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Long-term follow-up of early treatment with reverse headgear

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SUMMARY The purpose of this study was to investigate the long-term outcome of treatment with reverse headgear in young individuals with a reverse overjet and a skeletal Class III malocclusion due to maxillary deficiency. Lateral cephalograms were obtained from 21 subjects (8.4 ± 1.5 years; 17 girls and four boys) of an original sample of 30 consecutively treated young patients who were followed for 8 years after active treatment. There was a drop-out of nine subjects; their dentofacial morphology at start of treatment did not differ from those who remained in the study. The remaining subjects were divided into a stable group and a relapse group.

The results revealed that two out of three patients maintained a positive overjet 8 years after active treatment. The immediate treatment outcome in the sagittal plane was the same for the stable and relapse groups, but lower face height increased ($P < 0.08$) and the mandibular plane angle opened ($P < 0.05$) more in the relapse group. During the 8-year follow-up period, the dental compensation was similar in both groups, but the mandible outgrew the maxilla by four times in the relapse group, compared with twice that in the stable group. In young individuals diagnosed with maxillary deficiency treated with reverse headgear and who have an immediate positive treatment response, there is a potential risk that about one-third might be candidates for orthognathic surgery later in life, because of an unfavourable growth pattern.

Introduction

Skeletal Class III malocclusions may be due to maxillary retrognathism, mandibular prognathism or a combination of both (Proffit, 1999). It has been reported that two-thirds of skeletal Class III malocclusions in Caucasian individuals are due to either maxillary hypoplasia or a combination of maxillary hypoplasia and mandibular prognathism (Ellis and McNamara, 1984; Guyer *et al.*, 1986). Moreover, in the comparatively high prevalence of Class III malocclusions of a Chinese population, more than 70 per cent have a retrognathic maxilla and a normal mandible, or a combination of a retrognathic maxilla and prognathic mandible (Jin and Lin, 1985). In view of the high frequency of maxillary retrusion, maxillary advancement by reverse headgear has been considered as a major treatment option in young patients (Cozzani, 1981; Mermigos *et al.*, 1990; Merwin *et al.*, 1997; da Silva Filho *et al.*, 1998; Kapust *et al.*, 1998). Although some investigators (Wisth *et al.*, 1987; Chong *et al.*, 1996) have claimed that the effect of reverse headgear was mainly backward rotation of the mandible rather than maxillary advancement, quite a number of authors (Ngan *et al.*, 1992, 1996a,b; Takada *et al.*, 1993; Baccetti *et al.*, 1998) have shown a significant protraction effect on the maxilla. In a 4-year follow-up study, a 75 per cent success rate was reported for reverse headgear treatment, i.e. those patients who had maintained a positive overjet (Ngan *et al.*, 1997). These results indicate a high success rate in the treatment of young skeletal Class III patients due to maxillary retrognathism with reverse headgear in the short-term. However, at the time of the 4-year follow-up, the patients were only 12–14 years old, thus growth was still far from complete (Hägg and Taranger, 1982). Obviously, there was still a potential risk for unfavourable post-treatment changes due to growth in the Class III patients who had received early treatment with reverse headgear. Thus, the aim of this study was to evaluate the long-term effect of reverse headgear at the time when facial growth was close to completion or complete.

Subjects and methods

The original sample consisted of 30 consecutive Chinese Class III patients (20 girls and 10 boys) treated with a reverse headgear appliance (Ngan *et al.*, 1997). According to clinical assessment at the start of treatment, all patients had an anterior crossbite with no functional shift and a retrognathic maxilla and normal mandible. The mean age was 8.7 ± 1.4 years (Table 1). The type of appliance (reverse headgear plus rapid palatal expansion), the magnitude, duration, and direction of force were standardized and have been described in detail elsewhere (Ngan *et al.*, 1992, 1997). At the end of treatment, after a mean treatment time of 9.2 ± 0.3 months, all subjects had a positive overjet. There was a drop-out of nine subjects at the 8-year follow-up, of whom seven had emigrated and two refused to participate. Thus, 21 patients (17 females and four males) were included in the 8-year follow-up. During the 8-year follow-up period, six subjects had undergone fixed appliance treatment (Table 2). At the time of comprehensive orthodontic treatment, five of the six patients had a positive overjet and crowding, while one had a modest reverse overjet (–1 mm). At the 8-year follow-up, all six subjects had maintained a positive overjet. Patients with a positive overjet were defined as stable and those with a negative overjet as relapse (Ngan *et al*., 1996a,b, 1997). In the stable group, all subjects ($n = 14$) had maintained a positive overjet at the 8-year follow-up. In the relapse group ($n = 7$), apart from one subject who had fixed appliance treatment (camouflage treatment) at 11 years of age, all patients who had relapsed to a reverse overjet were considered to be in need of combined orthodontic and surgical correction.

