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A comparison of dentoalveolar inclination treated by two palatal expanders

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SUMMARY The objective of the present study was to evaluate buccal dentoalveolar inclinations in subjects treated with a Hyrax (tooth-borne) or acrylic-bonded (tooth-tissue borne) palatal expander.

The sample comprised 39 patients (10 males and 29 females) aged between 11 and 16 years randomly assigned to two groups. Rapid maxillary expansion (RME) was carried out with a Hyrax appliance in one group ($n=21$) and with an acrylic-bonded appliance in the other ($n=18$). Their mean ages were 13 years 9 months and 13 years 6 months, respectively. Orthodontic study models were obtained before RME (T1) and approximately 1 week after completion of maxillary expansion (T2). A line of barium sulphate solution was drawn between the upper first molars on the models, and radiographs were taken. The radiographic images of the models were transferred to digital medium, and buccal tipping of the molar crowns and alveolar processes were evaluated by means of a software program. The data were analysed by paired and Student's *t*-tests.

Both RME appliances produced significant ($P<0.001$) dentoalveolar tipping during RME, but this was greater in the Hyrax group ($P<0.05$).

Introduction

The objective of rapid maxillary expansion (RME) is to increase the transverse width of the maxillary dental arch at the apical base with minimal concomitant movement of the posterior teeth within the alveolus. This technique is usually undertaken with fixed jackscrew appliances which apply heavy forces to the teeth and supporting structures to mechanically separate the maxillary segments at the midpalatal suture. These appliances produce not only orthopaedic effects by splitting the midpalatal suture and separating the two maxillary arches (Wertz, 1970; da Silva Filho *et al.*, 1991) but also orthodontic effects by tipping the posterior teeth and alveolar structures laterally (da Silva Filho *et al.*, 1991; Ciambotti *et al.*, 2001; Chung and Font, 2004; Oliveira *et al.*, 2004).

Hicks (1978) stated that slight extrusion also occurs in the posterior dentoalveolar structures during tipping. Buccal tipping and extrusion of the upper posterior dentoalveolar structures results in downward and backward rotation of the mandible, an increased mandibular plane angle, and a reduced bite (Wertz, 1970; Bishara and Staley, 1987; Handelman *et al.*, 2000; Byloff and Mossaz, 2004).

Dentoalveolar inclinations caused by RME have been studied using different methods. Tipping movements of the posterior dental and/or alveolar structures have been evaluated on postero-anterior (PA) radiographs (Hicks, 1978; Asanza *et al.*, 1997; Byloff and Mossaz, 2004), computed tomography (CT; Garib *et al.*, 2005), and stone casts (da Silva Filho *et al.*, 1991; Northway and Meade, 1997; Ciambotti *et al.*, 2001; Chung and Goldman, 2003). On stone casts, laser scanning (Oliveira *et al.*, 2004), tracing of transverse palatal contours using a symmetrograph (Ciambotti *et al.*, 2001), measuring the height of the disto-buccal and disto-lingual tips of molars with a dial calliper (Northway and Meade, 1997), and taking laser photocopies (Chung and Goldman, 2003) or photographs (Özsoy, 2001) of trimmed models are the most popular methods used in the evaluation of dentoalveolar tipping.

Oliveira *et al.* (2004) evaluated dentoalveolar inclination following treatment with the Hyrax and Haas appliances, and demonstrated greater dentoalveolar tipping in the Hyrax group. Garib *et al.* (2005) compared the same appliances and found that Haas-type appliances produced a greater change in the axial inclination of appliance supporting teeth. Asanza *et al.* (1997) compared dental tipping caused by two tooth-borne appliances (conventional and bonded Hyrax) but found no significant difference between them.

Although the clinical use of full acrylic bonded RME appliances have increased in recent years (Memikoglu and Iseri, 1997; Iseri and Özsoy, 2004; Kılıç, 2005), it appears that no study comparing the resultant dentoalveolar inclinations caused by a tooth-borne (Hyrax) and tooth-tissue borne (full acrylic bonded) RME appliances exists in literature.

