European Journal of Orthodontics 31 (2009) 417–424
doi:10.1093/ejo/cjp016
Advance Access publication 9 June 2009

Comparison of the zygoma anchorage system with cervical headgear in buccal segment distalization

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SUMMARY This prospective study aimed to evaluate the effects of the zygoma anchorage system (ZAS) in buccal segment distalization in comparison with cervical headgear (CH). Thirty patients with Class II dental malocclusions were included in the study and were divided into two equal groups: the first group (10 females and 5 males, mean age 14.74 years at T1) received buccal segment distalization with ZAS and the second group (8 females and 7 males, mean age 15.26 years at T1) with CH. The skeletal, dental, and soft tissue changes were measured on cephalograms obtained before (T1) and after (T2) distalization, and these changes were statistically evaluated using a repeated measures analysis of variance, Mann–Whitney *U*-test, and Wilcoxon test.

The Class II buccal segment relationship was corrected to a Class I in an average period of 9.03 ± 0.62 months in the ZAS group and 9.00 ± 0.76 months in the CH group. Significant distalization was observed for the posterior teeth in both groups ($P < 0.001$). Distal tipping of all posterior teeth occurred in the CH group ($P < 0.001$), but only for the molars in the ZAS group ($P < 0.001$). The upper incisors retroclined, overjet decreased, and the upper and lower lips retruded in both groups. The ZAS provided absolute anchorage for distalization of the maxillary posterior teeth and can be used as an aesthetic and non-compliant alternative to extraoral traction in the treatment of Class II malocclusions.

Introduction

Class II malocclusions have a significant prevalence in most populations and have always been of interest to orthodontists (Graber, 1969). Non-extraction treatment protocols for correction of Class II malocclusions are based on obtaining a normal occlusion either by functional appliances (Fields and Proffit, 2000) or by distalizing the maxillary molars and using the space obtained to eliminate crowding and/or reduce an increased overjet (Bondemark and Karlsson, 2005).

Extraoral headgear traction, which has been used since the 1800s, is the oldest and most commonly used method to correct a Class II buccal segment relationship by restricting forward growth of the maxilla and/or distalizing the maxillary molars. A large number of studies have provided evidence of the effects on the craniofacial structures (Weinberger, 1926; Gould, 1957; Poulton, 1967; Armstrong, 1971; Baumrind *et al.*, 1983; Hubbard *et al.*, 1994; Godt *et al.*, 2007). Despite its efficacy, headgear treatment is dependent on patient co-operation. Furthermore, the difficulty of use and aesthetic concerns make patient co-operation difficult to maintain throughout treatment.

Since the late 1980s, various types of intraoral molar distalization devices have been introduced to reduce the need for patient compliance. Repelling magnets (Blechman, 1985), bimetric arches (Wilson and Wilson, 1984), superelastic nickel-titanium wires (Gianelly, 1998), the pendulum device (Hilgers, 1992), Jones Jig (Jones and White, 1992), distal jet (Ngantung *et al.*, 2001), the first class (Fortini *et al.*, 1999), and the intraoral bodily molar distalizer (Keles and Sayinsu, 2000) appliances have all been advocated as aesthetic and non-compliant alternatives to headgear.

In comparison with headgear, intraoral molar distalization methods are easier to use, more socially acceptable for patients, and the distalization time is shorter because they apply continuous forces. However, they have several disadvantages such as mesialization of the maxillary premolars, protrusion of the maxillary incisors, an increase in overjet, and anchorage loss (Wilson and Wilson, 1984; Blechman, 1985; Hilgers, 1992; Jones and White, 1992; Gianelly, 1998; Fortini *et al.*, 1999; Keles and Sayinsu, 2000; Ngantung *et al.*, 2001). Relapse of molar distalization is commonly seen as the molars are usually used as anchorage during distalization and retraction of the premolars and incisors.

In recent years, implant-supported intraoral molar distalization systems, which do not have the disadvantage of anchorage loss, have been introduced for the correction of Class II malocclusions. With palatal miniscrews (Mannchen, 1999; Byloff *et al.*, 2000; Karaman *et al.*, 2002; Keles *et al.*, 2003), alveolar microscrews (Park *et al.*, 2005), or zygoma plates (Sugawara *et al.*, 2006) evidence suggests that molars can be distalized without reciprocal movements of the premolars and incisors.

The purpose of this prospective study was to use the zygoma anchorage system (ZAS) for buccal segment distalization in the treatment of Class II malocclusions and to examine the effects on skeletal, dentoalveolar, and soft tissue structures in comparison with cervical headgear (CH).

Materials and methods

Ethical approval was obtained from the Başkent University Research and Ethics Committee and an informed consent was signed by all patients and parents.

This prospective study consisted of 60 lateral cephalometric radiographs of 30 patients who received orthodontic treatment in the Department of Orthodontics, Faculty of Dentistry, Başkent University. The records were obtained at the beginning (T1) and end (T2) of buccal segment distalization.