Lateral cephalograms obtained at the start of treatment (T_0), end of treatment (T_1), and 8 years post-treatment (T_2) were included. Therefore, (T_0–T_1) represented the treatment changes, (T_0–T_2) the total changes during treatment and the follow-up period, and (T_1–T_2) the changes during the follow-up period. Sagittal and vertical parameters were analysed on lateral cephalograms according to Pancherz (1982a,b; Figures 1 and 2).

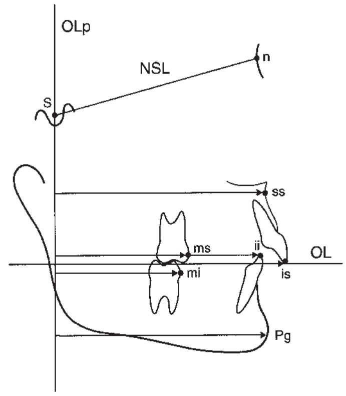

Figure 1 Cephalometric analysis of the sagittal dimension: overjet (is–ii), maxillary base (OLp–ss), mandibular base (OLp–Pg), base relationship (ss–Pg), maxillary incisor (ss–is), mandibular incisor (ii–Pg), maxillary molar (ms–ss), and mandibular molar (mi–Pg).

Statistical analysis

For the cephalometric analysis, comparison of treatment changes between the stable and relapse groups was performed using a two-tailed *t*-test. The level of significance used was $P < 0.05$, $P < 0.01$, and $P < 0.001$.

Table 1 Age (years) at start of treatment (T_0), end of treatment (T_1), and 8-year follow-up (T_2), and duration of treatment (T_0–T_1)/observation period (T_1–T_2).

Group	*n*	T_0		T_1		T_2		T_0–T_1		T_1–T_2	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Initial sample	30	8.7	1.4	9.4	1.5	–		–		–	
This sample	21	8.4	1.5	9.2	1.6	17.4	1.8	0.8	0.3	8.2	0.8
Stable group	14	8.4	1.4	9.1	1.5	17.6	1.7	0.7	0.2	8.5	0.6
Relapse group	7	8.5	1.9	9.3	2.0	17.0	2.0	0.8	0.3	7.7	1.1
Drop-out	9	9.2	2.1	10.0	2.1	–		–		–	
P value		0.549[1]		0.508[1]		0.480[2]		0.372[2]		0.042[2]	

[1]Null hypothesis: mean (initial sample) = mean (this sample) = mean (stable group) = mean (relapse group) = mean (drop-out group).
[2]Null hypothesis: mean (this sample) = mean (stable group) = mean (relapse group).

Table 2 Description of six patients (five in the stable group and one in the relapse group) who had comprehensive fixed appliance (FA) treatment during the 8-year follow-up period. Age at start (T_0) and end (T_1) of reverse headgear treatment and at follow-up (T_2).

	T_0	T_1	T_2	Age at start of FA	Malocclusion	Treatment
Stable group						
1	8.9	10.0	15.2	5 years after T1	Crowding	Extraction 14, 24, 34, 44
2	10.5	11.4	18.4	7 years after T1	Crowding	Extraction 14, 24, 34, 44
3	6.4	6.9	11.2	4 years after T1	Crowding	Extraction 14, 24, 34, 44
4	9.4	10.2	12.3	2 years after T1	Crowding with missing 12, 22	Non-extraction
5	8.9	9.6	12.6	3 years after T1	Crowding	Extraction 14, 24, 34, 44
Relapse group						
6	8.8	9.6	11.8	2 years after T1	Reverse overjet (–1 mm)	Non-extraction

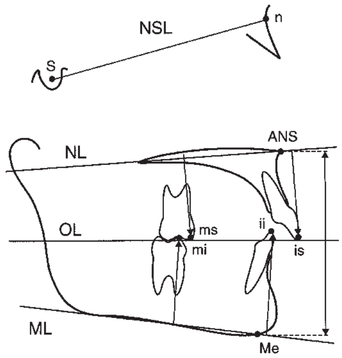

Figure 2 Cephalometric analysis of the vertical dimension: overbite (ii–OL), lower face height (ANS–Me), maxillary central incisor (is–NL), mandibular central incisor (ii–ML), maxillary permanent first molar (ms–NL), mandibular permanent first molar (mi–ML), mandibular plane angle (ML/NSL), nasal plane angle (NL/NSL), maxillary occlusal plane angle (OLs/NSL), and mandibular occlusal plane angle (OLi/NSL).

