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Effects of a modified maxillary orthopaedic splint: a cephalometric evaluation

Oktay Üner and Emel Yücel-Eroğlu
Department of Orthodontics, Faculty of Dentistry, Gazi University, Ankara, Turkey

SUMMARY Taking the presence of an interplay between the vertical and sagittal components of craniofacial development into consideration, the beneficial therapeutic potential impacts of controlling vertical development on the correction of Class II discrepancies has been previously investigated. In the present study, a modified maxillary orthopaedic splint combined with an anterior high-pull headgear was used for early correction of the vertical and consequently sagittal dentoskeletal discrepancy as the initial stage of treatment. The aim was to evaluate its effects on the maxillary and mandibular dentoskeletal development, as well as rotational growth pattern. In order to compare with and distinguish from the uninterrupted growth changes, a control group was formed by matching each one of the control subjects to a subject in the treatment group according to certain criteria. The initial and second standardized lateral cephalograms of each subject was evaluated by means of an adopted and biologically more substantial cephalometric analysis. Evaluation of the changes induced by the splint in comparison with the uninterrupted growth changes revealed that the splint had both orthopaedic and orthodontic effects on the growth pattern of the dentoskeletal structures. There seemed to exist a relationship between the direction of total mandibular and maxillary rotations. In addition, it was believed that in order to cause a forward mandibular rotation, i.e. to change the rotational mandibular growth pattern from a backward into a forward direction, the posterior vertical maxillary development should be restrained, but anterior vertical maxillary development should be relatively more restrained or reversed and, thereby, the rotational growth pattern of the maxilla should be changed from a backward into a forward direction. Moreover, the bite block effect of the splint seemed to cause a favourable change in the condylar growth direction from a backward to an upward direction.

Introduction

Even in Class II, discrepancies appear in many different combinations of dental, skeletal and profile problems which need to be treated quite differently. The presence of these individual differences in nature explains the reasons for seeking new and more sophisticated treatment approaches, and confrontations with many treatment approaches described when the literature is reviewed (Pfeiffer and Grobéty, 1972, 1975; Thurow, 1975; Teuscher, 1978; Wieslander and Lagerström, 1979; Fränkel and Fränkel, 1983; Bass, 1987).

Despite disagreements regarding treatment concepts of Class II discrepancies, it is generally agreed that early correction of skeletal discrepancies by means of biomechanical and/or functional appliances is indicated to prevent the detrimental effects of functional deviation on the craniofacial development, to allow a recovery of craniofacial growth pattern following treatment, and to bring about favourable changes in the growth pattern and the compensating dentoalveolar mechanism (Thurow, 1975; Teuscher, 1978; Fränkel and Fränkel, 1983; Fotis *et al.*, 1984; Bass, 1987).

The interplay between the vertical and sagittal components of craniofacial development has been demonstrated previously (Isaacson *et al.*, 1977a, b; Williams and Melsen, 1982b). Therefore, the application of high-pull traction through a maxillary splint for early correction of sagittal dentoskeletal discrepancy and the control of the vertical dentoskeletal development has been proposed previously by Thurow (1975) and others (Joffe and Jacobson, 1979; Caldwell *et al.*, 1984; Fotis *et al.*, 1984; Seçkin and Sürücü, 1990; Orton *et al.*, 1992). However, the design, clinical management, force direction, and magnitude used in these investigations are different. It seems rational to bring about different effects on the dentoskeletal structures by changing the force direction employed and the design used.

As also suggested by Teuscher (1978), the extra-oral force vector should be directed as far forward as possible, since mandibular growth in the sagittal plane is time consuming. Therefore, moving the force line to a backward direction causes rapid compensating dento-alveolar changes, but minimal skeletal changes.

Furthermore, as stated by Burstone (1977), in a high percentage of Class II the goal of treatment is to reduce or hold the vertical dimension rather than increase it in order to correct the sagittal skeletal discrepancy, to improve the soft-tissue profile, and to enhance post-treatment stability. Even in many Class II with open bite, as well as in Class II with deep bite, the control of vertical maxillary development not only at the molar region, but also at the incisor region is a primary concern of clinicians to improve facial aesthetics, and at least not to impair it by preventing a backward rotation of the maxilla and its dentition.

The aim of the present study was to evaluate, by means of an adopted biologically substantial cephalometric analysis, the effects of a modified maxillary orthopaedic splint combined with an anterior high-pull headgear on the maxilla and mandible, and their relationships, as well as its impact on the rotational growth pattern of both, the maxilla and the mandible.

Subjects and methods

In order to standardize the force direction and the design, a study sample of 13 children treated with an identical maxillary orthopaedic splint and with good co-operation was selected from 29 patients with Class II division 1 malocclusion, since some of these 29 patients were treated with a different maxillary orthopaedic splint in design and extra-oral force direction. As a result of this selection the sample consisted of six boys and seven girls in the mixed dentition whose data concerning their chronological and skeletal ages and the treatment period is given in Table 1. The common characteristic of malocclusion in most of them was an increased overbite with or without mucosal impingement of the mandibular incisors and an increased overjet. In all of the cases increased maxillary incisor exposure, with or without 'gummy' smile, was also evident when the lips were in repose.

In order to form a similar control sample, a selection was made on the basis of the following criteria; sex, treatment/follow-up period, skeletal age, dental characteristics, skeletal characteristics, and the signs of mandibular rotation, i.e. the morphological structural analysis as described by Björk (1969). As a result of the latter evaluation, 10 patients in the study sample were predicted to exhibit a mandibular growth pattern of a backward rotating type, whereas the remainder were predicted to exhibit a mandibular growth pattern of a forward rotating type, consequently each one of the control subjects was matched to a subject in the study sample according to the growth pattern of the mandible. Following two cephalometric parameters; the lower face height and the ss–n–sm angle, which represent the vertical and the sagittal skeletal characteristics, were used for the selection of the control subjects and matched with the ranges not exceeding ± 2 mm/degrees for each parameter. The mean treatment period in this study sample was 10.92 ± 4.03 months, while the mean follow-up period in the control sample was 11.31 ± 5.09 months (Table 1).

The data used in this study were derived from the initial and second standardized lateral cephalograms of each subject in both samples. Differences in centric occlusion-centric relationship were checked before and after treatment, but no difference was found. The distance from the source to the mid-sagittal plane was 155 cm,

Table 1 Data concerning chronological age, skeletal age, and follow-up/treatment period.

	Control group Mean ± SD	Treatment group Mean ± SD
Chronological age at the beginning (year)	10.39 ± 1.22	10.76 ± 1.33
Skeletal age at the beginning (year)	9.51 ± 1.05	9.28 ± 1.15
Follow-up/treatment period (months)	11.31 ± 5.09	10.92 ± 4.03

and the distance from the mid-sagittal plane to the film was 12.5 cm. The enlargement of the lateral cephalograms was 10 per cent, which was not compensated for in the measurements.

Method of treatment

A full coverage maxillary splint combined with an anterior high-pull headgear was worn by the patients as the initial stage of treatment, which has already been described in detail previously (Üner and Yücel-Eroğlu, 1993; Fig. 1). In order

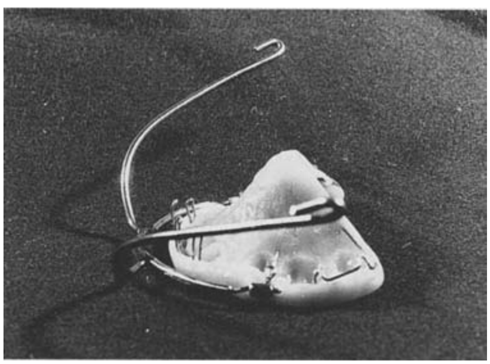

Figure 1 The maxillary orthopaedic splint.

Figure 2 Extra-oral force direction employed in the study.