The patients were included in the study according to the following criteria:

1. In the post-peak pubertal growth stage or non-growing [at CV4 or later stages according to the cervical vertebrae growth and maturation index (Hassel and Farman, 1995)]
2. Skeletal Class I or Class II but with a dental Class II relationship (buccal segments at least a half unit bilaterally)
3. Low-angle or normal vertical growth pattern (S.N/GoGn < 40 degrees)
4. All permanent teeth present and erupted (excluding third molars)
5. Anterior crowding in the maxillary dental arch and/or increased overjet
6. Mild or no crowding in the mandibular dental arch
7. Normal or increased overbite
8. Treatment on a non-extraction basis.

Thirty patients fulfilling these inclusion criteria were allocated to one of the two study groups. The first group consisted of 15 patients (10 females and 5 males, mean age 14.74 years at T1) who underwent buccal segment distalization with the ZAS and the second group 15 patients (8 females and 7 males, average age 15.26 years at T1) received buccal segment distalization with CH. Details of the study sample are shown in Table 1. All orthodontic treatment was carried out by the same operator (BK). All patients had 0.018 inch slot brackets (Roth Omni C-PM/Hook, GAC International Inc., Bohemia, New York, USA) bonded on the maxillary premolars and triple tube molar bands (Ideal Molar Bands, GAC International Inc.) on their maxillary molars. After levelling, the posterior teeth in both groups were distalized segmentally on a 0.016 × 0.022 inch stainless steel archwire (Figure 1). A vertical step was bent into the archwire to allow easier tooth cleaning.

The ZAS (Bollard Zygoma Anchor, Surgi-Tec, Bruges, Belgium), which was introduced as anchorage for canine retraction (De Clerck *et al.*, 2002), was used for distalization of premolars and molars as one unit in the first group. The zygoma anchor is a titanium miniplate with three holes, which continues with a round bar and a cylindrical unit at the end. A 1.5 cm vertical incision was made under local anaesthesia on the inferior crest of the zygomatico-maxillary buttress which extended to the border of the mobile and attached gingivae. A mucoperiosteal flap was elevated and the cortical bone surface at the implantat site was exposed.

Table 1 Details of the sample.

	Group 1 (*n* = 1)	Group 2 (*n* = 15)	*P*
	Mean ± SE	Mean ± SE	
Chronological age (year)	14.74 ± 0.65	15.26 ± 0.41	NS
Distalization time (month)	9.03 ± 0.62	9.00 ± 0.76	NS

SE, standard error of mean; NS, non-significant.

Figure 1 The main archwire and fixed appliance system used in both the zygoma anchorage and cervical headgear groups.

After the zygoma anchor was adapted to the curvature of the bone crest, the cylindrical unit was bent distally, the anchor was fixed with miniscrews, covered with mucoperiosteum, and sutured (Figure 2). One week after surgery, the sutures were removed and a distalization force of 450 g was applied on each side with nickel-titanium closed coil springs from the zygoma anchors to crimpable hooks placed mesial to the first premolar brackets (Figure 3).

The CH was used with the outer bow parallel to the occlusal plane. All posterior teeth were ligated together and a distalization force of 450 g per side was applied. The patients were instructed to wear their headgear at least 20 hours a day and to write down the duration of wear each day. The outer bows were bent 10–15 degrees upwards after spaces developed in the buccal segment, similar to Kloehn's prescription (Hubbard *et al.*, 1994).

Distalization was considered complete when a Class I buccal relationship was obtained in all patients.

Standardized lateral cephalometric radiographs of each subject were taken at T1 and T2 with the same cephalostat (Planmeca EC Proline, Helsinki, Finland). The subjects were positioned in the cephalostat with the sagittal plane at a right angle to the path of the X-rays, the Frankfort plane parallel to the horizontal, the teeth in centric occlusion, and the lips in a relaxed position.

Analysis of the lateral cephalometric radiographs

The radiographs were hand traced on orthodontic tracing paper on a conventional light box using a 0.3 mm lead pencil and measured by the same investigator (BK). When bilateral structures did not superimpose, the average of the two sides was used. For evaluation of the lateral cephalometric radiographs, in addition to the conventional reference planes, horizontal (HR) and vertical (VR) reference planes were constructed (Figures 4 and 5). The HR plane was constructed parallel to the occlusal plane, passing from tuberculum sella (T) and the VR plane from tuberculum sella perpendicular to the occlusal plane. The lateral cephalometric radiographs taken at T2 were superimposed on those taken at T1, on stable cranial structures, using the total structural superimposition method of Björk and Skieller (1983). These stable structures were the anterior wall of sella turcica, the intersection of the lower contours of the anterior clinoid processes and the anterior wall of sella turcica, the anterior contours of the middle cranial fossa, the contour of the cribriform plate of the ethmoid bone,

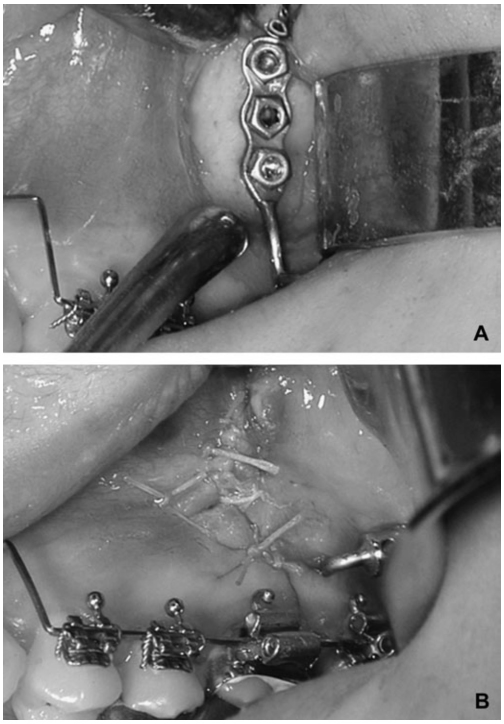

Figure 2 The zygoma anchor. (A) Adapted and fixed to the zygomatico-maxillary bone crest. (B) Covered with mucoperiosteum and sutured.