Method error study. For error measurements, all measurements on the cephalograms were retraced twice independently on two separate occasions with a 2-week interval between them. The system error was assessed using the paired *t*-test on the means of the individual variables obtained from the measurements made on the two different occasions. In addition, the size of the combined method error in locating and measuring the change in the different landmarks was calculated by the formula $SEM = \pm \sqrt{(\Sigma d^2/2n)}$, where d is the difference between two registrations of a pair and n is the number of double registrations. There was no systematic error, and no error exceeded 0.5 mm or 0.5 degrees.

Results

Dentofacial morphology (Table 3)

There was no statistically significant difference in dentofacial morphology at the start of treatment (T_0) between the drop-outs and those remaining in the study at the end of the 8-year follow-up.

There was no statistically significant difference in dentofacial morphology between the stable and relapse groups at the start of treatment (T_0) except for the position of the molars. At the end of reverse headgear treatment (T_1) there was no statistically significant difference in the sagittal plane between the two groups except for the position of the molars, which were still positioned more mesially in the relapse group. Lower face height was longer and the mandibular plane angle was steeper in the relapse group than in the stable group ($P < 0.05$) after active treatment. At the end of the 8-year follow-up (T_2) there was still the same pattern of differences in the vertical plane between the two groups (ns). In the sagittal plane the jaw base ($P < 0.05$) and molar ($P < 0.01$) relationship was significantly more Class III in the relapse group than in the stable group. The maxilla was more retruded and the mandible was more protruded in the relapse group than in the stable group, but the differences were not statistically significant.

Treatment changes (T_0–T_1)

There was no statistical difference in treatment changes in the sagittal plane between the stable and relapse groups (Table 4; Figure 3a). In both groups, there were significant increases in overjet, improvement of the molar relationship, and forward movement of the maxilla and maxillary incisors. The mandible was retruded (ns) and mandibular incisors uprighted (ns) in both groups. In the vertical plane there was a statistically significant reduction of overbite only in the relapse group (Table 5). Lower face height increased significantly in both groups, but the difference (1.8 mm) was not statistically significant ($P < 0.08$). The mandibular plane angle increased significantly in both groups, and significantly more in the relapse group ($P < 0.05$). The occlusal planes were reduced in both groups, but this was only statistically significant in the relapse group ($P < 0.05$).

Post-treatment changes (T_1–T_2)

During the post-treatment period, there was less reduction in overjet ($P < 0.05$) and less change in jaw base ($P < 0.01$) and molar relationship ($P < 0.05$) in the stable group than in the relapse group (Table 4; Figure 3b). The skeletal pattern changes were such that the maxilla came more forward and the mandible less forward in the stable group. All sagittal dental changes were more pronounced (ns) in the relapse group. There was no statistically significant difference in the vertical changes between the two groups during the follow-up period (Table 5). There were significant increases in lower face height and eruption of all molars and incisors in both groups during this period.

Total changes (T_0–T_2)

The combined differences in the sagittal plane during treatment and at the end of the 8-year follow-up period between the two groups remained statistically significant for overjet and jaw base relationship only, being less favourable for the relapse group (Table 4; Figure 3c). There was a statistically significant improvement in overjet in the stable group (4.4 mm; $P < 0.001$) but no change in the relapse group. The maxilla grew more forward and the mandible less forward in the stable group than in the relapse group, but the differences were not statistically significant. The maxillary incisors protruded and the mandibular incisors retruded significantly but by similar amounts in both groups. In

Table 3 Dentofacial morphology of the Class III subjects at the start of treatment (T_0), end of treatment (T_1) and 8-year follow-up (T_2).

