The effect of a modified reverse headgear force applied with a facebow on the dentofacial structures

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SUMMARY The purpose of this study was to evaluate the effects of a modified reverse headgear force applied with a facebow on the dentofacial structures of patients with skeletal Class III malocclusions characterized by maxillary retrognathism. Thirty individuals before the pubertal peak and in the mixed dentition were selected. Fifteen subjects (seven males, eight females, mean age 9.2 years) who formed the treatment group were compared with a control group comprising seven males and eight females (mean age 8.6 years). Maxillary deficiency and negative overjet were noted in all individuals included in the treatment and control groups. The combination of a full coverage maxillary removable appliance and an embedded facebow was used for treatment. The outer arms of the facebow were bent to deliver the force through the approximate centre of resistance of the maxilla. Extra-oral elastics extended from the reverse headgear to the outer arms of the facebow.

Statistical analysis indicated significant changes in angles SNA, NV–A, SV–ANS, SV–PNS and PP measurements, suggesting that the maxilla moved anteriorly. There was, however, no statistically significant difference in SN–MP, SN–PP and MP–PP measurements between the treatment and control groups. These results suggest that there was no maxillary or mandibular rotation, but that the molars moved mesially in the protraction group. The U6–PP(V) dimension did not display significant differences between the pre- and post-treatment measurements in the treated group. Anterior movement of the maxilla was obtained without rotation of the jaws and upper and lower maxillary heights were unaffected.

Introduction

Protraction headgear has been used in the treatment of Class III malocclusions for more than a century. Early interception with a chin cap or reverse headgear is the standard practice in orthodontics (Conte *et al.*, 1997). It has been suggested that treatment should be started early in subjects with a skeletal Class III malocclusion, but in severe cases it is necessary to delay treatment until growth has ceased before surgery is performed (Nanda, 1980).

Chin cap therapy is capable of affecting mandibular growth, but does not offer a solution for Class III cases that result from maxillary retrusion. In these subjects, maxillary protraction is required. The effects of posteroanterior orthopaedic forces on the maxillary complex and its anterior translation have been widely studied (Nanda and Goldin, 1980).

A major skeletal effect of reverse-pull headgear is a forward movement of the maxilla, via remodelling of the circummaxillary sutures. Bone age is a useful clinical indicator to determine the effective treatment plan with reverse-pull headgear (Suda *et al.*, 2000).

Delaire (1976) developed the orthopaedic facemask to stimulate maxillary development. It was initially used to correct clockwise rotation of the maxilla, then as a method to treat maxillary retrusion, but this is now carried out with a combination of protraction headgear and rapid maxillary expansion (Macey-Dare, 2000).

The protraction headgear developed by Hickham (1991) uses the head and chin as support. A headband and chin cap are connected with the arms parallel to the mandibular bases on both sides. Nanda (1980) developed a modified protraction headgear arch using elastics attached to a chin cap, the inner bows of which are inserted into the posterior openings of the molar tubes. Changing the vertical position of the outer arm controls occlusal cant.

An intra-oral anchorage system can be made from cast or removable plates (Sarnäs and Rune, 1987).

Orton *et al.* (1992) reported that elastic traction could be attached to a palatal expansion appliance or other fixed appliance. However, removable plates used in the mixed dentition will transfer these forces not only to the teeth but also to the palatal vault and thus to the whole maxilla.

Elastics running between the intra-oral anchorage system and the extra-oral appliance produce the necessary force for maxillary traction. With the Delaire system, traction hooks are placed distal to the lateral incisors and directed distally. Except in rare cases, traction is performed forward and downward.

Hata *et al.* (1987) applied different forces at the level of the maxillary arch and 5 and 10 mm above the Frankfort

horizontal plane (FHP). The first two produced anterior translation with slight counter-clockwise rotation, while the force level 10 mm above the FHP caused a clockwise rotation of the maxilla in combination with forward translation. Ishii *et al.* (1987) applied force from the molar and premolar levels and observed more forward translation of the maxilla in the first molar region in addition to a forward and upward rotation.