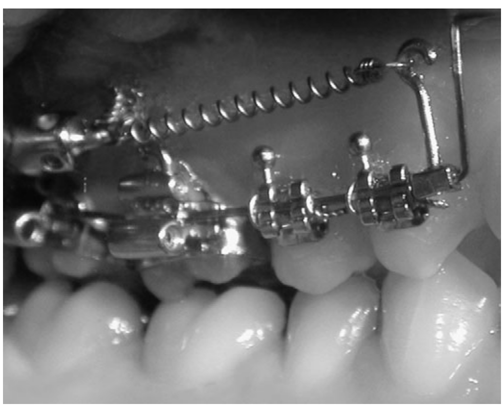

Figure 3 Application of a distalization force of 450 g with nickel-titanium closed coil springs in the zygoma anchorage group.

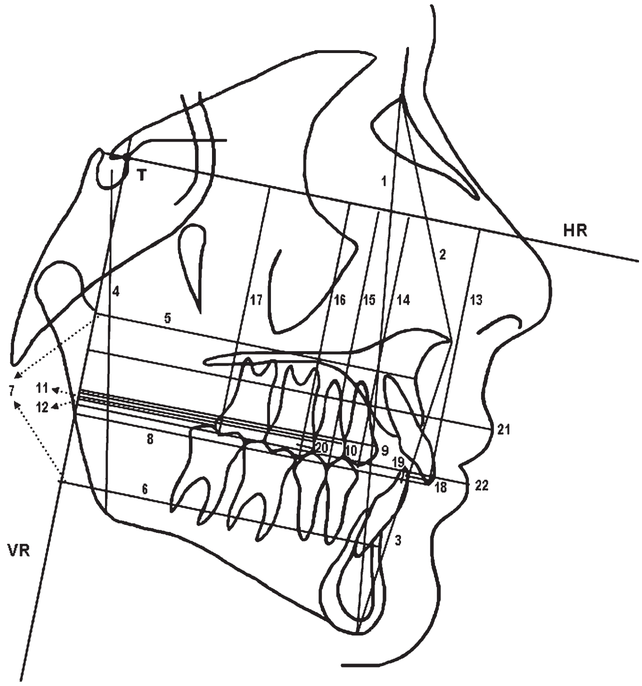

Figure 4 Linear measurements used in the study. 1, N–Me; 2, N–ANS; 3, ANS–Me; 4, S–Go; 5, A–vertical reference (VR); 6, B–VR; 7, A′–B′; 8, U1i–VR; 9, U4m–VR; 10, U5m–VR; 11, U6m–VR; 12, U7d–VR; 13, U1i–horizontal reference (HR); 14, U4t–HR; 15, U5t–HR; 16, U6t–HR; 17, U7t–HR; 18, Overjet; 19, Overbite; 20, Molar relationship; 21, Ls–VR; 22, Li–VR.

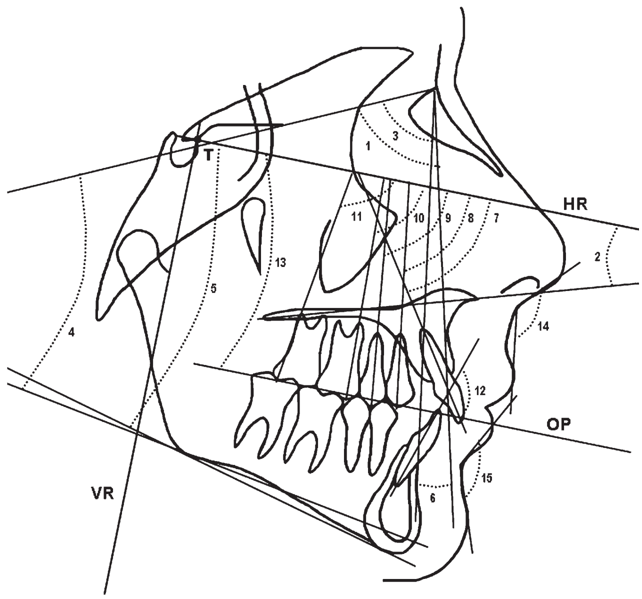

Figure 5 Angular measurements used in the study. 1, SNA; 2, horizontal reference plane (HR)/PP; 3, SNB; 4, S.N/GoGn; 5, HR/MP; 6, ANB; 7, U1/HR; 8, U4/HR; 9, U5/HR; 10, U6/HRl; 11, U7/HR; 12, U1/L1; 13, HR/OP; 14, Ta.Sn.Ls; 15, Li.Si.Pgs.

the contours of the bilateral fronto-ethmoidal crests, and the cerebral surfaces of the orbital roofs. The HR and VR planes were transferred from the T1 to the T2 radiograph. The sensitivity of the linear and angular radiographic measurements were 0.5 mm and 0.5 degrees, respectively.

