Original Article

Maxillary Molar Distalization with a Bone-Anchored Pendulum Appliance

Beyza Hancıoğlu Kircelli[a]; Zafer Özgür Pektaş[b]; Cem Kircelli[c]

ABSTRACT

To obtain an effective and compliance-free molar distalization without an anchorage loss, we designed the bone-anchored pendulum appliance (BAPA). The aim of this study was to evaluate the stability of the anchoring screw, distalization of the maxillary molars, and the movement of teeth anterior to maxillary first molars. The study group comprised 10 patients (mean age 13.5 ± 1.8 years) with Class II molar relationship. A conventional pendulum appliance was modified to obtain anchorage from an intraosseous screw instead of the premolars. The screw was placed in the anterior paramedian region of the median palatal suture. Skeletal and dental changes were measured on cephalograms, and dental casts were obtained before and after distalization. A super Class I molar relationship was achieved in a mean period of 7.0 ± 1.8 months. The maxillary first molars distalized an average of 6.4 ± 1.3 mm in the region of the dental crown by tipping distally an average of 10.9° ± 2.8°. Also, the maxillary second premolar and first premolar moved distally an average of 5.4 ± 1.3 mm and 3.8 ± 1.1 mm, respectively. The premolars tipped significantly distally. No anterior incisor movement was detected. The BAPA was found to be an effective, minimally invasive, and compliance-free intraoral distalization appliance for achieving both molar and premolar distalization without any anchorage loss.

KEY WORDS: Molar distalization; Pendulum appliance; Intraosseous screw; Anchorage

INTRODUCTION

Nonextraction treatment of Angle Class II malocclusion usually requires distalization of maxillary molars. Beginning in the 1980s, intraoral appliances, such as repelling magnets,[1] superelastic NiTi coil springs,[2] pendulum,[3] Jones-jig,[4] and distal-jet,[5] have been introduced to distalize molars with minimal patient compliance.

Intraoral distalization appliances have been designed to deliver a continuous reciprocal force on the maxillary first molars. Any action to move molars distally produces a mesial reaction force on the anchoring teeth.[6] As a consequence, if the premolars or incisors (or both) are the anchoring teeth, they move mesially, the incisors protrude, and overjet increases.[1–5,7–14] However, this effect is in contradiction with the main objective of Class II treatment. Furthermore, distalized molars are questionable anchors for the retraction of premolars and incisors, despite attempts (headgears, Nance appliance etc) that have been made to maintain them in their new positions.[7,8]

Recently, researchers have tried to overcome this major problem by designing new intraoral systems involving rigid skeletal anchorage. Byloff et al[15] designed the Graz implant-supported pendulum appliance. The anchorage part of this appliance consisted of a surgical plate (15 × 10 mm) fixed with four titanium miniscrews to the palatal bone. The acrylic part of the pendulum appliance was fitted to the cylinders, soldered to the center of the surgical plate, on the basis of a telescopic principle. They used this appliance in adult patients.[16]

Keleş et al[17] used an osseointegrated palatal implant instead of a Nance button in the Keles slider appliance. Carano et al[18] introduced the distal-jet in con-

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FIGURE 1. The intraosseous screw.

junction with a miniscrew anchorage system. Karaman et al[19] and Gelgör et al[20] used an intraosseous screw with their distalization mechanics containing compressed coil springs. Both the authors used this screw as an indirect rigid anchorage; the first premolars were connected to the intraoral neck of the screw via a heavy archwire, using light-cured composite resin.

To obtain an effective and compliance-free molar distalization without anchorage loss, we designed the bone-anchored pendulum appliance (BAPA). The aim of this study was to evaluate the stability of the anchoring screw, distalization of the maxillary molars, and the movement of the anchoring teeth anterior to the maxillary first molars.

MATERIALS AND METHODS

The study group comprised 10 patients (nine female and one male; mean age 13.5 ± 1.8 years) requiring intraoral molar distalization. The selection criteria for patients included good oral hygiene, permanent dentition, Class II molar relationship with a moderate space deficiency in the maxillary dental arch, and minimal or no crowding in the mandibular arch. No other appliance was used other than BAPA during the distalization phase. All patients and parents were informed about the surgical procedure and signed a consent form.

Intraosseous screw and surgical procedure

A titanium intraosseous screw (2.0 mm diameter × 8 mm length) (IMF intermaxillary fixation screw, Stryker, Leibinger, Germany) was used as a rigid bone anchor (Figure 1). The screw was inserted in the anterior paramedian region of the median palatal suture, 7–8 mm posterior to the incisive foramen and 3–4 mm lateral to the median line (Figure 2). A 1.3-mm-diameter drill was used to maintain primary stability of the screw. In two patients, the screws were inserted bilaterally to the median palatal suture. The screw position was checked on a lateral cephalometric radiograph (Figure 3). Minimum, maximum, and mean values for the screw angulation relative to the palatal plane are shown in Table 1.