The aim of the present investigation was to carry out a short-term assessment of the dentoalveolar inclinations in subjects treated by a full acrylic-bonded or a Hyrax appliance on plaster models using an evaluation method developed by Oktay and Kılıç (2007).

Subjects and methods

Thirty-nine patients with a severe maxillary arch width deficiency, bilateral crossbite, and deep palatal vault who underwent RME at the Department of Orthodontics, Faculty of Dentistry, Atatürk University, Erzurum, Turkey, were included in the investigation. The subjects were randomly assigned to two groups. RME was carried out using a conventional Hyrax appliance (Figure 1a) in 21 patients and with an acrylic-bonded appliance (Figure 1b; Memikoglu and Iseri, 1997) in 18 patients. Subjects with mucosal swelling during maxillary expansion were excluded from the study. The mean ages of the subjects were 13 years 6 months ± 12 months and 13 years 9 months ± 17 months in the acrylic-bonded and Hyrax expander groups, respectively. The RME appliances were activated twice a day, one-quarter turn in the morning and one in the evening, in both groups. Maxillary expansion in both groups was determined by the increase in maxillary intermolar distance.

Orthodontic study models were obtained from all subjects before RME (T1) and approximately 1 week after completion of maxillary expansion (T2). The evaluation of the models was carried out according to the method described by Oktay and Kılıç (2007). Briefly, a thin line (1 mm in diameter) was drawn on the maxillary study models using a paint-brush and barium sulphate solution. The line began from the gingival margin of the mesio-buccal cusp of the upper right first molar, passed through the tips of the mesio-buccal and mesio-palatal cusps of that tooth, crossed the palatal vault between the first molars, and ended at the vestibular gingival margin of the left molar (Figure 2). After this procedure, the models were placed in an eight cabinet plastic box which allowed X-rays to pass freely, and then a radiographic image of the box was obtained in a standardized manner (Figure 3). In order to achieve standardization and to obtain an image without distortion, special attention was given to the following points:

1. The parallelism of the posterior edges of the study models and barium sulphate lines to the film plane,
2. The parallelism of model bases to the horizontal plane,
3. The existence of a distance of approximately 2.5 cm between the barium sulphate line and film.

The radiographs were scanned (Epson Expression 1860 Pro, Seiko Epson Corp., Nagano-ken, Japan) under a magnification of 100 per cent and the resultant images were saved on a computer. They were then digitized with the Quick Ceph 2000 software program (Quick Ceph Systems, San Diego, California, USA).

The landmarks, planes, and angles used in this evaluation were adapted from the studies of Ciambotti *et al.* (2001) and Oliveira *et al.* (2004) (Figure 4a,b). In addition to the angular measurements, pre- and post-expansion model film images were superimposed in order to observe the changes in dentoalveolar structures using the software program (Figure 5). Superimposition was performed with the 'best fit' method described by Oliveira *et al.* (2004). The midpoint of the median palatal raphe and the base of palate were superimposed on the pre- and post-treatment images.

Statistical analysis

To determine the errors associated with digitizing and measurements, 15 radiographs were randomly selected. All procedures such as landmark identification, digitizing, and measurement were repeated 2 weeks later by the same author (NK). Intraclass correlation coefficients were performed to assess the reliability of the measurements as described by Houston (1983). No significant error was found.