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences Version 13.0 (SPSS Inc., Chicago, Illinois, USA). The normality of the distribution of the data was checked using the Shapiro–Wilks test and the homogeneity of the variances using Levene's test. The group means for age and distalization time were compared using a Student's *t*-test. The means of cephalometric variables, which were normally distributed and had homogeneous variances, were compared by 2×2 repeated measures analysis of variance and Bonferroni adjusted *t*-test. For variables which were not normally distributed and had heterogeneous variances, a Mann–Whitney *U*-test was used for the independent groups and Wilcoxon's test for the dependent groups. A *P*-value of <0.05 was considered to be statistically significant.

Method error

Three weeks after the first measurements were undertaken, they were repeated by the same author on 20 lateral cephalograms from 10 randomly selected patients. To assess the reliability of the measurements, intraclass correlation coefficients (*r*) were calculated for each variable on the T1 and T2 cephalograms. Intraclass correlation coefficients ranged from 0.912 to 1.000. No significant differences were found between the first and second measurements.

Results

At T1, the two groups were comparable and none of the parameters showed significant differences (Table 2). The Class II buccal segment relationship was successfully corrected in both groups, with a mean distalization time of 9.03 ± 0.62 months in the ZAS group and 9.00 ± 0.76 months in the CH group. The changes obtained with the two different buccal segment distalization techniques and their comparisons are shown in Table 3.

Throughout the distalization period, there was no obvious clinical mobility of the zygoma anchors and the positions of the miniscrews and zygoma anchors remained unchanged on the superimposed radiographs. However, gingival inflammation occurred in two patients and infection in one, due to poor oral hygiene. Mild gingival inflammation was managed using antiseptic mouthwash and improving the oral hygiene status of the patients. The patient with the more severe infection was successfully treated with drainage and an amoxicillin protocol for 1 week.

In the CH group, the majority of patients complied with the request to wear their headgear for 20 hours a day.

The total (N–Me), upper (N–ANS), and lower (ANS–Me) anterior face heights increased in both groups. SNA and A–VR (representing the sagittal position of the maxilla) decreased in both groups and confirmed the retrusion of point A.

Significant retrusion and distalization ($P<0.001$) were observed at the maxillary incisors, premolars, and molars in both groups. However, differences were found between the groups for second premolar and first molar distalization ($P<0.05$), and these were more significant in the ZAS group. The maxillary incisors and molars showed lingual and distal tipping in both groups ($P<0.001$). While the maxillary premolars in the ZAS group showed no tipping, in the CH group they were tipped distally ($P<0.001$). The maxillary incisors extruded ($P<0.001$) and the maxillary second molars intruded ($P<0.01$) in both groups. The maxillary premolars did not show significant vertical movement in the ZAS group, although significant extrusion was observed in the CH group.

Overjet decreased significantly in both groups. Overbite did not change significantly in the ZAS group, but decreased significantly in the CH group ($P<0.05$). Evaluation of the soft tissue changes showed that the upper and lower lips (Ls–VR and Li–VR) retruded significantly in both groups.

Discussion

In this study, the aim was to distalize the maxillary posterior teeth together, and to investigate an aesthetic and advantageous alternative to CH.

While randomization is advised for evidence-based studies for some clinical investigations it is not feasible. In the present study, in order to comply with the University's Research and Ethics Committee, both possible treatment methods were explained to the patients and they were then allowed to choose their preferred method. In an attempt to minimize any differences between the groups, subjects were recruited to the study based on strict inclusion criteria. Hence, although the sample size was small and the subjects were not randomly allocated, the groups did not show any baseline differences. However, it is acknowledged that a randomized study design would have been preferable.

The buccal segments were distalized 4.5–5 mm in the ZAS group and 3.5–4 mm in the CH group. The upper incisors were retroclined and retruded due to the transseptal gingival fibres, despite no direct force being applied to these teeth, and the overjet was decreased as a result of this in both groups. The retroclination of the incisors is thought to be the main reason for the upper incisor extrusion in both groups.

The premolars showed no tipping in the ZAS group, but significant distal tipping in the CH group. This difference may be the result of the clockwise force of moment applied to the buccal segments by the CH before the outer bows were bent upwards. In contrast, the counterclockwise force of moment applied to the buccal segments by the closed coil springs may be the reason for the unchanged inclination or mesial tipping observed for the premolars in the ZAS group.

Table 2 Descriptive statistics of the treatment groups before buccal segment distalization and comparison of the groups.