									T_0						T_1						T_2					
	Original		Dropout		Present		P–D		Stable		Relapse		S–R		Stable		Relapse		S–R		Stable		Relapse		S–R	
	(n = 30)		(n = 9)		(n = 21)				(n = 14)		(n = 7)				(n = 14)		(n = 7)				(n = 14)		(n = 7)			
Variables	Mean	SD	Mean	SD	Mean	SD	*d*	*P* value	Mean	SD	Mean	SD	*d*	*P* value	Mean	SD	Mean	SD	*d*	*P* value	Mean	SD	Mean	SD	*d*	*P* value
Pancherz's analysis																										
Sagittal plane																										
Overjet	–1.9	0.99	–2.1	1.07	–1.8	0.97	0.2	0.458	–1.5	0.87	–2.4	0.99	0.8	0.050	5.4	1.65	3.7	1.98	1.7	0.051	2.8	1.08	–2.6	4.19	5.5**	0.002
Maxillary base	70.0	3.01	70.5	1.70	69.8	3.44	–0.7	0.569	69.8	3.76	69.9	2.96	–0.2	0.952	71.9	3.76	71.7	2.45	0.2	0.900	77.8	5.72	75.3	2.69	2.5	0.291
Mandibular base	80.3	5.06	80.9	5.58	80.1	4.94	–0.8	0.699	79.6	5.31	81.1	4.32	–1.5	0.526	79.0	5.22	79.6	4.13	–0.6	0.794	91.7	6.29	96.2	7.43	–4.5	0.161
Base relationship	–10.3	4.22	–10.4	4.91	–10.3	4.02	0.1	0.954	–9.9	3.64	–11.1	4.89	1.3	0.532	–7.1	3.65	–7.9	4.47	0.8	0.665	–13.9	5.02	–20.9	7.68	7.1*	0.021
Maxillary incisor	7.7	1.99	7.8	1.94	7.6	2.06	–0.2	0.806	7.4	2.02	8.0	2.25	–0.6	0.544	10.5	2.31	10.0	2.06	0.5	0.634	12.4	2.60	13.4	1.97	–1.1	0.383
Mandibular incisor	–0.8	4.21	–0.6	5.31	–0.9	3.80	–0.3	0.862	–0.9	3.84	–0.8	4.01	–0.1	0.956	–1.9	3.38	–1.6	2.95	–0.4	0.844	–4.3	3.79	–4.9	5.74	0.5	0.776
Maxillary molar	–20.8	3.39	–20.6	2.87	–20.9	3.66	–0.2	0.829	–22.2	2.92	–18.2	3.73	–4.0*	0.014	–20.6	3.08	–17.3	2.51	–3.3*	0.024	–19.2	4.51	–14.6	3.55	–4.6*	0.030
Mandibular molar	–28.0	4.29	–28.4	3.71	–27.8	4.59	0.7	0.732	–29.3	2.24	–24.8	6.62	–4.5*	0.030	–27.8	2.57	–23.7	5.31	–4.1*	0.026	–29.1	2.87	–25.9	4.35	–3.2	0.057
Molar relationship	–3.1	2.78	–2.6	2.60	–3.4	2.87	–0.8	0.479	–2.8	2.29	–4.6	3.69	1.8	0.182	0.1	2.54	–1.4	3.46	1.5	0.272	–4.0	1.69	–9.6	3.64	5.7**	0.001
Vertical plane																										
Overbite	3.1	2.31	3.6	2.71	3.0	2.16	–0.6	0.523	2.8	2.33	3.3	1.91	–0.5	0.630	2.1	1.15	0.3	1.89	1.8*	0.013	1.8	0.77	0.5	2.50	1.3	0.085
Lower face height	59.4	3.53	60.8	3.93	58.5	2.75	–2.2	0.076	58.0	2.48	59.6	3.12	–1.6	0.216	60.8	3.26	64.2	3.31	–3.4*	0.037	69.3	4.43	71.5	4.63	–2.2	0.304
Maxillary incisor	26.0	2.13	27.0	2.35	25.6	1.94	–1.4	0.100	25.1	2.09	26.6	1.13	–1.5	0.095	25.6	1.64	26.2	1.82	–0.6	0.455	28.5	2.27	29.9	2.01	–1.5	0.184
Mandibular incisor	39.0	2.51	39.7	2.87	38.7	2.36	–0.9	0.327	38.6	2.59	38.9	2.01	–0.3	0.792	40.2	2.74	40.3	2.06	–0.1	0.933	46.0	2.69	45.7	1.98	0.3	0.797
Maxillary molar	20.3	1.86	19.9	1.83	20.5	1.89	0.6	0.428	20.3	2.05	20.7	1.63	–0.4	0.659	20.9	1.41	21.4	2.39	–0.5	0.551	24.8	2.12	25.4	3.31	–0.6	0.618
Mandibular molar	28.9	1.95	29.7	2.24	28.5	1.76	–1.1	0.126	28.9	1.52	27.9	2.12	1.0	0.228	30.0	2.08	29.8	2.16	0.2	0.840	35.6	2.59	35.4	2.99	0.1	0.876
Mandibular plane angle	36.3	3.07	35.8	2.92	36.5	3.18	0.7	0.576	35.8	3.34	38.1	2.32	–2.3	0.120	36.8	3.31	40.6	2.76	–3.8*	0.017	38.1	4.55	40.7	1.60	–2.6	0.163
Maxillary plane angle	10.2	2.43	9.1	3.18	10.7	1.93	1.6	0.099	10.6	1.99	10.9	1.95	–0.3	0.747	10.3	1.59	10.9	1.57	–0.6	0.423	11.4	2.37	10.7	2.81	0.6	0.555
Maxillary occlusal plane angle	22.2	4.18	22.4	5.23	22.1	3.79	–0.3	0.861	21.3	3.30	23.7	4.46	–2.4	0.178	19.7	3.69	21.4	2.94	–1.7	0.303	18.2	3.73	20.3	4.27	–2.1	0.261
Mandibular occlusal plane angle	17.9	4.86	19.3	5.59	17.3	4.52	–2.0	0.310	16.8	5.16	18.3	2.98	–1.5	0.488	16.4	4.24	19.7	4.07	–3.4	0.105	15.1	4.69	17.5	2.69	–2.4	0.228

