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Evaluation of extraction and non-extraction treatment effects by two different superimposition methods

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SUMMARY The aim of this study was to determine whether different evaluation methods may be the cause of the varied outcomes of research that have evaluated the effects of extraction and non-extraction therapy on jaw rotation. This retrospective study consisted of the pre- (T1) and post- (T2) treatment lateral cephalograms of 70 skeletal Class I subjects with an optimal vertical mandibular plane angle, who had undergone fixed orthodontic treatment. Thirty-five of the subjects (20 females and 15 males, mean age: 14.7 years) were treated with four first premolar extractions and 35 (22 females and 13 males, mean age: 15 years) without extractions. T1 and T2 radiographs were superimposed using Björk's structural method and Steiner's method of sella–nasion line registered at sella. A Wilcoxon test was used to evaluate the changes between T1 and T2 and the Mann–Whitney *U*-test to determine differences between the extraction and non-extraction and Björk and Steiner groups.

No significant difference was found between the methods of Steiner and Björk according to the spatial changes of the cephalometric points in the extraction and non-extraction groups. The maxilla showed forward rotation in the extraction group and backward rotation in the non-extraction group with both superimposition methods, but the differences were not significant in either inter- or intraclass comparisons. The mandible showed forward rotation in the extraction group with both superimposition methods but, in the non-extraction group, forward rotation was recorded with Björk's method and backward rotation with Steiner's method. These findings were not significant in either inter- or intraclass evaluations. No significant difference was found between the groups or methods.

Introduction

Premolars have the highest extraction incidence in orthodontic treatment (Proffit, 1994), and use of the extraction space varies according to anchorage need. This situation affects the position of the molars, which play a key role in the vertical dimensions. A common belief among clinicians is that extraction therapy may be beneficial for patients who have a dolicocephalic or hyperdivergent facial type. With the extraction of the premolars, the molars will drift mesially, the mandible will have a tendency to show anterior rotation, and thus anterior face height will decrease. On the other hand, non-extraction therapy is suggested for brachicephalic or hypodivergent patients as, with posterior rotation of the mandible, lower anterior face height (LAFH) will increase and maintain a more aesthetic face (Sassouni and Nanda, 1964; Schudy, 1965).

Pearson (1978) who treated high-angle open bite subjects using a vertical chin cap and extracting the premolars and reported that the average decrease of SN/GoGn angle was 3.9 degrees, and LAFH was also decreased. However, Pearson (1978) directed attention to the possibility of compression on the eruption of the posterior teeth from the chin cap and pointed out that growth of the bony structure could be affected by the conduction of force.

Chua *et al.* (1993) studied the effects of extraction and non-extraction therapy on skeletal Class I and Class II subjects and found a statistically significant increase in LAFH in the non-extraction group for both anomalies. However, no change in LAFH was reported in the extraction group.

In another study, Cusimano *et al.* (1993) investigated the effects of extracting the four first premolars in high-angle individuals and concluded that extraction had no effect on decreasing the vertical dimension. Gültan (1990) investigated 18 patients with a Class II division 1 malocclusion. The upper first premolars of nine, and the upper and lower first premolars of the other nine patients were extracted. He reported extrusion of the lower first molar and related this to intermaxillary elastics and the stimulative effect of this force system on the development of the posterior dentoalveolar structures.

Changes in craniofacial morphology caused by growth or treatment can be measured by superimposing a series of lateral cephalograms with reference to relatively stable landmarks, such as cranial base, cranial points, or lines (Graber, 1968). Several superimposition methods have been described (Steiner, 1953; Björk, 1969; Björk and Skieller, 1972, 1977, 1983; Ricketts, 1975; Pancherz, 1982;

Björk *et al.*, 1995). Every superimposition method has some deficiencies or difficulties in comparison with others, but in order to determine the effects of growth and/or treatment, it is important to be familiar with superimposition methods and how their comparisons are carried out. While the interpretation of a study will be undertaken according to superimposition methods, the accuracy of the results will be strongly related to the method. Therefore, many studies have evaluated the reliability of different superimposition methods (Baumrind et *al.*, 1987, 1992a,b; You and Hägg, 1999).

