Effects of a segmented removable appliance in molar distalization

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SUMMARY The aim of the present investigation was to evaluate the skeletal and dentoalveolar treatment effects of a segmented removable appliance [removable molar distalizer (RMD)] for molar distalization. The study was conducted on 28 patients (12 females and 16 males), with a mean age of 11.8 years. All presented with a skeletal Class I malocclusion and a bilateral dental Class II molar relationship. The pre- and post-distalization records included lateral head films, study models and standard photographs. The findings were evaluated with a paired samples *t*-test.

The average maxillary first molar distalization with the RMD was 3.98 mm, with 4.61 degrees of distal tipping. The maxillary second premolars drifted distally 2.13 mm on average with 1.54 degrees of distal tipping, while the maxillary first premolars showed 1.23 mm of mesial movement and 1.98 degrees of mesial tipping. The incisors protruded 1.09 mm with 1.27 degrees of labial tipping. The RMD was effective in distal molar movement and all patients attained a bilateral Class I molar relationship in an average period of 4.5 months. Hygiene problems and mucosal irritations, frequently found with fixed intraoral distalization techniques, were not observed during the distalization period.

Introduction

The treatment effects of extraoral forces in the correction of Class II malocclusions are well known. Although headgear use is usually inevitable in subjects with maxillary excess, co-operation problems seem to be a challenge for orthodontists (Clemmer and Hayes, 1979; El-Mangoury, 1981; Lima Filho *et al.*, 2003).

Since the use of headgear and removable appliances require considerable patient co-operation to be effective in correcting the molar relationship, research has been carried out to develop various non-compliance intraoral molar distalization methods. These treatment modalities, which have proved to be effective in subjects with a dental Class II malocclusion with mild to moderate space deficiency in the upper dental arch, include repelling magnets, Ni–Ti coil springs, molar distalizing bow (MDB), Ni–Ti wires, sectional jig assembly, pendulum appliance, Herbst, fixed piston, K-loop, distal jet appliances, bimetric maxillary distalizing arch and intraoral bodily molar distalizer (IBMD) (Gianelly *et al.*, 1988, 1997; Jeckel and Rakosi, 1991; Bondemark and Kurol, 1992; Locatelli *et al.*, 1992; Muse *et al.*, 1993; Johnson, 1994; Kalra 1995; Gulati *et al.*, 1998; Runge *et al.*, 1999; Bondemark, 2000; Brickman *et al.*, 2000; Haydar and Üner, 2000; Keleş and Sayınsu, 2000; Üçem *et al.*, 2000; Bolla *et al.*, 2002; Burkhardt *et al.*, 2003).

It has been demonstrated that the maxillary molars can be distalized with the above appliances in a short period of time with continuous force, regardless of patient co-operation. However, compared with other distalization methods, the Jones jig and pendulum appliances have become increasingly popular over the last 10 years. Mesial movement of the anchor unit and an increase in the overbite, patient discomfort and soft tissue irritation seem to be the disadvantages of these techniques (Bondemark, 2000; Keleş and Sayınsu, 2000; Burkhardt *et al.*, 2003).

Ghosh and Nanda (1996) and Keleş and Sayınsu (2000) suggested in their studies that anchorage loss could possibly be reduced if the anchor unit was adequately reinforced by full palatal coverage. The removable molar distilizer (RMD) is a segmented removable appliance which includes two parallel arches between the segments, and exerts a continuous force to the maxillary molars via compressing Ni–Ti open coil springs placed over the arches. The purpose of this study was to determine the skeletal and dentoalveolar effects of the RMD in maxillary first molar distalization and to introduce the appliance to clinical orthodontics.

Subjects and methods

The research was carried out according to the guidelines of the Human Treatment and Research Protocol of Gulhane Military Medical Academy Ethics Committee. The present study comprised 31 patients at the beginning of treatment; however, one declined treatment during the distalization period. All patients were instructed to keep a discomfort diary for 14 days, starting from the evening of insertion. The recall session at which the diaries were collected for evaluation was three weeks after insertion of the appliance. When assessing compliance, such as appointment keeping, oral hygiene habits, and appliance maintenance, it was found that two patients were unco-operative. These three

patients were excluded and the study was undertaken on the remaining 28 patients.

The study group comprised 12 females and 16 males with a mean age of 11.8 years. In 13 subjects the maxillary second molars were unerupted while in the remaining 15 the second molars were partly or completely erupted. The criteria in patient selection were:

1. Skeletal Class I and bilateral dental Class II malocclusion;
2. A normal or sagittally directed growth pattern;
3. Adequate transverse dimension in the maxillary dental arch;
4. Minimal or no space deficiency in the mandibular dental arch;
5. Molar crowns with adequate buccal undercuts and/or high clinical crown length.