S–R, difference between stable and relapse group; P–D, difference between the present subjects (n = 21) and drop-out group (n = 9).
*$P < 0.05$; **$P < 0.01$.

Table 4 Sagittal treatment changes (T_0–T_1), post-treatment changes (T_1–T_2), and total changes (T_0–T_2) in 21 Class III patients treated with reverse headgear (Pancherz's analysis, sagittal plane).

Variables	T_0–T_1						T_1–T_2						T_0–T_2					
	Stable		Relapse		S–R		Stable		Relapse		S–R		Stable		Relapse		S–R	
	Mean	SD	Mean	SD	*d*	*P* value	Mean	SD	Mean	SD	*d*	*P* value	Mean	SD	Mean	SD	*d*	*P* value
Overjet	6.9***	1.65	6.1***	1.95	0.9	0.523	–2.6**	1.97	–6.4***	5.24	3.8*	0.025	4.4***	0.99	–0.3	4.57	4.6**	0.002
Maxillary base	2.1***	0.84	1.8*	0.99	0.4	0.170	5.9***	3.23	3.6**	2.56	2.4	0.207	8.1***	3.33	5.4**	2.58	2.7	0.356
Mandibular base	–0.6	3.02	–1.5	3.07	0.9	0.765	12.7***	4.55	16.6***	6.97	–3.9	0.110	12.1***	5.00	15.1***	8.39	–3.1	0.314
Base relationship	2.8**	2.93	3.3***	2.66	–0.5	0.915	–6.8***	3.29	–13.1***	5.72	6.3**	0.008	–4.0**	3.69	–9.8**	7.38	5.8**	0.003
Maxillary incisor	3.1***	1.44	2.0**	1.96	1.1	0.562	1.8*	2.91	3.4**	2.01	–1.6	0.654	4.9***	2.94	5.4**	2.78	–0.5	0.406
Mandibular incisor	–1.0	3.08	–0.8	1.80	–0.3	0.956	–2.4**	2.99	–3.3	3.65	0.9	0.689	–3.4***	2.99	–4.1**	2.49	0.6	0.760
Maxillary molar	1.6**	1.64	0.9	2.56	0.6	0.159	1.4	3.03	2.7*	2.27	–1.3	0.610	3.0***	2.98	3.6	3.44	–0.6	0.691
Mandibular molar	1.5**	1.46	1.1	2.56	0.4	0.233	–1.3	3.15	–2.1*	2.15	0.9	0.080	0.2	3.00	–1.1	4.22	1.3	0.198
Molar relationship	2.9***	2.47	3.1***	2.12	–0.3	0.723	–4.1***	2.39	–8.2***	4.69	4.1*	0.018	–1.2	2.61	–5.1	6.15	3.9	0.053

