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The effects of early headgear treatment on dental arches and craniofacial morphology: a report of a 2 year randomized study

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SUMMARY The aim of the present study was to determine the effects of early headgear treatment on dental arches and craniofacial morphology in children in the early mixed dentition. The total study group comprised 68 children of both sexes (40 boys and 28 girls) aged 7.6 years [standard deviation (SD) 0.3]. The children, who had a Class II tendency in occlusion and moderate crowding of the dental arches, were randomly divided into two groups of equal size, matched according to gender. In the headgear (HG) group, treatment was initiated immediately. The mean treatment time was 16 months. In the second group, which served as the control, only interceptive procedures were performed during the follow-up period. The records, which included dental casts and lateral cephalograms, were obtained after follow-up periods of 1 and 2 years.

The lengths and the widths of the maxillary and mandibular dental arches were significantly increased in the HG group after the 2 year follow-up period. The mean increase in lower arch length and width was 2.4 mm (SD 1.7) and 2.2 mm (SD 1.2), respectively. On average, the space gain in the lower arch was half that of the upper arch. No significant changes were found in the arch dimensions of the control group. Maxillary growth restraint and labial tilting of the incisors were the most significant cephalometric findings in the HG group when compared with the controls.

The use of headgear in the early mixed dentition is effective in the treatment of moderate crowding. It is noteworthy that significant space gain in the dimensions of the lower arch can be achieved by headgear application to the upper first molars.

Introduction

Headgear is used to redirect or restrain maxillary growth, and to distalize upper molars in treating crowded dental arches (Ricketts, 1960; Poulton, 1964; Brandt and Root, 1975; Baumrind *et al.*, 1978).

In most studies, cervical headgear treatment has been combined with the use of edgewise appliances, functional appliances, bite plates, extractions, etc. The major findings have been that while forward movement of the maxilla is inhibited, postero-inferior redirection of its growth (Hanes, 1959; Brown, 1978; Melsen, 1978; O'Reilly *et al.*, 1993) and downward tipping of the palatal plane (Holdaway, 1956; King, 1957; Wieslander, 1974; Kirjavainen *et al.*, 2000) can occur. These result in a decrease in the SNA angle (Sandusky, 1965; Thompson, 1974; Wieslander, 1974; O'Reilly *et al.*, 1993; Tulloch *et al.*, 1997a,b, 1998), and opening of the bite and increase in anterior face height (Gianelly and Valentini, 1976; Cook *et al.*, 1994). Downwards and backwards rotation of the maxilla is followed by posterior rotation of the mandible (Klein, 1957; Kloehn, 1961; Brown, 1978). The results of the few studies where only cervical headgear has been used have mainly been similar to those mentioned above (Moore, 1959; Mills *et al.*, 1978). Very few data, however, are available on the effects of early headgear treatment, when started in early mixed dentition, in the cases of moderate crowding.

The purpose of the present longitudinal randomized investigation was to determine the effects of early headgear treatment on dental arches and craniofacial morphology in children in the early mixed dentition. The hypothesis was that with the early use of cervical headgear, significant increases in dental arch dimensions can be achieved.

Subjects and methods

A group of 7-year-old children were screened for the investigation. Children in need of orthodontic treatment due to moderate crowding and a Class II tendency were selected for comprehensive orthodontic examination. The total study group comprised 68 children of both sexes (40 boys and 28 girls) aged 7.6 years [standard deviation (SD) 0.3]. The crowding was clinically diagnosed as moderate based on the degree of space deficiency in the anterior regions of the dental arches. Twenty per cent of the children had an Angle Class II molar relationship. Eighty per cent had either a bilateral cusp to cusp molar relationship, a unilateral cusp to cusp relationship, or a Class I relationship on either side.

The children were randomly divided into two groups of equal size, matched according to gender. In the first group, headgear (HG) treatment was initiated immediately. The mean treatment time was 16 months. In the second group, which served as the control, only interceptive procedures were performed during the follow-up period. The records, which included dental casts and lateral cephalograms, were taken before (T0), and after follow-up periods of 1 (T1) and 2 years (T2). At T0, 87 per cent of the upper central incisors and 17 per cent of the upper lateral incisors had erupted. In the lower arch, all central and 79 per cent of the lateral incisors had erupted.