Superimposing radiographs rather than comparing pre- and post-treatment measurements will be more beneficial for evaluation of jaw rotations, and different superimposition methods may alter the outcomes. Growth of point nasion affects nasion point-dependent linear superimposition methods, such as S–N registered at sella. The anterior cranial base length (S–N) increases in males up to the age of 20 years and in females up to 16 years of age (Hahn von Dorsche *et al.*, 1999). The purpose of the present study was to determine whether different evaluation methods may be the cause of the varied outcomes in research that evaluated the effects of extraction and non-extraction therapy on jaw rotation.

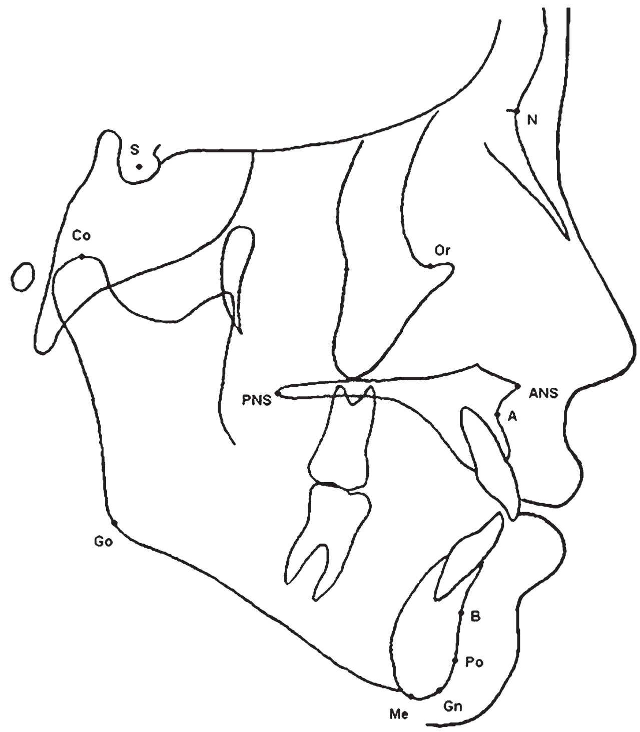

Figure 1 Cephalometric points used in the study. S (sella): centre of sella tursica; N (nasion): most anterior point of the frontonasal suture; Co (condylion): most superior point of the condylar head; Or (orbita): lowest point on the orbital floor; PNS (posterior nasal spine): the tip of posterior nasal spine; ANS (anterior nasal spine): the tip of anterior nasal spine; A (point A): deepest point of the concavity of the maxilla between ANS and prosthion; B (point B): deepest point of the concavity of the mandibular symphsis between infradentale and pogonion; Po (pogonion): most anterior point of the bony chin in the median plane; Gn (gnathion): most antero-inferior point on the symphysis of the chin; Me (menton): most inferior point on the mandibular symphysis; Go (gonion): point where the bisector of intersection of ramus plane and corpus plane intercepts mandible.

Materials and methods

This retrospective study was carried out on the pre- (T1) and post- (T2) treatment lateral cephalograms of 70 patients chosen from the archives of the Department of Orthodontics, Gazi University. All subjects had a skeletal Class I malocclusion with a SN/GoGN angle between 26 and 38 degrees. The patients were treated with the standard edgewise technique and the Roth system; 35 subjects had four first premolar extraction and the other 35 were treated non-extraction. The mean treatment time was 32.8 ± 10.5 and 20 ± 7.6 months, respectively. The extraction sample comprised 20 females and 15 males, with a mean age at T1 of 14.7 ± 1.8 years and the non-extraction sample 22 females and 13 males, with a mean age at T1 of 15 ± 2.3 years.

T1 and T2 radiographs were superimposed using Björk's structural method and Steiner's S–N line registered at sella. Björk's total structural method was used to evaluate the positional changes of 11 points (Figure 1), and the local maxillary and mandibular superimposition method to determine the rotations of the upper and lower jaws. All the tracings and superimposition were undertaken by the same researcher (CT).