S–R, difference between stable and relapse group; P–D, difference between the present subjects (n = 21) and drop-out group (n = 9).
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 5 Vertical treatment changes (T_0–T_1), post-treatment changes (T_1–T_2), and total changes (T_0–T_2) in 21 Class III patients (stable group n = 14; relapse group n = 7) treated with reverse headgear (Pancherz's analysis, vertical plane).

Variables	T_0–T_1						T_1–T_2						T_0–T_2					
	Stable		Relapse		S–R		Stable		Relapse		S–R		Stable		Relapse		S–R	
	Mean	SD	Mean	SD	*d*	*P* value	Mean	SD	Mean	SD	*d*	*P* value	Mean	SD	Mean	SD	*d*	*P* value
Overbite	–0.7	2.28	–3.0***	2.02	2.3*	0.035	–0.3	1.12	0.2	3.91	–0.5	0.133	–1.0	2.13	–2.8	3.16	1.8	0.656
Lower face height	2.8***	1.51	4.6***	2.92	–1.8	0.083	8.5***	4.45	7.3***	3.46	1.2	0.777	11.3***	4.25	11.9***	4.42	–0.6	0.548
Maxillary incisor	0.5	0.97	–0.4	1.44	0.9	0.106	2.9***	1.42	3.7**	1.91	–0.9	0.959	3.4***	1.60	3.4***	1.18	0.0	0.259
Mandibular incisor	1.5***	1.25	1.4***	0.85	0.2	0.738	5.8***	2.55	5.4***	0.98	0.4	0.564	7.4***	2.50	6.8***	0.70	0.6	0.702
Maxillary molar	0.5	1.99	0.6	1.86	–0.1	0.907	3.9***	1.98	4.1**	3.22	–0.1	0.849	4.5***	3.02	4.7**	2.23	–0.3	0.901
Mandibular molar	1.1*	1.60	1.9***	1.37	–0.8	0.281	5.6***	2.10	5.6***	2.63	–0.1	0.488	6.7***	2.69	7.6***	2.44	–0.9	0.947
Mandibular plane angle	1.0**	1.15	2.5***	1.89	–1.5*	0.039	1.3	3.38	0.1	3.39	1.1	0.824	2.3*	3.24	2.6*	2.72	–0.3	0.475
Maxillary plane angle	–0.3	1.07	0.0	0.58	–0.3	0.520	1.1	2.34	–0.1	2.79	1.2	0.441	0.8	2.46	–0.1	2.73	0.9	0.305
Maxillary occlusal plane angle	–1.6	3.45	–2.3*	3.30	0.7	0.672	–1.5	3.50	–1.1	4.98	–0.4	0.871	–3.1**	3.48	–3.4	4.31	0.3	0.835
Mandibular occlusal plane angle	–0.5	4.64	1.4*	2.23	–1.9	0.324	–1.2	3.04	–2.2	5.03	1.0	0.721	–1.7	5.85	–0.8	3.91	–0.9	0.575

S–R, difference between stable and relapse group; P–D, difference between the present subjects (n = 21) and drop-out group (n = 9).
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