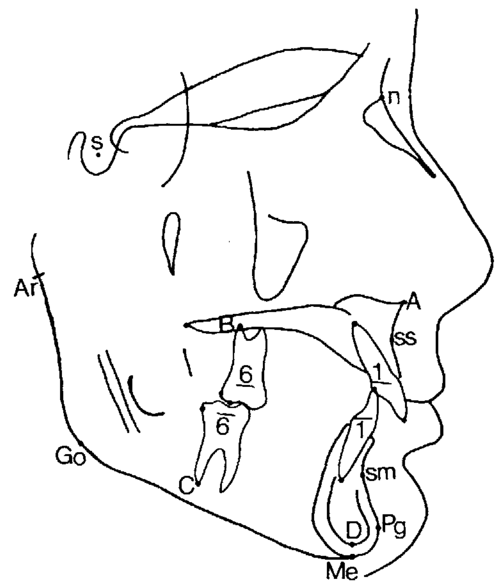

Figure 3 Structures and reference points used for the cephalometric analysis.

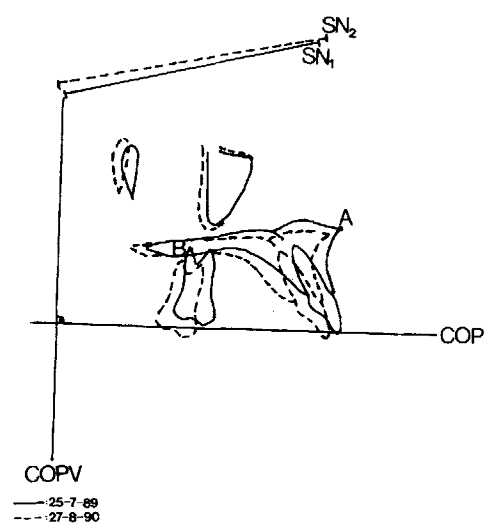

Figure 4 Maxillary structural superimposition.

to prevent the retroclination of the maxillary incisors and to produce more orthopaedic effects on the maxilla by transmitting the force through the roots, torque control auxiliaries were used (Thurow, 1975; Teuscher, 1978). In addition, they increased the stability of the splint at the posterior region by creating a reactive posterior rotating moment so that the extra-oral force vector could be directed further

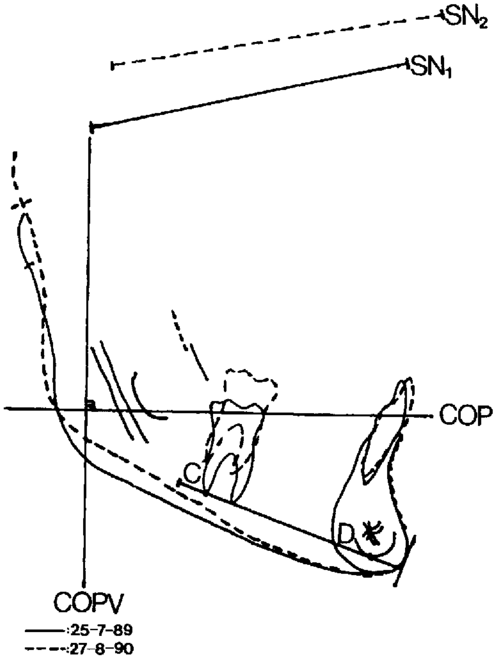

Figure 5 Mandibular structural superimposition.

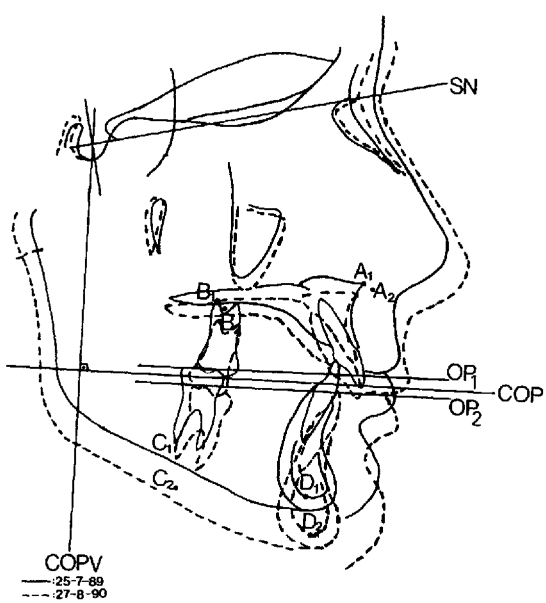

Figure 6 Structural superimposition on the anterior cranial base.

forward (Teuscher, 1978). Torque control auxiliaries were never activated.

The bite height was kept approximately 5 mm at the posterior part of the appliance, which is 2 mm beyond the freeway space, in order to prevent eruption of all lower teeth, as well as the posterior upper teeth and, if any, to stimulate condylar growth. Although the acrylic was adjusted occlusally to form a bite plate with even contact on all occlusal surfaces of the mandibular teeth, if necessary, the eruption of some mandibular posterior teeth was encouraged by removing the acrylic. In addition, the acrylic was adjusted so that the anterior part of the appliance directed the occlusal forces through the long axis of the mandibular anterior teeth. No attempt was made to procline or retrocline these teeth.

When additional support was necessary at the posterior part of the appliance the clasps were activated. The outer bow was shortened at the distal end of the permanent maxillary first molars, and bent approximately 35–45 degrees in an upward direction from the horizontal. The stability of the splint at the posterior region defined the limit of the forward force direction employed. As a consequence of this clinical limitation of defining the force direction and the subjectivity of locating the resistance centre of the maxilla, it was assumed that bending the outer bow 35–45 degrees upward from the horizontal was likely to direct the force vector just below, through, or just above the centre of resistance of the maxilla (Teuscher, 1978, 1986; Fig. 2). Because of the earlier stated potential risks of using heavier force (Teuscher, 1978) and on the basis of Baumrind and co-workers' (Baumrind *et al.*, 1983) findings that heavier forces tend to displace the teeth within the bone while lighter force tend to displace the bony matrix in toto, a force magnitude of 450–550 *g* on each side was used.

Patients were asked to wear the appliance full-time at the beginning of the treatment, except while eating and during sporting activities. Afterwards, if any improvement in the relationships, especially reduction in overbite, was seen, the wearing time was reduced to 16 hours per day to maintain co-operation. Patients were instructed to keep their mouths closed during day time and press their lips against the anterior part of the face bow in order to enhance the muscular activity and consequently increase the effects of the splint in the vertical direction.

Method of analyses

The first and second lateral cephalograms were traced by the same investigator on 0.003-inch

Table 2A Definitions of the measured and calculated parameters related to the sagittal and vertical relationships of the maxillary structures.†