The RMD consisted of one anterior and two posterior (molar) segments. The appliance exerted a continuous force to the maxillary first molars via Ni–Ti open coil springs (Ø 1 mm) compressed between the anterior and molar segments applying an initial force of 225 g. The maxillary first molars were distalized with the RMD, and lateral cephalograms, study models and clinical photographs of all the patients were taken before and after distalization.

Appliance construction

An upper study model was obtained and two palatal arches (Ø 0.9 mm), extending from the posterior border of the model to the opposite side, were constructed parallel to each other. The distance between the arches was 5 mm (Figure 1A). Four tubes, 1 mm in diameter and 0.8 mm in length, were fixed on the arches, so that the mesial margins of the tubes were at the level of the contact points of the second premolars and first molars (Figure 1B). The arches were coated with modelling wax from the mesial margins of the tubes to the level of the contact points of the lateral incisors and canines, as consistently and uniformly as possible (approximately 1.5 mm in diameter), and fixed on the model 1 mm above the palatal mucosa (Figure 1C). Adams' clasps (Ø 0.8 mm) were bent for the first premolars and molars, after the mesial and distal gingival margins of these teeth were scraped with a spatula to reinforce retention of the appliance. The clasps and a vestibular arch (Ø 0.7 mm) were also fixed on the model and the appliance was finished with self-cured orthodontic acrylic. After rough trimming, the acrylic plate covering the molar region was separated bilaterally from the anterior segment leaving the tubes in the molar segments (Figures 1D, E). The wax around the palatal arches was removed with boiling water and each segment was trimmed and polished. The palatal surfaces of the molar segments were also trimmed and polished to minimize mucosal friction. Four pieces of Ni–Ti open coil springs were placed over the palatal arches and inserted

through the empty space of the modelling wax (Figure 1F). The open coil springs were compressed by finger pressure and palatal arches were inserted through the tubes of the molar segments. The molar segments were pulled back with a gauge (006–013–00; Dentaurum, Pforzheim, Germany) until they were in contact with the anterior segment, and the force was measured. The springs were arranged until 225 g of initial force was exerted to each molar segment. The plate covering the embrasure between the second premolars and molars was blocked out. Finally, the arches were shortened and the distal ends were bent towards the palatal mucosa to prevent mucosal irritation (Figure 2).

Clinical management

The distal ends of the arches were controlled in the mouth for additional readjustments. Premolar clasps were seated in place and the patients were instructed to pull the molar segments mesially and press them on the maxillary first molars until the molar clasps were seated. They were advised to wear the appliance all the time, except during meals and were seen once every three weeks. The RMD was reactivated by replacing the pressure springs with longer ones if there was a reduction in force. The maxillary first molars were distalized until a bilateral Class I molar relationship was attained. The distalization period was 4.57 ± 1.29 months. A 'Quick Nance' (Hilgers, 1992) was used for the stabilization of the maxillary first molars, and orthodontic treatment was then carried out with edgewise mechanics. The intraoral photographs and study models of two patients are presented in Figures 3 and 4.

Cephalometric evaluation

Lateral cephalograms were obtained of all patients before treatment and at the end of the distalization period with standardized settings. Radiography was performed with the Frankfort horizontal (FH) plane parallel to the floor. The radiographs were traced by one author (EA) with verification of anatomic outlines and landmarks by the other two authors. The structures in question were retraced to the mutual satisfaction of the investigators. A single average tracing was made when bilateral structures were identified. In the few subjects with erupted second primary molars, the vertical distance of these teeth to the FH was measured. Nine patients without second primary molars and with second premolars below occlusal level, were excluded from the statistical evaluation of the U5–FH parameter. Twenty-four landmarks and 25 parameters were used in the study (Figure 5). The parameters were measured by each investigator, twice, at different times to eliminate measurement errors, and the mean findings were statistically evaluated. The treatment effects were determined by superimposing the maxilla on the palatal plane (Figure 6).
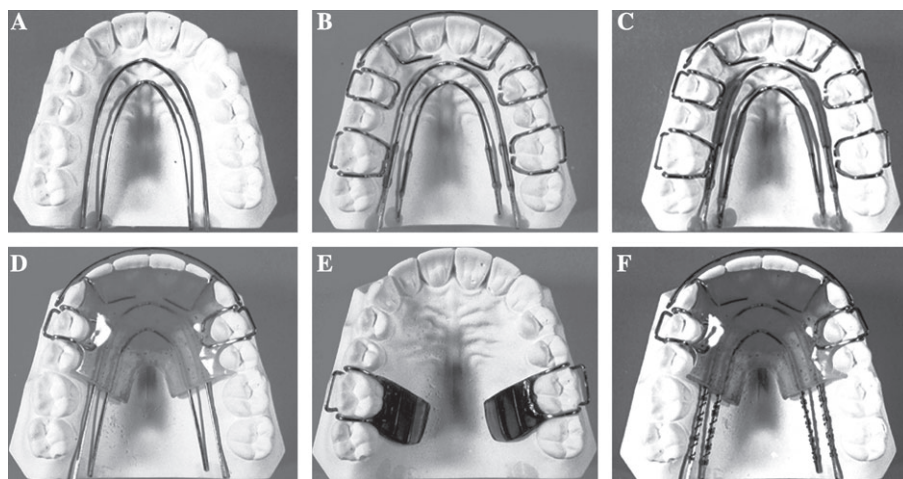
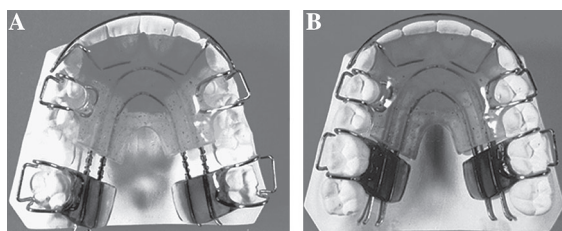**Figure 1** Fabrication steps of the removable molar distalization appliance.