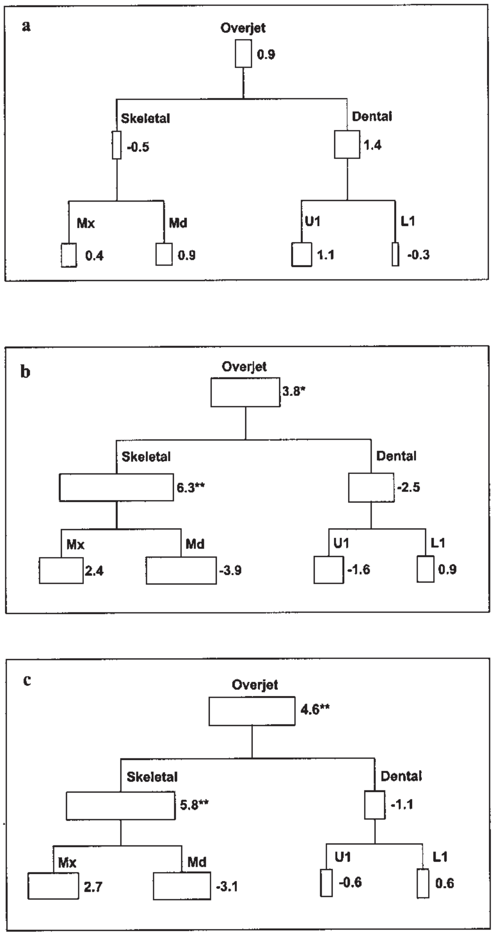

Figure 3 (a) Treatment changes between stable and relapse group (T_0–T_1); (b) 8-year post-treatment changes between stable and relapse group (T_1–T_2); (c) total changes between stable and relapse group (T_0–T_2).

the vertical plane, there was no significant difference between the two groups.

Discussion

The present study investigated the follow-up changes in a patient sample 8 years after active treatment with reverse headgear (Ngan *et al*., 1992, 1996a,b, 1997). The original sample comprised 30 consecutive young patients with skeletal Class III malocclusions due to maxillary deficiency, treated according to a prospective protocol with reverse headgear and rapid palatal expansion (Ngan *et al*., 1992). The immediate treatment changes and effects, as well as the short-term follow-up changes, have been reported previously (Ngan *et al*., 1996a,b, 1997). During the 8-year follow-up period there was a drop-out of 30 per cent (Table 1). However, the dentofacial morphology prior to treatment did not differ between the drop-outs and those who remained in the study (Table 3). Therefore, as the drop-out was random it did not bias the remaining sample, which was available for analysis at the 8-year follow-up. Almost one-third of the remaining subjects had undergone fixed appliance therapy, the main reason for treatment being crowding; only one patient was treated because of a (mild) reverse overjet (Table 2). The values of the dental parameters given may have been affected to a minor extent (Tables 3–5) by movements of the molars or incisors during treatment. Potentially the orthodontic treatment might have prevented development of a mild reverse overjet.

A commonly used method to assess success rate and stability has been to report the status of the overjet (Wisth *et al*., 1987; Takada *et al*., 1993; Baik, 1995; Battagel and Orton, 1995; Chong *et al*., 1996; Ngan *et al*., 1997; Deguchi *et al*., 1999; Lertpitayakun *et al*., 2001). In the present study, all patients achieved a positive and often over-corrected overjet during active treatment, i.e. within 8–10 months of treatment (Ngan *et al*., 1996b, 1997, 1998). Wisth *et al*. (1987) treated their patients with reverse headgear for a maximum of 12 months, and still 20 per cent had not achieved a positive overjet. Takada *et al*. (1993) and Nartallo-Turley and Turley (1998) reported that the patients in their retrospective sample were treated for up to 24 months before a positive overjet was achieved. In this context it should be borne in mind that only prospective studies will provide reliable data, since retrospective studies in general tend to include only 'successfully' treated patients.

In the earlier reports based on the present sample, it was possible to evaluate the effects of treatment by comparing changes in the patients treated with reverse headgear with the growth changes in an untreated matched control group (Ngan *et al*., 1997, 1998). For the present 8-year follow-up study no such control group was available, and thus the present analysis was limited to comparing the patients with 'stable overjet' with those in whom the overjet had relapsed (Tables 4 and 5). The patients were followed from the start of treatment at approximately 8.5 years to about 17.5 years of age at the end of the 8-year follow-up. The majority were females in the latter stage of the growth period or young adults (Hägg and Taranger, 1982). Therefore one would not assume that any major changes of the patients' overjets were due to growth only. If there is any further change of the overjet of some individuals within the present sample one would assume that the relapse group would increase rather than the stable group, since the mandible grows for a longer period and more than the maxilla (Björk, 1972).

The stable group comprised 14 subjects indicating a treatment 'success rate' of 67 per cent. Thus based on these results it can be assumed that about one-third of patients who are diagnosed with a reverse overjet in combination with a retrusive maxilla at a young age, and in whom the overjet is corrected with reverse headgear, relapse to a reverse overjet towards the end of the growth period. However, statistically, the 95 per cent confidence intervals for stable versus relapse result are 43–85 per cent and 15–57 per cent, respectively.