	Parameters		Definition
1.	A_1–A_2 on COP	(mm)	Maxillary sagittal development; the distance between A_1 and A_2 points projected perpendicularly on COP. The distance was measured when the tracings had been superimposed on the stable structures of the anterior cranial base (SSACB).
2.	ss ⊥ COPV	(mm)	Maxillary prognathism; the distance between subspinale and its perpendicular projection on COPV. Superimposition: SSACB.
3.	s–n–ss	(°)	Maxillary prognathism; the angle between nasion, sella, and subspinale Superimposition: SSACB.
4.	$\underline{1}$–$\underline{1}'$	(°)	The change in the inclination of the maxillary incisor within the maxilla; the angle between initial and final length axis of the most prominent maxillary incisor. Positive value, retroclination; negative value, proclination. The angle was measured when the tracings had been superimposed on the stable structure of maxilla (SS Max.).
5.	COP–$\underline{1}$	(°)	Inclination of the maxillary incisor related to the anterior cranial base; the upper and inner angle between the length axis of the most prominent maxillary incisor and COP. Positive value, retroclination; negative value, proclination. Superimposition: SSACB.
6.	UMol–COPV	(mm)	Sagittal position of maxillary molar; the distance between the most distal point on the crown of the maxillary first molar and its perpendicular projection on COPV. Superimposition: SSACB.
7.	$[(A_2–\underline{1}')–(A_1–\underline{1})]$	(mm)	Anterior maxillary vertical dentoalveolar development; the distance between A_1 and $\underline{1}$ (initial position of the incisal edge of the maxillary incisor) points subtracted from the distance between A_2 and $\underline{1}'$ (final position of the incisal edge of the maxillary incisor) points projected perpendicularly on to COPV. Superimposition: SSMax.
8.	$[(B_2–\underline{6}')–(B_1–\underline{6})]$	(mm)	Posterior maxillary vertical dentoalveolar development; the distance between B_1 and $\underline{6}$ (initial position of the tip of the distobuccal cusp of the maxillary first molar) points subtracted from the distance between B_2 and $\underline{6}'$ (final position of the tip of the distobuccal cusp of the maxillary first molar) points projected perpendicularly onto COPV. Superimposition: SS Max.
9.	A_1–A_2 on COPV	(mm)	Anterior maxillary vertical development; the distance between A_1 and A_2 points projected perpendicularly onto COPV. Superimposition: SSACB.
10.	B_1–B_2 on COPV	(mm)	Posterior maxillary vertical development; the distance between B_1 and B_2 points projected perpendicularly onto COPV. Superimposition: SSACB.
11.	7+9	(mm)	Anterior maxillary total vertical development.
12.	8+10	(mm)	Posterior maxillary total vertical development.
13.	SN–NL	(°)	Maxillary inclination.
14.	SN–AB	(°)	Inclination of A-B line related to SN line. Superimposition: SS Max.
15.	SN–OP	(°)	Inclination of occlusal plane.

†In the measurements of the parameters which included nasion point, the changes in the position of this point either in a vertical or sagittal direction were not taken into account.

acetate paper with 0.5 m black and red mechanical pencil leads, respectively. Dual images of bilateral structures were bisected to reduce them to the midline. Only necessary structures and reference points used for the evaluation were marked (Fig. 3). In order to avoid the inadequacy of the conventional cephalometric methods mentioned previously (Björk and Skieller, 1977a, b, 1983; Isaacson *et al.*, 1977a; Cooke and Wei, 1988), a biologically more substantial cephalometric analysis was developed by adopting Williams and Melsen's (1982b) method used in an implant study, and using Björk and Skieller's (1977a,b, 1983) structural superimposition methods. This was undertaken as if they were the images of inserted implants, four points: anterior nasal spine, the apex point of the distobuccal root of the permanent maxillary first molar, the apex point of the distal root of the permanent mandibular first molar and the deepest point of the inner contour of the cortical plate at the lower border of the symphysis called point A, B, C, and D which represent the anterior maxillary implant, posterior maxillary implant, posterior mandibular implant and anterior mandibular implant,

Table 2B Definitions of the measured and calculated parameters related to the sagittal and vertical relationships of the mandibular structures.†

Parameters			Definition
16.	D_1–D_2 on COP	(mm)	Mandibular sagittal development; the distance between D_1 and D_2 points projected perpendicularly on COP. Superimposition: SSACB.
17.	sm ⊥ COPV	(mm)	Mandibular prognathism; the distance between supramentale and its perpendicular projection on COPV. Superimposition: SSACB.
18.	Pg ⊥ COPV	(mm)	Mandibular prognathism, the distance between pogonion and its perpendicular projection on COPV. Superimposition: SSACB.
19.	s–n–sm	(°)	Mandibular prognathism; the angle between nasion, sella, and supramentale Superimposition: SSACB.
20.	s–n–Pg	(°)	Mandibular prognathism; the angle between nasion, sella, and pogonion. Superimposition: SSACB.
21.	$\bar{1}$–$\bar{1}'$	(°)	The change in the inclination of mandibular incisor within the mandible; the angle between initial and final length axis of the most prominent mandibular incisor. Positive value, retroclination; negative value, proclination. The angle was measured when the tracings had been superimposed on the stable structures of mandible (SS Mand).
22.	COP–$\bar{1}$	(°)	Inclination of the mandibular incisor related to the anterior cranial base; the lower and inner angle between the length axis of the most prominent mandibular incisor and COP. Positive value, retroclination; negative value, proclination. Superimposition: SSACB.
23.	LMol–COPV	(mm)	Sagittal position of mandibular molar; the distance between the most distal point on the crown of the mandibular first molar and its perpendicular projection on COPV. Superimposition: SSACB.
24.	$[(D_2–\bar{1}')–(D_1–\bar{1})]$	(mm)	Anterior mandibular vertical dentoalveolar development; the distance between D_1 and $\bar{1}$ (initial position of the incisal edge of the mandibular incisor) points subtracted from the distance between D_2 and $\bar{1}'$ (final position of the incisal edge of the mandibular incisor) points projected perpendicularly onto COPV. Superimposition: SSMand.
25.	$[(C_2–\underline{6}')–(C_1–\underline{6})]$	(mm)	Posterior mandibular vertical dentoalveolar development; the distance between C_1 and $\underline{6}$ points subtracted from the distance between C_2 and $\underline{6}'$ points projected perpendicularly onto COPV. Superimposition: SS Mand.
26.	D_1–D_2 on COPV	(mm)	Anterior mandibular vertical development; the distance between D_1 and D_2 points projected perpendicularly onto COPV. Superimposition: SSACB.
27.	C_1–C_2 on COPV	(mm)	Posterior mandibular vertical development; the distance between C_1 and C_2 points projected perpendicularly onto COPV. Superimposition: SSACB.
28.	Ar_1–Ar_2 on COP	(mm)	Condylar sagittal development; the distance between Ar_1 and Ar_2 points projected perpendicularly onto COP. Superimposition: SSMand.
29.	Ar_1–Ar_2 on COPV	(mm)	Condylar vertical development; the distance between Ar_1 and Ar_2 points projected perpendicularly onto COPV. Superimposition: SSMand.
30.	SN–CD	(°)	Inclination of C–D line related to SN line. Superimposition: SSMand.
31.	SN–ML	(°)	Mandibular inclination.
32.	GoA	(°)	Gonial angle

†In the measurements of the parameters which included nasion point, the changes in the position of this point either in a vertical or sagittal direction were not taken into account.

respectively, were marked on the first cephalogram tracing (Fig. 3). Then, the two cephalograms were superimposed, one by one, on the stable natural reference structures in the maxilla and the mandible as described by Björk and Skieller (1977a,b, 1983) and points A, B and C, D were transferred from the first cephalogram to the second one, respectively (Figs 4 and 5). Afterwards, occlusal planes on the first (OP1) and the second (OP2) cephalogram were separately constructed passing through the tip of the distobuccal cusp of the permanent maxillary first molar and a point bisecting the vertical overbite in the anterior region. Two cephalograms were superimposed on the natural reference structures in the anterior cranial base as described by Björk and Skieller (1983). Thus, the changes in the position of nasion and sella were eliminated, and a common occlusal plane (COP) was constructed as an angular bisector between the two occlusal planes OP1 and OP2 (Fig. 6). Finally, a co-ordinate system was

Table 2C Definitions of the measured and calculated parameters related to the relationships of maxillary and mandibular structures to each other.†

Parameters			Definition
33.	ss–n–sm	(°)	Sagittal jaw relationship; angle between subspinale, nasion and supramentale. Superimposition: SSACB.
34.	$[(A_2–D_2)–(A_1–D_1)]$	(mm)	Change in sagittal jaw relationship; the distance between A_1 and D_1 points subtracted from the distance between A_2 and D_2 points projected perpendicularly onto COP. Superimposition: SSACB.
35.	NL–ML	(°)	Vertical jaw relationship.
36.	Mol.rel.	(mm)	Molar relationship; the distance between the distal points on the crowns of the maxillary and mandibular first molars projected perpendicularly onto COP. Positive value, deterioration in molar relationship; negative value, improvement in molar relationship. Superimposition; SSACB.
37.	Overjet	(mm)	The distance between $\overline{1}$ and $\underline{1}$ points projected perpendicularly onto COP.
38.	Overbite	(mm)	The distance between $\overline{1}$ and $\underline{1}$ points projected perpendicularly onto COPV.