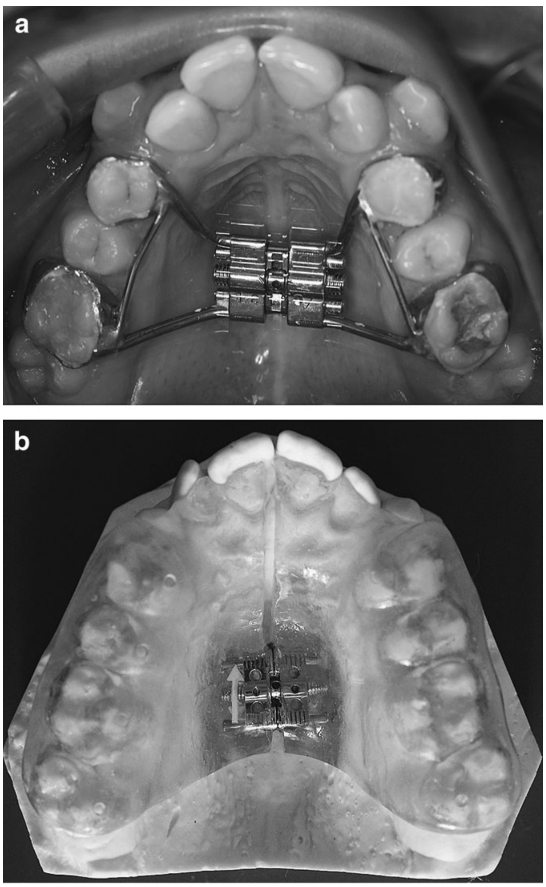

Figure 1 The Hyrax (a) and acrylic-bonded (b) appliances used in the study.

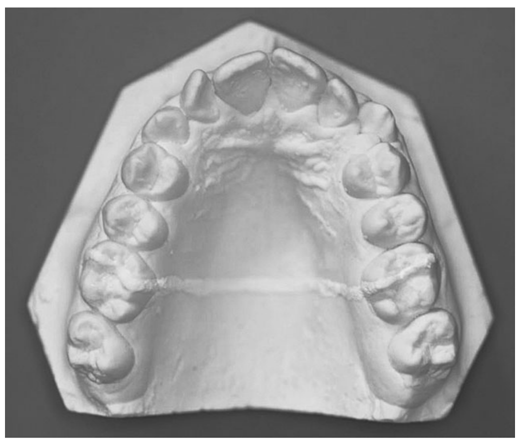

Figure 2 Barium sulphate line drawn on the plaster models between the maxillary first molars.