Parameters	Zygoma anchorage system			Cervical headgear			P
	Mean ± SE	Median	Min–max	Mean ± SE	Median	Min–max	
Face heights							
N–Me (mm)	124.16 ± 1.91	123.50	107.50–139.50	126.30 ± 1.45	127.50	114.00–134.00	NS
N–ANS (mm)	56.30 ± 0.99	54.50	52.50–67.00	57.06 ± 0.79	57.00	51.50–62.00	NS
ANS–Me (mm)	69.46 ± 1.63	69.50	54.50–84.50	71.26 ± 1.38	70.50	59.50–80.50	NS
S–Go (mm)	79.96 ± 1.60	79.50	65.50–90.00	82.96 ± 1.73	81.50	70.50–97.50	NS
Maxillary skeletal							
SNA (°)	79.16 ± 0.87	79.00	75.00–88.00	79.26 ± 1.05	80.00	69.50–84.00	NS
HR/PP (°)	−10.13 ± 0.86	−10.00	−15.00 to −5.00	−10.83 ± 1.03	−11.00	−18.00 to −5.00	NS
A–VR (mm)	72.40 ± 1.73	71.50	56.50–84.50	75.63 ± 1.24	74.50	68.50–84.00	NS
Mandibular skeletal							
SNB (°)	74.36 ± 0.71	74.50	70.00–81.00	74.83 ± 0.99	76.00	66.00–79.50	NS
S.N/GoGn (°)	32.26 ± 1.22	32.50	25.50–39.00	30.10 ± 1.44	29.00	18.50–39.50	NS
HR/MP (°)	15.36 ± 1.05	15.00	7.50–20.00	14.43 ± 0.78	15.00	9.00–19.50	NS
B–VR (mm)	70.33 ± 1.93	70.50	51.50–83.50	73.23 ± 1.62	72.00	65.50–84.00	NS
Maxillomandibular skeletal							
ANB (°)	4.80 ± 0.44	4.50	2.00–7.50	4.43 ± 0.35	4.50	2.00–7.50	NS
A′–B′ (mm)	2.06 ± 0.60	2.50	−2.00 to 5.00	2.40 ± 0.80	2.50	−4.00 to 8.00	NS
Maxillary dentoalveolar							
U1i–VR (mm)	79.46 ± 2.17	80.00	55.00–89.50	82.56 ± 1.46	83.00	76.00–93.50	NS
U4m–VR (mm)	66.40 ± 1.86	67.00	48.50–78.50	68.96 ± 1.40	69.00	61.00–78.50	NS
U5m–VR (mm)	59.33 ± 1.83	59.50	42.00–71.50	61.73 ± 1.38	62.50	54.50–71.00	NS
U6m–VR (mm)	52.10 ± 1.80	52.00	34.50–64.50	54.36 ± 1.30	54.00	47.00–62.50	NS
U7d–VR (mm)	27.96 ± 1.68	29.00	11.50–41.00	30.26 ± 1.21	29.50	23.00–38.00	NS
U1/HR (°)	63.13 ± 1.99	60.50	54.00–84.00	62.33 ± 1.69	62.50	52.00–73.00	NS
U4/HR (°)	76.46 ± 1.33	77.50	65.00–84.50	78.20 ± 1.12	78.00	71.00–84.00	NS
U5/HR (°)	84.73 ± 1.04	85.50	78.00–91.00	84.73 ± 0.97	84.50	77.00–94.00	NS
U6/HR (°)	87.03 ± 1.45	87.00	76.00–96.00	84.10 ± 1.29	85.00	76.50–92.00	NS
U7/HR (°)	99.56 ± 0.92	99.00	94.00–106.00	97.66 ± 1.27	97.00	89.00–106.00	NS
U1i–HR (mm)	63.70 ± 1.61	63.00	52.50–75.00	67.10 ± 1.49	66.50	55.00–79.50	NS
U4t–HR (mm)	63.23 ± 1.59	64.50	52.50–72.50	66.76 ± 1.40	66.50	56.50–77.50	NS
U5t–HR (mm)	63.73 ± 1.60	64.50	52.50–73.00	67.10 ± 1.43	66.50	56.50–78.50	NS
U6t–HR (mm)	63.10 ± 1.64	64.00	52.00–73.00	66.40 ± 1.43	66.00	55.50–77.50	NS
U7t–HR (mm)	61.06 ± 1.52	61.50	50.50–70.50	64.50 ± 1.34	64.50	54.00–75.50	NS
Maxillomandibular dentoalveolar							
Overjet (mm)	5.13 ± 0.43	5.50	2.50–8.50	5.63 ± 0.44	5.50	3.00–8.50	NS
Overbite (mm)	3.06 ± 0.51	3.00	0.50–7.00	3.66 ± 0.53	3.00	1.00–8.50	NS
U1/L1 (°)	130.93 ± 3.02	129.00	118.00–162.00	129.76 ± 2.99	130.00	114.50–155.00	NS
Molar relationship (mm)	−2.20 ± 0.39	−2.50	−5.00 to 0.00	−2.00 ± 0.31	−2.50	−4.00 to 0.00	NS
HR/OP (°)	0.00 ± 0.00	0.00	0.00–0.00	0.00 ± 0.00	0.00	0.00–0.00	NS
Soft tissues							
Ta.Sn.Ls (°)	112.86 ± 1.99	114.00	98.00–125.00	113.30 ± 2.24	112.00	94.00–126.00	NS
Li.Si.Pgs (°)	118.93 ± 3.54	119.00	92.50–140.50	121.20 ± 2.21	122.00	107.50–138.50	NS
Ls–VR (mm)	93.56 ± 1.83	93.50	78.00–106.50	96.53 ± 1.56	97.00	87.00–106.50	NS
Li–VR (mm)	91.13 ± 2.00	93.00	72.50–103.00	94.03 ± 1.71	93.00	83.00–104.50	NS

SE, standard error of mean; Min–max, minimum and maximum values; NS, non-significant.

