European Journal of Orthodontics 26 (2004) 223–231

European Journal of Orthodontics vol. 26 no. 2

Effects of bilateral upper first premolar extraction on the mandible

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SUMMARY The purpose of this study was to evaluate the effects of bilateral upper premolar extraction on mandibular growth. Twenty-six subjects (eight males, 18 females) in maximum pubertal growth with an Angle Class II molar relationship, normal to mild overjet increase, mild or no lower arch length discrepancy but severe upper arch discrepancy and no severe skeletal discrepancy were divided into two groups equal in number and gender, as extraction and control groups. The median chronological age was 11.2 years in the extraction group and 12.6 years in the controls. The subjects were observed for a median period of 1.1 years in the extraction group after bilateral extraction of the upper premolars and 1.2 years in the controls until termination of pubertal growth (DP_{3u}) without any orthodontic treatment. Twenty-nine linear and angular measurements were made on 52 lateral cephalograms and hand–wrist radiographs taken before and after the study period.

The increase in SNB measured on the total superimposition was significantly greater in the controls than in the extraction group ($P < 0.05$). In addition, anterior mandibular (counter-clockwise) rotation was only significant ($P < 0.05$) in the control group. Thus, it might be suggested that bilateral upper premolar extractions might affect the mandibular rotation tendency.

Introduction

Tooth extraction is a common approach in orthodontic treatment to resolve dental crowding, and its frequency in orthodontic patients has been reported to be 42.1 per cent (Peck and Peck, 1979).

Early extraction of a tooth affects alveolar development and the balance between the alveolar and basal arches (Enünlü, 1971). Animal studies have shown that extraction of upper incisors, in which the maxillary growth line was mostly vertical, produced mainly vertical growth inhibition and thus reduced face height in the cat (Baker, 1941), a marked length reduction of the mandible due to experimental lower incisor extraction in the rat (Riesenfeld, 1969) and a lack of growth of the jaws with the removal of the incisors in rabbits (Ranta *et al.*, 1973).

İşeri and Solow (1990) studied the sutural growth displacement of the maxilla on the Björk implant sample and found that horizontal displacement peaked at 11 years of age and terminated at 18 years of age, whereas vertical displacement peaked at 12 years of age and terminated at 15 years of age. According to these results, a noticeable difference would be expected in the vertical growth of the maxilla after extractions for orthodontic purposes within these age ranges. Any changes in the sagittal, vertical and/or transverse direction of maxillary growth will also result in changes in mandibular position.

Yamaguchi and Nanda (1991) drew attention to the necessity of vertical control of both the maxillary and mandibular molars, which would otherwise cause a posterior rotation of the mandible. Luecke and Johnston (1992) studied the effects of maxillary first premolar extraction and incisor retraction using the Edgewise technique on mandibular position in 42 patients and found that the mandibular basal bone displaced anteriorly in 70 per cent.

Some researchers claim that premolar extractions tend to decrease the vertical dimension of the face (Sassouni and Nanda, 1964; Schudy, 1964, 1965, 1968) and believe that mesial tipping of the molars causes anterior rotation of the mandible (Pearson, 1978; Fields *et al.*, 1988). Recent studies have shown that premolar extractions may not be effective in reducing lower anterior face height (Staggers, 1990; Yamaguchi and Nanda, 1991; Chua *et al.*, 1993) and may increase it even further (Gültan, 1990; Klapper *et al.*, 1992; Staggers, 1994; Saraç and Cura, 1995).

Most investigations have focused on treatment results in Class II division 1 subjects either following extraction of the upper first premolars only (Kessel, 1963; Battagel, 1990; Gültan, 1990; Luecke and Johnston, 1992), extraction of both the upper and lower first premolars (Gültan, 1990; Staggers, 1990, 1994; Yamaguchi and Nanda, 1991; Klapper *et al.*, 1992; Chua *et al.*, 1993; Bishara *et al.*, 1995; Saraç and Cura, 1995; Bishara, 1998), non-extraction treatment (Yamaguchi and Nanda, 1991; Klapper *et al.*, 1992; Chua *et al.*, 1993; Bishara *et al.*, 1995; Saraç and Cura, 1995; Bishara, 1998) or comparing the effects of non-extraction treatment with premolar extraction therapy (Yamaguchi and Nanda, 1991; Paquette *et al.*, 1992; Chua *et al.*, 1993; Luppanapornlarp and Johnston, 1993; Bishara *et al.*, 1995, 1997).

Most of these studies have been conducted on patients who have received concurrent orthodontic treatment, making it difficult to determine whether growth was affected by extractions and/or whether the treatment mechanics were responsible for the observed differences.