FIGURE 2. Intraoral view of screw in place.

FIGURE 3. Lateral cephalometric radiograph showing screw position.

TABLE 1. Screw Inclination Relative to Palatal Plane (Angle Between the Long Axis of the Screw and the Palatal Plane)

	N	Min	Max	Mean	SD
Screw-PP (°)	10	50	76	65	77,655

Construction of the BAPA

After soft tissue healing, impressions and stone casts were obtained with the IMF screws in place. On the stone model, the screw head was blocked out with wax, and the pendulum appliance was constructed according to Hilgers[3] descriptions, excluding the auxiliary wires that extend to the occlusal surface of the first and second premolars.

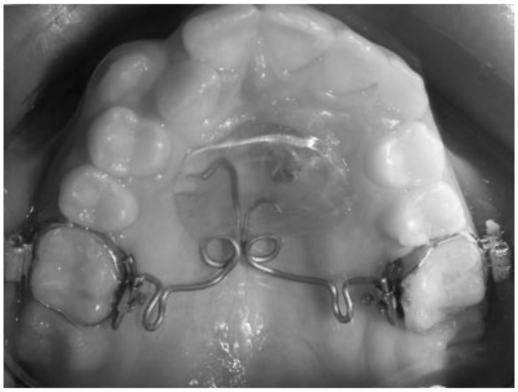

FIGURE 4. Intraoral application of bone-anchored pendulum appliance.

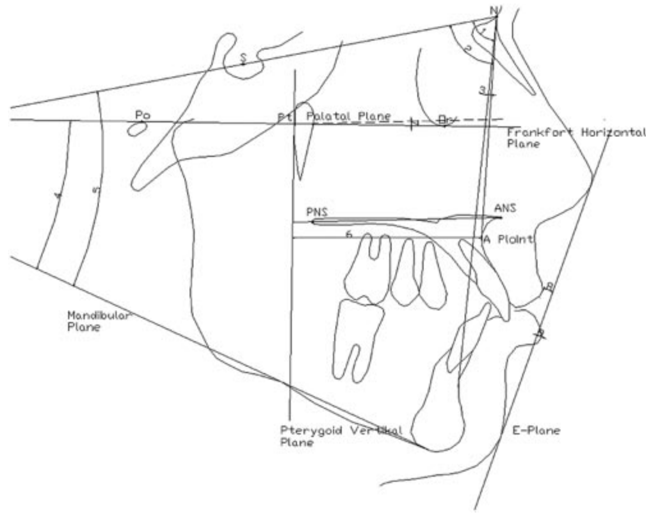

FIGURE 5. Skeletal and soft tissue measurements. (1) SNA. (2) SNB. (3) ANB. (4) FMA. (5) GoGnSn. (6) PTV-A point. (7) Palatal plane angle. (8) Upper lip to E-plane. (9) Lower lip to E-plane. PTV indicates pterygoid vertical plane.

The appliance adaptation was checked clinically, and the springs were activated parallel to the median palatal suture. The acrylic plate was connected to the screw head using cold-curing, methyl methacrylate-free acrylic resin (Ufi Gel hard, Voco GmbH, Cuxhaven, Germany). Finally, activated 0.032-inch titanium molybdenum alloy (TMA) springs (Ormco Corp, Glendora, Calif) were inserted into the lingual sheaths on the first molar bands (Figure 4).

Patients were specially educated to maintain their oral hygiene and were asked to use a mouthwash regularly. At every appointment, the soft tissue around the acrylic plate was checked. Also, the springs were reactivated if necessary.

Cephalometric and dental cast analysis

After achieving a super Class I molar relationship, a lateral cephalometric radiograph was obtained to assess dentoalveolar, skeletal, and soft tissue changes. The pterygoid vertical plane and the Frankfort horizontal plane were used as reference planes for measuring the cephalometric changes (Figures 5 and 6).

The degree of rotation of the maxillary first molars and the amount of expansion between the maxillary right and left first molars were measured on photocopies[21] of the maxillary plaster casts. On the photocopies, movements of the maxillary first molars were assessed according to the median palatal plane[22] (Figure 7).

Acquired arch lengths were also calculated from cast photocopies. The total arch length was measured as the arch perimeter from one upper first molar to the other. This measurement was over the contact points of the posterior teeth and the incisal edges of the incisors, both before treatment and after distalization. In addition, the acquired arch length in the anterior segment was calculated by measuring the arch perimeter between the mesial contact points of the first premolars. A piece of ligature wire was contoured to the line of occlusion and straightened out for the measurement.

