assumed here that no anchorage loss occurred as reflected by the incisors and soft tissues.[31]

Sagittal soft tissue position was not affected, except for the lower lip-E plane distance. The decrease in lower lip position relative to the E plane resulted in lower incisor retrusion due to the bite-opening effect of premolar occlusal rests during pendulum therapy. Significant soft tissue differences between the groups were found for changes in the lower lip and soft tissue B point only. A significantly greater retraction of the lower lip and soft tissue B point relative to the vertical plane was observed in the headgear group. Had the duration of cervical headgear treatment been longer (until a Class I classification existed), we expect that changes in the soft tissue profile between the groups would have been greater.

CONCLUSIONS

- The pendulum/K-loop appliance can be an efficient method for distal molar movement without resulting in any significant changes in soft tissue profile.
- No skeletal changes in the sagittal position of the maxilla or mandible were observed, and the mandibular plane angle was not affected by the pendulum/K-loop appliance.
- Cervical headgear caused a significant retrusion in skeletal, dental, and soft tissue structures.

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