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Vertical changes following orthodontic extraction treatment in skeletal open bite subjects

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SUMMARY The purpose of this investigation was to assess the vertical changes occurring in skeletal open bite patients treated orthodontically with different extraction patterns. The study was conducted using lateral cephalometric radiographs taken before and after treatment. Fifteen patients who had an anterior open bite (AOB) only were treated with first premolar extractions (Group E4). Seventeen patients with an AOB extending to the posterior teeth were grouped according to the extractions: extraction of second premolars (Group E5) and first molars (Group E6). Cephalometric data were analysed according to the 'two-factor experiment with a repeated measure on one factor' model. The treatment group factor had three levels, E4, E5, and E6, and the time factor two levels, pre- and post-treatment. The differences between the pre- and post-treatment periods were statistically significant for all the cephalometric variables ($P < 0.001$, $P < 0.0001$), except for ANS–Me/Na–Me. The time and group interaction were found to be statistically significant for the variables where the time factor is important, such as SN–GoGn angle, SGn–NBa angle, ANS–Me dimension, Na–Me dimension, forward movement of the maxillary and mandibular molars, and the distance to the mandibular plane of the lower molars. The severity of vertical dysplasia did not change in group E4. Generally, however, within the appropriate indications, extraction of the second premolars or the first molars led to a closing rotation of the mandible in subjects with a skeletal AOB extending to the posterior teeth.

Introduction

In the treatment of skeletal open bite, extraction of first premolars, even when crowding is deemed to be mild, has been accepted by many clinicians. It has been suggested that if the molar teeth are moved forward without extrusion towards the extraction spaces of the first premolars from the palatomandibular wedge, the mandible may show an anterior rotation (Isaacson *et al*., 1971; Ricketts, 1979; Ülgen, 1983). On the other hand, some authors have hypothesized that extraction therapy, which is preferable in subjects with a vertical growth pattern, is invalid in growing patients who tend to have more extrusion of the posterior teeth. Therefore, they proposed that orthodontic treatment should be postponed until the pubertal growth spurt is almost complete or until after puberty (Schudy, 1964; Björk, 1969; Nielsen, 1991).

A number of authors prefer extraction of the first molars, particularly in patients with a skeletal anterior open bite (AOB) extending to the posterior teeth (Dale, 1985; Fränkel and Fränkel, 1986). Literature concerning first molar extraction consists only of case presentations, whilst statistical data are available for patients treated with first premolar extractions. The case reports indicated that forward movement of the second molars after first molar extractions leads to anterior rotation of the mandible (Arvystas, 1977; Dale, 1985; Cooke and Newsome, 1990; Ortial, 1995; Vaden, 1998). Scientific studies that documented vertical changes in cases where the molars moved forward substantially following first premolar extraction found that there was no closing rotation of the mandible (Staggers, 1990; Cusimano *et al*., 1993). However, these investigations did not take into consideration patients in the late stages of pubertal development, when minimization of posterior teeth extrusion was claimed to have taken place.

The purpose of this study was to determine the vertical changes that occurred in skeletal open bite patients who had passed the peak stage of the pubertal growth spurt following first premolar, second premolar, or first molar extractions and treatment with fixed appliances.

Subjects and methods

This prospective study used the pre- and post-treatment lateral cephalometric radiographs of 32 skeletal open bite patients treated at the Department of Orthodontics, Ege University. In all patients, extraction orthodontic treatment was carried out. The patients were grouped according to the extraction procedures. Fifteen subjects (six boys and nine girls) who had a skeletal open bite consisting of the involvement of anterior teeth only underwent four first premolar extraction treatment (Group E4). The remaining 17 patients possessed an AOB extending to the second premolars or first molars. Nine (three boys and six girls) of the 17 patients were treated with the extraction of four second premolars (Group E5) and eight subjects (three boys and five girls) with extraction of first molars (Group E6). Care was taken to ensure that the first molars were healthy while forming groups E5 and E6. Accordingly, in Group E6, the presence of profound decay or restoration in one tooth at least, or enamel hypoplasia, dictated the extraction choice of four first molars.

