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Effects of three-dimensional bimetric maxillary distalizing arches and cervical headgear on dentofacial structures

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SUMMARY The aim of this study was to compare the dentofacial effects of an intraoral technique, the three-dimensional bimetric maxillary distalizing arch (3D-BMDA), with an extraoral technique, cervical headgear (CH), in subjects requiring maxillary molar distalization. Twenty-one patients (12 females, 9 males; mean age at the start of treatment: 14.7 years) were treated with 3D-BMDA and 18 subjects (11 females, 7 males; mean age at the start of treatment: 13.3 years) with CH. Since the treatment period was longer in the CH group, the results for this group were also compared with a separate 'untreated' control group of 17 subjects (12 females, 5 males; mean age at the start of observation: 13.1 years). The measurements were carried out on lateral cephalometric radiographs which were taken at two time points (T_1: start of treatment/control, T_2: end of molar distalization/control). Paired *t*-tests were performed within, and analysis of variance to determine the differences between the groups.

The total amount of distalization for the 3D-BMDA and CH was similar (3.55 and 4.56 mm, respectively). However, there were statistically significant differences in the total treatment period (3.4 and 10.2 months, respectively) and the monthly amount of distalization (1.11 and 0.55 mm, respectively). The 3D-BMDA system did not have a significant effect on mandibular rotation (an increase of 0.01 degrees), while the CH group showed a mean posterior rotation of the mandible of 1.08 degrees. The most significant differences between the two maxillary first molar distalization techniques were observed in the mandibular dental arches. Moderate anchorage loss in the mandibular dental arch was observed in the 3D-BMDA group. While the 3D-BMDA and CH techniques are both effective in distalizing maxillary molar teeth, the distalization time and rate of molar movement were significantly shorter with the 3D-BMDA than the CH.

Introduction

Several methods exist for the correction of a Class II molar relationship (Kingsley, 1880; Kloehn, 1961; Blechman and Smiley, 1978; Wilson and Wilson, 1980; Ten Hoeve, 1985; Gianelly *et al.*, 1991; Jeckel and Rakosi, 1991; Hilgers, 1992; Jones and White, 1992; Carano and Testa, 1996). The oldest and most common of these is the application of extraoral headgear forces on maxillary molar teeth (Kingsley, 1880; Kloehn, 1961). Although headgears are effective in distalizing maxillary molars, they are highly dependent on patient compliance and tolerance.

Wilson and Wilson introduced a system called 'modular orthodontics' for the correction of Class II malocclusions and the three-dimensional bimetric maxillary distalizing arch (3D-BMDA) is one of this system's components (Wilson, 1978; Wilson and Wilson, 1980, 1984, 1987, 1988). With this system, the maxillary molars are distalized by an open coil spring and Class II elastics (Wilson and Wilson, 1987, 1988). Since it is an intraoral approach, there is less need for patient co-operation.

The dental and skeletal effects of both 3D-BMDA and cervical headgear (CH) have been previously evaluated, but there are only a few publications comparing the effects of intra- and extraoral approaches (Taner *et al.*, 2003; Bondemark and Karlsson, 2005). The purpose of this study was to compare the effects of the 3D-BMDA and CH on dentofacial structures in subjects requiring maxillary molar distalization.

Subjects and methods

Originally 25 subjects were included in each treatment group. These subjects were selected from patients referred to the Department of Orthodontics of Ankara University, who fulfilled the following inclusion criteria:

1. A skeletal Class I or Class II malocclusion and a dental Class II relationship on both sides;
2. A non-extraction treatment plan;
3. SN/GoGn angle less than 40 degrees;
4. No or minimum crowding in the mandibular dental arch;
5. Erupted maxillary second molars in occlusion.

In the 3D-BMDA group, four of the 25 patients who failed to wear their Class II elastics and showed significant anchorage loss at the maxillary anterior region were excluded from the study. The remaining 21 individuals (12 females, 9 males) treated successfully with a 3D-BMDA were included in the study.

In the CH group, seven patients who refused to wear their headgear correctly were excluded from the study. The remaining 18 individuals (11 females, 7 males) finished treatment.

Since the treatment period was longer in the CH subjects, the results for this group were also compared with a separate control group. The control group comprised 17 'untreated' subjects (12 females, 5 males; mean age at the start of observation: 13.1 years) selected from the archives of the department using the same inclusion criteria as the treatment groups. Hand-wrist radiographs showed that the subjects in the control group had the same growth potential as the CH group. Comparing the treatment results of the CH group with a control group with the same growth potential and the same dentofacial structures would reflect the pure treatment effects in the CH group.

The distribution of subjects and the mean values, standard errors, minimum and maximum ages, and distalization/control periods of the subjects in both treatment and control groups are shown in Table 1.