†In the measurements of the parameters which included nasion point, the changes in the position of this point either in a vertical or sagittal direction were not taken into account.

established by constructing a perpendicular (COPV) to the common occlusal plane from the sella point (Williams and Melsen, 1982b).

The parameters used in this study were measured to the nearest 0.5 degrees or 0.5 mm and almost all in relation to the coordinate system (Table 2A, B and C).

One week later, tracings, point locations, and superimpositions were checked by the same investigator for accuracy. Moreover, 10 pairs of randomly selected cephalograms were retraced, superimposed, and the reliability of the 18 random parameters was examined by means of analysis of variance (the index of reliability) and paired *t*-test. Statistical analysis of the data included standard descriptive determinations and the non-parametric Wilcoxon and Mann–Whitney *U*-tests were used for examining intra- and inter-group differences, respectively.

Results

Clinical results

Full reduction in the bite, the upper lip and incisor relationship was improved in all cases with excessive deep bite. In the rest with normal or reduced overbite, but with gummy smile, the gingival display was reduced to a clinically observable level.

Class I or edge-to-edge molar relationship was established in all cases, except two. The overjet was fully corrected in the cases with less pronounced sagittal jaw discrepancy. Although in the rest of the cases, except two, the overjet was not fully corrected, there was sufficient reduction in overjet, as well as in the sagittal jaw relationship for initiation of a fixed appliance treatment. However, in two cases a second functional appliance treatment combined with an anterior high-pull headgear was needed before initiation of fixed appliance treatment, since the sagittal jaw relationship was not sufficiently improved which was ascribed to the presence of the pronounced sagittal jaw discrepancy at the beginning of the treatment and an occurring backward rotation of the mandible during treatment. All patients needed a second stage of fixed appliance treatment.

Cephalometric findings

The values of the calculated reliability index ranged from 87 to 99 per cent of which all were statistically significant ($P \leqslant 0.001$) and there were no significant differences between the mean values of each parameter on different occasions. The angular measurements were somewhat less reliable than the linear measurements. The structural maxillary superimposition expressed as the SN–AB angle (parameter 14) was the least reliable when compared with the others.

The changes that occurred in both groups over the period of the study were evaluated in two categories; the changes between and within the maxillary and mandibular dentoskeletal relationships in the sagittal and vertical directions.

Table 3A Descriptive statistical values of the parameters related to the sagittal relationships of the maxillary structures, and comparison of the initial and final values in and between groups.

Parameters	Control group ($n=13$) Initial (1) Mean	SD	Min.	Max.	P_{1-2}†	Second (2) Mean	SD	Min.	Max.	P_{1-3}†	Treatment group ($n=13$) Initial (3) Mean	SD	Min.	Max.	P_{3-4}†	Second (4) Mean	SD	Min.	Max.	P_{2-4}†
1. A_1–A_2 on COP	—	—	—	—	0.110	—	—	—	—	—	—	—	—	—	0.155	—	—	—	—	—
2. ss ⊥ COPV	75.62	4.76	62.00	80.00	0.010**	76.85	5.36	62.00	83.00	0.191	74.62	2.76	70.00	79.00	0.050*	73.50	2.71	69.00	77.50	0.006**
3. s–n–ss	79.50	2.74	75.00	85.00	0.010**	80.42	3.16	75.00	87.00	0.701	79.31	4.29	72.00	84.50	0.058	78.38	3.92	72.00	84.00	0.260
4. 1–1′	—	—	—	—	0.753	—	—	—	—	—	—	—	—	—	0.033*	—	—	—	—	—
5. COP-1	55.73	4.32	51.00	66.00	0.463	56.54	3.88	48.00	61.50	0.101	59.12	7.07	45.00	73.50	0.037*	56.69	5.19	48.50	63.50	0.701
6. UMol-COPV	37.54	4.21	27.50	43.50	0.011*	38.81	4.59	27.50	44.00	0.200	35.89	3.48	29.00	40.50	0.398	35.38	3.69	27.00	40.50	0.026*

*$P\leqslant0.05$; **$P\leqslant0.01$; ***$P\leqslant0.001$.

†The numbers written below the P values indicates the compared stages.

Dentoskeletal changes in the sagittal direction

All of the parameters representing maxillary prognathism (1, 2 and 3) were decreased in the treatment group, but increased in the control group, and the changes in all of these parameters were significant between the two groups ($P\leqslant0.05$, $P\leqslant0.001$, and $P\leqslant0.001$, respectively; Table 3A and B). All parameters representing mandibular prognathism increased in both groups. Although the mean increases in the sm to COPV and the Pg to COPV distances were slightly more in the control group than in the treatment group, the increase was significant in the treatment group ($P\leqslant0.05$, for both; Table 4A). There were no significant differences between the changes in the treatment and control groups for any of the parameters (Table 4B). The sagittal jaw relationship expressed as the ss–n–sm angle and the A–D distance were significantly improved in the treatment group ($P\leqslant0.05$ for both) and the differences between the changes in the control and treatment groups were found to be statistically significant ($P\leqslant0.001$ and $P\leqslant0.05$, respectively; Table 5A and B).

The maxillary molars came forward significantly in the control group ($P\leqslant0.05$), and the difference between these changes in the control and treatment groups was significant ($P\leqslant0.05$; Table 3A and B). Both in the control and treatment groups the mandibular molars came significantly forward ($P\leqslant0.01$ and $P\leqslant0.05$, respectively; Table 4A), but the difference between the changes was not significant (Table 4B). In the treatment group a significant improvement ($P\leqslant0.01$) in the molar relationship was found, whereas there was an insignificant deterioration in the control group (Table 5A). The difference between the changes in the control and treatment groups was significant ($P\leqslant0.05$; Table 5B).

Maxillary incisors were significantly proclined within the maxilla in the treatment group, resulting in a significant proclination relative to the anterior cranial base ($P\leqslant0.05$, for both; Table 3A). The change of the inclination relative to the anterior cranial base in the treatment group differed significantly from that in the control group ($P\leqslant0.05$; Table 3B). Mandibular incisors were significantly retroclined relative to the anterior cranial base in the treatment group ($P\leqslant0.01$), but insignificantly retroclined within

Table 3B The follow-up and treatment changes for the parameters related to the sagittal relationships of the maxillary structures and the corresponding biometrical test values.

Parameters	Control group ($n=13$)				Treatment group ($n=13$)				
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	P
1. A_1–A_2 on COP	0.615	1.14	−1.00	2.50	−0.500	1.02	−2.50	1.00	0.026*
2. ss ⊥ COPV	1.231	1.20	−1.00	3.00	−1.115	1.83	−5.50	0.50	0.001***
3. s–n–ss	0.923	0.86	−1.00	2.00	−0.923	1.58	−4.50	1.00	0.001***
4. $\underline{1–1'}$	0.731	4.41	−5.00	12.50	−2.385	3.50	−7.50	3.00	0.077
5. $\overline{\text{COP}}$–$\underline{1}$	0.810	3.90	−4.50	10.00	−2.423	3.60	−10.00	3.50	0.031*
6 UMol–$\overline{\text{COPV}}$	1.269	1.29	−1.00	3.50	−0.510	1.99	−3.50	2.50	0.030*

*$P \leqslant 0.05$ **$P \leqslant 0.01$; ***$P \leqslant 0.001$

the mandible; the difference between the changes of the inclinations relative to the anterior cranial base in the two groups was significant ($P \leqslant 0.01$; Table 4A and B). Overjet did not change in the control group whereas it was significantly decreased in the treatment group ($P \leqslant 0.01$) (Table 5A). The difference between the changes in the control and treatment group was statistically significant ($P \leqslant 0.05$) (Table 5B).