Figure 2 Passive (A) and active (B) forms of the appliance on the study model.

Study model analysis

Model analysis was performed to determine the transverse and rotational changes of the maxillary first molars. Central pits (CP–CPi), mesiobuccal (MB–MBi) and distopalatal (DP–DPi) cusp tips of the molars as described by Wheeler (1965) were defined with a pencil on the model. The transverse changes were determined by measuring the distance between the central pits of the right and left first molars, and rotations by measuring the distances between the mesiobuccal and distopalatal cusp tips of the first molars (Figure 7).

Statistical method

Statistical analyses were performed using the SPSS statistical package (SPSS Inc., Chicago, Illinois, USA) and the results were shown as the mean ± standard deviation. Thirteen randomly selected cephalograms and study models were remeasured one month later by the same investigator and the casual error (Dahlberg's formula) of the method did not exceed 0.75 degrees or 0.53 mm (Dahlberg, 1940). After the data was analysed to establish if the variables were suitable for parametric tests, the differences between the two measurements were evaluated with a paired-samples *t*-test. Difference in first molar movement between the patients with erupted and those with unerupted second molars was determined using an independent-samples *t*-test. *P* values less than or equal to 0.05 were considered statistically significant.

Results

Evaluation of the differences between the skeletal parameters showed that the mandibular plane angle, *Y*-axis angle and anterior face height increased by 0.59 degrees, 1.02 degrees and 0.98 mm, respectively, while SNB angle decreased by 0.27 degrees (Table 1).

The maxillary first molars were distalized 3.98 mm and extruded 0.82 mm, on average, with distal tipping of 4.61 degrees. A mean of 2.13 mm distalization with 0.45 mm of extrusion and 1.54 degrees of distal tipping was found for the maxillary second premolars. Conversely, the maxillary first premolars moved forwards 1.23 mm, were extruded 0.73 mm and tipped 1.98 degrees mesially. Protrusion of 1.09 mm and incisor proclination of 1.27 degrees were observed. Finally, the overjet and occlusal plane angle were increased on average by 1.13 mm and 0.13 degrees, respectively (Table 1).

Distal molar movement (*P* < 0.012) and tipping (*P* < 0.034) were significantly greater in the patients with unerupted second molars (Table 2).

Study model evaluation demonstrated significant maxillary transverse changes. The intermolar width increased by 1.86 mm, and the distances between the cusp tips (MB–MBi and DP–DPi) were both increased. However, the increase between the distopalatal cusp tips of the first molars was significantly greater (Table 3).