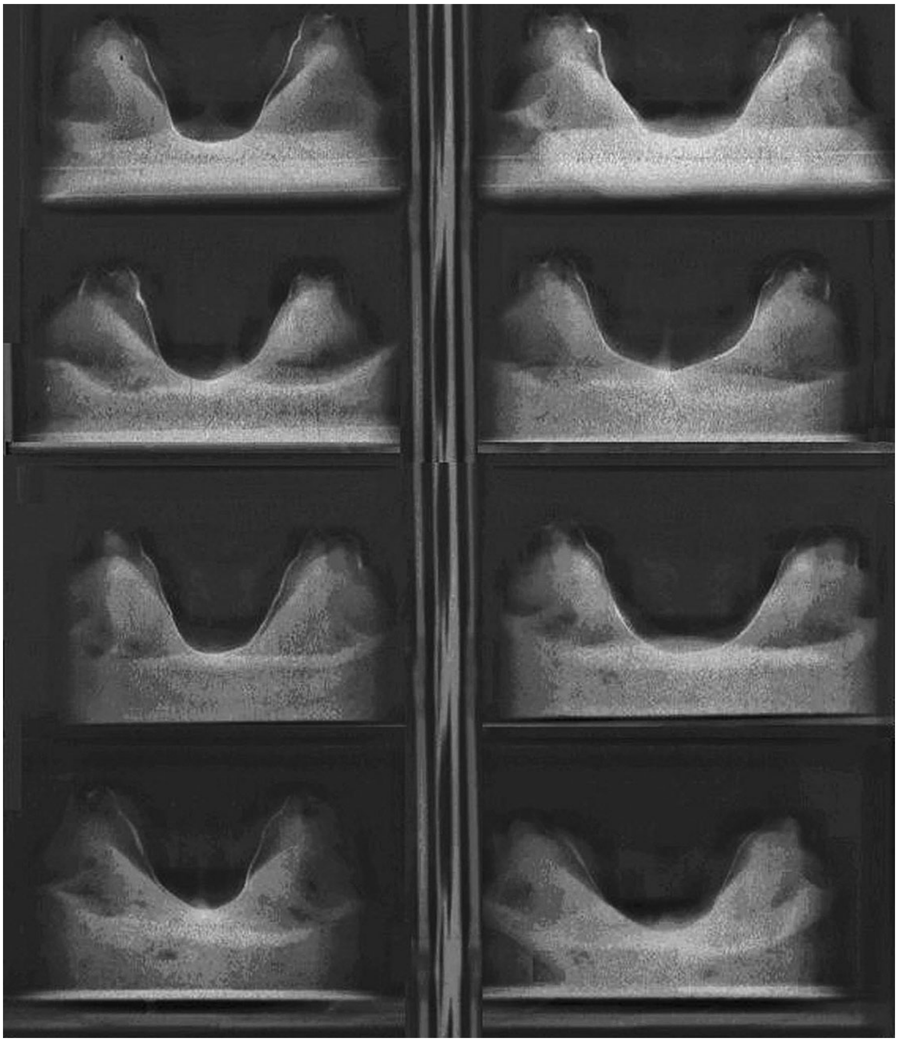

Figure 3 Radiographic images of eight orthodontic plaster models in a single film (18 × 24 cm).

Dentoalveolar inclinations caused by RME in each group were studied by paired *t*-test and their comparisons between the groups by a Student's *t*-test. All statistical analyses were performed using the Statistical Package for Social Sciences (Windows 98, version 10.0, SPSS Inc., Chicago, Illinois, USA).

Results

The coefficients of reliability regarding the reproducibility of the measurements were all above 0.90 (Table 1).

The amount of mean maxillary expansion was 7.31 ± 1.45 mm in the acrylic-bonded appliance group and 7.67 ± 1.99 mm in the Hyrax group.

The means and standard deviations (SDs) of the measurements for dentoalveolar inclination in the Hyrax and bonded groups and their within-group comparisons are shown in Tables 2 and 3, respectively. As can be seen, palatal angulations and molar crown tipping significantly increased in both groups.

The means and SDs of the treatment changes observed and their comparisons between the groups are shown in Table 4. Statistical analysis showed that the amount of maxillary expansion was similar in both groups. However, the Hyrax appliance produced more palatal angulation and more molar tipping than the acrylic-bonded appliance.

Discussion

RME increases the transverse dimension of the upper dental arch by separating the two maxillary halves by means of midpalatal suture splitting, but posterior teeth and alveolar processes accompany this expansion by moving buccally (Haas, 1961; Cotton, 1978; Hicks, 1978; Bishara and Staley, 1987). The amount of dentoalveolar tipping depends on factors such as the type of expansion appliance, mode of activation, resistance of skeletal and soft tissue structures surrounding the maxilla, and the age of the patient (Braun *et al.*, 2000). In order to reduce or overcome these undesirable

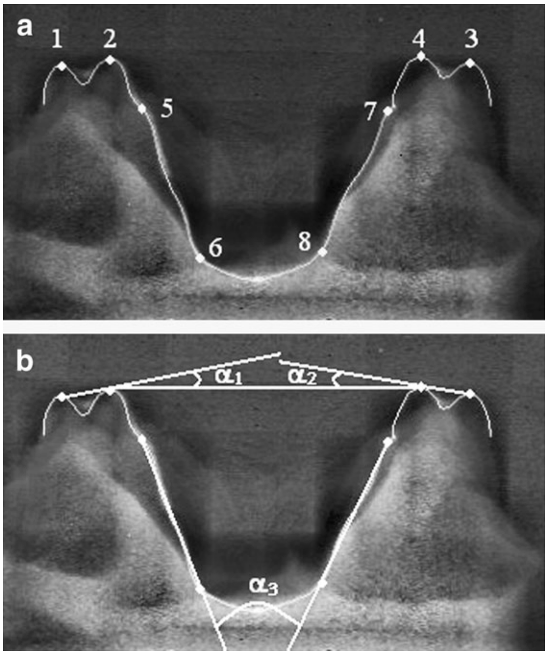

Figure 4 The reference points and angles used for evaluation of dentoalveolar inclination: (a) 1 and 3, right and left mesio-buccal cusp tips; 2 and 4, right and left mesio-palatal cusp tips; 5 and 7, right and left upper alveolar tipping points (midpoint of the junction between alveolar process and palatal gingiva of the first molar); and 6 and 8, right and left lower alveolar tipping points (midpoint of the junction between alveolar process and palatal shelf). (b) α_1 and α_2, inner angles between the transversal occlusal line connecting the mesio-palatal cusp tips of the right and left molars and the lines passing through the mesio-buccal and mesio-palatal cusp tips of the molars. α_3, inner angle between the right and left alveolar lines connecting the upper and lower alveolar tipping points in each side.