3D-BMDA group

In the 3D-BMDA group, a full-bonded mandibular dental arch was used as an anchorage unit for the Class II elastics (Figure 1a–c) and a 0.019 × 0.025-inch lower archwire to increase anchorage. The elastic load reduction principle (Wilson and Wilson, 1988) was modified. The initial elastic force for each patient was determined by adjusting the load until the 3D-BMDA was seated inside the 0.022-inch bracket slot. This initial force was approximately 175–185 g. The patients were examined at 10-day intervals, and the loads checked and adjusted at each visit.

CH group

In the CH group, only the maxillary first molars were banded and no other orthodontic intervention was performed. The headgear was adjusted to exert a force of 450–600 g and the long outer bows were not angulated. The patients were asked to wear their headgear daily for a period of 14–18 hours until a Class I molar relationship was achieved.

Cephalometric analysis

Lateral cephalometric radiographs were taken of all groups at two different time points: at the start of treatment/control (T_1) and after molar distalization was complete/end of control (T_2). The hand-wrist radiographs of the CH and control groups at T_1 and T_2 were also included and evaluated in the study to monitor the growth potential of the patients.

In order to define the similarities and differences between the 3D-BMDA and CH groups 10 angular and 21 linear parameters were measured by one author (ATA-A). Total structural superimpositions were applied to evaluate the changes in the craniofacial structures and soft tissues (Björk and Skieller, 1983).

In order to determine dentoalveolar changes, maxillary and mandibular local superimpositions were performed. Maxillary local superimpositions were undertaken along the palatal plane (ANS-PNS) registered at ANS (Broadbent, 1937). Mandibular local superimpositions were carried out based on the structural methods of Björk and Skieller (1983). The reference planes of the first radiographs were transferred to the second radiographs using these superimpositions. The total (Figure 2), maxillary (Figure 3), and mandibular (Figure 4) measurements were undertaken on the total vertical and horizontal and local vertical and horizontal reference planes.

Statistical analysis

Statistical analysis included calculations of the mean and standard error of the mean for each variable. Paired *t*-tests were performed to determine any significant changes between T_1 and T_2 within each group. Analysis of variance was conducted to determine significant differences in the amount of change between the groups.

Reliability (error of the method)

Thirty-five randomly selected cephalograms were retraced by the same author one month later. No significant differences between the two series were found and the reliability coefficients (*r*) ranged between 0.94 and 0.99.

Table 1 Mean (X), standard errors (Sx), minimum (min) and maximum (max) ages, and distalization/control periods of the subjects in the treatment and control groups.

			Pre-distalization/pre-control chronological age (years)				Distalization/control period (years)			
	n		X	Sx	Min	Max	X	Sx	Min	Max
3-D bimetric maxillary distalizing arches	21	F: 12 M: 9	14.70	1.50	12.67	16.25	0.28 (3.4 months)	0.10	0.16	0.5
Cervical headgear	18	F: 11 M: 7	13.34	1.47	11.33	16.67	0.85 (10.2 months)	0.31	0.42	1.17
Control	17	F: 12 M: 5	13.13	1.68	11.83	16.17	1.04 (12.5 months)	0.10	0.91	1.25

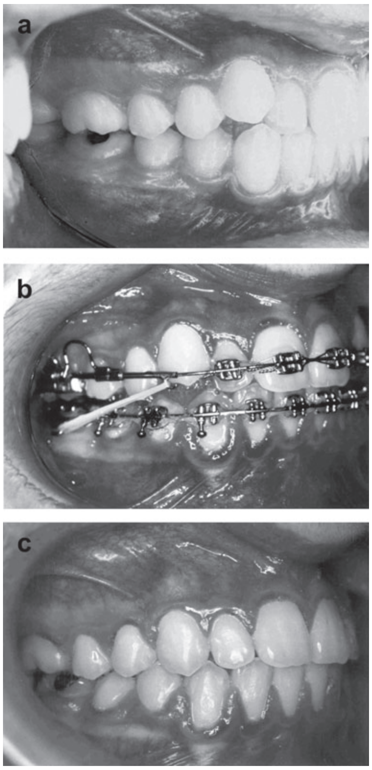

Figure 1 A 16-year-old female patient treated using three-dimensional bimetric maxillary distalizing arches (3D-BDMAs). (a) Before maxillary molar distalization, (b) 3D-BMDA *in situ* supported by Class II intermaxillary elastics, and (c) after 3D-BMDA therapy.