The mean pre-treatment age was 14.85 ± 1.05 years for group E4, 15.04 ± 1.20 for E5, and 14.61 ± 0.87 for E6. According to hand–wrist radiographs, the patients were in developmental stages between MP3-H (the beginning of fusion of the epiphysis and metaphysis of the middle phalanx of the third finger), and R–IJ (fusion of the distal epiphysis and metaphysis, or the radius was almost completed); i.e. they were in the deceleration period of the pubertal growth spurt or almost at the end of the pubertal period (Hägg and Taranger, 1980).

In all groups, a further selection criterion was the use of most of the extraction space for forward movement of the posterior teeth. All patients had a 0–5 mm overjet, mild to moderate crowding, and a Class I or Class II molar relationship. No extra-oral appliances were used.

All subjects underwent comprehensive orthodontic treatment with straightwire appliances carried out by the same orthodontist. The extraction spaces were closed with coil springs on a continuous archwire, and application of inter-maxillary Class II and Class III elastics was avoided. A 30-degree gable bend was placed in the archwire immediately distal to the tooth in front of the extraction space, and adjusted as necessary to maintain translation during space closure.

All cephalometric radiographs were taken on the same cephalostat. Structures appearing as bilateral images were identified by bisecting the outlines of the images. Two angular, eight linear, and one ratio cephalometric measurement were selected to evaluate vertical changes. Angular and linear measurements calculated to the nearest 0.5 mm and 0.5 degrees on the cephalometric radiographs are shown in Figure 1.

Statistical method

The homogeneity of the groups before treatment was tested using a Student's *t*-test. For all cephalometric variables, the significance level was calculated by constructing the 95 per cent confidence interval.

In order to evaluate the significance of the changes from pre- to post-treatment, statistical analysis of the experimental data was carried out with the SAS 8.0 statistical package, using the 'two-factor experiment with a repeated measure on a one factor' model. The two factors were treatment group and time. The treatment groups had three levels: E4, E5, and E6; and the time factor two levels: pre- and post-treatment. For the variables where the time factor is important, the results were carefully interpreted taking the significance of the interaction of the two factors into consideration. In situations

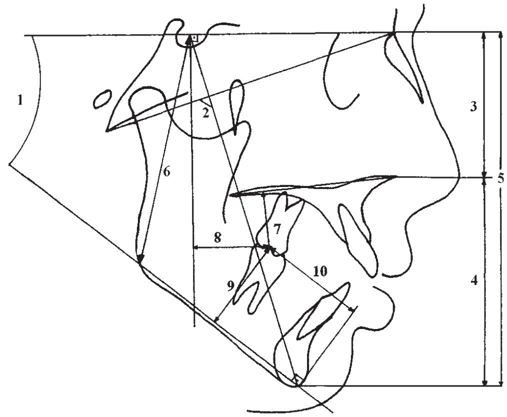

Figure 1 Angular and linear measurements used in the cephalometric analysis: 1, SN–GoGn (degrees); 2, SGn–NBa (degrees); 3, Na–ANS (upper face height, mm); 4, ANS–Me (lower face height, mm); 5, Na–Me (anterior face height, mm); 6, S–Go (posterior face height, mm); 7, UM to palatal plane (vertical distance from bisection of occlusal surface of maxillary first molar in groups E4 and E5 or maxillary second molar in group E6 to palatal plane, mm); 8, UM to SN horizontal (horizontal distance from bisection of occlusal surface of maxillary first molar in groups E4 and E5 or maxillary second molar in group E6 to perpendicular to SN line at sella, mm); 9, LM to mandibular plane (vertical distance from bisection of occlusal surface of mandibular first molar in groups E4 and E5 or mandibular second molar in group E6 to mandibular plane, mm); 10, LM to Gn horizontal (horizontal distance from bisection of occlusal surface of mandibular first molar in groups E4 and E5 or mandibular second molar in group E6 to perpendicular to mandibular plane at gnathion, mm).

where the interaction was not significant, the conclusions were drawn directly from the main effects of the two factors. The Duncan multiple comparison test was applied when the treatment group variation was found to be significant in the analysis of the variance (Cody and Smith, 1997).