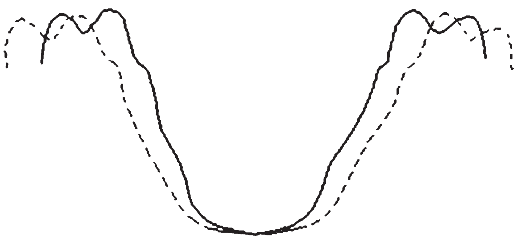

Figure 5 Superimposition of pre- and post-expansion images of dentoalveolar structures.

side-effects, using more rigid expansion appliances, changing the mode of activation, and weakening the maxillary resistance by bilateral buccal corticotomy have been recommended (Howe, 1982; Spolyar, 1984; Alpern and Yurosko, 1987; Sarver and Johnston, 1989; Memikoglu and Iseri, 1997; Orhan, 1999; Byloff and Mossaz, 2004; Iseri and Özsoy, 2004). However, dental tipping inevitably occurs to various degrees after RME (Haas, 1970; Wertz, 1970). Even if there are no angular changes of the teeth within each maxillary segment, the teeth would still appear tipped due to outward tilting of the alveolar processes (Wertz, 1970).

In the present study, both Hyrax and acrylic-bonded expanders produced significant alveolar and molar tipping, but dentoalveolar inclination was greater in the Hyrax group (Tables 2 and 4). Kılıç (2005) and Özsoy (2001) reported similar results for the acrylic-bonded RME appliance. The present findings regarding the Hyrax appliance are consistent with the literature (Davidovitch *et al.*, 2005). However, Asanza *et al.* (1997) and Garib *et al.* (2005) found less molar tipping in patients treated with a Hyrax appliance. This difference may be explained by the fact that RME in those studies was carried out on younger children and different measurement methods were used for determination of molar tipping.

Table 1 Coefficients of reliability of the measurements (Houston, 1983).

Parameters	R^2
Molar crown tipping, right (α_1)	0.9691
Molar crown tipping, left (α_2)	0.9452
Alveolar process inclination (α_3)	0.9603

In a three-dimensional study, Oliveira *et al.* (2004) demonstrated that tooth-tissue borne appliances produce greater orthopaedic movement, while tooth-borne expanders result in more dentoalveolar effects by increasing the palatal angulation of the alveolus. Acrylic coverage of bonded appliances would direct the force vector to the centre of resistance of the maxilla, leading to more bodily movement (Alpern and Yurosko, 1987; Davidovitch *et al.*, 2005).

According to some authors (Timms, 1980; Howe, 1982; Spolyar, 1984; Alpern and Yurosko, 1987; Sarver and Johnston, 1989; Memikoglu and Iseri, 1997), treatment outcomes with rigid acrylic-bonded appliances are skeletal rather than dentoalveolar. These types of appliance produce more parallel movement in supporting teeth and expand the maxillary halves in a more bodily fashion. The findings of the present study show that the acrylic-bonded expander also caused dentoalveolar inclination, but this was less than with the Hyrax appliance.

PA radiographs are commonly used for the determination of transverse changes. An important drawback of this method is that an additional radiograph for each patient has to be taken for such evaluation (Hicks, 1978; Asanza *et al.*, 1997). In addition, it is difficult to evaluate treatment changes in the dentoalveoler structures on these films because of the superimposition of many structures. Hence, wires or metal spurs soldered to molar bands are used to facilitate this evaluation. With the technique used the present study, the patients are not subjected to additional radiation, and radiographic images of eight models can be displayed on a single film.

In a recent clinical study, Garib *et al.* (2005) evaluated the changes in palatal morphology and buccal tipping of upper molars with CT, which is an expensive method. The study was performed on a small sample because of ethical concerns.