Discussion

It is known that removable appliances with active springs may pose problems in patient co-operation due to easy dislodgement, especially in subjects with short clinical
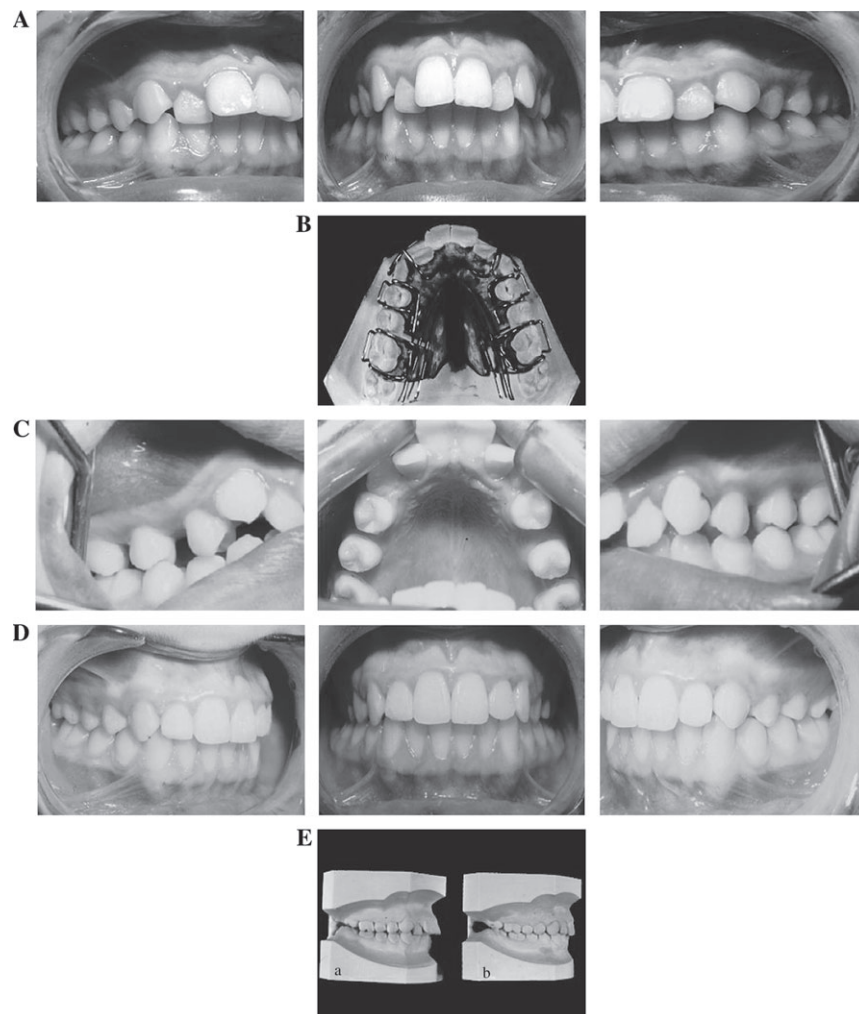
Figure 3 Intraoral photographs of patient 1 before distalization (A). The removable molar distalizer on the study model (B). Intraoral photographs after distalization (C). Intraoral photographs at the end of the orthodontic treatment (D). Study models before treatment (a) and after distalization (b) (E).

crown lengths. Because this was also supported by previous clinical experience with the RMD, normal or long posterior crown length was one criterion in patient selection. Stability of the RMD was satisfactory in nearly all of the patients; however, a bite plane, not exceeding the freeway space, was incorporated for some of the subjects to increase retention of the appliance when the buccal undercuts on the molar crowns were inadequate. Bite planes were also used to utilize the anchorage loss in the resolution of anterior crossbite in six of the patients. 'Z'-springs were used to correct the incisor position in these patients but they were not activated until the end of the distalization period. Reactivation of the pressure springs using stops would also be conceivable; however, replacement of the springs with longer ones was found more practical.

The force for distalizing the maxillary molars varied between 70 and 250 g. Considering the increased palatal coverage and additional incisor anchorage of the RMD, an initial force of 225 g, which was closer to the upper limit, was used in this study. The maxillary first molars were distalized efficiently with the RMD in an average of 4.5 months. Mucosal irritation was not observed, which is more or less a common finding for the Nance button or modified palatal appliances used for anchorage in the majority of intraoral distalization methods (Gianelly *et al*., 1989; Ghosh and Nanda, 1996; Keleş and Sayınsu, 2000).

Sergl *et al*. (1998) found that the severity of pain and discomfort experienced by patients wearing functional and fixed appliances was significantly more than in those treated with upper and/or lower removable plates. Miyawaki *et al*. (1999) also reported tongue soreness, and difficulties in chewing fibrous food, pronouncing the 't' and 's' sounds and tooth brushing in subjects undergoing fixed lingual orthodontic treatment. Since the RMD is a removable appliance, difficulties in chewing food and oral hygiene problems were not observed among the patients; however,
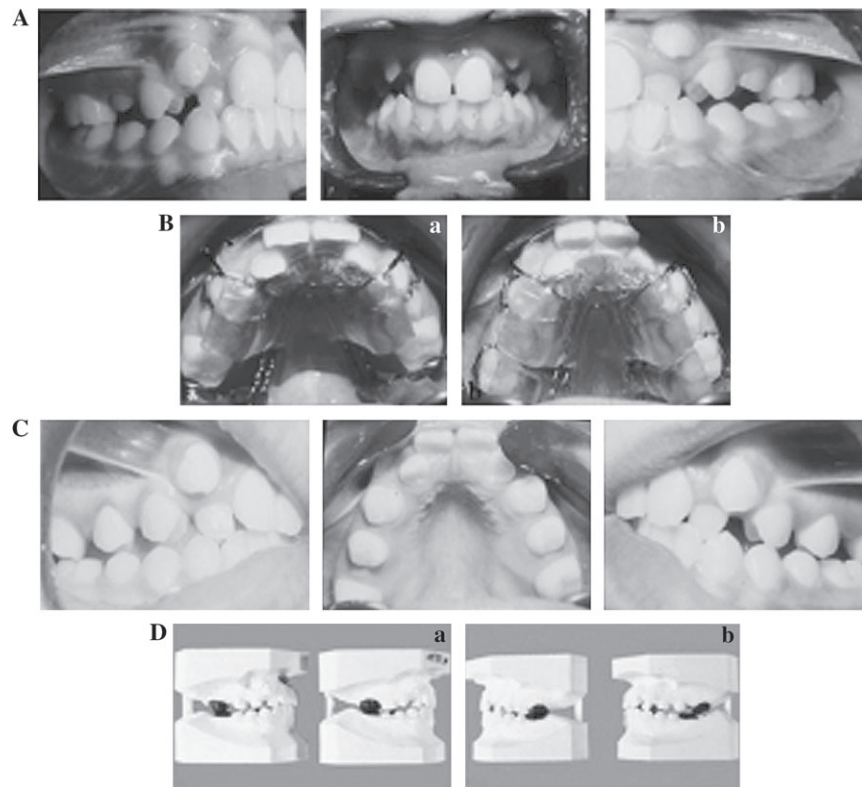
Figure 4 Intraoral photographs of patient 2 before distalization (A). Passive (a) and active (b) forms of the removable molar distalizer in the mouth (B). Intraoral photographs after distalization (C). Study models before treatment (a) and after molar distalization (b) (D).