Measurement reliability

The combined error of tracing and measurement was determined by tracing 10 randomly selected cephalometric radiographs and by repeating the measurements. Differences between the original and the retraced cephalometric radiographs were statistically analysed using a paired two-tailed *t*-test. In addition, the correlation coefficients were calculated to determine the strength of the relationship between repeated measurements. The combined tracing and measurement errors were not significant at the 0.05 level.

Results

The means and standard deviations for the cephalometric parameters for three groups are given in Table 1.

The 95 per cent confidence limits for each cephalometric variable before treatment are detailed in Table 2. No significant inter-group differences were observed for any of the cephalometric

Table 1 Means and standard deviations for cephalometric measurements in all the groups.

Cephalometric variables	Group E4 (n = 15)				Group E5 (n = 9)				Group E6 (n = 8)			
	Pre-treatment		Post-treatment		Pre-treatment		Post-treatment		Pre-treatment		Post-treatment	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SN–GoGn angle	42.06	3.25	41.86	3.07	43.11	2.20	42.05	1.87	42.81	3.29	41.31	3.66
SGn–NBa angle	85.53	2.85	85.73	2.96	84.88	2.71	85.50	2.63	86.25	3.69	87.43	3.91
Na–ANS (mm)	53.60	3.29	55.40	3.18	55.33	2.55	57.00	2.17	53.75	2.43	55.43	2.25
ANS–Me (mm)	73.20	6.66	76.80	7.19	74.55	4.61	76.88	4.70	75.12	5.38	76.50	4.92
Na–Me (mm)	126.80	7.40	132.20	7.85	129.88	6.19	133.88	5.71	128.87	7.10	131.93	6.42
S–Go (mm)	76.26	4.33	81.06	4.26	75.88	2.93	80.61	2.67	73.87	2.16	78.75	3.53
ANS–Me/Na–Me (%)	57.65	2.65	58.00	2.63	57.37	1.48	57.39	1.57	58.26	1.41	57.95	1.32
UM–palatal plane (mm)	23.16	3.21	25.70	3.67	20.22	3.38	22.27	3.28	19.62	3.29	21.93	3.38
UM–SN horizontal (mm)	23.60	3.60	27.26	3.67	20.11	1.90	24.00	2.23	15.50	3.89	21.62	3.85
LM–mandibular plane (mm)	32.33	2.71	34.73	2.67	31.55	1.66	33.34	1.25	31.12	2.03	32.67	2.21
LM–Gn horizontal (mm)	35.70	3.99	31.56	4.31	34.22	3.23	30.50	3.22	44.50	2.77	38.12	2.58

Table 2 Ninety-five per cent confidence limits for each cephalometric variable.

Cephalometric variables	Group E4 (n = 15)		Group E5 (n = 9)		Group E6 (n = 8)	
	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
SN–GoGn angle	40.26	43.86	41.42	44.80	40.06	45.56
SGn–NBa angle	83.96	87.10	82.47	86.63	83.16	89.34
Na–ANS (mm)	51.78	55.42	53.37	57.29	51.72	55.78
ANS–Me (mm)	69.51	76.89	71.01	78.09	70.61	79.63
Na–Me (mm)	122.70	130.90	125.13	134.63	122.92	134.82
S–Go (mm)	73.87	78.65	73.63	78.13	72.06	75.68
ANS–Me/Na–Me (%)	56.19	59.11	56.21	58.53	57.08	59.44
UM–palatal plane (mm)	21.39	24.93	17.63	22.81	16.87	22.37
UM–SN horizontal (mm)	21.61	25.59	18.65	21.57	12.24	18.76
LM–mandibular plane (mm)	30.83	33.83	30.25	32.85	29.42	32.82
LM–Gn horizontal (mm)	33.49	37.91	31.74	36.70	42.18	46.82

variables, except for LM–Gn horizontal, where there was a significant difference between groups E4 and E6, and between E5 and E6.