Although the effects of orthodontic treatment on the facial growth pattern have been reported, the effects of extractions alone on the mandibular growth pattern are not yet completely understood. It was, therefore, the aim of this study to evaluate the effects of bilateral upper first premolar extraction on mandibular position.

Subjects and method

Subjects

Twenty-six subjects in the peak pubertal growth period, without a history of mouth breathing, previous orthodontic treatment, thumb sucking or tongue thrust habits were included in the study. None of them had any skeletal sagittal and/or vertical discrepancy. Dental features included a half cusp Class II molar relationship and significant crowding in the maxillary dental arch with a normal to slightly increased overjet, but only 0–2 mm of crowding in the mandibular arch. These subjects were divided randomly into two groups, an extraction group and a control group.

The extraction group consisted of 13 subjects (nine girls and four boys) with a median overjet of 3.5 mm. The upper premolars were extracted bilaterally to create space in the maxillary dental arch (T_1). They were followed until the end of their pubertal peak period (DP_{3U}) (median 1.1 years) without any mechanical orthodontic treatment (T_2). The median chronological age at T_1 was 11.2 years and the skeletal age was 11.5 years. No subsequent appliance therapy for the alignment of their dental arches was instituted until the end of the study.

The control group consisted of 13 subjects (nine girls and four boys) with a median overjet of 3.5 mm, matched to the extraction group according to the growth period, gender, ANB and mandibular plane angle with reference to the sella–nasion line. The median chronological age at T_1 was 12.6 years and the skeletal age was 12.0 years. These subjects were followed up (median 1.2 years) until the end of their pubertal peak period (T_2) without any extractions or orthodontic treatment. At the end of the follow-up period, all subjects were treated using fixed appliances.

The hand–wrist radiographs taken at the beginning and end of treatment showed that the average skeletal maturity period according to Helm *et al.* (1971) for both groups was well within the S–MP_3 or MP_{3cap} period at T_1 and within or close to the DP_{3U} period at T_2. The skeletal age and growth potential were determined using the atlas of Greulich and Pyle (1959).

The research material consisted of 52 lateral cephalometric and hand–wrist radiographs taken at T_1 and T_2 under standard conditions. The lateral cephalograms were taken at maximum intercuspation with the Frankfort horizontal parallel to the floor.

Superimpositions

In order to differentiate skeletal and dental changes, disregarding displacement of the nasion, total and local superimposition methods were carried out as described by Björk and Skieller (1983). Within this method, a co-ordinate system with the sella–nasion as the *x*-axis and a perpendicular to this through the sella as the *y*-axis was constructed on the first cephalogram. For the total superimposition method, the first and second cephalograms of each subject were superimposed on stable bony structures in the anterior cranial base, and the co-ordinate system constructed on the first cephalogram was transferred to the second cephalogram. For the local superimposition method, the same co-ordinate system constructed on the first cephalogram was transferred to the second by superimposing the two cephalograms on mandibular structures (Björk and Skieller, 1983).

Measurements

Fifteen measurements on total superimposition (Figure 1) and eight measurements on local mandibular superimposition (Figure 2) were made in relation to the *x*- and *y*-axes of this co-ordinate system.

The mandibular rotation was measured as the angle between the first, transferred sella–nasion line (SN1) and the sella–nasion line on the second cephalogram (SN2). Anteriorly converging SN1 and SN2 lines were attributed to an anterior (counter-clockwise) mandibular rotation (Figure 2) and were assigned negative values, whereas posteriorly converging lines showing posterior (clockwise) rotation of the mandible were assigned positive values.

Six angular measurements were made on the pre- and post-study cephalograms (Figure 3), independently without using the superimposition method of Björk and Skieller (1983). For the assessment of SNB, two measurements were undertaken, either disregarding displacement of nasion as in the superimposition method or considering it by measuring this angle independently on pre- and post-study cephalograms.

All of the tracings, superimpositions and measurements were to the nearest 0.5 mm or degree and made by one investigator (HNI).