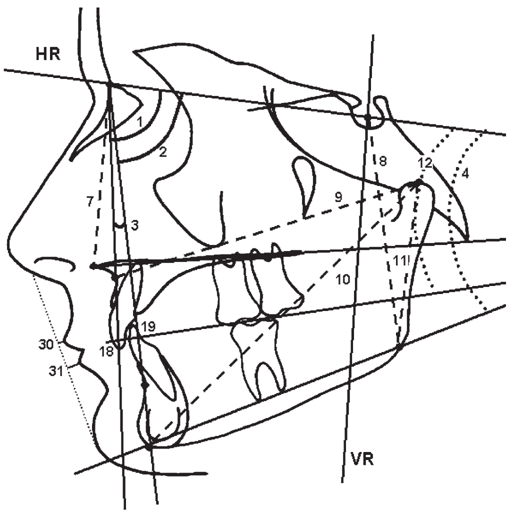

Figure 2 Measurements on total tracings—1: SNA, 2: SNB, 3: ANB, 4: SN/GoGn, 7: ANS–Me, 8: S–Go, 9: Co–A, 10: Co–Gn, 11: Co–Go, 12: SN/Occ, 18: overjet, 19: overbite, 30: Ls–(Steiner), 31: Li–(Steiner).

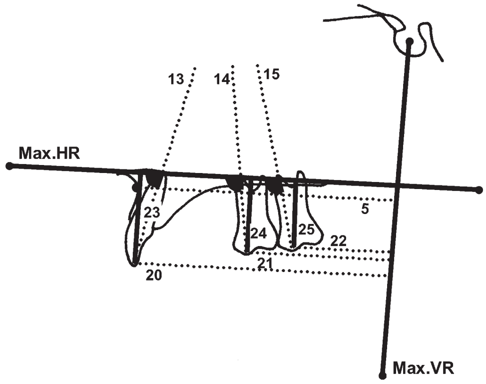

Figure 3 Measurements on maxillary local tracings—5: A–max.VR, 13: U1/max.HR, 14: U6/max.HR, 15: U7/max.HR, 20: U1i–max.VR, 21: U6t–max.VR, 22: U7t–max.VR, 23: U1i–max.HR, 24: U6t–max.HR, 25: U7t–max.HR.

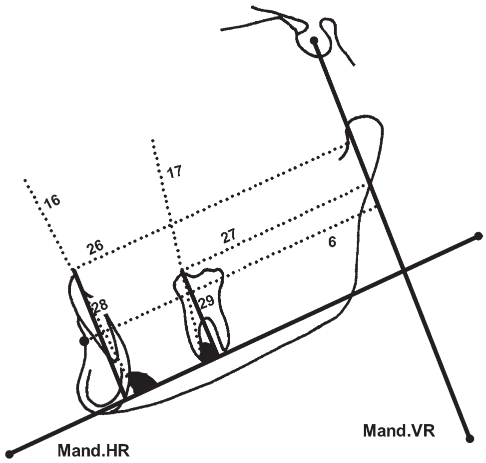

Figure 4 Measurements on mandibular local tracings—6: B–mand.VR, 16: L1/mand.HR, 17: L6/mand.HR, 26: L1i–mand.VR, 27: L6t–mand.VR, 28: L1i–mand.HR, 29: L6t–mand.HR.

Results

3D-BMDA

Dentoalveolar changes. The treatment changes that occurred in the 3D-BMDA group are shown in Table 2. In this group, a Class I molar relationship was achieved in 3.4 months. The mean amount of distalization was 3.55 ± 0.38 mm for the first molar and 2.86 ± 0.34 mm for the second molar. The Class I molar relationship was achieved not only by maxillary molar distalization but also by mesial displacement (mean 2.16 ± 0.28 mm) and mesial tipping (mean 6.06 ± 1.16 degrees) of mandibular molars.

Overjet and overbite were also significantly decreased (2.16 ± 0.54 and 1.58 ± 0.53 mm, respectively). These decreases resulted from protrusion and intrusion of the mandibular incisors (L1i–mand.VR: 2.82 ± 0.44 mm, L1/mand.HR: 9.53 ± 1.39 degrees, and L1i–mand.HR: −0.93 ± 0.31 mm) and extrusion of the maxillary incisors (U1i–max.HR: 1.60 ± 0.37 mm). The maxillary first and second molars showed significant distal tipping ($P < 0.01$) and intrusion ($P < 0.05$). The inclination of the occlusal plane increased significantly (4.38 ± 0.68 degrees).

Skeletal changes. SNB angle showed a significant increase (mean 0.53 ± 0.23 degrees) and Co–Gn and Co–Go also

Table 2 Evaluation of the mean values (X), standard errors (Sx), differences between the means (D), and standard error of the differences (Sd) pre- and post-distalization using paired *t*-test for the three-dimensional bimetric maxillary distalizing arch group.