Force application along the centre of resistance (CR) causes a pure translation on the force direction. When the direction of the force is distant from the CR, a combination of translation and moment occurs (Chabre, 1990).

It has been stated that changing the direction of the outer arms of the facebow results in different biomechanical effects on alveolar and skeletal units. Pure translation of these units could thus be achieved without causing any undesired rotations or moments (Kubein-Meesenburg *et al.*, 1984; Chabre, 1990).

The aim of this study was to evaluate the effects of orthopaedic forces on the dentofacial structures of Class III patients with maxillary retrusion when the force is directed through the approximate CR of the maxilla. Pure translation of the maxilla free of any rotation is expected with facemask therapy where the intra-oral anchorage system is modified with the addition of a facebow.

Subjects and methods

The treated subjects were eight girls and seven boys with an average age of 9.2 years [median 9.165, standard deviation (SD) 0.396] with Class III maxillary retrusion. The control group comprised eight girls and seven boys with a Class III malocclusion with an average age of 8.6 years (median 8.65, SD 0.494). Maxillary deficiency and a negative overjet were noted in all individuals in the treatment and control groups.

The duration of treatment was between 0.43 and 2.01 years (average 0.95 years, median 0.774, SD 0.429). The follow-up period in the control group was between 0.87 and 1.9 years (average 1.1 years, median 0.985, SD 0.331).

To form the control group, lateral cephalograms were taken, with parental permission, from subjects who applied for but were not accepted for treatment at that time. Subsequently most received treatment.

The appliance was used in the treatment group until the negative overjet was corrected. In subjects who required additional therapy, other treatment mechanics were utilized.

Lateral cephalograms were obtained from all subjects, pre- and post-treatment or control, using the Orthoceph 10s (Siemens, Hyryla, Finland). The cephalograms were taken with the teeth in centric relation, with the FHP parallel to the floor and were standardized by maintaining the distance between the patient and the X-ray source at 152 cm and the distance between the patient and the film holder at 14 cm. The tracings were carried out manually.

Appliance design

The intra-oral anchorage system consisted of a full coverage maxillary removable appliance and an embedded facebow. The acrylic extended on the vestibular side to the middle third of the teeth and retention was reinforced with extra clasps (Figure 1). The inner arms of the facebow entered the removable appliance approximately next to the first primary molars and the outer arms were bent to deliver the force through the approximate CR of the maxilla. An average force of 600 g was applied to each side of the maxilla with extra-oral elastics (Dentaurum, Potters Bar, UK) extending from the pre-labial anchorage attachment of the reverse headgear to the outer arms of the facebow (Figure 2). The Delaire-type facemask was used for extra-oral anchorage (Leone, Firenze, Italy).

Measurements

In total, 15 skeletal (seven angular and eight linear; Figures 3 and 4) and 11 dental (five angular and six linear; Figures 5 and 6) measurements were evaluated.

Statistical methodology

Twenty randomly selected lateral cephalograms were retraced 1 month later and differences between the tracings were evaluated using Dahlberg's formula (Dahlberg, 1940). The pre- and post-treatment and pre- and post-control comparisons were evaluated using Wilcoxon's paired sample test and the pre- and post-treatment and treatment and control changes with the Mann–Whitney *U*-test.

Results

The method error for each measurement is shown in Table 1, with descriptive statistics and comparisons in Table 2.



Figure 1 The appliance on a dental cast.



Figure 2 The appliance *in situ* on a patient.



Figure 4 Skeletal measurements. 8, PP (ANS–PNS): the sagittal dimension of the maxilla; 9, N–Me: total anterior face height; 10, N–ANS: upper anterior face height; 11, ANS–Me: the lower anterior face height; 12, NV–A: the perpendicular distance of point A to nasion vertical; 13, NV–Pg: the perpendicular distance of point Pg to nasion vertical; 14, SV–ANS: the perpendicular distance of point ANS to the sella vertical line; 15, SV–PNS: the perpendicular distance of point Plastance of point PNS to the sella vertical line.