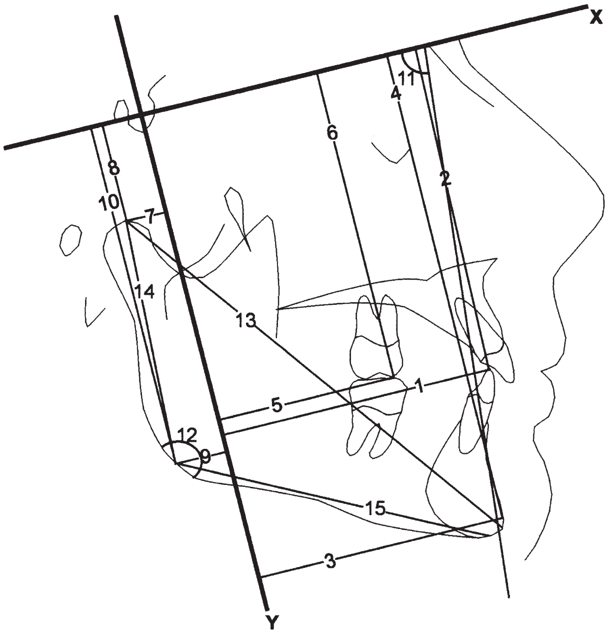

Figure 1 Measurements on total superimposition. X, S–N plane; Y, plane perpendicular to X at sella; 1, Lower 1 $edge_x$: sagittal position of lower incisal edge; 2, Lower 1 $edge_y$: vertical position of lower incisal edge; 3, Pg_x: sagittal position of pogonion; 4, Pg_y: vertical position of pogonion; 5, Lower 6_x: sagittal position of lower first permanent molar; 6, Lower 6_y: vertical position of lower first permanent molar; 7, Co_x: sagittal position of condylion; 8, Co_y: vertical position of condylion; 9, Go_x: sagittal position of gonion; 10, Go_y: vertical position of gonion; 11, SNB; 12, gonial angle; 13, Co–Gn: mandibular length; 14, Co–Go: ramal height; 15, Go–Me: corpus length.

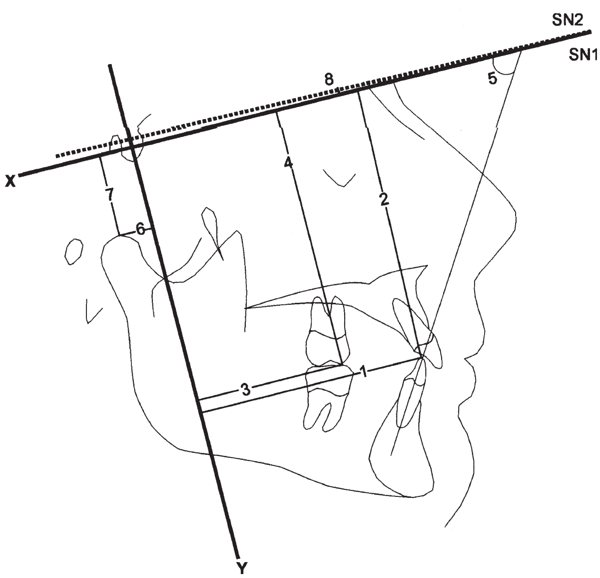

Figure 2 Measurements on local mandibular superimposition. 1, Lower 1 $edge_x$: sagittal position of lower incisal edge; 2, Lower 1 $edge_y$: vertical position of lower incisal edge; 3, Lower 6_x: sagittal position of lower first permanent molar; 4, Lower 6_y: vertical position of lower first permanent molar; 5, Lower 1/SN: inclination of lower incisor; 6, Co_x: sagittal position of condylion; 7, Co_y: vertical position of condylion; 8, mandibular rotation (SN1–SN2).

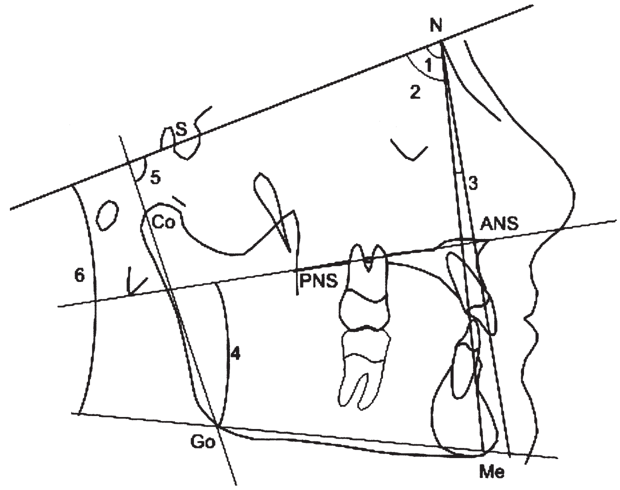

Figure 3 Angular measurements on cephalograms. 1, SNA; 2, SNB; 3, ANB; 4, ANS–PNS/Go–Me; 5, SN/Co–Go; 6, SN/Go–Me.