Vertically, the premolars did not move in the ZAS group, but extruded significantly in the CH group. This could be due to the difference in the direction of the forces applied by the two different types of mechanics. The distalization force with the ZAS is parallel to the occlusal plane, but backwards and downwards with the CH (Figure 6). This force vector could be the reason for the premolar extrusion in the CH group. Intrusion of the second molars at the distal cusps might be the result of distal tipping in both groups. The choice of horizontal-pull (combi) headgear rather than low-pull (cervical) headgear might have avoided the premolar and molar extrusion in the headgear group. However, extrusion of the posterior teeth was not thought to be a disadvantage in this study as most of the subjects had low maxillary mandibular planes angles. In addition, in comparison with combi-pull headgear, CH is easier for patients to use and is also more aesthetic so that patient co-operation may be enhanced.

Table 3 Descriptive statistics of the changes that occurred in the treatment groups due to buccal segment distalization and comparison of the groups.

Parameters	Zygoma anchorage system				Cervical headgear				P
	Mean ± SE	Median	Min–max	P	Mean ± SE	Median	Min–max	P	
Face heights									
N–Me (mm)	1.26±0.43	1.00	−1.00 to 4.00	***	2.30±0.58	1.00	0.00–7.50	***	NS
N–ANS (mm)	0.40±0.12	0.00	0.00–1.00	***	0.66±0.24	0.00	−0.50 to 2.50	***	NS
ANS–Me (mm)	0.83±0.45	0.50	−1.5 to 4.50	***	1.53±0.41	1.00	−0.50 to 4.50	***	NS
S–Go (mm)	−0.23±0.38	−0.50	−2.00 to 3.00	NS	1.33±0.36	1.00	0.00–4.00	**	**
Maxillary skeletal									
SNA (°)	−1.30±0.50	−1.00	−6.50 to 1.00	*	−0.50±0.11	−0.50	−1.00 to 0.50	**	NS
HR/PP (°)	0.00±0.33	0.00	−2.00 to 2.50	NS	0.60±0.22	0.50	−0.50 to 2.50	NS	NS
A–VR (mm)	−0.80±0.43	−0.50	−4.50 to 2.50	*	−0.63±0.19	−0.50	−2.00 to 0.50	**	NS
Mandibular skeletal									
SNB (°)	−0.90±0.27	−1.00	−3.00 to 0.50	*	−0.16±0.21	0.00	−1.50 to 1.50	NS	*
S.N/GoGn (°)	1.10±0.45	0.50	−1.00 to 4.50	***	0.83±0.24	1.00	−0.50 to 2.50	***	NS
HR/MP (°)	0.50±0.43	−0.50	−1.50 to 3.00	**	1.00±0.31	0.50	−0.50 to 4.00	**	NS
B–VR (mm)	−1.06±0.43	−0.50	−4.00 to 1.00	*	−0.20±0.43	0.50	−3.50 to 2.00	*	NS
Maxillomandibular skeletal									
ANB (°)	−0.43±0.31	0.00	−3.50 to 1.00	NS	−0.33±0.14	−0.50	−1.50 to 0.50	*	NS
A′–B′ (mm)	0.26±0.41	0.50	−2.00 to 3.00	NS	−0.43±0.31	−1.00	−2.00 to 2.00	NS	NS
Maxillary dentoalveolar									
U1i–VR (mm)	−2.70±0.75	−2.50	−8.50 to 1.50	***	−2.43±0.50	−2.50	−7.00 to 0.00	***	NS
U4m–VR (mm)	−4.63±0.35	−4.50	−7.50 to −2.50	***	−3.63±0.36	−3.00	−6.50 to −2.00	***	NS
U5m–VR (mm)	−4.80±0.27	−4.50	−7.00 to −3.50	***	−3.56±0.38	−3.00	−6.50 to −2.00	***	*
U6m–VR (mm)	−5.03±0.30	−5.00	−7.00 to −3.50	***	−4.03±0.37	−3.50	−7.00 to −2.00	***	*
U7d–VR (mm)	−4.30±0.45	−4.50	−6.50 to −1.00	***	−3.60±0.37	−3.50	−6.50 to −2.00	***	NS
U1/HR (°)	5.20±1.61	4.00	−5.50 to 20.00	***	5.86±1.76	5.00	−0.50 to 25.00	***	NS
U4/HR (°)	0.93±1.91	0.50	−14.50 to 14.50	NS	11.3±1.25	10.50	4.50 to 21.50	***	***
U5/HR (°)	2.00±1.56	3.00	−10.00 to 11.50	NS	9.16±1.29	8.00	3.00–21.50	***	***
U6/HR (°)	5.43±1.36	3.50	0.50–19.50	***	9.16±1.70	8.50	0.50–23.00	***	NS
U7/HR (°)	5.00±1.60	2.50	−1.50 to 18.50	***	7.96±1.81	8.00	−4.00 to 22.00	***	NS
U1i–HR (mm)	1.63±0.41	2.00	−1.00 to 5.00	***	1.63±0.31	1.50	0.00–5.00	***	NS
U4t–HR (mm)	−0.03±0.31	0.00	−2.50 to 2.50	NS	2.56±0.35	2.50	0.00–5.00	***	***
U5t–HR (mm)	0.00±0.29	−0.50	−1.50 to 1.50	NS	1.46±0.33	1.50	−1.00 to 4.00	**	**
U6t–HR (mm)	−0.13±0.27	0.00	−2.00 to 2.00	NS	0.96±0.32	1.00	−1.00 to 4.00	NS	NS
U7t–HR (mm)	−0.86±0.37	−0.50	−3.50 to 2.00	**	−1.13±0.57	−1.00	−5.00 to 3.00	**	NS
Maxillomandibular dentoalveolar									
Overjet (mm)	−1.16±0.50	−0.50	−5.00 to 1.50	*	−1.80±0.41	−1.00	−5.50 to 0.00	***	NS
Overbite (mm)	0.50±0.31	0.50	−2.00 to 3.00	NS	−0.73±0.24	−0.50	−2.50 to 0.50	*	**
U1/L1 (°)	6.56±1.94	5.00	−7.50 to 22.50	***	6.50±2.30	4.00	−6.00 to 33.00	***	NS
Molar relationship (mm)	5.03±0.35	5.00	2.50–8.00	***	4.86±0.43	5.00	2.00–7.50	***	NS
HR/OP (°)	3.40±0.59	3.00	−0.50 to 6.50	***	3.23±0.49	2.50	1.00–7.00	***	NS
Soft tissues									
Ta.Sn.Ls (°)	1.86±1.90	−1.00	−8.00 to 17.00	NS	1.63±1.32	4.00	−8.50 to 11.00	NS	NS
Li.Si.Pgs (°)	0.96±1.58	0.00	−12.00 to 12.00	NS	2.83±1.52	2.00	−7.00 to 14.50	NS	NS
Ls–VR (mm)	−0.86±0.54	−0.50	−5.00 to 2.50	*	−0.76±0.33	−1.00	−3.50 to 2.00	*	NS
Li–VR (mm)	−1.36±0.62	−1.00	−6.00 to 2.00	**	−1.20±0.40	−1.00	−5.00 to 0.50	**	NS