Figure 5 Dental measurements. 16, U1P–PP (angle): angle of the maxillary central incisor to the maxillary plane; 18, U1P–NA: inclination of the maxillary central incisor to nasion–A line; 19, L1P–MP: inclination of the mandibular central incisor to the mandibular plane; 21, L1P–NB: angle of the mandibular central incisor to nasion–B line; 22, U1P–L1P: interincisal angle.

Pre- and post-treatment and pre- and post-control within-group comparisons

Post-treatment measurements showed increases in SV–PNS and L6–SV (P < 0.05) and PP, N–Me, N–ANS, ANS–Me, NV–A, U1P–PP, U1–PP(V), L1–MP(V) and L6–MP(V) (P < 0.01). For SNA, ANB, SV–ANS and U6–SV, the measurements were significant at P < 0.001.



Figure 3 Skeletal measurements. 1, SNA: the relationship of the maxilla to the anterior cranial base; 2, SNB: the relationship of the mandible to the anterior cranial base; 3, ANB: the relationship of the maxilla and the mandible to each other; 4, SN–MP: the angle between the mandibular plane and the anterior cranial base; 5, SN–PP: the angle between the palatal plane and the anterior cranial base; 6, MP–PP: the angle between the palatal and mandibular planes; 7, SN–Occ: the angle between the anterior cranial base and the occlusal plane.

Pre-treatment and pre-control between-group comparisons

U1P–PP and U6–PP(V) measurements were significantly smaller in the treated group than in the controls (P < 0.05) and U1P–NA was again smaller (P < 0.01).



Figure 6 Dental measurements. 17, U1–PP(V): the distance of the upper incisor to the maxillary plane; 20, L1–MP(V): the distance of the lower incisor tip to the mandibular plane; 23, U6–PP(V): the distance of the mesial cusp tip of the first molar to the maxillary plane; 24, U6–SV: the distance of the mesial cusp tip of the first molar to the sella vertical line; 25, L6–MP(V): the distance of the mesial cusp tip of the first molar to the sella vertical line; 26, L6–SV: the distance of the mesial cusp tip of the first molar to the sella vertical line.

The SN–PP measurement decreased significantly (P < 0.05) as did those for SNB and U1P–L1P (P < 0.01).

Pre- and post-control comparisons

There were increases in N–Occ, L1–MP(V) and U6–PP(V) (P < 0.05) and N–Me, N–ANS, ANS–Me and U1–PP(V) (P < 0.01). NV–A decreased significantly (P < 0.05).

Treatment and control changes between-group comparison

In the treated group, SN–Occ, SNB and U1P–L1P measurements were smaller (P < 0.05, P < 0.01, P < 0.01, respectively). There were increases in SV–PNS, U1P–PP and L6–MP(V) (P < 0.05), PP (P < 0.01) and SNA, ANB, NV–A, SV–ANS and U6–SV (P < 0.001).

A clinical examination revealed a positive change in facial profile, a change in the molar relationship to

Class II and correction of the negative overjet in the treated group.

Irritation of the forehead and chin area, which supported the facemask, was observed in some subjects. In these instances, either the force level was decreased or the appliance was not worn for a short period of time.

A further difficulty during the course of treatment was the decrease in retention of the maxillary appliances. The patients attended more often than usual for adjustment of the clasps. Transfer of force to the maxilla with the facebow enabled application of the force in the desired direction.

Discussion

Nanda (1980) developed a modified protraction headgear for Class III cases which can control variables such as the degree, direction and point of application of force to overcome the undesired side-effects of extrusion of anchorage teeth, mandibular rotation and increase in lower face height. In the present study, a similar biomechanical system was used, but with a different intra-oral anchorage system. The aim was to stimulate maxillary growth in subjects with maxillary retrusion through controlled and anteriorly directed forces.

An acrylic removable appliance was preferred as the patients were in the early mixed dentition period and fixed appliance therapy was not applicable. It has been reported that fixing the whole arch reinforces anchorage (So, 1996). Therefore, the appliance design used in the present study covered the occlusal surfaces and vestibular halves of the teeth.