Parameter	Pre-distalization		Post-distalization		Difference		Test
	X	±Sx	X	±Sx	D	±Sd	
SNA (°)	80.37	0.96	80.36	0.98	−0.01	0.23	
SNB (°)	76.20	0.94	76.73	0.98	0.53	0.23	*
ANB (°)	4.17	0.37	3.63	0.38	−0.54	0.26	
SN/GoGn (°)	33.41	1.09	33.42	1.09	0.01	0.24	
A–max.VR (mm)	69.44	0.98	68.58	0.97	−0.85	0.29	**
B–mand.VR (mm)	95.86	1.25	95.65	1.26	−0.21	0.17	
ANS–Me (mm)	70.41	1.12	70.97	1.02	0.57	0.32	
S–Go (mm)	82.19	1.17	83.25	1.19	1.06	0.26	**
Co–A (mm)	88.35	1.37	88.42	1.24	0.08	0.50	
Co–Gn (mm)	115.68	1.48	117.40	1.47	1.72	0.46	*
Co–Go (mm)	59.14	1.0	61.26	1.0	2.12	0.33	**
SN/Occ (°)	15.78	1.12	20.16	1.33	4.38	0.68	**
U1/max.HR (°)	69.33	1.13	68.46	1.40	–0.87	1.38	
U6/max.HR (°)	97.19	1.40	102.70	1.23	5.51	1.08	**
U7/max.HR (°)	109.79	1.11	114.17	1.25	4.38	1.04	**
L1/mand.HR (°)	97.62	0.99	107.15	1.52	9.53	1.39	**
L6/mand.HR (°)	77.08	1.18	83.14	0.97	6.06	1.16	**
Overjet (mm)	4.00	0.47	1.85	0.45	−2.16	0.54	**
Overbite (mm)	3.73	0.37	2.15	0.42	−1.58	0.53	**
U1i–max.VR (mm)	73.54	1.13	73.60	1.13	0.06	0.47	
U6t–max.VR (mm)	42.97	0.92	39.43	0.94	−3.55	0.38	**
U7t–max.VR (mm)	29.92	0.87	27.06	0.89	−2.86	0.34	**
U1i–max.HR (mm)	29.74	0.73	31.33	0.60	1.60	0.37	**
U6t–max.HR (mm)	24.29	0.51	23.59	0.51	−0.70	0.20	*
U7t–max.HR (mm)	21.22	0.48	20.44	0.50	−0.78	0.21	*
L1i–mand.VR (mm)	94.39	1.18	97.21	1.17	2.82	0.44	**
L6t–mand.VR (mm)	67.40	1.04	69.56	1.10	2.16	0.28	**
L1i–mand.HR (mm)	42.73	0.57	41.80	0.63	–0.93	0.31	*
L6t–mand.HR (mm)	32.16	0.49	33.75	0.46	1.60	0.23	*
Ls–(Steiner) (mm)	−0.98	0.39	−1.08	0.43	−0.10	0.28	
Li–(Steiner) (mm)	0.37	0.38	2.03	0.41	1.66	0.24	**

*$P < 0.05$, **$P < 0.01$.

increased (1.72 ± 0.46 and 2.12 ± 0.33 mm, respectively). SN/GoGn showed almost no change, although there was a significant extrusion of the mandibular first molars (mean 1.60 ± 0.23 mm) due to the use of intermaxillary elastics. This extrusion of the molars could have been compensated by the significant increase in S–Go (mean 1.06 ± 0.26 mm). Point A was distally displaced (mean A–max.VR: −0.85 ± 0.26 mm).
Soft tissue changes. The mean protrusion of the lower lip was 1.66 ± 0.24 mm ($P < 0.01$).

CH versus controls

The distalization/observation periods for the CH and control groups were 10.2 and 12.5 months, respectively. The differences between the groups are shown in Tables 3 and 4. Analysis of variance was used to determine the exact changes in the CH group (Table 5).
Dentoalveolar changes. CH distalized the maxillary first molars (mean 3.54 ± 0.71 mm), but in the control group, mesial movement of the same teeth occurred (mean 0.88 ± 0.48 mm). Similarly, the second molars moved distally (mean 3.37 ± 0.59 mm) in the CH group and mesially (mean 0.97 ± 0.44 mm) in the control group. In the CH group, the first and second maxillary molars tipped distally (mean 6.16 ± 1.48, 6.97 ± 1.87 degrees, respectively) from T_1 to T_2, which was statistically significant. In the control group, the first molars remained relatively stable, whereas the second molars tipped slightly in a mesial direction. The monthly changes for the maxillary first molars in the CH group showed a significant distal displacement (mean 0.45 ± 0.09 mm/month) while in the control group these teeth moved mesially (mean 0.08 ± 0.04 mm/month).

While the maxillary molars moved distally in the CH group, the mandibular incisors and molars also moved significantly in a distal direction (mean −0.75 ± 0.39, −0.32 ± 027 mm, respectively). On the other hand, in the control group, the mandibular dentition moved mesially. The mandibular incisors tipped distally in the CH group, whereas they tipped slightly mesially in the control subjects. In addition, the decrease in overbite was greater in the CH group when compared with the control group.
Skeletal changes. In the CH group, ANB showed a statistically significant decrease (mean 0.82 ± 0.24 degrees), but remained relatively stable in the control group. SN/GoGn

Table 3 Evaluation of the mean (X), standard errors (Sx), differences between the means (D), and standard error of the differences (Sd) pre- and post-distalization using a paired *t*-test for the cervical headgear group.