Orthodontic study models have frequently been used in diagnosis, treatment planning, and evaluation of treatment efficiency (Epker *et al.*, 1995; Kuroda *et al.*, 1996; Hayashi

Table 2 Descriptive statistics of the pre- and post-expansion measurements in the Hyrax group (*N* = 21) and their within-group comparisons.

Parameters	Pre-expansion				Post-expansion				Significance
	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	
Molar crown tipping, right (α_1)	2.70	20.40	9.52	4.67	8.50	28.50	19.00	5.12	***
Molar crown tipping, left (α_2)	4.10	18.20	9.59	3.55	10.30	25.20	18.70	4.03	***
Alveolar process inclination (α_3)	41.60	87.00	59.80	12.08	54.80	93.70	71.10	10.86	***

Table 3 Descriptive statistics of the pre- and post-expansion measurements in the acrylic-bonded group (*N* = 18) and their within-group comparisons.

Parameters	Pre-expansion				Post-expansion				Significance
	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	
Molar crown tipping, right (α_1)	−1.10	15.20	10.08	4.15	5.70	23.50	17.09	4.46	***
Molar crown tipping, left (α_2)	−0.50	18.00	10.16	4.34	4.60	25.00	16.95	5.12	***
Alveolar process inclination (α_3)	45.90	75.50	61.81	8.55	54.50	79.10	68.97	7.17	***

Table 4 Descriptive statistics of the differences between the pre- and post-expansion measurements and their between-group comparisons.

Parameters	Hyrax group (*N* = 21)				Bonded group (*N* = 18)				Significance
	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	
Maxillary intermolar distance	3.50	10.5	7.66	1.99	4.62	9.20	7.31	1.45	NS
Molar crown tipping, right (α_1)	2.5	18.10	9.47	4.00	2.00	12.70	7.01	3.24	*
Molar crown tipping, left (α_2)	2.9	14.30	9.16	3.88	−0.20	13.8	6.79	3.27	*
Alveolar process inclination (α_3)	5.50	21.7	11.30	4.59	2	20.7	7.16	4.85	*

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

et al., 2003; Proffit and Sarver, 2003). In the studies carried out on plaster models, some authors (Northway and Meade, 1997; Özsoy, 2001; Chung and Goldman, 2003) evaluated only buccal molar tipping, whereas Ciambotti *et al.* (2001) investigated two-dimensional and Oliveira *et al.* (2004), three-dimensional changes in dentoalveoler structures. Ciambotti *et al.* (2001) assessed alveolar inclination and buccal molar tipping by means of a symmetrograph. Oliveira *et al.* (2004) used laser scanning in order to obtain three-dimensional computerized images of duplicated models. Although their method had some advantages such as high reliability, providing more comprehensive data, and giving more precise cross-sectional areas of the investigated structures (Kusnoto and Evans, 2002; Oliveira *et al.*, 2004), it was expensive and required careful laboratory work.

In this study, radiographic images of maxillary study models were obtained after a thin line was drawn with barium sulphate solution between the first molars. These radiographic images give a detailed cross-sectional view of the molar crowns and palatal vault, allowing dentoalveolar inclinations occurring during expansion to be investigated.

Barium sulphate is a radiopaque agent which has been used medically for diagnosis, especially of the gastro-intestinal system. This substance does not allow X-rays to pass through any tissue or organ coated with it, and will appear white on the X-ray films (Hendee, 1994). This substance can also be used in orthodontics to determine the skeletal asymmetries and the accompanying soft tissue deficiencies or excesses on radiographs (Epker *et al.*, 1995).

The method provides precise cross-sectional views of palatal and dental morphology at the molar region. Using these views, the changes occurring as a result of treatment can be objectively evaluated using both angular measurements and superimposition of the images by computerized or traditional methods. Another important advantage of this method is that it is cost-effective and does not require laboratory work.

Conclusions

Both the Hyrax and acrylic-bonded appliances produced significant dentoalveolar tipping after RME. However, the acrylic-bonded appliance tipped the alveolar processes and molars less than the Hyrax appliance.

This new method used to evaluate the buccal inclination of the maxillary posterior dentoalveolar structures is simple, reliable, and inexpensive.

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