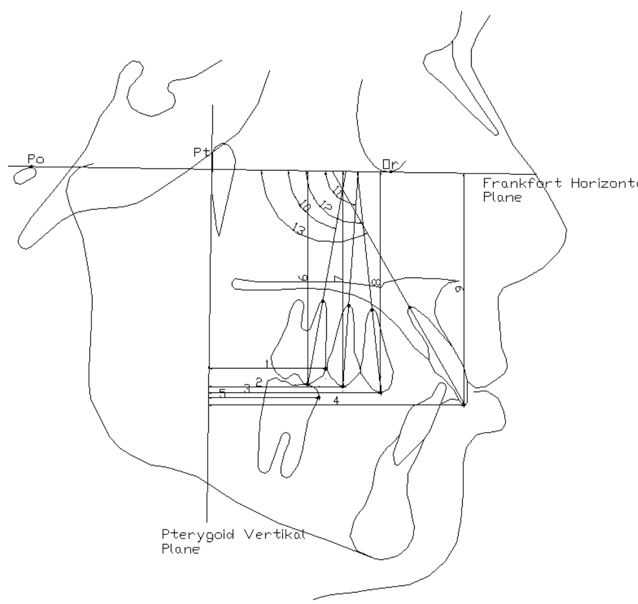

FIGURE 6. Dental linear measurements. (1) U6-PTV. (2) U5-PTV. (3) U4-PTV. (4) U1-PTV. (5) L6-PTV. (6) U6-FH. (7) U5-FH. (8) U4-FH. (9) U1-FH. Dental angular measurements. (10) U6-FH. (11) U5-FH. (12) U4-FH. (13) U1-FH. PTV indicates pterygoid vertical plane; FH, Frankfort horizontal plane.

Statistical analysis

The initial measurements were repeated after 1 week. Spearman's rho coefficients were calculated to analyze repeatability. Coefficients were found to be close to 1.00. Nonparametric Wilcoxon sign rank test

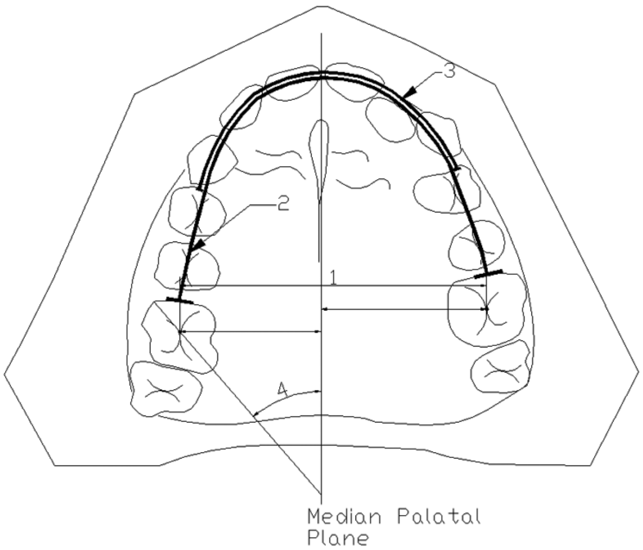

FIGURE 7. Maxillary model photocopy measurements. 1. Intermolar distance. 2. Length of total arch perimeter. 3. Length of anterior arch perimeter. 4. Maxillary first molar-Median palatal plane (°).

was used for comparison of paired values of the measurements. A probability of .05 was accepted as critical significance.

RESULTS

A super Class I molar relationship was achieved in a mean period of 7.0 ± 1.8 months. In the region of the dental crown, the maxillary first molars distalized an average of 6.4 ± 1.3 mm tipping distally, an average of 10.9° ± 2.8°. Also, the maxillary second premolar and first premolar moved distally an average of 5.4 ± 1.3 mm and 3.8 ± 1.1 mm, respectively. No anterior movement of the incisors was detected.

The mean, standard deviation, and statistical significance of the skeletal, dental, and soft tissue cephalometric changes from pretreatment to after achieving a super Class I molar relationship with BAPA are summarized in Table 2. The dental cast measurements are shown in Table 3. Figures 8 through 13 demonstrate a sample case treated with BAPA.