discomfort and speech difficulties were common in the majority of them.

There is no concept in the prediction of patient compliance but Bartsch *et al*. (1993) and El-Mangoury (1981) suggested that psychological tests and clinical information would be useful for this purpose. The use of the RMD needed some manual ability at the beginning but clinical observations demonstrated that it was not difficult for the patients to become accustomed to the appliance. The force type of the RMD is 'intermittent', as in conventional screw or spring-type removable appliances. However, the distalization period seems to be shorter than with screw-type plates. Unfortunately, a comprehensive removable appliance study dealing with molar distalization was not found in the literature, so the results of this investigation were only compared with non-compliance methods.

The findings revealed 3.98 mm of maxillary first molar distalization with 4.61 degrees of distal tipping. The degree of the tipping was noticeable despite application of the force being close to the centre of resistance of the molar. These findings are similar to the results of other contemporary techniques (Gianelly *et al*., 1989; Jeckel and Rakosi, 1991; Locatelli *et al*., 1992; Gulati *et al*., 1998; Runge *et al*., 1999; Bondemark, 2000). A review of the literature shows that tipping of the molars is greater with the pendulum appliance

than with other methods (Ghosh and Nanda, 1996; Byloff and Darendeliler, 1997; Byloff *et al*., 1997; Bussick and McNamara, 2000).

Byloff *et al*. (1997) reported that a pendulum appliance with root uprighting activations reduced molar tipping; however, this led to increased anchorage loss and treatment time. Using an IBMD, Keleş and Sayınsu (2000) demonstrated 5.23 mm of distal bodily movement of molars without distal tipping or extrusion, but the increased anchorage loss due to parallel movement was similar to the findings of Byloff *et al*. (1997).

Jeckel and Rakosi (1991), Runge *et al*. (1999), Brickman *et al*. (2000) and Ghosh and Nanda (1996) did not observe vertical changes in the maxillary molars. However, an extrusion of 0.82 mm was found in the maxillary molars with the RMD, coinciding with the findings of Haydar and Üner (2000) and Bolla *et al*. (2002). In contrast, significant intrusion of the maxillary molars was observed with the pendulum appliance (Byloff and Darendeliler, 1997; Byloff *et al*., 1997; Bussick and McNamara, 2000).