Tracing, superimposition, and maintenance of the *XY* coordinate system are shown in Figure 2. Following these procedures, tracing paper was placed on a 1 mm grid paper to measure positional changes in the *XY* system.

The degree of rotation of the maxilla and mandible was also investigated. To evaluate mandibular rotation with Steiner's method, the angle between the T1 and T2 Go–Me line was used, and for maxillary rotation, the ANS–PNS line (Figure 3a). Björk's local mandibular and maxillary superimpositions were used to evaluate jaw rotation values. The angle between T1 and T2 S–N lines was used to determine maxillary and mandibular total rotation. With both methods, positive values corresponded to posterior rotation, where SN2 is above SN1 in Björk's superimposition, and the mandibular plane at T2 (Go–Me2) is below Go–Me1 in Steiner's superimposition. This was *vice versa* for anterior rotation and corresponded to negative values (Figure 3b).

Statistical analysis

Examiner reliability was evaluated by the same examiner remeasuring five extraction and five non-extraction randomly selected cases from the sample group, 1 month after the first measurements. This procedure consisted of

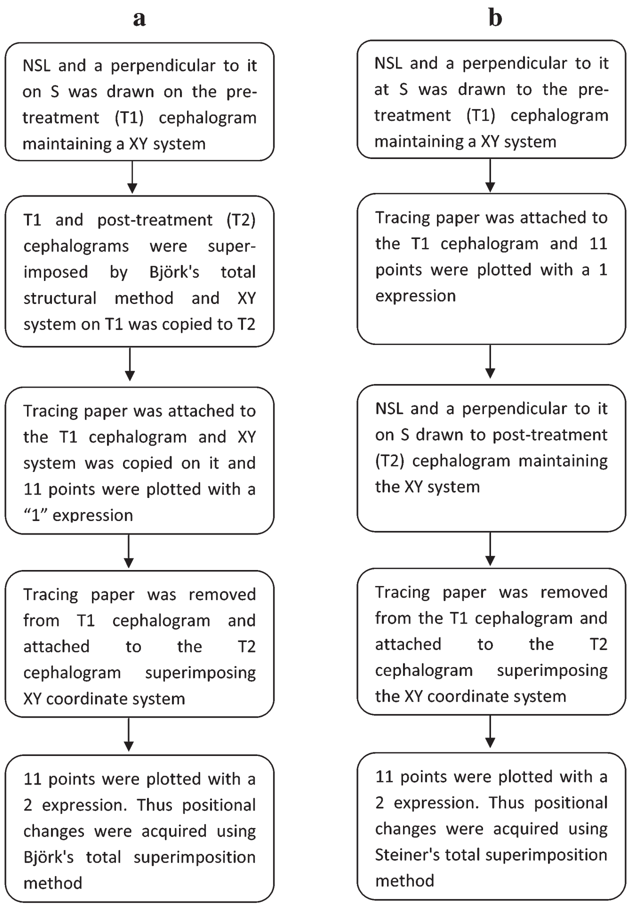

Figure 2 Flowchart explaining plotting and superimposition procedure using (a) Björk's total superimposition and (b) Steiner's superimposition methods.

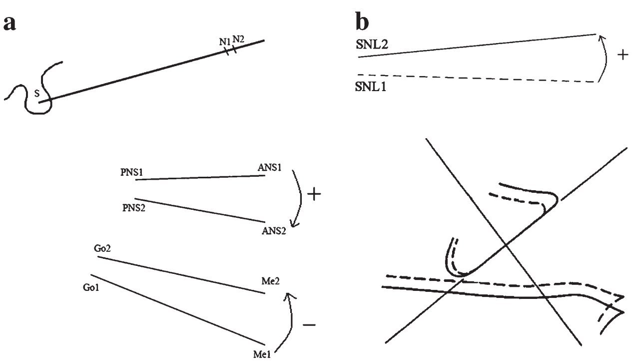

Figure 3 Drawings of posterior maxillary and anterior mandibular rotation using Steiner's method (a) and posterior maxillary rotation using Björk's local superimposition method (b).

landmark identification, superimposition, and measurements. Measurements were evaluated with analysis of variance, and the reliability coefficient was calculated for each parameter for each superimposition technique.