TABLE 2. Changes in Cephalometric Skeletal, Soft Tissue, and Dental Measurements From Pretreatment to After Distalization[a]

Measurements	Pretreatment Mean ± SD	After Distalization Mean ± SD	Difference Mean ± SD	Significance
Skeletal				
SNA (°)	78.3 ± 3.7	79.0 ± 3.9	0.7 ± 0.8*	.03
SNB (°)	74.8 ± 2.3	74.8 ± 2.3	0 ± 0.6	NS
ANB (°)	3.6 ± 2.1	4.2 ± 2.9	0.6 ± 0.9	NS
FMA (°)	29.9 ± 2.8	30.8 ± 2.5	0.9 ± 1.1*	.03
GoGnSn (°)	38.5 ± 3.1	39.4 ± 2.9	0.9 ± 1.1*	.03
PTV-A point (mm)	51.4 ± 2.9	52.0 ± 3.0	0.6 ± 0.6*	.03
PTV-B point (mm)	42.8 ± 3.8	42.6 ± 3.6	−0.2 ± 1.3	NS
PTV-palatal plane (°)	1.1 ± 2.7	1.1 ± 2.4	0 ± 1.4	NS
Soft tissue				
Upper lip to E-plane (mm)	−2.7 ± 2.3	−2.4 ± 2.4	0.3 ± 1.1	NS
Lower lip to E-plane (mm)	−1.5 ± 1.4	−1.2 ± 1.1	0.3 ± 1.0	NS
Dental-linear sagital (mm)				
Maxillary first molar-PTV	26.7 ± 2.9	20.3 ± 2.6	−6.4 ± 1.3**	.005
Maxillary second premolar-PTV	30.1 ± 3.6	24.7 ± 3.5	−5.4 ± 1.3**	.005
Maxillary first premolar-PTV	37.6 ± 3.7	33.8 ± 3.8	−3.8 ± 1.1**	.005
Maxillary incisor-PTV	54.9 ± 4.0	54.7 ± 4.1	−0.2 ± 0.7	NS
Mandibular first molar-PTV	24.0 ± 2.6	24.3 ± 2.5	0.3 ± 0.6	NS
Overjet	4.1 ± 1.1	4.4 ± 1.3	0.3 ± 0.6	NS
Dental-linear vertical (mm)				
Maxillary first molar-FH	46.5 ± 4.0	46.6 ± 4.1	0.1 ± 0.5	NS
Maxillary second premolar-FH	49.0 ± 3.0	49.1 ± 1	0.1 ± 0.6	NS
Maxillary first premolar-FH	50.2 ± 3.3	50.6 ± 3.1	0.4 ± 0.7	NS
Maxillary incisor-FH	54.5 ± 3.7	54.5 ± 3.8	0 ± 0.6	NS
Overbite	4.0 ± 2.0	3.45 ± 2.0	−0.5 ± 0.5*	.03
Dental-angular (°)				
Maxillary first molar-FH	73.0 ± 4.3	62.1 ± 5.1	−10.9 ± 2.8**	.005
Maxillary second premolar-FH	83.1 ± 5.1	66.8 ± 5.5	−16.3 ± 6.5**	.005
Maxillary first premolar-FH	91.2 ± 4.8	80.2 ± 4.4	−3.8 ± 1.1**	.005
Maxillary incisor-FH	106.6 ± 7.6	106.0 ± 8.6	−0.6 ± 1.8	NS

[a] PTV indicates pterygoid vertical plane; FH, Frankfort horizontal plane; and NS, non significant.
* $P < .05$.
** $P < .01$.

TABLE 3. Changes in Dental Cast Measurements From Pretreatment to After Distalization

Measurements	Pretreatment Mean ± SD	After Distalization Mean ± SD	Difference Mean ± SD	Significance[a]
Intermolar distance (mm)	46.6 ± 2.0	49.6 ± 2.7	3.0 ± 3.0**	.01
Length of total arch perimeter (mm)	74.9 ± 2.8	88.8 ± 5.1	13.9 ± 4.1**	.008
Length of anterior arch perimeter (mm)	46.1 ± 3.5	52.3 ± 3.8	6.2 ± 3.2***	.000
Maxillary first molar-MPP (°)	28.3 ± 6.5	32.4 ± 10.8	4.1 ± 9.0	NS

[a] NS indicates non significant.
** $P < .01$.
*** $P < .001$.

In all the patients, the 2 × 8–mm intraosseous screw remained stable during the distalization period. However, we observed a minimal rotational movement of the acrylic plate during spring reactivation, especially in patients presenting a shallow palatal vault. After experiencing this effect, we placed two screws bilaterally to mid-palatal suture in two patients.

After removing the acrylic plate, mild to moderate soft tissue irritation was detected on the palatal mucosa, but this was resolved in a few days (Figure 12). Relatively less irritation was observed in patients whose pendulums were supported with bilateral screws.

DISCUSSION

The pendulum appliance has experienced widespread clinical use,[23] and various studies have demonstrated its skeletal and dentoalveolar effects.[8–12] Invariably, the pendulum was found to be an effective appliance for distalizing maxillary molars. However, associated anterior anchorage loss, which represented 30–43% of the space created between molars and premolars, was a constant finding of these studies.

Today, rigid bone anchors including osseointegrated implants,[17,24–26] titanium miniscrews,[18–20,27–30] and miniplates[15,16] are powerful candidates to solve the anchorage concern. Elimination of the osseointegration period (2–6 months), wider range of application sites, simple surgical procedures during the insertion and removal processes, and decreased cost make intraosseous screws preferable rigid bone anchors.