There has been no previous report on the long-term follow-up of a group treated with reverse headgear followed to the late stages of the growth period or early adulthood. Recently two studies with 6-year follow-up after treatment of very mild skeletal Class III malocclusions with reverse headgear in the primary dentition have been published, i.e. the sample was followed only to 10–12 years of age (Deguchi *et al*., 1999; Lertpitayakun *et al*., 2001). At that age the children were approaching or were at the beginning of the adolescent period, i.e. substantial facial growth was still expected (Hägg and Taranger, 1982). The treatment success rate reported at follow-up (Deguchi *et al*., 1999; Lertpitayakun *et al*., 2001) seems to be comparatively high in absolute figures, i.e. 85 per cent, but in relative figures the success rate was not so impressive since the self-correction rate in the control groups was as high as 75 per cent. The reported high incidence of self-correction might indicate that potential treatment with reverse headgear should be postponed to the early mixed dentition period.

In this study, assessment of the dentofacial changes was made mainly by distance (Pancherz, 1982a,b) rather than angular measurements (e.g. Björk, 1947), which have been commonly used in previous investigations of reverse headgear treatment (Mermigos *et al*., 1990; Takada *et al*., 1993; Battagel and Orton, 1995; Chong *et al*., 1996; Kapust *et al*., 1998). Bookstein (1997) showed that linear measurements are more accurate for the description of dentofacial changes than angular measurements. Using Pancherz's analysis (1982a,b) all measurements are made in relation to the occlusal plane, i.e. close to the 'problem area'. Pancherz's method (1982a) is also reported to be more suitable for assessment of dentofacial changes in samples than other superimposition methods (You and Hägg, 1999).

The results of this study show that during treatment there was no significant difference in the changes in the sagittal plane between the two groups (Table 4). However, the increase in lower face height and opening of the mandibular plane angle, side-effects that have also been reported from previous studies on reverse headgear (Wisth *et al*., 1987; Takada *et al*., 1993; Battagel and Orton, 1995; Chong *et al*., 1996, Kapust *et al*., 1998; Nartallo-Turley and Turley, 1998; Macdonald *et al*., 1999), were significantly less pronounced in the stable group compared with the relapse group (Table 5).

The positive overjet at the end of active treatment in the stable group (5.4 mm) was reduced to half that at follow-up (Table 3). In the relapse group the positive overjet at the end of treatment changed from 3.7 to –2.6 mm, which was not much different from the pre-treatment value of –2.4 mm (Table 3). It seems that dental compensation, i.e. protrusion of the maxillary incisors and retrusion of the mandibular incisors, was similar in both groups, and the difference in the change of overjet during the follow-up period was mainly due to the more unfavourable skeletal pattern in the relapse group (Table 4). In the vertical plane the changes in dentofacial morphology seem to be of a similar magnitude in the two groups during the follow-up period, which is in contrast to the treatment period when the face tended to become longer ($P < 0.05$) in the relapse group (Table 5). Subsequent relapse after initially successful treatment with reverse headgear in young skeletal Class III patients with maxillary deficiency seems to be mainly due to a combination of a less positive immediate treatment response resulting in a longer face, and an increasingly unfavourable sagittal jaw base relationship developing during the follow-up period. Overall, it might be that the more favourable growth pattern in the 'stable group' was enhanced by the reverse headgear therapy at a young age, i.e. bringing the maxilla forward in combination with a brief 'chin-cup' effect was sufficient to provide favourable conditions for those individuals' future growth. In the relapse group the inherent unfavourable skeletal growth pattern was not obvious at the start of treatment or from the 'immediate' treatment response of reverse headgear (Tables 3–5). In the relapse group the unfavourable post-treatment growth was too pronounced to be camouflaged by dento-alveolar compensation, which was only just sufficient to maintain the original overjet, similar to that seen in untreated skeletal Class III subjects (Miyajima *et al*., 1997). Even prolonged treatment with chin-cup therapy, although often resulting in an initial positive change, would not inhibit mandibular growth in the long-term (Sakamoto *et al*., 1984; Sugawara *et al*., 1990; Sugawara and Mitani, 1997).

Conclusions

This prospective longitudinal study shows that early treatment of maxillary deficiency with reverse headgear resulted in a positive overjet in all patients, but at long-term follow-up the positive overjet was maintained only in two out of three patients. Of those developing a negative overjet, one had comprehensive orthodontic treatment and those remaining were considered to be candidates for orthognathic surgery.

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