Parameter	Pre-distalization		Post-distalization		Difference		Test
	X	±Sx	X	±Sx	D	±Sd	
SNA (°)	78.06	0.93	77.17	1.05	−0.88	0.31	*
SNB (°)	74.50	0.80	74.50	0.88	−0.01	0.29	
ANB (°)	3.55	0.51	2.73	0.58	−0.82	0.24	**
SN/GoGn (°)	34.78	1.07	35.26	1.14	0.48	0.28	
A–max.VR (mm)	66.50	1.26	66.25	1.45	−0.25	0.33	
B–mand.VR (mm)	92.09	1.55	91.70	1.45	−0.39	0.29	
ANS–Me (mm)	67.19	1.26	68.83	1.30	1.64	0.22	**
S–Go (mm)	76.35	1.97	78.94	1.93	2.59	0.27	**
Co–A (mm)	87.40	0.98	87.21	1.16	−0.19	0.67	
Co–Gn (mm)	111.89	1.23	113.96	1.05	2.07	0.69	**
Co–Go (mm)	59.03	1.24	57.97	1.14	1.94	0.26	**
SN/Occ (°)	18.16	0.80	17.24	0.83	−0.91	0.33	*
U1/max.HR (°)	72.09	1.67	71.07	1.44	−1.02	0.70	
U6/max.HR (°)	98.62	1.16	104.78	1.76	6.16	1.48	**
U7/max.HR (°)	110.58	1.55	117.54	1.47	6.97	1.87	**
L1/mand.HR (°)	95.96	1.34	94.22	1.43	−1.74	0.65	*
L6/mand.HR (°)	82.05	1.00	81.25	1.01	−0.80	0.75	
Overjet (mm)	3.47	0.35	3.29	0.51	−0.17	0.27	
Overbite (mm)	5.15	0.42	4.13	0.45	−1.02	0.23	**
U1i–max.VR (mm)	69.13	1.41	69.18	1.47	0.05	0.39	
U6t–max.VR (mm)	37.47	1.34	33.94	1.55	−3.54	0.71	**
U7t–max.VR (mm)	27.00	1.24	23.63	1.48	−3.37	0.59	**
U1i–max.HR (mm)	29.32	0.71	29.67	0.75	0.34	0.12	*
U6t–max.HR (mm)	21.85	0.69	22.99	0.70	1.14	0.24	**
U7t–max.HR (mm)	18.22	0.65	18.17	0.74	−0.05	0.40	
L1i–mand.VR (mm)	89.35	1.60	88.60	1.48	−0.75	0.39	
L6t–mand.VR (mm)	63.19	1.31	62.87	1.25	−0.32	0.27	
L1i–mand.HR (mm)	40.57	0.74	40.83	0.72	0.26	0.24	
L6t–mand.HR (mm)	29.57	0.72	30.21	1.00	0.64	0.55	
Ls–(Steiner) (mm)	−0.89	0.53	−1.74	0.46	−0.85	0.26	**
Li–(Steiner) (mm)	0.21	0.59	−0.51	0.56	−0.72	0.22	**

*$P < 0.05$, **$P < 0.01$.

angle increased in the CH subjects (mean 0.48 ± 0.28 degrees), while it decreased in the control group (mean −0.49 ± 0.35 degrees). In addition, Co–Go increased significantly in the control group (mean 3.27 ± 0.39 mm), when compared with the CH group (mean 1.94 ± 0.26 mm).

3D-BDMA versus CH

The maxillary first molars moved distally 1.11 ± 0.13 mm/month in the 3D-BMDA group and 0.55 ± 0.09 mm/month in the CH group (Table 6). The timing and rate of distal molar movement were significantly shorter for the 3D-BMDA group than for the CH group ($P < 0.01$).

Dentoalveolar changes. The mean amount of maxillary first molar distalization was similar in both groups. However, the amount of distal movement of the maxillary second molars was significantly greater in the CH group than in the 3D-BMDA group ($P < 0.01$). Distal molar tipping was similar in both groups, and no significant difference was observed.

In the 3D-BMDA group, due to anchorage loss, the mandibular incisors and molars moved mesially and proclined. In the CH group, the corresponding measurements all decreased, showing distal movement and retroclination. The maxillary incisors were significantly extruded in the 3D-BMDA group, whereas they remained relatively stable in the CH group. The maxillary first molars were intruded while the mandibular first molars were extruded in the 3D-BMDA group; the maxillary and mandibular molars were slightly extruded and intruded, respectively, in the CH group.