Screws are attached to the bone by mechanical retention. Osseointegration is not a goal when screws are placed. However, primary stability is a prerequisite for future stability.[30,31]

In a recent study, Deguchi et al[28] placed 96 small titanium screws in eight dogs and demonstrated a successful rigid osseous fixation (97%). Huga et al[30] claimed that the bone supporting monocortical screws would most likely withstand immediate loading and support tooth-moving forces; they tested the pull-out strength of monocortical miniscrews with mechanical testing.

On the other hand, Fritz et al[29] investigated the clinical suitability of the titanium miniscrews for orthodontic anchorage purposes (predominantly used for premolar distalization, molar uprighting, and mesial movement of the molar) and reported a failure rate of 30%.

In our study, a suitable area to insert the screw was localized with respect to a computerized tomographic study in which Bernhart et al[32] indicated the area for implant placement was 6 to 9 mm posterior to the incisive foramen and 3 to 6 mm lateral to the mid-palatal suture. Moreover, Costa et al[33] reported a mean 10.57-mm bone depth in the paramedian area in the premaxilla region of the palate.

At first sight, one can assume that severe mucosal irritation might occur with the BAPA; however, the screw head in the palatal acrylic acts as a stop so that the palatal mucosa cannot be compressed. In this study, unilateral screws were applied in eight and bilateral screws in two patients. Although none of the unilateral screws had failed to withstand reciprocal forces during the distalization period, we suggest bilateral screws for eliminating both rotational movements during spring activations and diminishing soft tissue irritations. Also, bilateral screws might present more predictable results for the clinicians when using this system.

Despite the fact that all patients were strictly encouraged to maintain their oral hygiene, some plaque accumulation was evident under the acrylic plate. However, this condition did not affect the screw stability. This might be attributed to the dense, thick, and keratinized structure of the attached palatal mucosa.

The only difficulty experienced with the BAPA was detaching the acrylic plate from the screw head when removing the appliance. We used a carbide bur with an aerator under copious irrigation. As a suggestion, if the acrylic plate is made no thicker than 2 mm over the screw head and the grooves at the top of the screw are filled with a thin layer of wax, it will facilitate detaching the acrylic plate.

When the BAPA is compared with other systems, the Graz implant-supported pendulum appliance[15,16] seems convenient regarding its removable property,