Dentoskeletal changes in the vertical direction

Anterior maxillary vertical dentoalveolar height was significantly decreased in the treatment group ($P \leqslant 0.01$), but significantly increased in the control group ($P \leqslant 0.05$); the difference between the changes was highly significant ($P \leqslant 0.001$; Table 6A and B). Posterior maxillary vertical dentoalveolar height was significantly increased in both groups ($P \leqslant 0.05$ for both; Table 6A). In the treatment group, the anterior and posterior mandibular vertical dentoalveolar heights increased slightly less than those of the control group (Table 7A and B).

The anterior and posterior vertical maxillary developments (sutural) were significant in the control group ($P \leqslant 0.01$, for both), and only the difference between the changes of anterior maxillary vertical development in the two groups was significant ($P \leqslant 0.05$) (Table 6A and B). The anterior and posterior vertical mandibular developments (skeletal) were significant in the control group ($P \leqslant 0.01$, for both), but posterior vertical mandibular development was less significant in the treatment group ($P \leqslant 0.05$); suggesting a growth-restriction effect (Table 7A). The anterior mandibular developmental change in the treatment group was significantly different from that in the control group ($P \leqslant 0.05$; Table 7B).

When the total vertical developments in the maxilla and in the mandible were evaluated, the changes markedly revealed themselves; suggesting a growth-retardation effect on the anterior maxilla and a growth-restriction effect on the posterior maxilla and the mandible, and the anterior mandible (Tables 6A and B, and 7A and B).

As a result of these vertical changes in the dentoskeletal structures, overbite (Table 5A) and occlusal plane angle (Table 6A) were significantly reduced in the treatment group ($P \leqslant 0.01$ for both). The reductions in the treatment group were found to be highly significantly different when compared with those of the control group ($P \leqslant 0.001$ for both; Tables 5B and 6B).

Sagittal (backward) condylar development was significant in both groups, but it was more significant in the control group ($P \leqslant 0.01$) than in the treatment group ($P \leqslant 0.05$) (Table 7A). The changes in the treatment group were significantly different from that of the control group ($P \leqslant 0.01$) (Table 7B). Vertical (upward) condylar development was significant in both groups ($P \leqslant 0.01$ for both; Table 7A). However, the difference between the changes in the two groups was not significant (Table 7B).

There was a significant backward maxillary matrix rotation in both groups, whereas there was a backward mandibular matrix rotation in the control group and a forward rotation in the treatment group (Tables 6A and 7A); there were no differences between the groups (Tables 6B and 7B). Insignificant backward total rotation, i.e. true rotation in the maxilla and the mandible occurred over the period of the study

Table 4A Descriptive statistical values of the parameters related to the sagital relationships of the mandibular structures and comparison of the initial and final values in and between groups.

Parameters	Control group $n=13$									Treatment group ($n=13$)								
	Initial (1)					Second (2)					Initial (3)					Second (4)			
	Mean	SD	Min.	Max.	P_{1-2}†	Mean	SD	Min.	Max.	P_{1-3}†	Mean	SD	Min.	Max.	P_{3-4}†	Mean	SD	Min.	Max.	P_{2-4}†
16. D_1–D_2 on COP	—	—	—	—	0.081	—	—	—	—	—	—	—	—	—	0.055	—	—	—	—	—
17. sm ⊥ COPV	73.19	5.11	61.50	79.00	0.064	74.15	5.37	61.00	82.00	0.016*	69.27	3.58	62.50	73.00	0.050*	70.00	3.37	63.00	74.00	0.003**
18. Pg ⊥ COPV	76.08	4.42	66.00	82.50	0.064	77.12	4.44	65.50	82.00	0.005**	70.96	3.45	64.00	76.00	0.050*	71.85	3.27	64.00	77.00	0.001***
19. s–n–sm	73.94	2.94	69.50	80.50	0.084	74.46	3.03	70.00	81.50	0.457	72.73	3.95	64.50	79.50	0.108	73.15	3.63	64.50	78.00	0.505
20. s–n–Pg	74.85	2.52	71.00	81.00	0.117	75.23	2.42	72.50	81.50	0.663	73.38	4.05	65.00	79.00	0.120	73.81	3.87	65.00	78.00	0.663
21. 1–$\bar{1}$	—	—	—	—	1.000	—	—	—	—	—	—	—	—	—	0.059	—	—	—	—	—
22. COP–$\bar{1}$	68.08	5.95	59.50	79.00	0.813	67.73	6.86	58.00	79.00	0.038*	62.73	6.31	51.00	74.50	0.009**	65.73	6.43	51.00	78.00	0.538
23. LMol–COPV	37.12	5.23	26.00	43.00	0.010**	38.69	5.23	26.00	43.50	0.124	35.08	3.69	27.00	41.00	0.045*	36.08	3.77	27.50	41.00	0.058

* $P \leqslant 0.05$; ** $P \leqslant 0.01$; *** $P \leqslant 0.001$.

† The numbers written below the P values indicates the compared stages.

in the control group (Tables 6A and 7A). Whereas the mandible and the maxilla rotated forward in the treatment group, only forward mandibular total rotation was significant ($P \leqslant 0.05$; Tables 6A and 7A). The differences between the amount of the total rotations in the two groups were significant for both the maxilla and the mandible ($P \leqslant 0.05$ and $P \leqslant 0.01$, respectively; Tables 6B and 7B).

The distribution of the maxillary and mandibular rotational growth patterns of these cases are presented in Table 8. The maxilla and the mandible rotated forward in the majority of the cases in the treatment group, whereas the direction of maxillary and mandibular rotation was backward in the majority of the cases in the control group.

Discussion

In the present study, a maxillary orthopaedic splint was designed and a force was employed from a more forward position than in previous studies (Thurow, 1975; Joffe and Jacobson, 1979; Caldwell *et al.*, 1984; Fotis *et al.*, 1984; Seçkin and Sürücü, 1990; Orton *et al.*, 1992) in order to reduce overbite and/or gummy smile, in other words, to restrain and redirect and maybe reverse the excessive vertical dento-alveolar and/or skeletal maxillary development anteriorly as well as posteriorly. In addition, improvement in the sagittal jaw relationship and reduction in overjet were also expected as a consequence of restriction of vertical and sagittal dentoskeletal maxillary development; if any, stimulation of sagittal mandibular development by means of the bite block effect of the splint, and by deblocking the mandible from its habitual position and, moreover, changing the rotational growth pattern of the mandible from a backward to a forward direction. Thus, the aim of the present study was to investigate these expected effects of the splint on the growth pattern of the maxillary and mandibular dento-skeletal structures.

Simulation of the effects of force directions employed in previous studies (Thurow, 1975; Joffe and Jacobson, 1979; Fotis *et al.*, 1984; Seçkin and Sürücü, 1990; Orton *et al.*, 1992), as proposed by Teuscher (1986), revealed that quite different results could be expected (Fig. 7). Since the mandibular growth in the sagittal plane is time consuming (Teuscher, 1978;

Table 4B The follow-up and treatment changes for the parameters related to the sagittal relationships of the mandibular structures and the corresponding biometrical test values.

	Control group ($n=13$)				Treatment group ($n=13$)				
Parameters	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	P
16. D_1–D_2 on COP	0.885	1.62	−2.00	3.50	0.981	1.60	−2.00	4.00	0.939
17. sm ⊥ COPV	0.962	1.63	−2.00	3.50	0.731	1.15	−1.50	3.00	0.626
18. Pg ⊥ COPV	1.038	1.73	−2.00	3.50	0.885	1.42	−1.50	3.50	0.778
19. s–n–sm	0.519	0.95	−1.50	2.00	0.423	0.89	−1.50	2.00	0.682
20. s–n–Pg	0.385	0.82	−1.50	1.50	0.423	0.84	−1.00	2.00	0.878
21. $\bar{1}$–$\bar{1}'$	0.038	2.25	−3.00	5.00	1.885	3.17	−4.00	8.50	0.069
22. COP–$\bar{1}$	−0.346	2.10	−4.00	3.00	3.000	2.98	−1.00	10.00	0.003**
23. LMol–COPV	1.577	1.61	−1.50	4.50	1.000	1.50	−1.50	3.50	0.330

*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.