Due to these dentoalveolar changes, the occlusal plane angle and overjet were significantly but differently affected in both treatment groups. In the 3D-BMDA group, SN/Occ significantly increased and overjet significantly decreased, while both variables increased slightly in the CH group.

Skeletal changes. SN/GoGn angle remained stable in the 3D-BMDA group even though there was a statistically significant change in the vertical position of the molars. In the CH group, SN/GoGn angle increased significantly over the 3D-BMDA group ($P < 0.05$). In the 3D-BMDA group, Co–Go increased significantly whereas it decreased in the CH group ($P < 0.05$).

Soft tissue changes. The lower lip protruded significantly in the 3D-BMDA group, while it retruded slightly in the CH group due to the dentoalveolar changes.

Table 4 Evaluation of the mean (X), standard errors (Sx), differences between the means (D), and standard error of the differences (Sd) using a paired *t*-test for the control group.

Parameter	Pre-control		Post-control		Difference		Test
	X	±Sx	X	±Sx	D	±Sd	
SNA (°)	80.96	0.56	80.88	0.59	−0.08	0.41	
SNB (°)	78.31	0.49	78.26	0.62	−0.05	0.39	
ANB (°)	2.64	0.53	2.62	0.51	−0.03	0.22	
SN/GoGn (°)	31.37	0.94	30.88	1.07	−0.49	0.35	
A–max.VR (mm)	69.12	0.87	69.24	0.96	0.12	0.33	
B–mand.VR (mm)	95.16	1.35	95.81	1.42	0.57	0.54	
ANS–Me (mm)	65.70	0.88	66.56	0.98	0.86	0.43	
S–Go (mm)	78.23	1.46	80.61	1.51	2.38	0.54	**
Co–A (mm)	87.73	1.05	90.41	1.76	2.68	2.24	
Co–Gn (mm)	116.25	1.41	120.03	1.87	3.78	2.11	
Co–Go (mm)	58.88	0.97	62.15	1.02	3.27	0.39	**
SN/Occ (°)	17.10	0.68	16.38	0.90	−0.72	0.36	
U1/max.HR (°)	68.85	1.47	69.48	1.67	0.63	0.69	
U6/max.HR (°)	97.18	1.30	97.27	1.39	0.10	0.79	
U7/max.HR (°)	103.60	1.68	101.71	1.63	−1.89	1.03	
L1/mand.HR (°)	92.52	1.36	93.51	1.43	0.46	0.80	
L6/mand.HR (°)	82.16	0.95	82.86	0.82	0.74	0.96	
Overjet (mm)	2.27	0.14	2.22	0.20	−0.04	0.17	
Overbite (mm)	3.65	0.27	3.32	0.41	−0.33	0.21	
U1i–max.VR (mm)	72.56	0.98	72.86	1.10	0.30	0.32	
U6t–max.VR (mm)	41.25	1.00	42.14	0.99	0.88	0.48	
U7t–max.VR (mm)	31.01	1.01	31.98	0.99	0.97	0.44	
U1i–max.HR (mm)	27.87	0.46	27.92	0.55	0.05	0.23	
U6t–max.HR (mm)	22.49	0.33	23.34	0.44	0.85	0.31	*
U7t–max.HR (mm)	18.84	0.51	19.94	0.48	1.10	0.41	*
L1i–mand.VR (mm)	91.83	1.14	92.43	1.24	0.47	0.49	
L6t–mand.VR (mm)	66.72	0.90	68.20	1.01	1.40	0.62	*
L1i–mand.HR (mm)	39.73	0.64	40.30	0.65	0.58	0.25	
L6t–mand.HR (mm)	30.38	0.54	31.06	0.70	0.68	0.32	
Ls–(Steiner) (mm)	−1.84	0.57	−2.16	0.67	−0.31	0.48	
Li–(Steiner) (mm)	−1.25	0.71	−1.47	0.59	−0.22	0.62	

$^*P < 0.05$, $^{**}P < 0.01$.

Discussion

In the present study, the average distalization time for upper first molars from a Class II to a Class I relationship with the 3D-BMDA was 3.4 months. As the distalization period for this group was shorter, the differences that occurred were not compared with the control group. In the CH group that comprised 18 subjects of the same gender, the average treatment time to correct the molar relationship was 10.2 months. The dentofacial differences of this treatment group were compared with a control group of 17 untreated subjects with similar dentoskeletal structures and pubertal growth patterns. The selection of subjects for the control group was undertaken on hand-wrist radiographs with the aim of determining the pure treatment effects achieved with CH.

While efforts were made to keep the number of patients in each group the same, due to co-operation problems, this parameter was different between the groups. The patients were closely matched, although it was not ethically possible to select patients to be treated according to gender. There were 12 females in the 3D-BMDA and control groups and 11 females in the CH group. As the treatment effects of the 3D-BMDA were not being compared with the control group, the difference of nine males in one group (3D-BMDA) and five males in the other (control) should not affect the results of the study, while seven males in the CH group and five males in the control group could be considered close.