The mean overjet in the HG group before follow-up was 3.9 mm (SD 2.11) and in the controls 3.8 mm (SD 1.38). The mean overbite in the HG group was 2.6 mm (SD 1.31) and in the controls 2.3 mm (SD 1.95).

The comprehensive investigations included a clinical examination, impressions for dental casts and a radiographic examination (dental pantomogram and a lateral cephalogram).

In the HG group, the maxillary first molars were banded and cervical headgear was used, but no other appliances were applied. The long outer bows of the headgear were bent 10 degrees upwards in relation to the inner bow and a force of 700–1000 g was applied. The inner bow of the headgear was expanded and constantly held 10 mm wider than the dental arch. The patients were instructed to wear the headgear during sleep, for 8–10 hours. For safety reasons, the cervical headgear was only worn during sleep to avoid possible accidents during active periods of the day.

Six linear dimensions were measured on dental casts, using a digital calliper (Mitutoyo™, Kanagawa, Japan). The variables used are shown in Figure 1 and the 10 angular measurements registered on the lateral cephalograms in Figure 2.

The first full examination of patients was performed immediately before treatment and then after follow-up periods of 1 and 2 years. For statistical analyses both groups were pooled, as there was no significant difference between the initial values of the gender groups and because, in previous studies, analogous pooling has been performed as no significant gender difference in treatment effects has been found (Tulloch *et al.*, 1997a,b).

Statistical methods

Wilcoxon's signed rank test was used to analyse significant differences between the first (T0), second (T1) and third (T2) measurements, and the Mann–Whitney *U*-test was used for independent observations between the control and HG groups. The normality of the sample was assessed before the analyses and, as there were minor deviations, non-parametric tests were preferred.

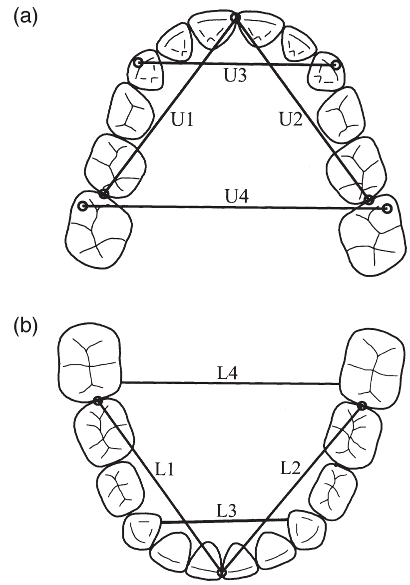

Figure 1 Dimensions of the dental arches measured on the three sets of dental casts (n = 68). (a) U1, U2, distance from the mesial contact point of the upper right and left first permanent molars to the most extensive point of the mesiolabial edge of the first incisor in the same quadrant; U3, distance between the highest points of the upper primary canines; U4, distance between the highest points of the mesiobuccal cusps of the first upper permanent molars. (b) L1, L2, distance from the mesial contact point of the lower right and left first permanent molars to the most extensive point of the mesiolabial edge of the first incisor in the same quadrant; L3, shortest distance between the mesiolingual surfaces of the lower primary canines; L4, shortest distance between the lingual surfaces of the first lower permanent molars.

The SPSS 10.0 statistical package (SPSS Inc., Chicago, IL, USA) was used for the analyses.

Results

At T1 the mean treatment time in the HG group was 8 months and at T2 16.2 months. During the period T0–T2, treatment procedures in the control group included any necessary interceptive procedures. These included extraction of the upper primary canines in 38 per cent of the subjects and of the lower primary canines in 35 per cent, to ease the eruption of the lateral incisors. In addition, in 19 per cent of the patients in the control group, some interdental stripping was carried out.

Maxillary dental arch changes

At T1 and T2 the length of the maxillary arch (U1 + U2) was significantly greater ($P \leq 0.001$) in the HG group than in the controls. The mean increase in the HG group after the 1 year (T0–T1) interval was 4.7 mm (SD 2.42) and after the 2 year (T0–T2) interval 6.0 mm (SD 3.61). The corresponding values in the control group were 0.2 mm (SD 2.01) and 0.2 mm (SD 2.78) (Table 1).