Measurement error

In order to evaluate the individual error, either during tracing, superimposing or transferring the co-ordinate system from the first cephalogram to the second or measuring the parameters, the pre- and post-study lateral cephalograms of eight subjects randomly selected from each study group were repeated at least 2 weeks later. Using variance analysis, two separate (intraclass) repeatability coefficients were calculated from two independent measurements regarding the same parameter. The first was calculated from the measurements carried out on the pre-study cephalograms regarding the tracing and measuring, the second from the post-study cephalograms regarding the tracing, transferring the co-ordinate system and measuring. The repeatability coefficients for either tracing and measuring or tracing, superimposing and measuring, ranged between 0.94 and 0.99.

Statistical method

Comparisons between the two groups were undertaken using a two-tailed Mann–Whitney *U*-test. Pairwise comparisons between related assessments made at various time intervals were made using a two-tailed Wilcoxon signed rank test.

To test whether the data were normally distributed, a Kolmogorov–Simirnov normality test was used. No significant differences were found, except for three pre-study measurements, Lower 1 edge, Pg_x and Lower 6_x ($P < 0.01$, $P < 0.05$ and $P < 0.01$, respectively).

Results

A comparison of chronological and skeletal age and growth potential between the groups at T_1 and T_2, and changes from T_1 to T_2, are shown in Table 1 and comparison of the total superimposition measurements between groups at T_1 and T_2, and changes from T_1 to T_2, in Table 2. At T_1 there were statistically significant differences between the groups regarding the vertical position of the gonion and mandibular ramal height. At T_2, the vertical positions of condylion and gonion points were significantly different between the groups (Table 2).

The comparison of mandibular superimposition measurements between groups at T_1 and T_2, and changes from T_1 to T_2, are given in Table 3 and for traditional angular measurements between groups at T_1 and T_2, and changes from T_1 to T_2, in Table 4.

Sagittal mandibular growth

SNB measured on the total superimposition showed a significant increase of 2.0 degrees in the control group, whereas in the extraction group there was no increase. The comparison between groups revealed a statistically significant difference (Table 2). When the same angle was measured on T_1 and T_2 cephalograms independently (using the traditional method), an increase of 1.0 degree was seen for the controls and 0.5 degrees for the extraction group; these differences were not statistically significant (Table 4).

When measured on the total superimposition, sagittal growth of pogonion was statistically significant with a median of 2.0 mm in the controls but only 1.0 mm in the extraction group. However, the difference between groups was not significant (Table 2).

Vertical mandibular growth

When measured on the pre- and post-study cephalograms, the mandibular plane angle showed a statistically significant decrease, with a median value of 1.5 degrees in the control group, whereas the median decrease in the extraction group was only 0.5 degrees, but the difference between the groups was not significant (Table 4). Changes within the groups regarding the maxillo-mandibular plane (ANS–PNS/Go–Me) angle support the changes in the mandibular plane (SN/Go–Me) angle (Table 4).

Neither vertical nor sagittal growth of the condyle showed any significant difference between groups. However, when the vertical position of the condylion (Co_y) between groups was compared, the difference was statistically significant at T_2, although there was no significant difference at T_1 when measured on the total superimposition (Table 2). During the observation period, a significant vertical displacement of Co_y in the control group (median 2.5 mm) was observed. In the extraction group, this value was nearly one-fifth (median 0.5 mm) of that of the controls (Table 2). However, when measured on the local mandibular superimposition, this difference within groups could not be shown (Table 3).

When mandibular rotation was evaluated on the local mandibular superimposition, a statistically significant anterior rotation of 1.0 degree in the control group, measured on the anterior cranial base (Figure 2), was found, whereas in the extraction group the median anterior rotation of the mandible was 0.5 degrees, which was not significant. However, this difference in the amount of anterior mandibular rotation was not statistically significant when the difference between groups was verified (Table 3). In the extraction group, seven of the 13 subjects (54 per cent) showed anterior mandibular rotation, five (39 per cent) showed posterior rotation and one (7 per cent) remained unchanged; in the control group, 10 subjects (77 per cent) anterior rotation, two (16 per cent) posterior rotation and one (7 per cent) remained unchanged.

Dentoalveolar changes

The differences between the two groups regarding vertical movement of the lower incisor edge (Lower 1

Table 1 Comparison of age and growth potential between groups ($n_{control} = 13$, $n_{extraction} = 13$) at T_1 and T_2, and changes from T_1 to T_2.