Distal movement and tipping of the maxillary first molars was significantly greater in the 13 patients who did not have erupted maxillary second molars when compared with those whose second molars were erupted. Although this was contrary to Muse *et al*. (1993) and Ghosh and Nanda (1996),
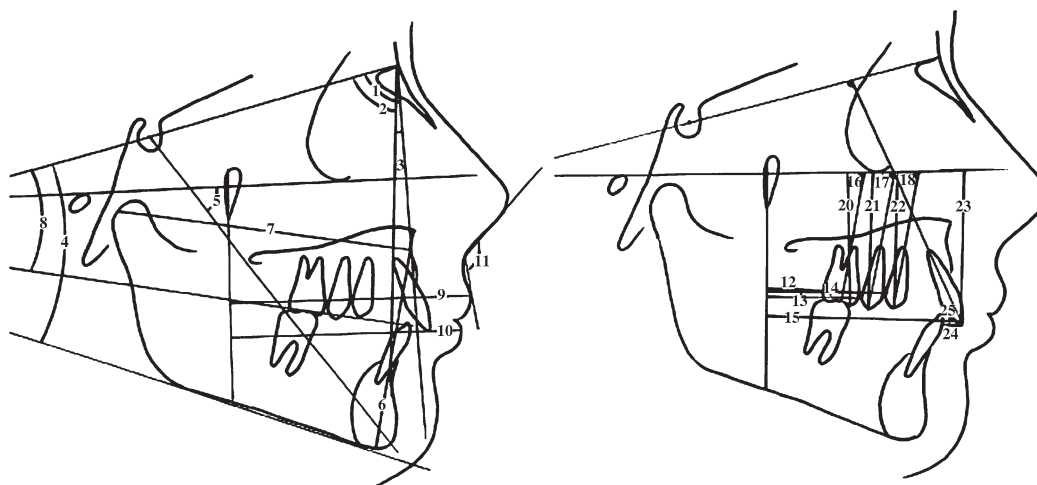
Figure 5 Skeletal, dentoalveolar and soft tissue measurements used in the lateral cephalometric analysis. (1) SNA, (2) SNB, (3) ANB, (4) MP angle, (5) Y-axis angle, (6) ANS–Me, (7) Co–A, (8) OP angle, (9) PtV–Ls: the perpendicular distance of the anterior point of the upper lip to PtV, (10) PtV–Li, (11) nasolabial angle, (12) U6–PtV: the perpendicular distance of the distal point of the maxillary first molar to pyterigoid vertical, (13) U5–PtV, (14) U4–PtV, (15) U1–PtV, (16) U6/FH: the distal angle between the long axis of the maxillary first molar and FH, (17) U5/FH, (18) U4/FH, (19) U1/FH, (20) U6–FH: the perpendicular distance of the maxillary first molar to FH, (21) U5–FH, (22) U4–FH, (23) U1–FH, (24) overjet, (25) overbite.
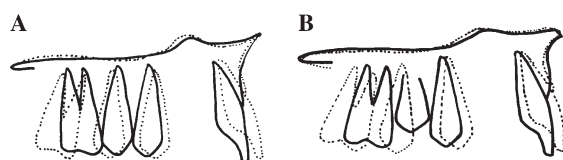

Figure 6 Cephalometric superimpositions of the patients 1 (A) and 2 (B) at the palatal plane before (-) and after (..) distalization.

Figure 7 Measurements used in the study model analysis. MB, mesiobuccal; CP, cusp tip; DP, distopalatal.

the findings of Jeckel and Rakosi (1991) and Gianelly *et al.* (1997) support these results. On the other hand, Bolla *et al.* (2002) also reported that tipping movement of the first molars was significantly more when second molars were unerupted. However, those authors did not find any difference in the mean distalization between patients with erupted or unerupted second molars.

Study model evaluation demonstrated that the transverse width at the maxillary first molars increased by 1.86 mm, which was accompanied by a distobuccal rotation. This has been reported to be an undesired molar rotation in the correction of Class II malocclusions which was also found with the distal jet appliance (Lemons and Holmes, 1961; Bolla *et al.*, 2002).

Expansion of the first molars during distal movement is a treatment objective to prevent the development of a posterior crossbite and was similar to the findings in nearly all previous studies. However, a favourable distopalatal molar rotation was noted when using repelling magnets, the Jones jig and pendulum appliance (Bondemark and Kurol, 1992; Hilgers, 1992; Ghosh and Nanda, 1996; Gulati *et al.*, 1998). On the other hand, Keleş and Sayınsu (2000) did not observe any transverse changes at the maxillary first molars with the IBMD appliance.
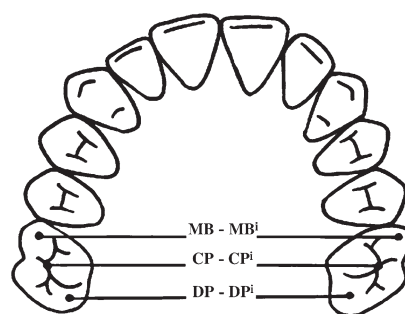
The maxillary second premolars drifted distally (2.13 mm), were distally tipped (1.54 degrees) and extruded (0.45 mm). This headgear effect was due to the transseptal fibres between the first molars and second premolars and it was a favourable finding since subsequent distalization of these teeth would be easier. The reported treatment effects of the Jones jig, pendulum appliance, repelling magnets and Ni–Ti coils were contrary to the present finding as an inevitable result of the appliance design (Byloff *et al.*, 1997; Byloff and Darendeliler, 1997; Runge *et al.*, 1999; Bondemark, 2000; Bussick and McNamara, 2000; Haydar and Üner, 2000). However, they were similar to the findings of Bolla *et al.* (2002) who used the distal jet appliance for maxillary molar distalization.