Rotational movements of the maxilla are important as they affect the mandibular position (Baik, 1995; Gallagher and Miranda, 1998). En-masse anterior translation of the maxilla, prevention of mandibular counter-clockwise rotation and beneficial autorotation are desired, particularly in Class III subjects with an open bite tendency. In the treated patients in this investigation, in addition to the direction of extra-oral force, it is suggested that the muscular forces resulting from augmentation of the acrylic thickness in the occlusal part of the appliance prevented counter-clockwise rotation.

Deguchi et al. (2002) stated that an optimal force system should be utilized to achieve changes in

Table 1	Dahlberg's method e	rror.
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1	SNA	0.547	10	N-ANS	0.689	19	L1P–MP	0.915
2	SNB	0.591	11	ANS-Me	0.977	20	L1-MP(V)	0.570
3	ANB	0.370	12	NV-A	0.720	21	L1P–NB	0.984
4	SN-MP	0.945	13	NV–Pg	1.081	22	U1P-L1P	0.993
5	SN-PP	0.802	14	SV-ANS	1.164	23	U6-PP(V)	0.866
6	MP-PP	1.072	15	SV-PNS	1.003	24	U6–SV	0.925
7	SN-Occ	1.060	16	U1P-PP	0.951	25	L6-MP(V)	0.617
8	PP	0.847	17	U1-PP(V)	0.707	26	L6–SV	0.741
9	N-Me	1.206	18	U1P-NA	1.045			

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		Pre-trei (T1)	atment	Post-tré (T2)	eatment	Treatme changes	ant (TC)	Pre-cont (C1)	trol	Post-con (C2)	trol	Control changes	(CC)	T1-C1 (P)	T1-T2 (P)	C1-C2 (P)	TC-CC(P)
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD				
.	SNA		3 630	80.87	3 980	3 18	1 011	77 13	2 855	00 22	2 413	-010	1 005	SN	0 0007***	SN	0.0000***
- 0	SNB	77.67	3.189	76.60	3.007	-1.00	1.000	77.90	2.681	70.77	2.438	0.10	1.049	SN	0.0033 **	SN	0.0087^{**}
l က	ANB	0.10	2.072	4.30	2.259	4.11	1.129	-0.77	1.741	-0.93	1.751	-0.20	0.487	NS	0.0007***	NS	0.0000***
4	SN-MP	38.27	4.586	37.87	4.533	-0.57	1.517	36.07	3.736	36.40	3.714	0.33	1.096	NS	NS	NS	NS
S	SN-PP	9.37	2.924	8.23	2.321	-1.32	1.647	9.87	2.364	9.80	2.043	-0.10	1.441	NS	0.0294^{*}	NS	NS
9	MP-PP	29.03	4.715	29.40	5.015	0.29	4.656	26.57	4.026	27.00	4.255	0.43	1.579	NS	NS	NS	NS
7	SN-Occ	20.63	4.198	20.00	3.935	-0.82	2.406	18.10	5.319	20.33	2.883	0.97	1.652	NS	NS	0.0268^{*}	0.0295*
8	PP	43.60	3.418	46.67	4.761	3.07	2.555	43.97	2.793	44.20	2.743	0.23	1.720	NS	0.0019^{**}	NS	0.0012^{**}
6	N–Me	111.80	4.475	114.60	5.302	2857	3.231	111.60	6.501	114.90	7.457	3.33	2.710	NS	0.0088^{**}	0.0015^{**}	NS
10	N–ANS	49.07	2.492	50.47	2.560	1.36	1.499	49.80	3.406	51.40	3.225	1.60	1.352	NS	0.0088^{**}	0.0024^{**}	NS
11	ANS-Me	62.07	3.807	64.13	3.815	2.21	2.359	61.80	4.021	63.53	5.080	1.73	1.840	NS	0.0088^{**}	0.0033 * *	NS
12	NV-A	-1.33	3.604	1.73	3.746	3.04	3.195	-0.67	3.559	-1.67	3.981	-0.47	2.481	NS	0.0023^{**}	0.0446*	0.0005***
13	NV-Pg	-2.43	6.408	-3.30	5.046	-0.82	5.882	0.83	7.724	-0.03	7.463	-0.87	3.930	NS	NS	NS	NS
14	SV-ANS	71.13	3.925	76.33	4.865	5.07	2.432	72.03	3.038	72.30	2.945	0.27	1.709	NS	0.0007^{***}	NS	0.0000***
15	SV-PNS	27.80	5.158	29.63	6.108	1.68	2.462	28.50	3.650	28.00	4.207	-0.47	2.481	NS	0.0144^{*}	NS	0.0329*
16	U1P-PP	106.70	6.408	109.80	5.017	2.93	2.986	112.30	4.648	112.70	4.605	0.47	3.102	0.0112^{*}	0.0047^{**}	NS	0.0220*
17	U1-PP(V)	24.20	2.651	26.10	1.981	1857	1.915	25.83	3.149	27.00	3.108	1.20	1.424	NS	0.0027^{**}	0.0046^{**}	NS
18	U1P-NA	20.43	6.173	21.20	6.301	0.68	3.576	25.87	4.434	26.40	3.611	0.53	2.875	0.0051 **	NS	NS	NS
19	L1P-MP	88.50	5.828	88.93	5.535	0.71	2.509	90.20	6.505	89.67	6.360	-0.53	2.166	NS	NS	NS	NS
20	L1-MP(V)	35.73	1.990	37.20	1.801	1.50	1.286	34.87	2.642	35.60	2.634	0.73	1.265	NS	0.0026^{**}	0.0146^{*}	NS
21	L1P-NB	24.50	5.644	24.23	5.809	-0.11	2.661	23.73	4.419	24.00	3.932	0.27	2.381	NS	NS	NS	NS
22	U1P-L1P	134.60	7.890	130.80	7.473	-3.86	4.525	130.60	6.602	130.70	5.589	0.03	2.936	NS	0.0031 **	NS	0.0046^{**}
23	U6-PP(V)	18.60	1.502	19.27	1.624	0.71	1.325	20.60	2.501	21.47	2.532	0.87	1.125	0.0211*	NS	0.0113*	NS
24	U6-SV	26.83	3.692	32.43	4.777	5.71	2.792	29.30	3.683	29.30	3.422	0.00	2.625	NS	0.0007***	NS	0.0000***
25	L6-MP(V)	26.57	2.120	28.33	2.335	1.79	1.368	26.30	2.313	26.83	2.304	0.53	1.394	NS	0.0021 **	NS	0.0138*
26	L6–SV	29.40	3.795	31.77	4.996	2.54	4.097	30.23	5.274	31.23	4.602	1.00	2.679	NS	0.0303*	NS	NS