The results of the variance analysis based on the 'two-factor experiment with a repeated measure on one factor' model are presented in Table 3. For the UM–palatal plane, UM–SN horizontal, and LM–Gn horizontal distances, there were significant differences among the groups ($P < 0.05$, $P < 0.001$, and $P < 0.001$, respectively). However, the difference in the treatment groups for UM–SN horizontal and LM–Gn horizontal was not independent from the time factor, i.e. the group × time interaction was found to be significant for these characteristics ($P < 0.001$, $P < 0.0001$). For UM–palatal plane the interaction was not significant; Duncan multiple test grouping was made for this characteristic. This test exhibited significant differences at a level of $P < 0.05$ between groups E4 and E5, and between groups E4 and E6. The differences between the pre- and post-treatment period were significant for all the cephalometric variables ($P < 0.001$, $P < 0.0001$), except for ANS–Me/Na–Me. The time and group interaction was significant for SN–GoGn, SGn–NBa,

Table 3 Results of the analysis of variance based on the 'two-factor experiment with a repeated measure on one factor'.

Cephalometric variables	Variation sources		
	Treatment groups	Time (pre-treatment–post-treatment)	Time × group interaction
SN–GoGn angle	NS	F = 23. 76***	F = 4. 75*
SGn–NBa angle	NS	F = 17. 73**	F = 3. 49*
Na–ANS (mm)	NS	F = 200. 18***	NS
ANS–Me (mm)	NS	F = 184. 67***	F = 13. 95***
Na–Me (mm)	NS	F = 245. 81***	F = 7. 21**
S–Go (mm)	NS	F = 398. 73***	NS
ANS–Me/Na–Me (%)	NS	NS	F = 4. 36*
UM–palatal plane (mm)	F = 4. 09*	F = 372. 22***	NS
UM–SN horizontal (mm)	F = 16. 20***	F = 714. 81***	F = 10. 85**
LM–mandibular plane (mm)	NS	F = 295. 61***	F = 3. 42*
LM–Gn horizontal (mm)	F = 21. 35***	F = 841. 16***	F = 22. 15***

NS, not significant; *$P < 0.05$; **$P < 0.001$; ***$P < 0.0001$.

ANS–Me, Na–Me, UM–SN horizontal, LM–mandibular plane, and LM–Gn horizontal, which are variables where the time factor is important because the differences observed between the pre- and post-treatment periods for the groups were not the same. Time × group interactions found to be significant were explained by graphical procedures (Figures 2–8).

Whereas SN–GoGn remained almost constant in group E4 during treatment, decreases in groups E5 and E6 were observed for this angle, with the largest decrease being in group E6 (Figure 2). In group E4, there did not seem to be any difference in SGn–NBa during treatment, whereas increases in groups E5 and E6 were observed for this angle (Figure 3). Whereas ANS–Me dimension showed increases in all groups, the largest increase was observed in group E4 and the smallest in group E6 (Figure 4). The Na–Me dimension increased in all groups. The

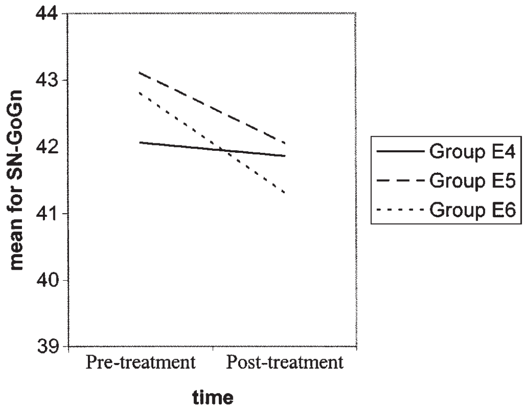

Figure 2 A graphical explanation of the significance of group × time interaction for SN–GoGn. The SN–GoGn angle remained almost constant in group E4, and decreased in groups E5 and E6 with the largest decrease being in group E6.