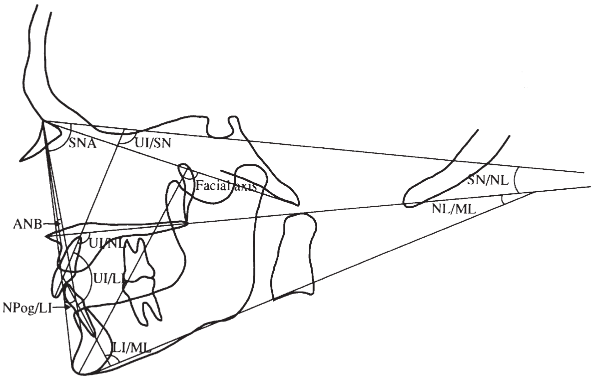

Figure 2 Angular dimensions measured on the lateral skull radiographs. SNA, the angle between the lines from nasion to sella and nasion to point A; ANB, the angle between the lines from nasion to point A and nasion to point B; SN/NL, the angle between a line from nasion to sella and the line intersecting the anterior and posterior nasal spines; NL/ML, the angle between the line intersecting the anterior and posterior nasal spines and a line from the inferior surface of the symphysis to the antegonial notch; UI/SN, the angle between the long axis of the upper first incisor and the line from nasion to the midpoint of sella; UI/NL, the angle between the long axis of the upper first incisor and the line intersecting the anterior and posterior nasal spines; LI/ML, the angle between the long axis of the lower first incisor and a line from the inferior surface of the symphysis to the antegonial notch; Npog/LI, the angle between the long axis of the lower first incisor and the line from nasion to pogonion; UI/LI, the angle between the long axis of the upper incisor and the long axis of the lower incisor; facial axis, the angle between the line from basion to nasion and the Ptm–Gn line.

After 1 (T0–T1) and 2 (T0–T2) years of headgear therapy, the width of the upper arch was increased by 2.9 mm (SD 1.38) and 3.7 mm (SD 2.05) when measured as the distance between the primary canines (U3) ($P \leq 0.001$) and 5.4 mm (SD 2.76) and 5.6 mm (SD 2.12) when measured as the distance between the upper first molars (U4)($P \leq 0.001$). There was a small but significant increase in the control group in the width of the maxillary arch after 1 and 2 years when measured as the distance between the upper molars, the mean increase being 0.6 mm (SD 1.51) and 1.1 mm (SD 1.87) ($P \leq 0.01$). The differences between the HG and control groups were highly statistically significant after the 1 and 2 year ($P \leq 0.001$) follow-up periods when measured as the distance between the primary canines and between the upper first molars (Table 1).

Mandibular dental arch changes

After the 1 and 2 year follow-up periods, the length of the mandibular dental arch (L1 + L2) was significantly greater ($P \leq 0.001$) in the HG group than in the controls. The mean increase in the HG group from T0 to T1 was 2.1 mm (SD 1.35) and from T0 to T2 2.4 mm (SD 1.68) (Table 1). The corresponding values in the control group were –0.4 mm (SD 1.41) and –0.5 mm (SD 1.76) (Table 1).

The width of the lower dental arch after 1 (T0–T1) and 2 (T0–T2) years of headgear therapy was increased by 1.4 mm (SD 0.82) and 1.3 mm (SD 0.90) when measured as the distance between the primary canines (L3) ($P \leq 0.001$) and 1.9 mm (SD 1.16) and 2.2 mm (SD 1.18) when measured as the distance between the lower first molars (L4)($P \leq 0.001$). There was no significant increase in the control group in the width of the mandibular dental arch after 1 and 2 years, the mean changes being 0.0 mm (SD 0.47) and 0.1 mm (SD 0.68) when measured as the distance between the lower first molars. The difference between the control and HG groups was highly statistically significant ($P \leq 0.001$) after the follow-up periods when measured as the distance between the lower first molars, but the difference was not significant between the groups in the distance between the primary canines (Table 1).

No significant difference in overjet was found between the groups after the follow-up periods. There was a significant difference between the groups in overbite at T1 and T2. The mean overbite at T1 in the HG group was 2.4 mm (SD 1.65) and in the controls 3.2 mm (SD 1.72), and at T2 2.7 mm (SD 1.44) in the HG group and 3.6 mm (SD 1.65) in the controls ($P \leq 0.001$) (Table 1).