Both the 3D-BMDA and CH were successful in achieving a Class I molar relationship. In the CH group, correction was achieved purely by distal movement of the maxillary molars, but in the 3D-BMDA group both distal movement of the maxillary molars and mesial movement of the mandibular molars contributed to the result. This mesial movement of the mandibular molars was a result of anchorage loss caused by the Class II intermaxillary elastics. In the CH group, retrusion of the mandibular incisors and distal tipping of the mandibular first molars were observed. These changes can be explained by distal drift of the mandibular and maxillary teeth, due to the tight occlusal interdigitation (Funk, 1967).

In the 3D-BMDA group, not only the mandibular molars displaced and tipped mesially but also the mandibular incisors protruded significantly as a result of the Class II

Table 5 Evaluation of the means of differences (D) and standard error of the differences (Sd) for pre-distalization/pre-control and post-distalization/post-control periods of the cervical headgear and control groups using variance analysis.

Parameter	Cervical headgear		Control		Test
	D	±Sd	D	±Sd	
SNA (°)	−0.88*	0.31	−0.08	0.41	
SNB (°)	−0.01	0.29	−0.05	0.39	
ANB (°)	−0.82**	0.24	−0.03	0.22	*
SN/GoGn (°)	0.48	0.28	−0.49	0.35	*
A–max.VR (mm)	−0.25	0.33	0.12	0.33	
B–mand.VR (mm)	−0.39	0.29	0.57	0.54	
ANS–Me (mm)	1.64**	0.22	0.86	0.43	
S–Go (mm)	2.59**	0.27	2.38**	0.54	
Co–A (mm)	−0.19	0.67	2.68	2.24	
Co–Gn (mm)	2.07**	0.69	3.78	2.11	
Co–Go (mm)	1.94**	0.26	3.27**	0.39	**
SN/Occ (°)	−0.91*	0.33	−0.72	0.36	
U1/max.HR (°)	−1.02	0.70	0.63	0.69	
U6/max.HR (°)	6.16**	1.48	0.10	0.79	**
U7/max.HR (°)	6.97**	1.87	−1.89	1.03	**
L1/mand.HR (°)	−1.74*	0.65	0.46	0.80	*
L6/mand.HR (°)	−0.80	0.75	0.74	0.96	
Overjet (mm)	−0.17	0.27	−0.04	0.17	
Overbite (mm)	−1.02**	0.23	−0.33	0.21	*
U1i–max.VR (mm)	0.05	0.39	0.30	0.32	
U6t–max.VR (mm)	−3.54**	0.71	0.88	0.48	**
U6t–max.VR (monthly) (mm)	−0.45**	0.09	0.08*	0.04	**
U7t–max.VR (mm)	−3.37**	0.59	0.97	0.44	**
U1i–max.HR (mm)	0.34*	0.12	0.05	0.23	
U6t–max.HR (mm)	1.14**	0.24	0.85*	0.31	
U7t–max.HR (mm)	−0.05	0.40	1.10*	0.41	
L1i–mand.VR (mm)	−0.75	0.39	0.47	0.49	*
L6t–mand.VR (mm)	−0.32	0.27	1.40*	0.62	*
L1i–mand.HR (mm)	0.26	0.24	0.58	0.25	
L6t–mand.HR (mm)	0.64	0.55	0.68	0.32	
Ls–(Steiner) (mm)	−0.85**	0.26	−0.31	0.48	
Li–(Steiner) (mm)	−0.72**	0.22	−0.22	0.62	

$*P < 0.05$, $**P < 0.01$.

Table 6 Comparison of the mean differences (D) and standard error of the differences (Sd) between the cervical headgear (CH) and control groups and three-dimensional bimetric maxillary distalization arch (3D-BMDA) group, by variance analysis.