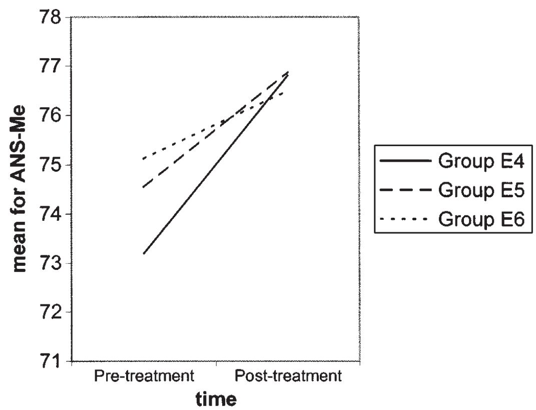

Figure 4 A graphical explanation of the significance of group × time interaction for ANS–Me. ANS–Me dimension showing increases in all groups, with the largest increase in group E4 and the smallest in group E6.

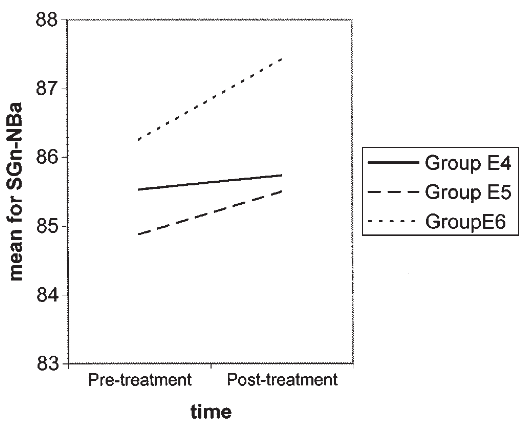

Figure 3 A graphical explanation of the significance of group × time interaction for SGn–NBa. In group E4, there was seemingly no difference in SGn–NBa angle, whereas increases in group E5 and E6 were observed.

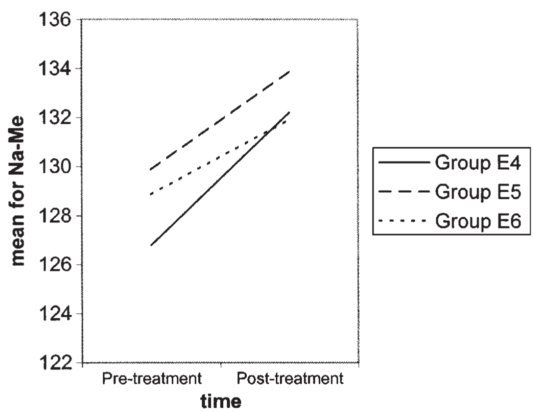

Figure 5 A graphical explanation of the significance of group × time interaction for Na–Me. The Na–Me dimension increased in all groups, the largest increase being in group E4 and the smallest in group E6.

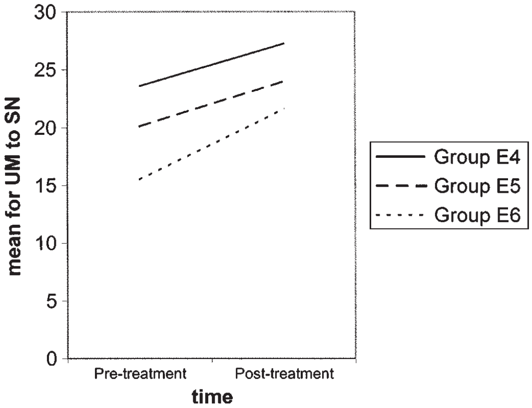

Figure 6 A graphical explanation of the significance of group × time interaction for UM to SN horizontal. While forward movement of the maxillary molar teeth was largest in group E6, this movement was slightly more in group E4 than in group E5.