Cephalometic measurements

In the HG group, SNA significantly decreased after the 1 and 2 year intervals (–1.3 degrees, SD 1.08, $P \leq 0.001$ and –1.7 degrees, SD 1.39, $P \leq 0.001$, respectively). No significant changes occurred in the control group (Table 2). ANB was significantly decreased in the HG group at T1 (–1.8 degrees, SD 1.25, $P \leq 0.001$) and T2 (–2.6 degrees, SD 1.45, $P \leq 0.001$). No significant changes occurred in the control group (Table 2). There was a significant difference in ANB between the groups at T2 ($P \leq 0.01$)(Table 2).

There were no significant differences in SN/NL, NL/ML or in the facial axis angles in the HG group compared with the control group at either T1 or T2.

The cephalometric measurements showed that the upper incisors were labially tilted in the HG group, the mean change in UI/SN angle being 4.3 degrees (SD 3.69) at T1 and 4.7 degrees (SD 5.88) at T2 ($P \leq 0.001$). For UI/NL angle, the measurements were 4.8 (SD 3.62) and 5.7 degrees (SD 6.63)($P \leq 0.001$), respectively. No significant changes occurred in the control group during the 2 year follow-up period. The difference between the groups was highly significant at T1 and T2 ($P \leq 0.001$) (Table 2).

The lower incisors were found to be labially tilted in the HG group at the follow-up periods, the mean change in LI/ML angle being 2.6 degrees (SD 3.63; $P \leq 0.01$) at T1 and 2.6 degrees (SD 4.50; $P \leq 0.05$) at T2. The mean change in NPog/LI angle was 2.2 degrees (SD

Table 1 Linear measurements made on the dental casts of children in the headgear (n = 34) and control (n = 34) groups immediately before treatment (T0) and after a follow-up period of 1 (T1) and 2 (T2) years.

		T0		T1		T2		Difference T0–T1[b]			Difference T0–T2[b]		
		x	SD	x	SD	x	SD	x	SD	P	x	SD	P
U1 + U2	Headgear group	70.2	3.75	75.6	4.65	76.8	3.97	4.7	2.42	***	6.0	3.61	***
	Control group	70.4	3.52	70.6	4.32	70.6	4.74	0.2	2.01	NS	0.2	2.78	NS
	Difference[a]	–0.2 NS		5.0***		6.2***		5.2***			6.4***		
U3	Headgear group	31.6	2.13	34.5	2.42	35.3	2.22	2.9	1.38	***	3.7	2.05	***
	Control group	31.1	2.53	31.5	2.67	31.6	2.66	0.4	1.48	NS	0.5	2.41	NS
	Difference[a]	0.5 NS		3.0***		3.7***		2.5***			3.2***		
U4	Headgear group	49.6	1.98	55.0	3.30	55.2	2.66	5.4	2.76	***	5.6	2.12	***
	Control group	49.1	2.55	49.7	2.57	50.2	2.35	0.6	1.51	**	1.1	1.87	**
	Difference[a]	0.5 NS		5.3***		5.0***		4.8***			4.5***		
L1 + L2	Headgear group	63.5	3.31	65.6	3.36	65.9	3.41	2.1***	1.35	***	2.4	1.68	***
	Control group	62.9	2.74	62.5	2.95	62.4	3.27	–0.4	1.41	NS	–0.5	1.76	NS
	Difference[a]	0.6 NS		3.1***		3.5***		2.5***			2.9***		
L3	Headgear group	20.2	2.28	21.2	1.89	21.5	1.57	1.4	0.82	***	1.3	0.90	***
	Control group	20.9	2.15	20.9	1.71	21.1	1.96	0.0	0.76	NS	0.2	1.04	NS
	Difference[a]	–0.7 NS		0.3 NS		0.4 NS		1.0***			1.1***		
L4	Headgear group	31.7	1.81	33.6	1.74	33.9	1.75	1.9	1.16	***	2.2	1.18	***
	Control group	31.4	1.59	31.4	1.63	31.5	1.65	0.0	0.47	NS	0.1	0.68	NS
	Difference[a]	0.3 NS		2.2***		2.4***		1.9***			2.1***		
Overbite	Headgear group	2.6	1.31	2.4	1.65	2.7	1.44	–0.2	0.87	NS	0.1	0.92	NS
	Control group	2.3	1.95	3.2	1.72	3.6	1.65	0.9	0.98	***	1.3	1.36	***
	Difference[a]	0.3 NS		–0.8***		–0.9***		–1.3***			–1.2***		
Overjet	Headgear group	3.9	2.11	3.8	1.93	3.9	1.55	–0.1	1.14	NS	0.0	1.55	NS
	Control group	3.8	1.37	3.4	1.46	3.7	1.60	–0.4	1.06	NS	–0.1	1.47	NS
	Difference[a]	0.1 NS		0.4 NS		0.2 NS		0.3 NS			0.1 NS		