	Group	T_1			T_2			T_1 to T_2		
		Median	Range	*P*	Median	Range	*P*	Median	Range	*P*
Chronological age (years)	Control	12.6	9.7, 13.2		13.8	10.8, 15.0		1.2***	1.0, 2.1	
	Extraction	11.2	10.6, 14.5	ns	12.3	11.6, 15.6	ns	1.1***	0.84, 1.7	ns
Skeletal age (years)	Control	12.0	10.4, 13.4		13.4	12.7, 15.5		1.9***	1.3, 2.5	
	Extraction	11.5	10.2, 13.5	ns	13.3	12.5, 15.3	ns	2.0***	1.6, 2.5	ns
Growth potential (%)	Control	10.2	6.8, 13.3		3.8	2.2, 6.9		–5.1***	–10.1, 3.9	
	Extraction	11.1	8.1, 16.0	ns	4.9	2.6, 5.9	ns	–6.0***	–10.0, –3.9	ns

***$P < 0.001$.
ns, not significant.

Table 2 Comparison of total superimposition measurements between groups ($n_{control}$ = 13, $n_{extraction}$ = 13) at T_1 and T_2, and changes from T_1 to T_2.

Measurement	Group	T_1			T_2			T_1 to T_2		
		Median	Range	*P*	Median	Range	*P*	Median	Range	*P*
Lower 1 $edge_x$ (mm)	Control	59.0	48.5, 64.0		60.0	50.0, 69.0		2.0*	–1.5, 5.5	
	Extraction	58.0	48.0, 63.5	ns	58.5	48.0, 64.0	ns	0.5	–2.0, 4.0	ns
Lower 1 $edge_y$ (mm)	Control	76.5	66.5, 82.0		80.0	68.0, 88.0		3.0**	–1.0, 10.5	
	Extraction	76.5	62.0, 81.0	ns	78.0	63.5, 85.0	ns	3.0**	0.5, 6.5	ns
Pg_x (mm)	Control	49.5	33.5, 54.0		52.5	33.0, 59.0		2.0*	–0.5, 6.0	
	Extraction	47.0	33.0, 52.0	ns	49.0	32.0, 55.0	ns	1.0	–3.0, 7.0	ns
Pg_y (mm)	Control	109.0	99.0, 123.0		113.0	98.0, 129.0		4.0**	–1.0, 16.5	
	Extraction	106.5	89.0, 117.0	ns	109.0	90.0, 124.5	ns	3.5**	1.0, 9.5	ns
Lower 6_x (mm)	Control	31.0	23.0, 39.5		35.0	27.0, 40.0		3.0*	–2.0, 13.0	
	Extraction	31.5	25.0, 29.5	ns	32.0	24.0, 39.5	ns	1.0	–2.5, 4.0	ns
Lower 6_y (mm)	Control	70.0	66.0, 76.5		74.5	66.0, 83.5		3.5**	0.0, 16.0	
	Extraction	70.5	59.5, 74.5	ns	74.0	60.0, 79.0	ns	3.0**	0.5, 7.0	ns
Co_x (mm)	Control	16.0	13.0, 20.5		19.0	14.5, 22.0		1.5*	–2.5, 6.0	
	Extraction	17.5	12.0, 21.0	ns	18.5	13.0, 23.5	ns	1.5**	–2.0, 6.0	ns
Co_y (mm)	Control	17.5	13.0, 23.0		22.0	15.5, 26.5		2.5*	–4.5, 9.0	
	Extraction	16.5	14.5, 23.5	ns	18.5	15.0, 22.0	*	0.5	–3.5, 3.0	ns
Go_x (mm)	Control	16.0	10.0, 23.5		17.0	10.0, 24.5		1.0*	–1.0, 5.0	
	Extraction	17.5	9.5, 22.5	ns	19.5	10.5, 24.5	ns	1.5*	–3.0, 4.5	ns
Go_y (mm)	Control	75.0	68.0, 80.0		80.5	71.5, 96.0		3.5**	–1.0, 18.0	
	Extraction	72.5	65.0, 78.5	*	74.5	66.5, 83.5	*	4.0**	0.0, 7.0	ns
SNB (°)	Control	77.0	69.0, 83.0		77.0	70.0, 86.0		2.0**	–0.5, 4.5	
	Extraction	76.5	70.0, 80.0	ns	77.0	69.0, 80.5	ns	0.0	–1.5, 3.0	*
Gonial angle (°)	Control	127.0	119.0, 137.0		127.0	118.0, 139.0		–1.0	–5.0, 2.5	
	Extraction	128.0	118.0, 138.0	ns	127.0	119.0, 138.0	ns	–0.5	–3.0, 1.0	ns
Co–Gn (mm)	Control	112.5	101.5, 122.0		116.0	103.5, 125.0		3.5**	–3.0, 13.5	
	Extraction	108.5	100.0, 117.0	ns	111.5	103.0, 126.0	ns	3.5**	1.0, 9.0	ns
Co–Go (mm)	Control	57.0	52.0, 61.5		60.0	51.5, 72.0		2.0	–7.0, 14.0	
	Extraction	54.0	51.0, 58.5	*	56.5	50.0, 63.5	ns	1.5**	–1.0, 8.0	ns
Go–Me (mm)	Control	67.5	60.5, 76.0		71.0	61.0, 81.0		3.5**	0.5, 5.0	
	Extraction	67.0	61.0, 76.0	ns	68.0	64.0, 79.5	ns	2.5**	–0.5, 6.5	ns