SE, standard error of mean; Min–max, minimum and maximum values; NS, non-significant. *$P<0.05$; **$P<0.01$; ***$P<0.001$.

The amount of distalization obtained in the ZAS group was greater compared with other implant-supported distalization systems (Mannchen, 1999; Byloff *et al.*, 2000; Karaman *et al.*, 2002; Keles *et al.*, 2003; Park *et al.*, 2005; Sugawara *et al.*, 2006). The reason for this could be the dental characteristics of the subjects in the ZAS group, as most started treatment with a full unit Class II buccal segment relationship and required more distalization.

Park *et al.* (2005) used microscrews to distalize the buccal segments but the 1.64 mm distalization obtained was limited because of the location of the screw between the roots of the maxillary posterior teeth. However, zygoma anchors are positioned at the zygomatico-maxillary buttress, at a safe distance from the roots of the maxillary molars and allow a full unit buccal segment distalization.

Sugawara *et al.* (2006) used a similar system to the ZAS and obtained 3.78 mm molar crown and 3.20 mm root

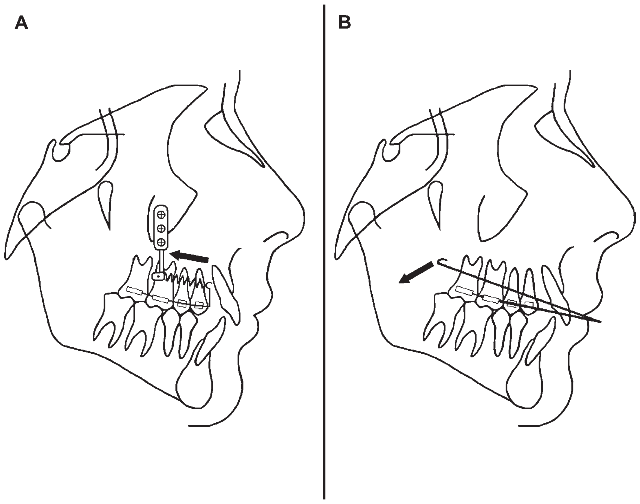

Figure 6 A schematic drawing of the force vectors applied in the groups. (A) Zygoma anchorage group. (B) Cervical headgear group (after the outer bows of the facebow have been bent upwards).

distalization. The greater amount of distalization obtained in the present study may be due to differences in patient selection and the materials used during distalization. Sugawara *et al.* (2006) included Class I, II, and III patients with average age of 23 years 11 months in their study and used 0.018×0.025 inch blue Elgiloy as the main archwire.

With both conventional and palatal implant-supported intraoral molar distalization systems, the reported distalization period is short (Hilgers, 1992; Gianelly, 1998; Fortini *et al.*, 1999; Keles and Sayinsu, 2000; Karaman *et al.*, 2002; Keles *et al.*, 2003). However, the molars demonstrate significant distal tipping and anchorage loss with conventional intraoral systems (Wilson and Wilson, 1984; Blechman, 1985; Hilgers, 1992; Jones and White, 1992; Gianelly, 1998; Fortini *et al.*, 1999; Keles and Sayinsu, 2000; Ngantung *et al.*, 2001). Following distalization, it is recommended that the molars are not used as anchorage for distalization and retraction of other teeth but instead should be supported with headgear to prevent relapse (Gianelly, 1998). The time required for correction of anchorage loss and prevention of relapse is a factor that significantly increases total treatment time.