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$.
SD, standard deviation; NS, not significant.
[a]Mann–Whitney U-test for independent samples; [b]Wilcoxon's signed rank test for paired observations.

4.16; $P \leq 0.01$) at T1 and 2.2 degrees (SD 4.61; $P \leq 0.05$) at T2. The difference in Npog/LI angle between the HG group and the controls was significant at both observation periods, but for LI/ML angle the difference was significant only at T1. The interincisal angle (UI/LI) was found to be decreased in the HG group at T1 and T2 ($P \leq 0.001$). There was no significant change in the interincisal angle in the control group. The difference between the groups was significant both at T1 and T2 ($P \leq 0.001$; Table 2).

Discussion

A longitudinal randomized investigation was undertaken to determine the treatment effects of cervical headgear on the dimensions of the dental arches, intermaxillary relationships and skeletal parameters in patients with moderate crowding and a Class II tendency in occlusion.

During normal growth, point A moves forward and downward with respect to the Frankfort horizontal and sella–nasion planes. The results from the present study show a significant reduction in SNA and ANB angles, implying that cervical headgear wear reduced maxillary anterior growth. The skeletal changes may result from the use of relatively strong forces. The orthopaedic effect seems, however, slightly less than that observed by Kopecky and Fishman (1993). They reported that maximum effect was achieved during the pubertal growth spurt. The reduction in SNA angle in this study, however, is in good agreement with the change reported for patients treated before the pubertal growth spurt by Kopecky and Fishman (1993) and the finding of Tulloch *et al.* (1997a,b). The distalization and forward growth restraining effects on the maxilla are in accordance with many findings (Poulton, 1959; Wieslander, 1974; Cangialosi *et al.*, 1988). The reduction in maxillary protrusion was not, however, followed by a decrease in overjet. This is partly explained by the increased labial inclination of the incisors in the HG group, especially in the upper arch. The palatal plane descends during normal growth. The slight anterior downward tipping of the palatal plane anteriorly found in the present investigation was not significant. A similar trend has been observed in other studies (Wieslander, 1974; Cangialosi *et al.*, 1988). No difference between the groups in mandibular growth direction or in the palatomandibular angle was seen in this study, which indicates that early use of cervical headgear does not have marked effects on the vertical growth of the face.

Marked arch length and width increases were obtained with early use of cervical headgear, indicating that the method is effective for the treatment of subjects

Table 2 Angular measurements made on the cephalograms of children in the headgear (n = 30) and control (n = 30) groups immediately before treatment (T0) and after follow-up periods of 1 (T1) and 2 (T2) years.