As the data was not normally distributed, non-parametric tests were used. The changes between T1 and T2 were evaluated with Bonferroni corrected paired *t*- and Bonferroni corrected Wilcoxon tests. The level of significance was set at $P < 0.025$. Differences between the Björk and Steiner groups and the extraction and non-extraction groups were tested with Mann–Whitney *U*-tests.

Results

The calculated reliability coefficients for examiner reliability were between 0.56 and 1.00 (Table 1).

To evaluate the homogeneity of the extraction and non-extraction groups, treatment time, chronological age at T1, and ANB and SN/Go–Gn angle were considered (Table 2). Treatment time in the extraction group was significantly longer ($P < 0.001$).

In the assessment of the extraction group with Björk's method (Table 3), anterior displacement of N, backward displacement of Co ($P < 0.01$), and downward displacement of PNS ($P < 0.01$) and B, Po, Gn, Me, and Go ($P < 0.001$) were statistically significant. In the assessment of the extraction group with Steiner's method, anterior displacement of N, downward displacement of B, Po, Gn, Me, and Go ($P < 0.001$), anterior displacement of Or ($P < 0.01$), and ANS, Po, and Me ($P < 0.05$) were statistically significant (Table 4).

Backward displacement of Go ($P < 0.05$), downward displacement of ANS and A, backward displacement of PNS and Co ($P < 0.01$), and downward displacement of B, Po, Gn, Me, and Go ($P < 0.001$) were statistically significant in the evaluation of the non-extraction group with Björk's method (Table 3). For the same group with Steiner's method (Table 4), anterior displacement of N, downward displacement of A and ANS ($P < 0.01$), and B, Po, Gn, Me, and Go ($P < 0.001$), and backward displacement of Go and Co ($P < 0.05$) were statistically significant.

A comparison of Björk's and Steiner's superimposition methods with regard to positional changes of the landmarks in the extraction and non-extraction groups is shown in Table 5. No statistically significant change was observed for any variable.

Anterior displacement of N was significantly greater ($P < 0.05$) in the extraction group compared with the non-extraction group with both methods. With Björk's method, ANS and PNS showed anterior displacement in the extraction group and posterior displacement in the non-extraction group; the differences were significant. However, the same measurement was not found to be significant with respect to Steiner's method (Table 6). Maxillary and mandibular rotations did not show any significant differences in either group or with either method.

Discussion

Different findings have been reported from studies that have evaluated the effects of extraction therapy on jaw rotation

Table 1 Coefficients of reliability for the superimposition methods of Björk and Steiner (1: pre- and 2: post-treatment).

	Björk		Steiner	
	x	*y*	*x*	*y*
N1	0.99	1.00	0.99	1.00
N2	0.94	0.79	0.95	1.00
Or1	0.98	0.86	0.98	0.86
Or2	0.91	0.68	0.90	0.56
ANS1	0.92	0.89	0.92	0.89
ANS2	0.73	0.83	0.82	0.77
PNS1	0.91	0.91	0.91	0.91
PNS2	0.89	0.95	0.95	0.94
A1	0.98	0.93	0.98	0.93
A2	0.91	0.95	0.87	0.85
B1	0.99	0.96	0.99	0.96
B2	0.79	0.95	0.87	0.97
Po1	0.99	0.98	0.99	0.98
Po2	0.83	0.91	0.90	0.99
Gn1	0.99	0.99	0.99	0.99
Gn2	0.83	0.98	0.88	0.99
Me1	0.99	0.99	0.99	0.99
Me2	0.86	0.97	0.87	0.99
Go1	0.97	0.98	0.97	0.98
Go2	0.88	0.93	0.91	0.95
Co1	0.89	0.81	0.89	0.81
Co2	0.90	0.71	0.92	0.83
Maxillary rotation	0.96		0.71	
Mandibular rotation	0.81		0.91	

Table 2 Homogeneity control of the extraction and non-extraction groups pre-treatment.