Mesial movement of the anchor unit is also a common finding of intraoral distalization techniques and anchorage loss of 1 to 4.33 mm has been reported in the above-mentioned studies. Despite the anchorage loss, the first premolars were tipped distally with the distal jet due to the

Table 1 Descriptive statistics and mean and standard deviation of the cephalometric measurements before (T1) and after (T2) distalization.

Measurements	T1 $n = 28$		T2 $n = 28$		ΔT1–T2		Significance
	Mean	SD	Mean	SD	Mean	SD	
Skeletal							
SNA (°)	80.54	2.11	80.34	2.10	0.20	0.53	ns
SNB (°)	77.63	2.14	77.36	2.24	0.27	0.57	*
ANB (°)	2.91	0.84	2.98	0.96	−0.07	0.87	ns
MP (°)	34.32	2.59	34.91	2.70	−0.59	0.81	***
Y-axis (°)	65.89	3.54	66.91	3.84	−1.02	1.06	***
ANS–Me (mm)	66.04	3.03	67.02	3.05	−0.98	0.65	***
Co-A (mm)	85.71	2.92	85.84	2.88	−0.13	0.52	ns
Dentoalveolar							
PtV–U6 (mm)	15.61	1.72	11.63	1.98	3.98	0.95	***
PtV–U5 (mm)	25.02	1.90	22.89	2.13	2.13	0.90	***
PtV–U4 (mm)	31.77	1.82	33.00	1.81	−1.23	0.50	***
PtV–U1 (mm)	55.98	2.20	57.07	2.19	−1.09	0.39	***
FH/U6 (°)	73.71	3.19	68.11	3.95	4.61	1.42	***
FH/U5 (°)	80.61	3.59	79.07	3.83	1.54	094	***
FH/U4 (°)	82.30	3.13	84.29	3.18	−1.98	0.84	***
SN/U1 (°)	103.11	2.77	104.38	2.94	−1.27	0.55	***
FH–U6 (mm)	44.55	2.04	45.38	2.26	−0.82	0.70	***
FH–U5 (mm)	45.00	2.04	45.45	2.18	−0.45	0.67	**
FH–U4 (mm)	45.71	2.04	46.45	2.29	−0.73	0.62	***
FH–U1 (mm)	51.84	2.14	51.91	2.13	−0.07	0.69	ns
SN/Occ. (°)	19.39	2.09	19.52	2.05	−0.13	0.26	*
Interdental							
Overjet (mm)	1.66	0.96	2.79	1.04	−1.13	0.35	***
Overbite (mm)	2.30	0.86	2.16	1.00	0.14	0.49	ns
Soft tissue							
PtV–Ls	70.50	2.04	70.68	2.03	−0.18	0.53	ns
PtV–Li	68.93	1.97	69.05	1.94	−0.13	0.50	ns
Nasolabial (°)	102.75	3.06	102.95	2.84	−0.20	0.61	ns

$*P < 0.05$; $**P < 0.01$; $***P < 0.001$. ns, not significant.

design of the appliance. The reported anchorage loss in the study of Keleş and Sayınsu (2000) was considerably more than with the other treatment techniques because of the resistance of the maxillary molars to parallel movement. In the present study, mesial movement of the maxillary first premolars was 1.23 mm on average. This was accompanied by 1.98 degrees of mesial tipping. The anchorage loss was nearly 30 which was similar to those of Gulati *et al*. (1998) and Brickman *et al*. (2000).

The anchorage loss in four of the patients was not considered as clinically important and this was related to increased palatal coverage and incisor anchorage of the RMD. On the other hand, maxillary first premolars and other teeth can be distalized with headgear therapy, and such treatment has a considerable advantage over intraoral distalization methods (Weislander, 1975; Triftshauser and Walters, 1976). Üçem *et al*. (2000) also observed distal drift of the maxillary premolars and canines with the bimetric distalizing arch and mentioned this as the most significant finding of their study.

It has been shown in previous investigations that the incisors are proclined, retracted, intruded, or extruded with intraoral distalization methods, depending on the technique and force mechanics (Muse *et al*., 1993; Byloff and Darendeliler, 1997; Gulati *et al*., 1998; Bondemark, 2000; Haydar and Üner, 2000; Keleş and Sayınsu, 2000; Üçem *et al*., 2000). In the present study, the maxillary incisors were protruded 1.09 mm and showed 1.27 degrees of labial tipping. However, contrary to the findings of Ghosh and Nanda (1996), Gulati *et al*. (1998) and Haydar and Üner (2000), vertical change was not significant. The findings were also contrary to those of Runge *et al*. (1999) and Bolla *et al*. (2002) who observed that incisor position was not significantly affected by the Jones jig or distal jet appliances.