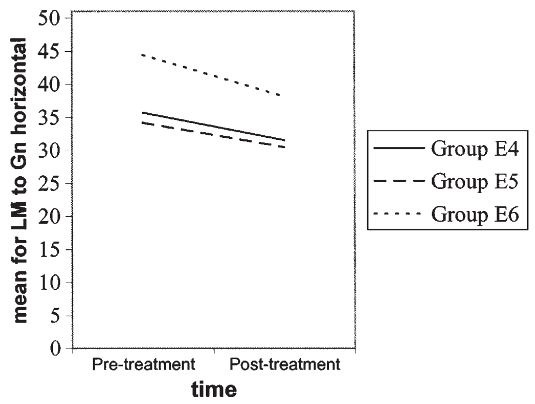

Figure 8 A graphical explanation of the significance of group × time interaction for LM to Gn horizontal. In all groups, LM to Gn horizontal distance decreased due to forward movement of the molar teeth. The amount of forward movement of the molar teeth in groups E4 and E5 was similar, whereas it was the largest in group E6.

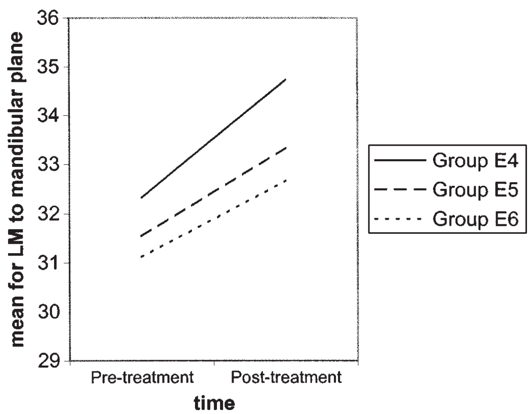

Figure 7 A graphical explanation of the significance of group × time interaction for LM to mandibular plane. The increase in dentoalveolar height of the mandibular molar teeth was similar in groups E5 and E6, the highest being observed in group E4.

largest increase was in group E4 and the smallest in group E6 (Figure 5). Whereas forward movement of the maxillary molar teeth was largest in group E6, this movement was slightly more in group E4 than in group E5 (Figure 6). The increase in dentoalveolar height of the mandibular molar teeth was similar in groups E5 and E6, whereas this increase was larger in group E4 than in other groups (Figure 7). In all groups, LM–Gn horizontal distance decreased due to forward movement of the molar teeth. While the amount of forward movement of the mandibular molar teeth in groups E4 and E5 was similar, this movement was the largest in group E6 (Figure 8).

Discussion

The extraction of teeth in patients with a steep mandibular plane is widespread. Often the sole purpose of extracting premolars is to protract the molar teeth in order to allow anterior rotation of the mandible. Some investigators have emphasized the necessity of trying to prevent extrusion during protraction of the molar teeth, and a vertical chin cup has been advocated in full-bonded appliance therapy (Schudy, 1965, 1968; Pearson, 1973, 1986, 1997). Because the tendency to extrude the posterior teeth decreases when there is less active growth, late treatment has been recommended, especially if extractions are necessary and the patient is unwilling to co-operate in wearing the appliances necessary to control vertical height (Schudy, 1964; Björk, 1969; Pearson, 1973, 1986, 1997; Nielsen, 1991). Thus, it has been hypothesized that particularly in adolescents who have passed the peak stage of the pubertal growth spurt, forward movement of the posterior teeth causes a closing rotation of the mandible.