NS, not significant. *P < 0.05, **P < 0.01, ***P < 0.001.

craniofacial morphology. Accordingly, application of force in relation to the CR of the maxilla and the dentition should be considered, along with the degree and direction of force (Nanda and Goldin, 1980; Nanda and Hickory, 1984).

The mechanical principles of protraction headgear are the same as those of cervical or high pull headgear, only the direction of force is different. Thus, in subjects with maxillary deficiencies it should be determined whether clockwise or counter-clockwise maxillary rotation is desirable, together with the anterior translation. For example, in subjects with normal overbite and normal vertical ratios, the anterior translation should be realized free of rotational moments. Translation in anterior open bite patients should be accompanied by clockwise rotation, whereas counter-clockwise rotation is desirable in deep bite cases (Staggers *et al.*, 1992).

In this study, the force direction and point of application were controlled by adjustment of the outer arms of the facebow. The elastics used were applied extra-orally and the facebow inserted into the appliance could be adjusted to avoid any irritation to the lips. For that reason, irritation caused by intra-orally used elastics to the lips, which hinder force adjustment, did not occur with this appliance.

Protraction headgears possess anchorage pads at the chin and forehead and elastics apply the force from a point in the maxilla to the labial arch, providing an anterior force (Ishii *et al.*, 1987). The positions of the elastics are adjusted according to the lip position for patient comfort. However, the use of elastics for force delivery does not allow determination of the direction and point of force application (Nanda, 1980; Staggers *et al.*, 1992). In these cases, eruption of anchorage teeth, changes in the cant of the occlusal plane, mandibular clockwise rotation and increases in lower anterior face height are observed (Ishii *et al.*, 1987).