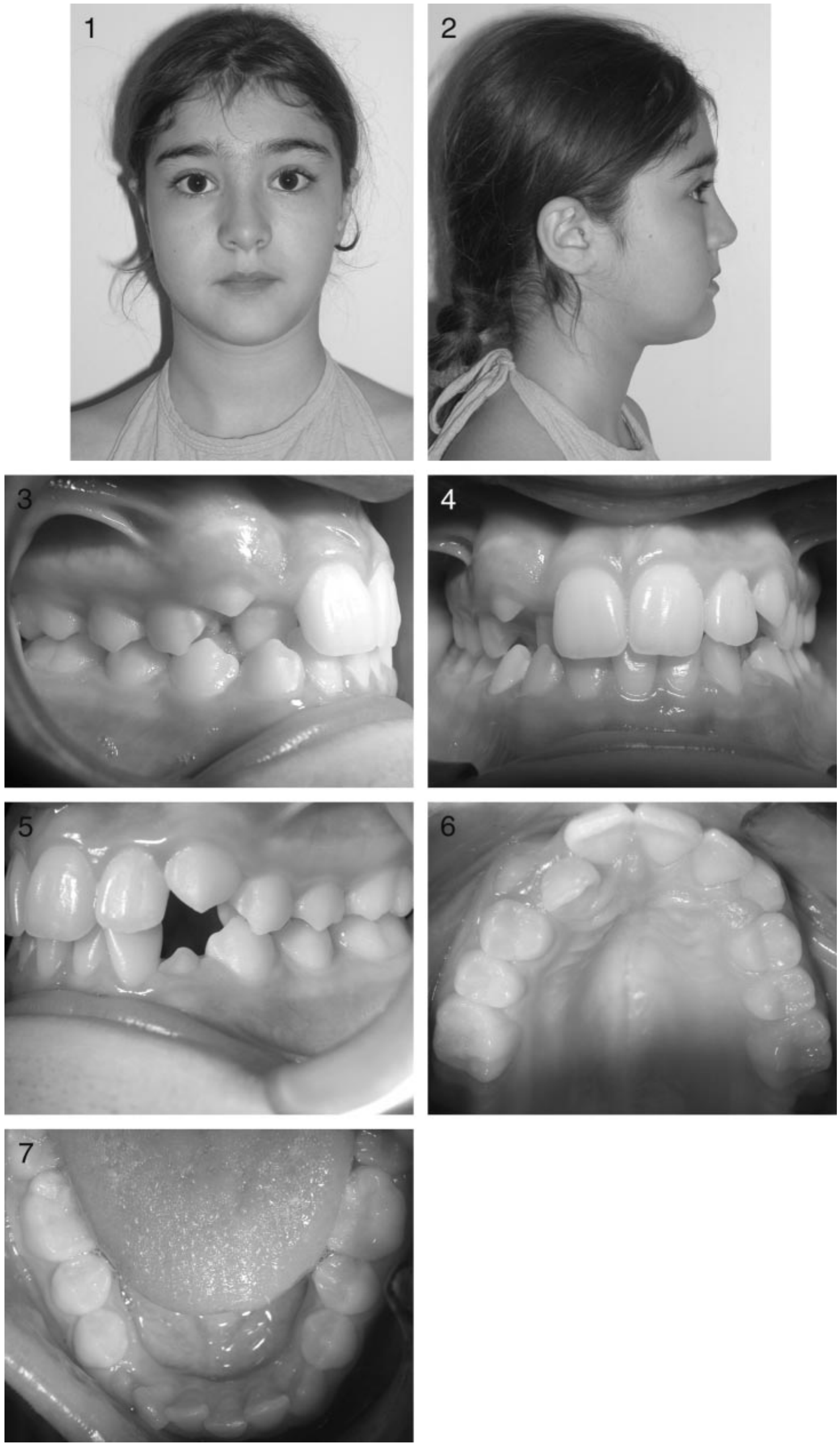

FIGURE 8. Pretreatment photographs of a 13-year-old patient.

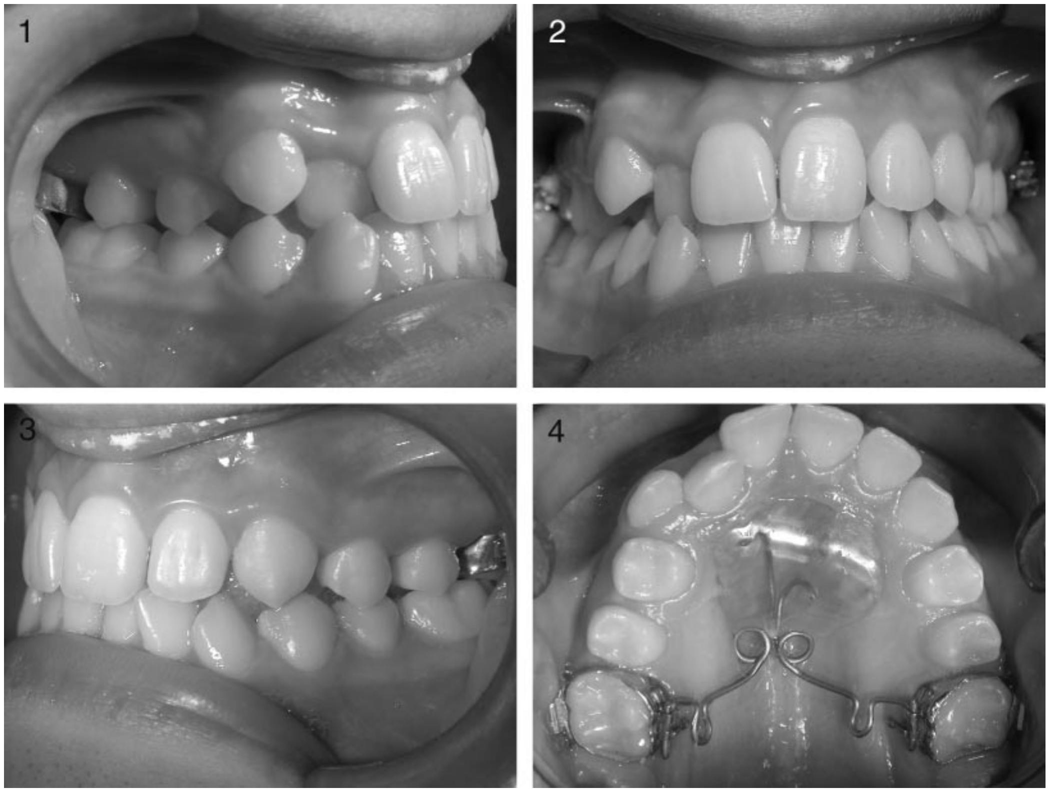

FIGURE 9. Postdistalization intraoral photographs. Note maxillary molar and premolar distalization providing adequate space for maxillary canines spontaneously.

FIGURE 10. Lateral cephalometric radiograph after distalization.