Although palatal implant-supported molar distalization systems do not cause anchorage loss, the amount of premolar distalization obtained may not be sufficient to correct a Class II premolar relationship, resulting in the need for significant premolar distalization in the second phase of treatment (Mannchen, 1999; Byloff *et al.*, 2000; Karaman *et al.*, 2002; Keles *et al.*, 2003). Buccal segment distalization with the ZAS may be used in preference to this system, as it provides the opportunity to attain a Class I buccal relationship in the first phase of treatment.

Buccal segment distalization has been reported to take 12.3 ± 5.7 months with microscrews (Park *et al.*, 2005) and 19 months with a different type of zygoma anchor (Sugawara *et al.*, 2006) but smaller amounts of distalization were obtained with both these systems than in the present investigation. The reason for the faster tooth movement in the present study may be due to the greater distalization force used and the younger age of the patients.

While palatal implant-supported systems are useful in the dental correction of Class II malocclusions, skeletal and soft tissue changes do not occur (Mannchen, 1999; Byloff *et al.*, 2000; Karaman *et al.*, 2002; Keles *et al.*, 2003). However, the ZAS is able to retract the incisors, decrease the overjet, retract point A, and retract the lips as they naturally follow the dentoalveolar structures. While the skeletal and soft tissue improvements with the ZAS are similar to those achieved with CH, the ZAS is able to correct skeletal as well as dental Class II malocclusions (Poulton, 1967; Graber, 1969; Armstrong, 1971). An increase in anterior face heights occurs with all types of distalization methods as a result of mandibular posterior rotation due to maxillary molar extrusion (Poulton, 1967; Armstrong, 1971; Wilson and Wilson, 1984; Hilgers, 1992; Jones and White, 1992; Keles and Sayinsu, 2000; Karaman *et al.*, 2002; Keles *et al.*, 2003).

The mechanics used in the ZAS group were similar to those used by Park *et al.* (2005), in which the maxillary posterior teeth were distalized with the help of microscrews. In both studies, sliding mechanics were used with closed coil springs on straightwire systems. The force in the current study was approximately two times greater. Park *et al.* (2005) noted that microscrews (1.2 mm diameter and 8 mm length) could withstand only low forces such as 200 g, but if no screw failure was observed, increasing the level of the distalization force could positively affect tooth movement.

In the ZAS group in the current study, the distalization force was not limited to 200 g because each zygoma anchor was fixed to the solid bone structure of the zygomatico-maxillary buttress with three miniscrews (2.3 mm diameter and 7 mm length). Thus, the ZAS successfully withstood a distalization force of 450 g, which was equal to that used in the CH group. This amount of force has frequently been applied with CH to obtain dental effects and is approximately twice that of intraoral distalization devices (Graber, 1969; Wilson and Wilson, 1984; Blechman, 1985; Hilgers, 1992; Jones and White, 1992; Gianelly, 1998; Fortini *et al.*, 1999; Mannchen, 1999; Byloff *et al.*, 2000; Keles and Sayinsu, 2000; Ngantung *et al.*, 2001; Karaman *et al.*, 2002; Keles *et al.*, 2003; Lima Filho *et al.*, 2003; Park *et al.*, 2005). The ability to apply high distalization forces, similar to CH, is an important advantage of the ZAS. Sugawara *et al.* (2006) used a force of 200 g for single molar distalization and 500 g for buccal segment distalization.

In the ZAS group, the neck of the zygoma anchor and the crimpable hook were positioned at the same level. This allowed application of the distalization force close to the centre of resistance of the first molar and hence resulted in bodily movement of the posterior teeth.

In the CH group, the patients in general complied with the request to wear their headgear for at least 20 hours a day. This compliance was felt to be due to allowing them to choose the distalization method, thus selecting patients who were willing to use headgear. This may be different with a randomized study design.

To evaluate the efficiency of distalization, it is necessary to consider the number of teeth distalized, the amount of distalization, the time spent to correct anchorage loss, and the total treatment time. Thus, the ZAS may be the most advantageous of all the above-mentioned distalization systems. Although the distalization time is increased, the expected total treatment time is shorter with the ZAS, as the second phase of treatment is relatively short. The zygoma anchors can also be used as anchorage to prevent relapse of buccal segment distalization and to retract the anterior segment. Consequently, orthodontic forces can be applied directly from the zygoma anchors during all stages of treatment.

Conclusions

1. The buccal segment was efficiently distalized and the incisors, point A, and the lips retruded in both the ZAS and CH groups.
2. The ZAS provided absolute anchorage to apply the same distalization force and to obtain similar effects as with CH.
3. More significant vertical change and extrusion occurred in the CH group.
4. The ZAS is an aesthetic and non-compliant alternative to extraoral traction.

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Funding

Başkent University Research Foundation (project number D-KA05/04).

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