*P < 0.05; **P < 0.01.
ns, not significant.

Table 3 Comparison of mandibular superimposition measurements between groups ($n_{control}$ = 13, $n_{extraction}$ = 13) at T_1 and T_2, and changes from T_1 to T_2.

Measurement	Group	T_1			T_2			T_1 to T_2		
		Median	Range	*P*	Median	Range	*P*	Median	Range	*P*
Lower 1 $edge_x$ (mm)	Control	59.0	48.5, 64.0		60.0	49.5, 66.0		1.0	–1.5, 2.0	
	Extraction	58.0	48.0, 63.5	ns	57.5	49.0, 63.0	ns	0.0	–1.5, 2.5	ns
Lower 1 $edge_y$ (mm)	Control	76.5	66.5, 82.0		75.5	68.0, 78.5		–1.0	–6.0, 1.5	
	Extraction	76.5	62.0, 81.0	ns	75.5	62.0, 80.0	ns	–1.0**	–1.5, 0.0	ns
Lower 6_x (mm)	Control	31.0	23.0, 39.5		33.5	25.5, 38.5		1.0	–2.0, 9.5	
	Extraction	31.5	24.5, 39.5	ns	31.5	24.5, 39.0	ns	0.0	–2.5, 3.0	ns
Lower 6_y (mm)	Control	70.0	66.5, 76.5		69.5	65.5, 75.5		–0.5*	–5.0, 0.5	
	Extraction	70.5	57.5, 74.5	ns	69.5	59.5, 74.5	ns	–1.0*	–3.0, 2.0	ns
Lower 1/SN (°)	Control	50.0	37.5, 57.5		50.0	39.5, 57.0		–1.0	–3.5, 9.0	
	Extraction	50.0	38.0, 56.0	ns	48.5	34.5, 56.0	ns	0.5	–4.0, 3.5	ns
Co_x (mm)	Control	16.0	13.0, 20.5		18.0	14.0, 26.0		0.5	–4.0, 8.5	
	Extraction	17.5	12.0, 21.0	ns	17.0	13.5, 24.0	ns	1.5	–2.5, 6.0	ns
Co_y (mm)	Control	17.5	13.0, 23.0		15.5	10.5, 21.5		–4.0**	–9.5, 1.5	
	Extraction	16.5	14.5, 23.5	ns	14.0	15.0, 22.0	ns	–3.0**	–11.0, 0.5	ns
Mandibular rotation	Control							–1.0*	–5.0, 1.5	
	Extraction							–0.5	–4.0, 3.0	ns

*P < 0.05; **P < 0.01.
ns, not significant.

Table 4 Comparison of angular measurements between groups ($n_{control} = 13$, $n_{extraction} = 13$) at T_1 and T_2, and changes from T_1 to T_2.

Measurement	Group	T_1			T_2			T_1 to T_2		
		Median	Range	*P*	Median	Range	*P*	Median	Range	*P*
SNA (°)	Control	80.0	74.0, 87.5		80.0	77.0, 88.0		0.5**	–0.5, 5.0	
	Extraction	80.0	73.5, 84.5	ns	80.0	75.5, 85.0	ns	0.5	–1.5, 2.0	ns
SNB (°)	Control	77.0	69.0, 83.0		77.0	73.5, 85.0		1.0**	0.0, 4.5	
	Extraction	76.5	70.0, 80.0	ns	76.0	71.0, 80.5	ns	0.5**	–0.5, 2.0	ns
ANB (°)	Control	4.0	1.5, 6.5		3.5	2.0, 5.5		–0.5	–1.5, 0.5	
	Extraction	4.0	2.0, 6.0	ns	4.0	1.0, 6.0	ns	0.0	–2.0, 1.5	ns
ANS–PNS/Go–Me (°)	Control	25.5	20.0, 35.0		23.0	17.0, 30.0		–1.5*	–5.0, 4.0	
	Extraction	24.0	21.0, 31.0	ns	25.0	20.0, 32.5	ns	–0.5	–4.5, 2.5	ns
SN/Go–Co (°)	Control	90.0	85.0, 95.0		88.0	83.0, 93.0		–1.0	–4.0, 3.0	
	Extraction	91.0	84.5, 96.0	ns	90.5	82.0, 96.0	ns	–0.5	–3.0, 3.0	ns
SN/Go–Me (°)	Control	36.0	26.0, 43.0		32.0	26.0, 38.5		–1.5**	–5.0, 0.0	
	Extraction	34.0	26.5, 42.0	ns	33.5	25.0, 42.5	ns	–0.5	–1.5, 1.5	ns