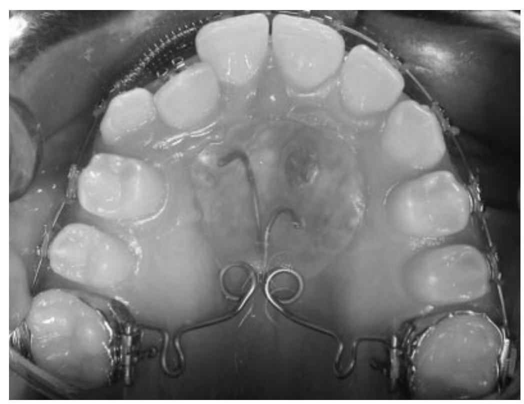

FIGURE 11. BAPA can be held in place during the full fixed therapy; thus minor activation of the springs supports the molar anchorage. BAPA indicates bone-anchored pendulum appliance.

thereby enabling activations extraorally. The pendulum appliance fixed to an osseointegrated implant[26] could present a more reliable anchorage when an uprighting bend is added to the springs. However, both systems are more invasive than applying a screw.

Maxillary molar and premolar distalization

In all patients, a super Class I molar relationship was achieved in approximately 7 months. The maxillary molars moved distally a mean of 6.4 mm and the second and first premolars drifted distally a mean of 5.4 and 3.8 mm, respectively. Because reactive forces arising from the pendulum springs were directly resisted by an intraosseous screw, the premolars were free from any attachment, and they drifted distally via transeptal fibers during the distalization period. As a result, in the study group, a Class I relationship was simultaneously achieved in the second premolars.

The mesial movement of the premolars with the con-

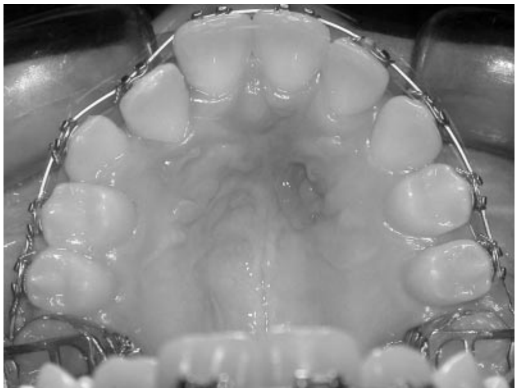

FIGURE 12. Soft tissue status immediately after the removal of BAPA. BAPA indicates bone-anchored pendulum appliance.

ventional pendulum or other intraoral distalizing appliances is a well-established finding in the literature.[1–5,7–14] However, this can also occur when distalizing molars using indirect skeletal anchorage in which reactive forces are initially resisted by premolars stabilized by a rigid anchor. Gelgör et al[20] demonstrated a slight anchorage loss in the anterior segment and attributed this effect to mesial tipping of first premolars during molar distalization. In the same manner, a 4.1 mm anterior incisor movement was reported in a study[34] where premolars were indirectly anchored to an osseointegrated palatal implant with a special abutment.

The most beneficial finding of BAPA is the simultaneous distal movement of premolars with molars. This is advantageous in several aspects. The new molar position has not been jeopardized because there is no need to retract the anterior teeth. An unnecessary anterior movement has been avoided at the premolars and incisors. Moreover, anterior crowding has been spontaneously solved out because of the stretched transeptal fibers. As a consequence, the total treatment time is shortened. In this study, after molar distalization, an average of 13.9 and 6.2 mm of space was gained in the total maxillary arch and in the anterior segment, respectively.

Distal tipping

A significant distal tipping was observed with both premolar and molar distalization. Mean tipping values for the crowns of the maxillary first molars, second premolars, and first premolars were 10.9°, 16.3°, and 3.8°, respectively.

Distalization with a tipping movement can be questioned because a quantity of space can be lost with molar uprighting when full fixed therapy is initiated.[8,14] However, in this system, there is no need to remove the appliance immediately after distalization. Thus, minor activation of the pendulum springs (terminal double back bend is eliminated) helps maintain molar position when a continuous archwire is applied to upright the molars. Also, the molar position is maintained when leveling and retracting first premolars and canines. In the present study, this so-called active anchorage concept, defined by Byloff et al,[15] coped with the anchorage concern of the distalized molars.

On the other hand, overcorrection of the molar relationship is another goal that taxes molar anchorage[20] during full fixed therapy, especially if distal tipping exists. Again, a problem appears for the conventional intraoral distalization appliances because the amount of distal movement correlates with the amount of anchorage loss.[8] In this context, one can use the BAPA to freely move the molars to a super Class I relationship without considering anchorage loss.