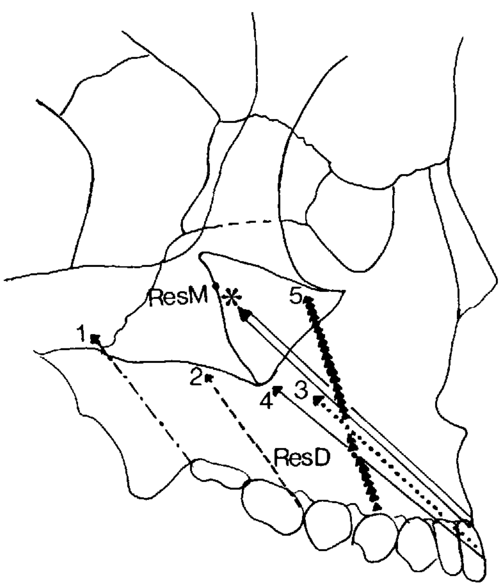

Figure 7 Force directions employed in the previous studies [shown by the numbers: (1) Fotis *et al.* (1984); (2) Joffe and Jacobson (1979); (3) Seçkin and Sürücü (1990); (4) Thurow (1975); (5) Orton *et al.* (1992)] and the present study (✻). Since Caldwell *et al.* (1984) had made variations in the direction of pull, it could not be shown.

Woodside *et al.*, 1987), moving the force line to a backward direction causes rapid compensating dentoalveolar changes, but minimal skeletal changes, and consequently no improvement in the soft tissue relationships (Teuscher, 1978). Therefore, much attention has been focused upon the importance of controlling the cant of the occlusal, nasal, and also the mandibular planes (Burstone, 1977; Teuscher, 1978). Improvement of the soft tissue relationship is not only essential for the concern of patients, but also to ensure post-treatment stability (Burstone, 1977). Thus, the force vector was directed as far forward as possible in this present study. Animal experiments and clinical studies have shown that posterior mandibular opening without forward positioning, i.e. bite block, as well as forward mandibular positioning induces proliferation of condylar cartilage and adaptive changes in the glenoid fossa during juvenile and adolescent periods, but it is not clear whether these changes in the condyle and glenoid fossa increase the absolute length of the mandible or whether these changes are temporary (Harvold and Vargervik, 1971; Stöckli and Willert, 1971; Pfeiffer and Grobéty, 1972, 1975; Teuscher, 1978; McNamara and Carlson, 1979; Wieslander and Lagerström, 1979; McNamara *et al.*, 1982, 1985; Williams and Melsen, 1982a; Woodside *et al.*, 1983, 1987; Pancherz, 1984; Altuna and Woodside, 1985; Vargervik and Harvold, 1985; Bass, 1987). Moreover, potential beneficial effects of inhibition of the buccal segment's eruption in both jaws on horizontal mandibular growth direction have been discussed previously (Woodside and Linder-Aronson, 1986). On the other hand, it has been stated that excessive posterior mandibular opening causes a backward rotation of the maxilla and mandible (Harvold and Vargervik, 1971; Vargervik and Harvold, 1985; Williams and Melsen, 1982a,b), and undesirable fatigue of the orofacial musculature (Fränkel and Fränkel, 1983; Teuscher, 1978). In view of this present knowledge, the bite height was kept within a limit of 4–6 mm which was assumed an adequate height to prevent the eruption of the posterior teeth. Nevertheless, with the fear that even this amount of bite construction might

Table 5A Descriptive statistical values of the parameters related to the relationships of the maxillary and mandibular structures to each other, and comparison of the initial and final values in and between groups.

Parameters	Control group ($n=13$)										Treatment group ($n=13$)									
	Initial (1)					Second (2)					Initial (3)					Second (4)				
	Mean	SD	Min.	Max.	P_{1-2}†	Mean	SD	Min.	Max.	P_{1-3}†	Mean	SD	Min.	Max.	P_{3-4}†	Mean	SD	Min.	Max.	P_{2-4}†
33. ss–n–sm	5.56	1.56	4.00	9.50	0.76	6.04	1.45	4.00	9.00	0.101	6.58	1.75	4.50	10.00	0.018*	5.23	1.83	2.50	9.00	0.219
34. A–D on COP	7.46	2.95	1.00	11.00	0.799	7.31	3.10	1.00	11.00	0.001***	11.92	2.49	7.00	14.50	0.013*	10.4	2.11	6.50	13.50	0.006**
35. NL–ML	30.27	3.69	24.00	35.50	0.224	29.77	3.30	24.50	34.00	0.005**	34.46	2.88	29.00	38.50	0.295	33.96	3.88	27.00	38.00	0.012*
36. Mol.rel.	0.42	2.13	−4.50	4.00	0.505	0.12	2.10	−4.00	2.50	0.489	0.81	2.04	−3.00	3.50	0.004**	−0.69	1.77	−5.00	1.50	0.174
37. Overjet	8.27	1.74	5.50	11.00	0.834	8.31	2.30	5.50	13.00	0.112	7.08	1.81	4.00	10.00	0.006**	6.00	1.90	3.00	9.50	0.010**
38. Overbite	3.81	2.24	0.00	6.50	0.814	3.89	2.16	0.00	6.50	0.608	4.58	2.75	0.00	9.00	0.003	1.77	1.50	0.00	4.00	0.014
Lower face height	66.27	4.72	59.50	76.00	—	—	—	—	—	0.442	67.62	4.41	61.00	74.00	—	—	—	—	—	—

$*P \leq 0.05$; $**P \leq 0.01$; $***P \leq 0.001$.
† The numbers written below the P values indicates the compared stages.

cause a backward mandibular rotation and, furthermore, in order to increase the muscular activity, to eliminate weakness and flaccidity of perioral musculature and to increase the effect of the splint in the vertical direction, the patients were instructed to keep their mouth closed during the day time and press their lips against the anterior part of the face bow (Fränkel and Fränkel, 1983).

The phenomenon of surface bone remodelling which masks the rotational changes in the maxilla and mandible during the growth period has been well documented earlier by Björk and Skieller (1977a,b, 1983) by means of metallic implants. They found that some structures in the mandible and the maxilla are stable in relation to the implants over the period of growth which can be used as natural reference structures for determining the growth changes. They further stated that these structures seem to be stable during treatment and, therefore, can be used for determining treatment changes as well (Björk and Skieller, 1976). Nielsen's (1989) findings have also supported this idea.

Evaluation of the changes induced by the splint in comparison with the uninterrupted growth changes revealed that the splint had both orthopaedic and orthodontic effects on the growth pattern of the dentoskeletal structures. This finding is in agreement with those of Thurow (1975), Joffe and Jacobson (1979), Fotis *et al.* (1984), Seçkin and Sürücü (1990), and Orton *et al.* (1992), but in disagreement with Caldwell *et al.* (1984). On the other hand, the findings of these studies are not comparable with those of the present study because of the difference in the force direction and the design. However, our findings are in agreement with those of Fotis *et al.* (1984), Caldwell *et al.* (1984), Seçkin and Sürücü (1990), and Orton *et al.* (1992); except some of their findings, such as a backward rotation of occlusal, nasal, and mandibular planes, retroclination of the maxillary incisors and reversal of the posterior vertical maxillary dentoskeletal development. These controversies in the findings could be attributed to the difference in the force direction and the design. Since Thurow (1975), and Joffe and Jacobson (1979) presented no data, it was not possible to compare our finding with theirs. Reduction in overjet was somewhat less, whereas reduction in overbite was more than in previous studies when the mean values were

Table 5B The follow-up and treatment changes for the parameters related to the relationships of the maxillary and mandibular structures to each other and the corresponding biometrical test values.