$*P < 0.05$; $**P < 0.01$.
ns, not significant.

edge$_y$), both on total and local superimpositions, were similar (Tables 2 and 3). When measured on the total superimposition, forward movement of the lower incisor edge (Lower 1 edge$_x$) was statistically significant with a median of 2.0 mm in the controls but only 0.5 mm in the extraction group. However, the difference between groups was not significant (Table 2).

The lower first permanent molar showed significant vertical movement (Lower 6$_y$) in both of the groups with each superimposition method, but no significant difference between groups (Tables 2 and 3). When measured on the total superimposition, forward movement of the lower first permanent molar (Lower 6$_x$) was statistically significant with a median of 3.0 mm in the controls but only 1.0 mm in the extraction group. However, the difference between groups was not significant (Table 2).

Discussion

Many investigators have shown that vertical and sagittal growth of the mandible, which is a determinant factor of the facial profile, depends on vertical growth of the nasomaxillary complex including the posterior dentoalveolar region (Schudy, 1964, 1965, 1968; Pearson, 1978; Yamaguchi and Nanda, 1991). In most of the studies on the effects of extraction treatment, changes due to tooth extraction, treatment mechanics and growth have been evaluated together (Battagel, 1990; Gültan, 1990; Staggers, 1990, 1994; Yamaguchi and Nanda, 1991; Klapper *et al.*, 1992; Luecke and Johnston, 1992; Paquette *et al.*, 1992; Chua *et al.*, 1993; Luppanapornlarp and Johnston, 1993; Bishara *et al.*, 1995; Bishara, 1998); while in others, changes due to growth and the effects of treatment mechanics were differentiated by using control groups (Luppanapornlarp and Johnston, 1993; Bishara *et al.*, 1997). Results regarding the sole effects of upper premolar extraction on craniofacial growth are so far missing.

In the present study, growing subjects with a Class II dental relationship and severe crowding were selected with the aim of evaluating the sole effects of bilateral upper premolar extraction on mandibular growth. The subjects in the two study groups had similar skeletal and chronological ages and growth potential.

The sagittal position of the mandible in the present investigation was evaluated by the change in SNB measured both traditionally on pre- and post-study cephalograms independently and when these had been superimposed. When this angle was measured on the total superimposition, that is when the change at nasion was disregarded, the increase was not only statistically significant in the control group, but the difference between groups was also statistically significant. However, if the change at the nasion was not eliminated, that is when this angle was measured traditionally, the difference regarding SNB between groups was not statistically significant. It is therefore apparent that different values obtained from two methods of measurement regarding the same angle seem to be due to the change at nasion in different directions in the two groups. Buschang *et al.* (1986) found the reliability of the total superimposition to be 98–99 per cent, and of the mandibular local superimposition 93–99 per cent. Taylor (1969) pointed out that changes at the nasion affect the measurements connected to this point. Linear and angular measurements concerning the apical base of the mandible result in different interpretations of the effects of cervical headgear (Ülgen and Gögen, 1989). Wieslander (1974) reported that nasion moves downward 1 mm by the effect of cervical headgear. These previous studies and the present findings could be interpreted as the nasion point moving downward in the extraction group and upward in the control group.

Schudy (1964) suggested that maxillary growth was responsible for 70 per cent of total vertical facial growth. Therefore, the maxilla has an important influence on the mandible. In a previous study (İplikçioğlu, 1993), bilateral upper first premolar extraction resulted in maxillary posterior rotation in Class II malocclusion subjects when no orthodontic appliance interfered with growth and development. In Class II non-extraction controls on the contrary, normal growth and development resulted in maxillary anterior rotation.