	Extraction group, mean ± SD	Non-extraction group, mean ± SD	*P*
Chronological age (months)	179.69 ± 23.40	180.43 ± 30.53	0.909
Treatment time (months)	32.88 ± 10.56	20.02 ± 7.66	0.000***
ANB	2.17 ± 1.27	2.02 ± 1.32	0.648
SN/GoGn	34.15 ± 3.21	32.97 ± 2.97	0.114

***$P < 0.001$.

(Pearson, 1978; Staggers, 1990, 1994; Chua *et al.*, 1993; Cusimano *et al.*, 1993; Kocadereli, 1999). The aim of the present research was to investigate if these findings are related to the superimposition method used. For this reason, the results obtained using two different superimposition methods, one of which (Björk's method) is claimed to eliminate the effects of growth and development, were compared. Although SN length increases due to growth-related changes of nasion up to the ages of 16 and 20 years in females and males, respectively (Hahn von Dorsche *et al.*, 1999), it is widely used as a reference line, and point N serves as a superimpositional reference point. Arat *et al.* (2003) reported significant displacement at points S, N, and Ba, which were used as reference points for superimposition in their study.

Sagittal and vertical anomalies have a tendency to worsen with growth, and the growth pattern may dominate the effects of treatment. Thus, only skeletal Class I and optimum angle cases were selected for the present study. Karlsen (1997) observed 29 low- and 29 high-angle subjects for 9 years and found that an increase in LAFH had a weak correlation with mandibular rotation, but a high and positive correlation with corpus length. Schendel *et al.* (1976) emphasized that posterior rotation of the mandible is often seen in high-angle individuals.

Extraction and non-extraction subjects were compared in terms of SN/Go–Gn and ANB angles, age at T1, and treatment time. Only treatment time showed a significant difference between the groups, which was 12.9 months longer in the extraction group. In previous studies, extraction has been shown to lengthen total treatment time (Erbay and Ülgen, 1995). The longer treatment time observed in the extraction group should be taken into consideration as it might have resulted in different amounts of growth-related landmark displacement.

Calculated reliability coefficients for evaluation of examiner reliability were generally close to 1, but some were lower. Lower values were found for Or, ANS, Co, and maxillary rotation with Steiner's method based on the ANS–PNS line. Most errors in cephalometric investigations originate during landmark identification and plotting (Baumrind and Frantz, 1971a,b; Chen *et al.*, 2000). Richardson (1966) stated that Or and Bolton points have a greater error margin than other cranial points and reported that an error factor appeared in vertical measurements. In the current study, vertical measurements also had smaller reliability coefficients. Chen *et al.* (2004) observed statistically significant errors for Po, Ar, and ANS points. Ghafari and Efstratiadis (1989) and Nielsen (1989) also reported significant differences in identification of ANS. Midtgàrd *et al.* (1974) found the greatest error margin for Or, which had a mean deviation of 2.08 mm whereas supramental, Po, and ANS had an average of 1 mm.

Points on anatomic edges are more easily identified than those on anatomic curves (Richardson, 1966; Baumrind and Frantz, 1971a,b). Thus, Or, ANS, and Co are more difficult to identify and have lower reliability.

You and Hägg (1999) compared the methods of Björk, Ricketts, and Pancherz and found that the reliability coefficient was lower and the standard deviation was higher with Björk's method, but no significant difference was observed between methods. The present findings also did not demonstrate significantly different coefficient or deviation values.

As 1 mm grid paper was used to measure the amount of point displacement in this study, it can be assumed that the maximum precision for the data gathered was 0.5 mm. If changes of less than 1 mm are not considered clinically

Table 3 Pre- (T1) and post- (T2) treatment means and standard deviation (SD) of the extraction and non-extraction groups studied with Björk's method.