The second and first premolars were extruded 0.45 mm and 0.73 mm, respectively. Extrusion of the second premolars was similar to the findings of Bolla *et al*. (2002) and extrusion of the first premolars with the results of Ghosh and Nanda (1996), Brickman *et al*. (2000), Byloff and Darendeliler (1997), Byloff *et al*. (1997), Bussick and McNamara (2000), and Keleş and Sayınsu (2000). However, Runge *et al*. (1999) and Bolla *et al*. (2002) did not find significant vertical changes in the anchor teeth. Contrary to the present findings, Haydar and Üner (2000) observed intrusion of the second premolars with the Jones jig. Dentoalveolar changes resulted in an increase in the overjet

Table 2   The mean and standard deviation (SD) of maxillary first molar movement in the patients with unerupted and erupted maxillary second molars, and the difference between the groups.

Movement	Erupted $n = 15$		Unerupted $n = 13$		Difference		Significance
	Mean	SD	Mean	SD	Mean	SD	
Distalization	4.47	0.95	3.57	0.75	0.90	0.33	*
Tipping	5.23	1.55	4.07	1.08	1.16	0.51	*

*$P < 0.05$.

Table 3   Descriptive statistics and mean and standard deviation for the study model measurements before and after distalization.

Measurements	Before distalization		After distalization		Difference		Significance
	Mean	SD	Mean	SD	Mean	SD	
Central pits of the maxillary first molars (mm)	50.50	4.11	52.36	4.31	−1.86	0.74	***
Mesiobuccal cusp tips of the maxillary first molars (mm)	53.54	3.97	54.80	4.33	−1.27	1.14	***
Distopalatal cusp tips of the maxillary first molars (mm)	47.39	4.10	49.68	4.00	−2.29	1.08	***

***$P < 0.001$.

(1.13 mm) as reported for the majority of non-compliance techniques (Gulati *et al*., 1998; Runge *et al*., 1999; Bondemark, 2000; Brickman *et al*., 2000; Bussick and McNamara, 2000). A mild increase was also observed at the occlusal plane angle.

When the skeletal differences were evaluated, the mandibular plane angle, Y-axis angles and lower anterior face height were increased by 0.59 degrees, 1.02 degrees and 0.98 mm, respectively. SNB angle decreased by 0.27 degrees. Similar findings, indicating a counterclockwise rotation of the mandible, were also observed by Bondemark (2000), Runge *et al*. (1999), Ghosh and Nanda (1996), Bussick and McNamara (2000), and Keleş and Sayınsu (2000). These skeletal changes could be related to extrusion of the posterior teeth and cuspal interferences. However, in their study with the distal jet appliance, Bolla *et al*. (2002) mentioned that the mandibular plane angle remained approximately the same during molar distalization. Soft tissue changes may be attributed to anchorage loss and incisor tipping and this has frequently been seen in non-compliance distalization methods (Bussick and McNamara, 2000; Muse *et al*., 1993). The findings in the present study showed that the soft tissues were not affected significantly by molar distalization, in agreement with Runge *et al*. (1999) and Bolla *et al*. (2002).

It seems impossible to eliminate anchorage loss in intraoral distalization methods without using bone-supported implants (Byloff *et al*., 2000). Mesial movement of the anchorage unit raises the question of the 'true value' of non-compliance distalization methods (Runge *et al*., 1999). To reinforce anchorage, it might be advantageous to use extraoral forces or Class II elastics; however, this would not be a non-compliance therapy (Ghosh and Nanda, 1996; Runge *et al*., 1999; Brickman *et al*., 2000). Moreover, the stability of distally tipped molars is questionable and they need to be stabilized and uprighted before incisor retraction (Ghosh and Nanda, 1996; Byloff *et al*., 2000). The pendulum appliance with uprighting bends can be a solution for distal tipping but may pose some other problems such as increased anchorage loss and treatment time (Byloff *et al*., 1997). According to Ghosh and Nanda (1996) and Gianelly *et al*. (1997) headgear use still seems to be the primary option for this purpose.

Conclusions

1. The RMD is an alternative in the treatment of Class II malocclusions. The maxillary first molars are distalized with the RMD appliance as effectively as with fixed non-compliance techniques, and a Class I molar relationship is established on average in 4.5 months.
2. Distal drift of the maxillary second premolars during molar distalization facilitates subsequent treatment of the increased overjet and shortens treatment time.
3. The palate and all the teeth mesial to the maxillary second premolars can be used as the anchorage unit and clinical observations indicate that the reciprocal effects of the RMD are acceptable.
4. The RMD is a hygienic appliance when compared with other fixed distalization methods and mucosal irritations were not observed during distalization. However, patient compliance is required, which introduces inefficiency into the treatment.

5. The retention of the appliance decreases in patients with short clinical crown length, and this must be taken into consideration during case selection.

6. The RMD is cost effective and reduces chair-side time. However, in its present form, it requires significant laboratory procedures. Prefabricated rigid palatal bars and adequate open coil springs, thicker than in the present study, would increase the stability and effectiveness of the appliance.

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