Battagel (1990) treated some Class II division 1 malocclusion subjects by non-extraction methods using Fränkel appliances, and others by the standard Edgewise technique involving upper and, in some cases, lower first premolar extraction. She observed no significant change in the extraction group with regard to SNB. Gültan (1990) treated cases of Class II division 1 malocclusion by extracting both upper and lower first premolars and only upper first premolars using fixed Edgewise mechanics combined with cervical headgear. He observed a non-significant decrease in SNB in both groups, which he attributed to the use of Class II elastics. Yamaguchi and Nanda (1991) showed almost similar results in their study.

Bishara (1998) in his comparative study on cross-sectional and longitudinal data of normal, Class II division 1 untreated, Class II division 1 extraction and non-extraction treatment subjects, found that the change in SNB was smaller in the extraction female subjects than in non-extraction and normal females, but no difference between extraction and non-extraction Class II male subjects.

Luecke and Johnston (1992) treated 42 patients with Class II division 1 malocclusions with upper premolar extractions using the Edgewise technique, and evaluated the mandibular position using Björk's superimposition method. They found that the mandible rotated in an anterior direction in 70 per cent of subjects and in a posterior direction in 30 per cent. They noted that cases showing posterior mandibular displacement were non-growers.

In the present study, the control group showed a statistically significant anterior mandibular rotation, whereas in the extraction group the mean anterior rotation was not significant. Although the difference between the two groups was not statistically significant, these findings might suggest different rotation tendencies, as the percentage of subjects who displayed anterior mandibular rotation was greater in the control than in the extraction group. Björk and Skieller (1983) reported that mandibular posterior rotation was observed in two of the 21 patients (9.5 per cent) who were followed for 6 years covering the pre- and post-pubertal periods; whereas anterior rotation was observed in 19 (90.5 per cent). Those authors inferred that anterior rotation is a general characteristic of facial growth. They reported that during the observation period, the patients, although having various types of malocclusion, had no orthodontic treatment. In the control group in the present investigation, anterior rotation was seen in 77 per cent and posterior rotation in 16 per cent. In the extraction group these percentages were 54 and 39, respectively. The difference could be attributed to extraction of the upper first premolars which might change the direction of maxillary rotation, resulting in a change in mandibular rotation from anterior to posterior.

The inclination of the mandibular plane in the control group decreased almost three times more than in the extraction group, but the difference between the two groups was not significant.

Gültan (1990) found that mandibular plane inclination increased significantly in four first premolar extraction cases due to the use of Class II elastics. Staggers (1994), in her study, compared a four premolar extraction group with a non-extraction group and found that the mandibular horizontal plane (MP–HP) angle increased in both groups. Saraç and Cura (1995) compared a four premolar extraction group with a non-extraction group and reported that most of the measured parameters increased in a vertical direction without there being any significant difference between the groups. The reason was attributed to growth and development.

In other studies (Bishara *et al.*, 1995; Bishara, 1998) comparing the effects of extraction and non-extraction treatment in Class II division 1 malocclusions, no significant difference was observed in the mandibular plane angle in both male and female subjects. However, when the long-term data of the male subjects were evaluated, the mandibular plane angle with reference to Frankfort horizontal decreased more in the non-extraction cases compared with the extraction cases (Bishara *et al.*, 1995).

In the present study the change in the sagittal position of pogonion might explain the results concerning the change in SNB and confirm the anterior rotation of the mandible in the control group.

Björk and Skieller (1972) drew attention to a strong correlation between condylar growth direction and rotation of the mandible. Although the mean value for the vertical position of the condyle measured on the total superimposition was significantly greater in the control group after the observation period, the vertical displacement of the condyle did not reveal either an anterior mandibular rotation in the control group or a posterior tendency in the extraction group.

As a compensatory adaptation to anterior mandibular rotation, the dental arch as a whole shifts anteriorly with forward tipping of the incisors and molars in relation to the jaws (Björk and Skieller, 1972). Similarly, in the present study, forward movement of the lower incisor edge (Lower 1 edge$_x$) and the lower permanent molar (Lower 6$_x$) was significant only in the control group; however, the difference between the groups was not significant. Thus, it might be suggested that comparison of these dental changes might reflect different mandibular rotation tendencies in the groups.

Conclusions

1. The findings of the present study should be interpreted with some caution because of the small sample size.
2. It might be suggested that the effect of bilateral extraction of upper premolars results in inhibition of anterior growth of the mandible. The long-term effects on a greater sample should be considered clinically.

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Acknowledgement

The authors wish to thank Professor Dr Fikret Gürbüz, Department of Biometry and Genetics, Faculty of Agriculture, Ankara University for assistance with the statistical procedures.

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