Parameter	Differences in the 3D-BMDA group		Differences between the CH and control group		Test
	D	±Sd	D	±Sd	
SNA (°)	−0.01	0.23	−0.80	0.59	
SNB (−)	0.53*	0.23	−0.02	0.55	
ANB (°)	−0.54	0.26	−0.86*	0.34	
SN/GoGn (°)	0.01	0.24	1.08*	0.47	*
A–max.VR (mm)	−0.85**	0.29	−0.38	0.50	
B–mand.VR (mm)	−0.21	0.17	−1.01	0.23	
ANS–Me (mm)	0.57	0.32	0.85	0.59	
S–Go (mm)	1.06**	0.26	0.26	0.57	
Co–A (mm)	0.08	0.50	−3.15	1.20	
Co–Gn (mm)	1.72*	0.46	−1.92	1.40	
Co–Go (mm)	2.12**	0.33	−1.33	1.03	*
SN/Occ (°)	4.38**	0.68	−0.11	0.42	**
U1/max.HR (mm)	−0.87	1.38	−1.77	0.95	
U6/max.HR (mm)	5.51**	1.08	5.78**	1.02	
U7/max.HR (mm)	4.38**	1.04	8.99**	1.40	
L1/mand.HR (mm)	9.53**	1.39	−2.61*	1.86	**
L6/mand.HR (mm)	6.06**	1.16	−1.57	1.16	**
Overjet (mm)	−2.16**	0.54	−0.17	0.41	**
Overbite (mm)	−1.58**	0.53	−0.75*	0.30	
U1i–max.VR (mm)	0.06	0.47	−0.26	0.61	
U6t–max.VR (mm)	−3.55**	0.38	−4.56**	0.75	
U6t–max.VR (monthly) (mm)	−1.11**	0.13	−0.55**	0.09	**
U7t–max.VR (mm)	−2.86**	0.34	−4.49**	0.68	*
U1i–max.HR (mm)	1.60**	0.37	0.28	0.32	*
U6t–max.HR (mm)	−0.70*	0.20	0.28	0.19	*
U7t–max.HR (mm)	−0.78*	0.21	−1.18	0.25	
L1i–mand.VR (mm)	2.82**	0.44	−1.30*	0.83	**
L6t–mand.VR (mm)	2.16**	0.28	−1.80*	0.93	**
L1i–mand.HR (mm)	−0.93*	0.31	−0.32	0.36	
L6t–mand.HR (mm)	1.60*	0.23	−0.09	0.28	*
Ls–(Steiner) (mm)	−0.10	0.28	−0.48	0.58	
Li–(Steiner) (mm)	1.66**	0.24	−0.48	0.67	**

$*P < 0.05$, $**P < 0.01$.

intermaxillary elastics. These findings show that the traditional full-bonded mandibular arch is not sufficient to control anchorage. Muse *et al.* (1993) presented three patients who were treated using the same approach, but as their study used a combination of different mandibular anchorage support, the results cannot be compared.

The 3D-BMDA did not have a significant effect on mandibular rotation (mean increase of 0.01 degrees), while in the CH group there was a mean posterior rotation of 1.08 degrees. Despite the fact that the intermaxillary Class II elastics caused extrusion of the mandibular molars, this did not give rise to an increase in mandibular rotation contrary to previous reports (Reddy *et al.*, 2000; Ucem *et al.*, 2000). This contradiction can be explained by the compensatory increase in posterior face and ramus heights in the 3D-BMDA group. These increases indicate appositional growth of the condyle in the 3D-BMDA group. Thus, Co–Gn showed a significant increase.

When the two treatment groups were compared for mandibular length changes, differences were observed although they were not statistically significant. The increase in forward movement and length of the mandible can be explained by the appositional changes of the condyles due to the use of Class II intermaxillary elastics. Microscopic (Meikle, 1970) and cephalometric (McNamara, 1980) evidence shows that Class II intermaxillary elastics can stimulate growth of the condyles even in adult primates. McNamara (1980) also reported that proliferation of the condylar cartilage was stimulated in less than 2 weeks.

The maxillary first molars showed a statistically significant intrusion in the 3D-BMDA group, but only a very slight extrusion was recorded in the CH group (Muse *et al.*, 1993; Doganay, 1996; Yuksel *et al.*, 1996; Rana and Becher, 2000; Ucem *et al.*, 2000). This intrusion of the maxillary first molars in the 3D-BMDA group can be explained by the dentoalveolar compensation mechanism against the extrusion of the mandibular first molars (1.60 mm, $P < 0.05$).

Extrusion of the maxillary incisors was evaluated in both treatment groups. In the 3D-BMDA group the extrusion was caused by the Class II intermaxillary elastics, which is a common finding in other studies (Muse *et al.*, 1993; Doganay, 1996; Rana and Becher, 2000).

Regarding the soft tissue profile, the lower lip protruded in the 3D-BMDA group, but retruded in the CH group. These findings are consistent with the movements of the maxillary and mandibular incisors in the 3D-BMDA group and the posterior rotation of the mandible in the CH group.

Conclusions

1. 3D-BMDA and CH techniques are both effective in distalizing the maxillary molars.
2. A Class I relationship was achieved purely by maxillary molar distalization in the CH group but in the 3D-BMDA group both distalization of the maxillary molars and mesialization of the mandibular molars contributed to the result.
3. Distalization time and rate of distal molar movement were significantly shorter with the 3D-BMDA than with CH.
4. Moderate anchorage loss in the mandibular dental arch was observed in the 3D-BMDA group.
5. Full-bonded dental arches are not sufficient to support mandibular anchorage.
6. To achieve successful results with either of these techniques, the effects of each treatment modality on dentofacial structures need to be taken into consideration for each individual patient.

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