	Extraction group (n = 35)					Non-extraction group (n = 35)				
	Mean T1 (mm)	SD	Mean T2 (mm)	SD	P	Mean T1 (mm)	SD	Mean T2 (mm)	SD	P
Nx	70.89	3.16	71.73	3.44	0.001**	71.41	3.48	71.77	3.42	0.070
Ny	0.00	0.00	−0.31	1.79	0.349	0.00	0.00	−0.24	1.75	0.257
Orx	50.36	2.97	51.04	3.20	0.028	51.54	3.77	51.66	3.79	0.828
Ory	−29.19	1.75	−29.19	1.96	1.000	−28.23	2.57	−28.69	2.32	0.067
ANSx	65.60	3.86	66.11	4.59	0.259	67.29	4.61	66.71	4.39	0.077
ANSy	−54.89	2.80	−55.74	3.72	0.062	−55.81	4.88	−57.11	4.68	0.002**
PNSx	12.77	2.78	12.79	2.85	0.963	14.07	2.45	13.37	2.73	0.009**
PNSy	−46.13	3.19	−46.94	3.81	0.005**	−47.27	4.35	−47.57	4.19	0.128
Ax	59.79	4.28	60.00	4.40	0.583	60.93	4.04	60.34	4.32	0.094
Ay	−60.26	3.17	−61.17	3.71	0.028	−60.70	4.45	−62.23	4.33	0.002**
Bx	46.56	6.45	47.31	7.20	0.273	49.17	4.79	48.36	6.82	0.367
By	−102.87	6.02	−105.34	6.48	0.000***	−103.04	8.88	−105.96	8.89	0.000***
Pox	45.53	6.95	46.41	6.82	0.230	49.01	5.08	48.33	7.45	0.611
Poy	−114.51	6.31	−117.84	7.47	0.000***	−113.63	9.43	−117.21	10.06	0.000***
Gnx	42.57	7.32	43.53	6.80	0.235	46.19	5.15	45.41	7.61	0.447
Gny	−119.01	6.32	−123.11	6.74	0.000***	−118.53	9.93	−122.01	10.17	0.000***
Mex	38.57	7.27	39.47	6.82	0.233	42.20	5.08	41.53	7.52	0.501
Mey	−120.17	6.33	−124.41	6.83	0.000***	−119.89	9.85	−123.20	10.22	0.000***
Gox	−20.16	5.27	−20.90	4.92	0.146	−17.30	6.86	−18.73	7.67	0.018*
Goy	−76.67	5.54	−80.53	5.84	0.000***	−76.00	12.37	−78.27	12.55	0.000***
Cox	−16.30	3.19	−17.49	2.77	0.002**	−14.16	5.78	−15.19	5.59	0.008**
Coy	−16.70	3.60	−16.20	3.11	0.158	−16.11	3.90	−16.29	2.82	0.668

*$P < 0.025$ (with Bonferroni correction), **$P < 0.01$, ***$P < 0.001$.

Table 4 Pre- (T1) and post- (T2) treatment means and standard deviation (SD) of the extraction and non-extraction groups studied with Steiner's method.