	Control group ($n=13$)				Treatment group ($n=13$)				
Parameters	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	P
33. ss–n–sm	0.481	0.82	−0.50	2.00	−1.346	1.61	−5.00	1.50	0.001***
34. $[(A_2-D_2)-(A_1-D_1)]$	−0.154	1.31	−2.50	2.00	−1.519	1.73	−5.00	1.00	0.040*
35. NL–ML	−0.500	1.29	−3.00	2.00	−0.500	1.74	−2.50	2.00	0.878
36. Mol.rel.	−0.308	1.38	−3.00	2.00	−1.500	1.32	−4.00	0.50	0.034*
38. Overjet	0.038	1.33	−3.00	2.00	−1.077	0.95	−3.00	0.50	0.019*
38. Overbite	0.077	0.79	−1.00	1.00	−2.808	1.97	−7.00	1.00	0.000***

$*P \leqslant 0.05$; $**P \leqslant 0.01$; $***P \leqslant 0.001$.

compared (Caldwell *et al.*, 1984; Fotis *et al.*, 1984; Seçkin and Sürücü, 1990; Orton *et al.*, 1992; Table 5A and B). These were due to the force direction employed in the present study and to the proclination of the maxillary incisors under this force direction.

Improvement in the sagittal jaw relationship was due partly to the retardation of sagittal maxillary development and partly to the proceeding sagittal mandibular development which was ascribed to the vertical control of maxillary and mandibular dentoalveolar development, restriction of maxillary vertical sutural development, redirection of condylar growth and consequently relative mandibular forward rotation (Tables 3A–7A and 3B–7B). Sagittal mandibular development did not differ between the control and treatment groups, but the developmental change in the treatment group was significant for some of the measured parameters expressing sagittal mandibular development (Table 4A and B). On the basis of these findings, sagittal mandibular development appeared not to be stimulated by the splint treatment, but its growth pattern was changed from a vertical to a horizontal direction, which was due to redirection of condylar growth and a relative mandibular forward rotation (Tables 4A and B, and 7A and B). Interestingly, there are two distinct opinions in the literature regarding the irreversible therapeutic induction of condylar growth i.e. induction of horizontal mandibular development under the effect of functional appliance (Harvold and Vargervik, 1971; Wieslander and Lagerström, 1979; Williams and Melsen, 1982a; Pancherz, 1984; McNamara *et al.*, 1985; Vargervik and Harvold, 1985).

According to Isaacson *et al.* (1977a, b), condylar vertical growth (and the fossa) is associated with vertical maxillary sutural development, and vertical maxillary and mandibular dentoalveolar development; when the vertical condylar development exceeds the sum of the vertical maxillary sutural development and the vertical maxillary and mandibular dentoalveolar development, a forward mandibular rotation occurs. In the treatment group, total mandibular rotation was forward which was ascribed to the restriction effect of the splint on the vertical maxillary and mandibular dentoalveolar development, and the vertical maxillary sutural development (Table 6A and B, and 7A and B). Moreover, the bite block effect of the splint seemed to cause favourable change in the condylar growth direction (Table 7A and B). Björk and Skieller (1972, 1983) have demonstrated that an upward and a backward condylar growth direction is associated with a backward rotating mandible. In the control group the condylar growth of the mandible was upward and significantly more backward when compared with the treatment group. In the control group, this significantly more backward growth of the condyle supplemented the posterior rotation of the mandible, whereas in the treatment group the condylar growth direction was mostly upward which consequently supplemented the forward rotation of the mandible (Table 7A and B).

It has been previously well documented that there is a little difference between cervical and high-pull headgear regarding their effects on the maxilla (Baumrind *et al.*, 1983), but both tended to increase the mandibular plane angle (Baumrind *et al.*, 1978); a high-pull headgear combined with a fixed appliance holds the anterior part of the nasal plane in position,

Table 6A Descriptive statistical values of the parameters related to the vertical relationships of the maxillary structures and comparison of initial and final in and between groups.

Parameters	Control group (n=13) Initial (1) Mean	SD	Min.	Max.	P_{1-2}†	Second (2) Mean	SD	Min.	Max.	P_{1-3}†	Treatment group (n=13) Initial (3) Mean	SD	Min.	Max.	P_{3-4}†	Second (4) Mean	SD	Min.	Max.	P_{2-4}†
7. A-1 on COPV	30.73	3.40	24.50	38.00	0.023*	31.65	3.90	25.50	40.00	0.238	32.27	3.99	26.00	43.00	0.003**	30.19	3.92	25.5	41.00	0.159
8. B-6 on COPV	20.69	1.35	18.50	23.50	0.014*	21.42	1.54	19.00	24.50	0.682	21.04	1.68	18.50	24.00	0.033*	22.04	2.45	19.00	27.00	0.590
9. A_1–A_2 on COPV	—	—	—	—	0.007**	—	—	—	—	—	—	—	—	—	0.695	—	—	—	—	—
10. B_1–B_2 on COPV	—	—	—	—	0.009**	—	—	—	—	—	—	—	—	—	0.310	—	—	—	—	—
11. 7+9	—	—	—	—	0.004**	—	—	—	—	—	—	—	—	—	0.007**	—	—	—	—	—
12. 8+10	—	—	—	—	0.003**	—	—	—	—	—	—	—	—	—	0.013*	—	—	—	—	—
13. SN–NL	7.00	2.94	3.00	13.00	0.045*	8.12	2.58	3.00	12.50	0.608	6.39	2.74	2.00	11.50	0.799	6.50	2.74	2.50	11.50	0.174
14. SN–AB	7.96	4.56	0.00	15.00	0.108	8.65	4.95	1.00	16.50	0.608	8.04	5.23	1.50	20.00	0.221	7.19	5.26	0.50	19.50	0.442
15. SN–OP	19.92	2.59	14.00	25.00	0.067	20.62	3.14	14.00	27.00	0.739	20.27	4.19	13.00	28.00	0.002**	16.96	4.28	9.50	25.00	0.020*

*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.

†The numbers written below the P values indicates the compared stages.

while the posterior part is displaced superiorly, thus causing a backward rotation of the nasal plane (Baumrind *et al.*, 1983); the same is true for the splint according to the previous studies (Thurow, 1975; Joffe and Jacobson, 1979; Caldwell *et al.*, 1984; Fotis *et al.*, 1984; Seçkin and Sürücü, 1990; Orton *et al.*, 1992); whereas the cervical-pull headgear causes a relatively greater downward displacement in the anterior part of the nasal plane (Baumrind *et al.*, 1983). So far as the relationship between the vertical maxillary development and sagittal mandibular development was concerned in the view of current knowledge and the findings of this present study, it has been suggested that relatively more retardation or reversal of vertical maxillary development in the posterior than the anterior region would lead to a backward rotation of the maxilla, i.e. the nasal and occlusal planes, compensating over-eruption of posterior mandibular teeth, and a subsequent backward rotation of the mandible. Therefore, in order to cause a forward mandibular rotation, i.e. to change rotational mandibular growth pattern from a backward to a forward direction, the posterior vertical maxillary development should be restrained, but anterior vertical maxillary development should be relatively more restrained or reversed and, thereby, the rotational growth pattern of the maxilla should be changed from a backward to a forward direction which is believed to contribute in the forward rotation of the mandible. Moreover, the condylar growth direction should be changed from a backward to an upward direction. When the changes in the rotational growth pattern of the maxilla and mandible were evaluated on an individual basis in order to come to a clear conclusion regarding the impact of the splint on the rotational pattern of maxilla and mandible in comparison with the uninterrupted rotational changes, which was possible because of the matched design of the present study, it was found that the maxilla and mandible rotated forward in the majority of the cases in the treatment group, whereas the direction of maxillary and mandibular rotation was backward in the majority of the cases in the control group. On the other hand, there seemed to exist a relationship between the total rotation of the maxilla and mandible, but the presence of individual variations could not be ignored (Table 8).