In accordance with the above-mentioned hypothesis, which tooth to extract regarding the type of open bite is important. The occlusal contacts in the posterior teeth that block the closing rotation of the mandible are reduced by extracting the most anterior occluding tooth. The remaining occlusal contacts are then protracted out of the palatomandibular wedge. The groups in the study were established by using the same principle. However, there was a deviation from this principle while forming groups E5 and E6, depending on whether the first molars were healthy or not. For instance, in subjects with an open bite where occlusal contact was limited to first and second molars only, if the first molars were healthy, the second premolars were extracted.

Scientific investigations carried out in patients where the molars protracted forward substantially following first premolar extraction revealed that there was no decrease in the mandibular plane angle (Staggers, 1990; Klapper *et al*., 1992; Cusimano *et al*., 1993). In these studies, the extrusion of molars due to growth and treatment was stressed as a factor preventing the closing rotation of the mandible. Staggers (1990) attributed the extrusion to the general extrusive nature of all-orthodontic mechanics in her study, but did not include any information regarding the pre-treatment vertical growth pattern of the patients, and merely presented statistical data on the changes in the vertical dimensions and angles; also the subjects in that study had a wide age range (from 9 to 16 years). Klapper *et al*. (1992) investigated the correlation between facial axis change and the amount of anteroposterior movement of the upper molars in boys between the ages of 12 and 15 years with brachyfacial and dolichofacial growth patterns. They found no significant correlation in both facial types undergoing extraction treatment. Cusimano *et al*. (1993) analysed high angle patients with an average age of 11 years 10 months. According to these authors significant extrusion of molar teeth involved compensatory vertical eruption of the molar teeth into the inter-maxillary space to keep pace with the increase in anterior facial height. It has to be emphasized that the present study considered the pubertal development period according to hand–wrist radiographs, whilst other investigations have not.

In group E4, the mean amount of forward movement for the maxillary and mandibular molars was 3.66 and 4.14 mm, respectively. The mean occlusal movement for the maxillary and mandibular molars was 2.29 and 2.4 mm, respectively (Table 1). This orthodontic extrusion was demonstrated by the increase in maxillary molar to palatal plane and mandibular molar to mandibular plane measurements, as described by Staggers (1990, 1994). In group E4, there was no significant change in SN–GoGn and SGn–NBa angles and ANS–Me/Na–Me ratio reflecting mandibular rotation (Table 3, Figures 2 and 3). This finding did not differ from the results of Staggers (1990), Klapper *et al*. (1992), and Cusimano *et al*. (1993), where pubertal growth was not taken into consideration.

It is believed that second premolar extractions are useful in the treatment of patients with an open bite and long lower face by limiting the increase in the posterior alveolar height (Logan, 1973; Brandt, 1975; Joondeph and Riedel, 1976; Garlington and Logan, 1990). In the current second premolar extraction group, the maxillary and mandibular first molar height increased on average 1.76 and 1.79 mm, respectively (Table 1). The value found especially for mandibular molars was lower than in group E4 and those reported by other authors (Dougherty, 1968; Pearson, 1986; Staggers, 1990, 1994; Cusimano *et al*., 1993) following first premolar extractions. In group E5, there were significant changes in SN–GoGn and SGn–NBa angles, indicating a closing rotation of the mandible (Table 3, Figures 2 and 3).

In agreement with the findings of previous case reports (Arvystas, 1977; Dale, 1985; Cooke and Newsome, 1990; Ortial, 1995; Vaden, 1998), group E6 in the present study showed significant changes in the SN–GoGn and SGn–NBa angles, reflecting anterior rotation of the mandible. The magnitude of this rotation was slightly greater than that of group E5 (Table 3, Figures 2 and 3). The difference was probably due to the fact that the molars in Group E6 had a greater forward movement compared with those in group E5 (Figures 6 and 8).