	Extraction group (n = 35)					Non-extraction group (n = 35)				
	Mean T1 (mm)	SD	Mean T2 (mm)	SD	P	Mean T1 (mm)	SD	Mean T2 (mm)	SD	P
Nx	70.89	3.16	72.03	3.34	0.000***	71.41	3.48	71.99	3.37	0.007**
Ny	0.00	0.00	0.00	0.00	1.000	0.00	0.00	0.00	0.00	1.000
Orx	50.36	2.97	51.17	3.26	0.006**	51.54	3.77	52.06	3.42	0.126
Ory	−29.19	1.75	−28.94	1.94	0.274	−28.23	2.57	−28.60	2.21	0.202
ANSx	65.60	3.86	66.57	4.92	0.021*	67.29	4.61	67.16	4.04	0.719
ANSy	−54.89	2.80	−55.33	3.59	0.250	−55.81	4.88	−56.61	3.95	0.007**
PNSx	12.77	2.78	13.41	3.71	0.065	14.07	2.45	13.81	2.73	0.409
PNSy	−46.13	3.19	−46.77	3.71	0.033	−47.27	4.35	−47.64	4.34	0.064
Ax	59.79	4.28	60.09	4.83	0.492	60.93	4.04	60.84	3.75	0.813
Ay	−60.26	3.17	−60.93	3.32	0.052	−60.70	4.45	−62.17	4.59	0.001**
Bx	46.56	6.45	47.47	7.52	0.105	49.17	4.79	49.04	5.96	0.210
By	−102.87	6.02	−105.39	5.79	0.000***	−103.04	8.88	−105.37	8.82	0.000***
Pox	45.53	6.95	46.97	8.03	0.024*	49.01	5.08	48.94	6.52	0.272
Poy	−114.51	6.31	−117.96	6.57	0.000***	−113.63	9.43	−117.14	10.16	0.000***
Gnx	42.57	7.32	44.07	8.24	0.032	46.19	5.15	46.06	6.46	0.339
Gny	−119.01	6.32	−122.99	6.51	0.000***	−118.53	9.93	−121.93	10.24	0.000***
Mex	38.57	7.27	40.09	8.29	0.020*	42.20	5.08	42.33	6.41	0.152
Mey	−120.17	6.33	−124.10	6.47	0.000***	−119.89	9.85	−123.06	10.28	0.000***
Gox	−20.16	5.27	−20.69	5.85	0.327	−17.30	6.86	−19.40	3.94	0.017*
Goy	−76.67	5.54	−80.36	5.97	0.000***	−76.00	12.37	−80.11	7.30	0.000***
Cox	−16.30	3.19	−17.01	2.91	0.037	−14.16	5.78	−15.76	3.09	0.012*
Coy	−16.71	3.59	−16.30	3.30	0.438	−16.11	3.90	−16.33	2.97	0.270

*$P < 0.025$ (with Bonferroni correction), **$P < 0.01$, ***$P < 0.001$.

Table 5 Comparison of Björk's and Steiner's superimposition methods with regard to positional changes of landmarks.

	Björk			Steiner		
	Treatment groups	Difference (mm)	SD	Difference (mm)	SD	*P*
Nx	Extraction	0.84	1.34	1.14	1.28	0.388
	Non-extraction	0.36	1.13	0.57	1.18	0.288
Ny	Extraction	−0.31	1.80	0.00	0.00	0.265
	Non-extraction	−0.24	1.75	0.00	0.00	0.504
Orx	Extraction	0.69	1.77	0.81	1.64	0.859
	Non-extraction	0.11	2.02	0.51	1.94	0.464
Ory	Extraction	0.00	1.57	0.24	1.29	0.476
	Non-extraction	−0.46	1.43	−0.37	1.69	0.686
ANSx	Extraction	0.51	2.65	0.97	2.37	0.715
	Non-extraction	−0.57	1.86	−0.13	2.10	0.175
ANSy	Extraction	−0.86	2.37	−0.44	2.16	0.657
	Non-extraction	−1.30	2.42	−0.80	3.06	0.662
PNSx	Extraction	0.01	1.81	0.64	2.00	0.423
	Non-extraction	−0.70	1.51	−0.26	1.82	0.266
PNSy	Extraction	−0.81	1.59	−0.64	1.71	0.638
	Non-extraction	−0.30	1.14	−0.37	1.15	0.585
Ax	Extraction	0.21	2.29	0.30	2.56	1.000
	Non-extraction	−0.59	2.01	−0.09	2.13	0.117
Ay	Extraction	−0.91	2.35	−0.67	1.97	0.704
	Non-extraction	−1.53	2.62	−1.47	2.31	0.795
Bx	Extraction	0.76	4.02	0.91	3.25	0.972
	Non-extraction	−0.81	3.60	−0.13	3.47	0.420
By	Extraction	−2.47	3.51	−2.51	3.29	0.976
	Non-extraction	−2.91	2.96	−2.33	2.54	0.604
Pox	Extraction	0.89	4.29	1.44	3.61	0.746
	Non-extraction	−0.69	3.91	−0.07	3.71	0.600
Poy	Extraction	−3.33	3.89	−3.44	3.43	0.967
	Non-extraction	−3.59	3.02	−3.51	2.96	0.977
Gnx	Extraction	0.96	4.68	1.50	3.98	0.764
	Non-extraction	−0.77	4.02	−0.13	3.74	0.592
Gny	Extraction	−4.10	3.98	−3.97	3.76	0.809
	Non-extraction	−3.49	3.10	−3.40	3.00	0.995
Mex	Extraction	0.90	4.39	1.51	3.69	0.651
	Non-extraction	−0.67	4.12	0.13	3.92	0.368
Mey	Extraction	−4.24	4.18	−3.93	3.97	0.548
	Non-extraction	−3.31	3.25	−3.17	3.03	0.977
Gox	Extraction	−0.74	2.81	−0.53	3.15	0.706
	Non-extraction	−1.43	3.06	−2.10	5.64	0.967
Goy	Extraction	−3.86	3.46	−3.69	3.49	0.742
	Non-extraction	−2.27	2.48	−4.11	9.55	0.548
Cox	Extraction	−1.19	2.05	−0.71	1.95	0.330
	Non-extraction	−1.03	2.06	−1.60	4.68	0.846
Coy	Extraction	0.51	2.01	0.41	2.22	0.701
	Non-extraction	−0.17	2.35	−0.21	2.13	0.864
Maxillary rotation	Extraction	−0.45	2.95	−0.10	1.50	0.580
	Non-extraction	1.00	3.60	0.57	1.90	0.537
Mandibulary rotation	Extraction	−0.05	2.70	−0.73	1.96	0.741
	Non-extraction	−0.33	1.94	0.07	1.99	0.679