		T0		T1		T2		Difference T0–T1[b]			Difference T0–T2[b]		
		x	SD	*x*	SD	*x*	SD	*x*	SD	*P*	*x*	SD	*P*
SNA	Headgear group	78.9	2.99	77.6	3.27	77.2	3.03	–1.3	1.08	***	–1.7	1.39	***
	Control group	78.1	3.38	77.9	3.52	78.1	3.73	–0.2	0.92		0.0	1.08	NS
	Difference[a]	0.8 NS		–0.3 NS		–0.9 NS							
ANB	Headgear group	5.2	1.46	3.4	1.60	2.6	1.53	–1.8	1.25	***	–2.6	1.45	***
	Control group	4.4	2.22	4.3	2.25	4.2	2.34	–0.1	1.10	NS	–0.2	2.23	NS
	Difference[a]	0.8 NS**		1.1 NS		–1.6**							
SN/NL	Headgear group	7.9	1.93	8.4	2.31	8.5	2.24	–0.5	1.12	NS	–0.6	1.17	NS
	Control group	8.8	2.73	8.7	3.19	8.7	3.08	–0.1	0.93		–0.1	1.10	NS
	Difference[a]	1.1 NS		–0.3 NS		–0.2 NS							
NL/ML	Headgear group	28.4	3.88	28.0	3.82	27.3	4.08	–0.4	1.48	*	–1.1	1.38	*
	Control group	28.5	3.24	28.1	3.34	27.2	3.63	–0.4	1.07		–1.3	1.73	*
	Difference[a]	–0.1 NS		–0.1 NS		0.1 NS							
Facial axis	Headgear group	90.8	3.34	90.8	3.72	90.7	3.96	0.0	1.26	NS	–0.1	1.54	NS
	Control group	90.7	3.53	90.2	3.59	90.6	3.74	–0.5	1.92	NS	–0.1	2.45	NS
	Difference[a]	0.1 NS		0.6 NS		0.1 NS							
UI/SN	Headgear group	100.9	6.32	105.2	6.19	105.6	5.61	4.3	3.69	***	4.7	5.88	***
	Control group	98.4	5.74	98.6	7.43	98.5	9.33	0.2	4.61	NS	0.1	6.16	NS
	Difference[a]	2.5 NS		6.6***		7.1***							
UI/NL	Headgear group	108.4	6.50	113.2	5.90	114.1	5.47	4.8	3.62	***	5.7	6.63	***
	Control group	105.8	6.07	106.6	6.10	107.0	8.09	0.8	4.60		1.2	6.17	NS
	Difference[a]	2.6 NS		6.6***		7.1***							
NPog/LI	Headgear group	24.1	5.85	26.3	4.16	26.3	4.46	2.2	4.16	**	2.2	4.61	*
	Control group	22.9	4.79	23.0	4.98	23.8	5.13	0.1	3.09		0.9	2.81	NS
	Difference[a]	1.2 NS		3.3**		2.5*							
LI/ML	Headgear group	93.5	6.95	96.1	5.94	96.1	6.03	2.6	3.63	***	2.6	4.50	**
	Control group	92.4	5.08	92.7	5.06	93.6	5.06	0.3	3.00		1.2	2.71	*
	Difference[a]	1.1 NS		3.4**		2.5 NS							
UI/LI	Headgear group	129.4	8.91	122.6	7.84	122.6	7.84	–6.8	5.23	***	–6.8	7.57	***
	Control group	132.7	8.17	131.6	7.91	132.2	9.61	–1.1	5.47		–0.5	6.42	NS
	Difference[a]	–3.3 NS		–9.0***		–9.6***							

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$.
SD, standard deviation; NS, not significant.
[a]Mann–Whitney *U*-test for independent samples; [b]Wilcoxon's signed rank test for paired observations.

with mild or moderate crowding. However, part of the increase in arch length was a result of increased labial tipping of the incisors. It is important that the dental arch widening was significant in the lower arch, the degree of the widening being about half that seen in the upper arch, although no active treatment was applied to the lower arch in the HG group.

The finding that the use of cervical headgear increases labial inclination of the upper and lower incisors conflicts with many previously reported treatment effects. Ghafari *et al.* (1998), however, analogously reported labial flaring of both the upper and lower incisors after headgear use. One phenomenon which may have affected the findings in the present study, is that the bow was adjusted to be at least 2 mm in front of the incisors, preventing the lip from exerting pressure on the teeth. The method used has been different in other studies. Cook *et al.* (1994) reported that the face bow was pushed against the upper incisors, exerting direct force on them. In the headgear group of Keeling *et al.* (1998), a Hawley retainer was used in addition to the headgear. Another factor may be the effect of extraction of the primary canines in one-third of the control children, which may partly explain the differences between the groups.

The decrease in the interincisal angle was caused by labial inclination of the incisors in the HG group. No change was seen in overbite in the HG group, while in the control group this was increased. These differences may be due to the very early initiation of treatment, which possibly prevented a deepening of the bite in the HG group, whereas in the control group a significant increase in overbite was seen due to eruption of the incisors.

Conclusions

The results of this randomized prospective study show that early cervical headgear is effective in the treatment of subjects with moderate crowding. Space was gained in both dental arches by widening the arches and labial inclination of the incisors. With a distal force on the upper first molars, a restraint of maxillary growth distally was also observed. Marked correction of overjet cannot, however, be successfully carried out with orthopaedic cervical headgear alone as the sole early treatment method.

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