In patients with vertical growth, the centre of rotation is located at the most distal occluding molars (Björk, 1969). This posterior rotation can result in an AOB, depending on the extent of vertical dentoalveolar compensation. Despite an increased vertical jaw relationship, in patients without an AOB, vertical dentoalveolar compensation is complete. Patients with an AOB extending to the posterior teeth, in contrast, have no or negative dentoalveolar compensation (Solow, 1980; Altuğ, 1987; Nielsen, 1991; Chang and Moon, 1999). The patients in group E4 may be more prone to extrusion of the posterior teeth during forward movement of the molar teeth into the premolar extraction space where vertical dentoalveolar compensation is present; i.e. in group E4, the greater amount of extrusion of the lower molars may be associated with dentoalveolar compensation (Figure 7). In this group, the larger extrusion of the lower molars is compatible with the view that 'increase in mandibular alveolar height is greater than that of the maxilla during orthodontic treatment' (Schudy, 1965). Another reason for extrusion of the lower molars may be related to the treatment itself in that as the number of teeth moved forward increases, the mechanics may become inadequate, making vertical control of the teeth difficult. As a result, despite similar amounts of protraction of the molars in groups E4 and E5, a greater extrusion of the lower molars in group E4 prevented forward rotation of the mandible.

There were significant differences among the groups for the distance from the upper molar to the palatal plane. This distance was larger in group E4 than in the other two groups. However, the group × time interaction was not significant for this measurement because the difference between the pre- and post-treatment periods for the groups was similar (Table 3). For the horizontal distances of the upper molar to SN and the lower molar to Gn, there were significant differences among the groups (Table 3). These differences are probably due to the distances from the first molars in groups E4 and E5 and the second molars in group E6 to the reference plane. The group × time interaction was also significant for these measurements.

The number of subjects in the present study was small due to the fact that the incidence of an open bite anomaly is low, and in addition to pubertal growth the amounts of crowding and Angle classification were included in the criteria for selection. For the reasons mentioned above no untreated AOB control group was included.

Nanda and Rowe (1989) showed that a disproportionate absolute increase in posterior dimensions of the face over anterior dimensions may reduce or maintain the severity of a skeletal open bite for 3 years before and after the pubertal growth spurt. Furthermore, Nanda (1990) reported that the mandibular plane angle closed on average approximately 0.5 degrees from 15 to 17 years of age in females and males with an untreated open bite. The average age of the subjects in the present study was approximately 15 years at the beginning of orthodontic treatment, which continued for approximately 2 years. In this connection, when compared with the findings of Nanda (1990), the decrease in the mandibular plane angle in group E5 and E6 was slightly greater. On the other hand, post-adolescent growth leads to a backward rotation with possible relapse in treated open bite cases (Björk and Skieller, 1972; Nemeth and Isaacson, 1974). Such reports should not be disregarded. The termination of active pubertal growth in females occurs approximately 2 years earlier than in males and it is generally accepted that this takes place at 14 years of age (Hägg and Taranger, 1980; Foley and Mamandras, 1992). Accordingly, in the present study, where the pre-treatment age was approximately 15 years and most of the patients were girls, the subjects were either close to or at the end of the pubertal growth spurt period.

All face height measurements were increased in the current study. Because of the fact that the changes in especially ANS–Me and Na–Me dimensions were due to a combination of treatment and growth, these dimensions in groups E5 and E6 showing a closing rotation of the mandible did not increase as much as those in group E4 (Figures 4 and 5).

Conclusions

The following conclusions have been derived from the present study, which was conducted on open bite patients in the deceleration period or at the end of the pubertal growth spurt:

1. No significant mandibular rotational change was observed following orthodontic treatment with first premolar extractions in subjects with a skeletal open bite consisting of anterior teeth involvement only.
2. Within the appropriate indications, the extraction of the second premolars or the first molars led to a closing rotation of the mandible in skeletal anterior open bite extending to the posterior teeth.

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