Skeletal and soft tissue effects

- In this study, the cant of the palatal plane remained unchanged and the mandibular plane rotated by 0.9° in a clockwise direction. This agrees with the results demonstrated by other studies with the conventional pendulum.[8,10] This clockwise rotation can be attributed to the maxillary molars moving distally into the wedge of occlusion and to the cusp interferences. Although it is clinically negligible, point A moved anteriorly by 0.6 mm. This effect might be remodeling because of reciprocal forces affecting the anterior palate. No significant difference was observed regarding the upper and lower lip positions relative to the esthetic line. Conversely, protrusion is a result of the action of a conventional pendulum.[8,10] However, future studies with greater sample size would permit more reliable statements to be made regarding the clinical success of the BAPA.

CONCLUSIONS

- Molar distalization, as well as premolar distalization, was achieved with BAPA without any anchorage loss.
- Besides the space gained in the posterior segment, a quantity of space was also gained in anterior segment, and spontaneous alignment of anterior crowding was achieved during molar distalization.
- In this study, the BAPA presented an effective and minimally invasive, compliance-free alternative for intraoral molar distalization in nonextraction Class II treatment.

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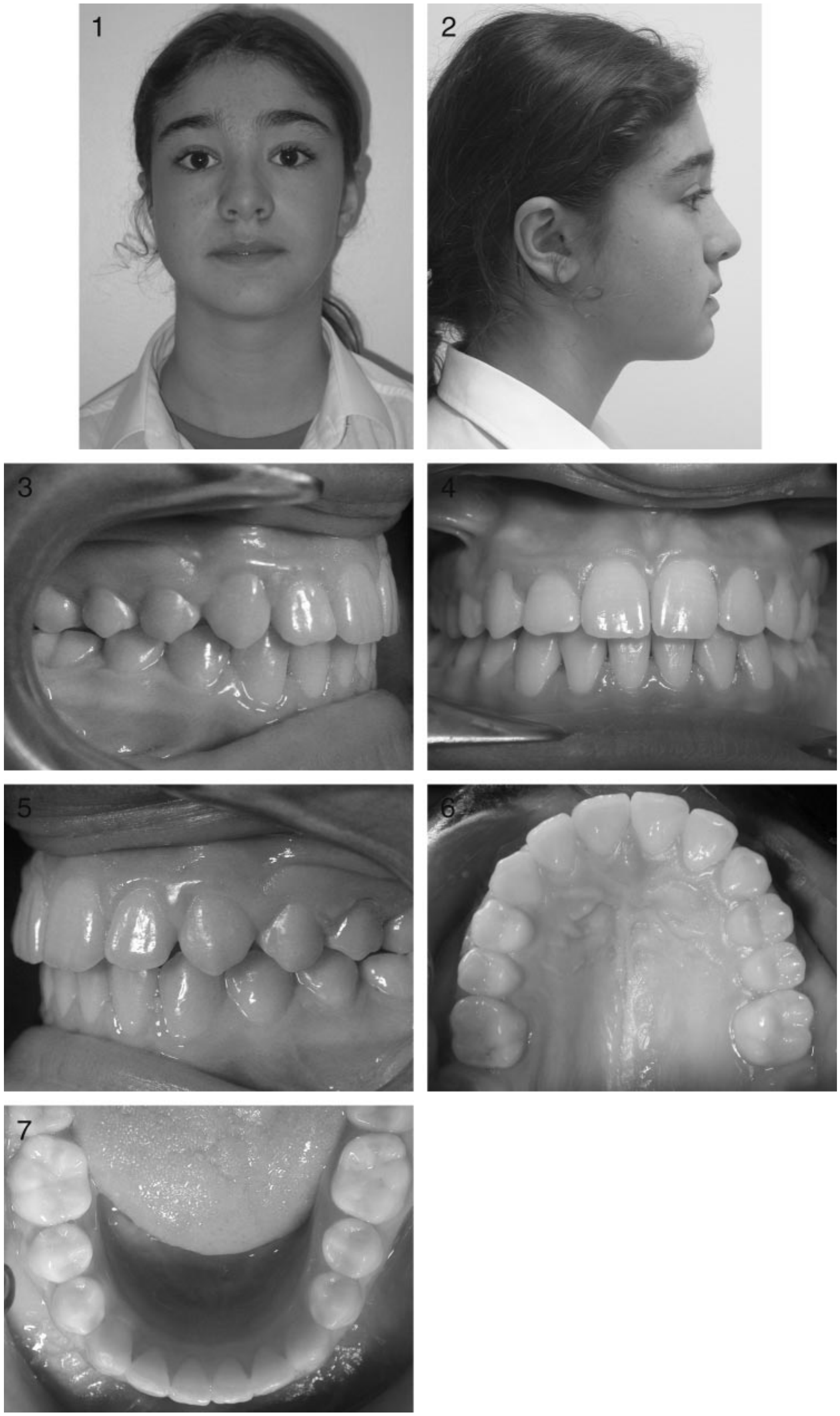

FIGURE 13. Posttreatment photographs.

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