Table 6B The follow-up and treatment changes for the parameters related to the vertical relationships of the maxillary structures and the corresponding biometrical test values.

	Control group ($n=13$)				Treatment group ($n=13$)				
Parameters	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	P
7. $[(A_2-\underline{1}')-(A_1-\underline{1})]$	0.923	1.15	−1.00	3.00	−2.077	1.32	−5.00	0.00	0.000***
8. $[(B_2-\overline{6}')-(B_1-\overline{6})]$	0.731	0.81	−0.50	2.00	1.00	1.32	−1.50	3.00	0.608
9. A_1-A_2 on COPV	1.423	1.32	−1.00	4.00	−0.154	1.85	−2.50	3.00	0.023*
10. B_1-B_2 on COPV	1.000	0.94	−0.50	2.00	0.327	0.99	−1.50	2.00	0.107
11. 7+9	2.346	1.48	0.00	4.00	−2.231	2.20	−6.50	1.00	0.000***
12. 8+10	1.731	1.11	0.00	3.50	1.327	1.34	−1.50	3.00	0.505
13. SN–NL; matrix rotation of maxilla	1.115	1.37	−2.50	3.00	0.115	1.43	−2.50	2.50	0.055
14. SN–AB; total rotation of maxilla	0.692	1.42	−2.00	3.00	−0.846	2.74	−4.50	5.00	0.030*
15. SN–OP	0.692	1.11	−1.00	2.50	−3.308	2.96	−9.00	0.50	0.000***

*$P \leqslant 0.05$; **$P \leqslant 0.01$; ***$P \leqslant 0.001$.

The variation in the other treatment results was also evident (Tables 3A–7A and 3B–7B). By means of the adopted cephalometric analysis the intra- and inter-individual variation in the co-ordinate system due to growth and/or treatment as well as the variations in the other reference planes due to the surface remodelling was eliminated or avoided. The inter-individual variation between the two groups was assumed to be limited by means of the matched design of the present study. Moreover, although the force direction employed in the present study was standardized, it was somewhat variable because of the stability problem of the splint at the posterior region and the subjectivity of locating the resistance centre of the maxilla. Consequently, with the exception of these predictable variation sources, the variation in the treatment results was mostly attributed to unpredictable individual variation in the response to the treatment. Therefore, the effects of treatments should be checked continuously and reconsidered, as stated earlier (Baumrind *et al.*, 1978; Fotis *et al.*, 1984; Üner and Yücel-Eroğlu, 1993).

According to the clinical experience gained in the treatment of Class II cases with this appliance, which also supports the view of Thurow (1975) about the advantages and disadvantages of the splint, it was more effective in the treatment of the selected cases in the mixed dentition, namely Class II cases with less pronounced mandibular retrognathism and/or maxillary prognathism, but with excessive dental deep bite with or without moderate vertical facial skeletal problem, either being deficient or excessive. Even in open bite cases the application of this type of splint, but with some modifications and in combination with a vertical chin cup might be beneficial. Further studies are currently being conducted to evaluate the effects of the splint combined with a vertical chin cup and to compare the effects of this splint with the effects of an identical activator combined with a high-pull traction in the same force direction.

Address for correspondence

Dr Emel Yücel-Eroğlu
Department of Orthodontics
Faculty of Dentistry
Gazi University
06510 Emek
Ankara
Turkey

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Table 7A Descriptive statistical values of the parameters related to the vertical relationships of the mandibular structures and comparison of the initial and final values in and between groups.

	Control group ($n=13$)										Treatment group ($n=13$)									
	Initial (1)					Second (2)					Initial (3)					Second (4)				
Parameters	Mean	SD	Min.	Max.	P_{1-2}†	Mean	SD	Min.	Max.	P_{1-3}†	Mean	SD	Min.	Max.	P_{3-4}†	Mean	SD	Min.	Max.	P_{2-4}†
24. D–$\bar{1}$ on COPV	37.42	5.98	22.00	48.00	0.004**	38.58	6.27	23.00	50.00	0.356	38.96	2.33	35.00	43.50	0.051	39.58	2.23	36.00	44.00	0.682
25. C–$\bar{6}$ on COPV	21.46	5.59	17.00	39.50	0.086	22.19	5.45	17.50	39.50	0.457	19.69	1.54	16.50	22.50	0.636	19.92	2.22	15.00	24.50	0.096
26. D_1–D_2 on COPV	-	—	—	—	0.002**	—	—	—	—	—	—	—	—	—	0.078	—	—	—	—	—
27. C_1–C_2 on COPV	—	—	—	—	0.002**	—	—	—	—	—	—	—	—	—	0.023*	—	—	—	—	—
28. Ar_1–Ar_2 on COP	—	—	—	—	0.003**	—	—	—	—	—	—	—	—	—	0.014*	—	—	—	—	—
29. Ar_1–Ar_2 on COPV	—	—	—	—	0.002**	—	—	—	—	—	—	—	—	—	0.006**	—	—	—	—	—
30. SN–CD	45.77	3.87	41.00	53.00	0.183	46.12	3.55	41.50	53.00	0.086	48.27	7.50	30.50	57.00	0.011*	47.31	7.78	30.00	56.00	0.228
31. SN–ML	37.42	1.98	33.00	39.50	0.407	37.58	1.85	33.00	40.00	0.026*	40.85	4.07	34.50	48.00	0.424	40.50	4.07	34.00	48.00	0.021*
32. GoA	128.96	4.42	121.50	135.50	0.388	128.58	3.94	123.00	134.00	0.238	131.23	3.99	123.50	137.00	1.000	131.27	4.11	122.50	137.00	0.091

* $P \leqslant 0.05$; ** $P \leqslant 0.01$; *** $P \leqslant 0.001$.

†The numbers written below the P values indicates the compared stages.

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Table 7B The follow-up and treatment changes for the parameters related to the vertical relationships with mandibular structures and the corresponding biometrical test values.

	Control group ($n = 13$)				Treatment group ($n = 13$)				
Parameters	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	P
24. $[(D_2-\bar{1})-(D_1-\bar{1})]$	1.154	0.72	0.00	2.50	0.615	0.94	−1.00	2.50	0.082
25. $[(C_2-6')-(C_1-\underline{6})]$	0.731	1.17	−2.00	2.50	0.231	1.36	−1.50	3.00	0.260
26. D_1-D_2 on COPV	2.577	1.31	0.50	5.00	0.962	1.70	−3.00	3.00	0.020*
27. C_1-C_2 on COPV	2.500	1.31	1.00	5.00	1.385	1.47	−2.00	3.50	0.118
28. Ar_1-Ar_2 on COP	2.000	1.47	−0.50	5.00	0.596	0.56	0.00	1.50	0.007**
29. Ar_1-Ar_2 on COPV	1.731	1.38	0.50	5.00	1.808	1.39	0.00	4.00	0.739
30. SN–CD; total rotation of mandible	0.346	0.80	−1.00	2.00	−0.962	0.97	−2.50	0.50	0.003**
31. SN–ML; matrix rotation of mandible	0.154	0.59	−1.00	1.00	−0.346	1.39	−2.00	2.00	0.183
32. GoA	−0.385	1.50	−2.50	2.50	0.038	1.15	−1.50	2.00	0.489

*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.

Table 8 Distribution of maxillary and mandibular rotational growth patterns.

	Total Mandibular Rotation							
Total	Backward		Parrallel Lowering		Forward			
	Control Group	Treatment Group	Control Group	Treatment Group	Control Group	Treatment Group		
4	3		1				Control Group	Total Maxillary Rotation: Forward
10		2		1		7	Treatment Group	Total Maxillary Rotation: Forward
9	3		4		2		Control Group	Total Maxillary Rotation: Backward
3				1		2	Treatment Group	Total Maxillary Rotation: Backward
26	6	2	5	2	2	9	Total	

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