The mechanics used aimed to apply pure translatory forces to the maxilla free of rotation. The outer arms of the facebow were bent upwards to deliver the force above the CR of the dentition and through the CR of the maxilla.

Previous investigations of maxillary protraction show a clockwise rotation of the mandible, a change in the cant of the mandibular plane, an increase in SNA and a decrease in SNB, resulting in correction of a negative ANB (Baik, 1995; Gallagher and Miranda, 1998; Pangrazio-Kulbersh *et al.*, 1998).

The significant changes in angles SNA, NV–A, SV–ANS, SV–PNS and PP measurements found in this study indicate that the maxilla moved anteriorly. The insignificant changes in the same measurements in the control group suggest that these changes were a result of the protraction therapy.

The measurements for SN–MP, SN–PP and MP–PP did not, however, show statistically significant differences

between the treatment and control groups. These results suggest that the maxilla and the mandible did not rotate, the NV–Pg dimension did not change and the sagittal position of the mandible was not affected. Reduction in SNB angle was related to forward movement of nasion rather than clockwise rotation of the mandible. It has been stated that nasion moves anteriorly with posteroanterior forces. Thus, increases in SNA are masked by this movement and SNB is decreased (Jackson *et al.*, 1979;

Hata *et al.*, 1987; Sung and Baik, 1998). N–Me, N–ANS and ANS–Me demonstrated statistically significant increases between the pre- and post-treatment records. However, because the same rate of increase was also observed in the control group, it can be assumed that these changes result from growth and development. Mermigos *et al.* (1990) found that total anterior and posterior face heights increased, indicating that this is probably a reflection of growth and development.

Dental changes related to orthopaedic protraction forces to the maxilla have been widely studied and in many cases maxillary incisor protrusion, mandibular incisor retrusion and achievement of normal overjet and overbite have been reported (Sarnäs and Rune, 1987; Takada *et al.*, 1993). These changes, except for lower incisor retrusion, were also observed in the present investigation. Interincisal angle, on the other hand, demonstrated a significant decrease. While the distance of the upper incisor to PP and lower incisor to MP was increased, there was no difference between the treatment and control groups.

Evaluation of maxillary molar sagittal movements demonstrated that the changes in the U6–SV dimension were statistically significant between the treatment and control groups and that the molars moved mesially in the treated group. Clinically, the resultant molar relationship was either half or full unit Class II. However, the L6–SV dimension did not show statistically significant differences between the treatment and control groups.

Vertical movement of the upper and lower molars was also observed. While there was no significant difference for the dimension U6–PP(V) in the treated group pre- and post-treatment, L6–MP(V) demonstrated significant differences. The differences in the measurement for U6–PP(V) between the treatment and control groups and inhibition of mandibular rotation despite lower molar eruption may be related to the inhibition of upper molar eruption with the appliance.

It has been demonstrated that anterior force application to molars causes mesial and vertical movement of the upper molars and a related change in the cant of the occlusal plane (Tindlund, 1989). In the present study, the SN–Occ measurement displayed significant differences between the control and treatment groups, although pre- and post-treatment differences were insignificant.

Sinclair and Little (1985) showed that vertical eruption of the upper and lower molars was closely related to mandibular rotation and face dimensions. Protraction headgear is widely used in Class III subjects with maxillary underdevelopment. The degree and direction of force and stabilization of the maxillary dental arch are important factors in the treatment of such cases. Counter-clockwise rotation of the maxilla should be avoided in Class III open bite subjects where the vertical dimensions have increased, as this can result in a deterioration of the situation.

Conclusions

The results of this study suggest that:

- 1. Maxillary anterior growth and development were stimulated resulting in anterior translation of the maxilla.
- 2. No rotations of the maxilla and mandible were observed.
- 3. Upper and lower face heights were not affected by the treatment.

Use of a facebow in combination with a facemask is advantageous, as the direction of force can be adjusted to meet individual need. Use of the present appliance is suggested in Class III high angle patients with an open bite tendency and maxillary retrusion.

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