important, the precision of these measurements may be sufficient for evaluation. Ghafari *et al.* (1987) investigated four superimposition methods and reported that changes of less than 1 mm were not clinically significant. Their findings also revealed that the amount of point displacement was not statistically different for SNL at sella with the superimposition and structural superimposition techniques.

In the present study, during the superimposition process, Björk's method required high-quality radiographs while Steiner's method needed only identification of points S and N for superimposition, which are relatively easy to determine. When displacement of point N was evaluated, no significant change was noted regarding its vertical position (Tables 3 and 4). The data showed that elimination of growth at N will not result in any difference in jaw rotations in the short term. Pancherz and Hansen (1984) in a study in which NSL registration error was evaluated, expressed the view that use of the structural method is not effective in longitudinal studies covering a short period of time as the possible benefit of compensating for a smaller displacement of N and S points occurring during a restricted growth period will not outweigh the

Table 6 Comparison of the extraction (n = 35) and non-extraction (n = 35) groups with regard to superimposition methods.

	Superimposition technique	Extraction		Non-extraction		P
		Difference (mm)	SD	Difference (mm)	SD	
Nx	Björk	0.84	1.34	0.36	1.13	0.044*
	Steiner	1.14	1.28	0.57	1.18	0.042*
Ny	Björk	−0.31	1.80	−0.24	1.75	0.934
	Steiner	0.00	0.00	0.00	0.00	1.000
Orx	Björk	0.69	1.77	0.11	2.02	0.180
	Steiner	0.81	1.64	0.51	1.94	0.392
Ory	Björk	0.00	1.57	−0.46	1.43	0.115
	Steiner	0.24	1.29	−0.37	1.69	0.057
ANSx	Björk	0.51	2.65	−0.57	1.86	0.040*
	Steiner	0.97	2.37	−0.13	2.10	0.149
ANSy	Björk	−0.86	2.37	−1.30	2.42	0.273
	Steiner	−0.44	2.16	−0.80	3.06	0.232
PNSx	Björk	0.01	1.81	−0.70	1.51	0.048*
	Steiner	0.64	2.00	−0.26	1.82	0.099
PNSy	Björk	−0.81	1.59	−0.30	1.14	0.369
	Steiner	−0.64	1.71	−0.37	1.15	0.981
Ax	Björk	0.21	2.29	−0.59	2.01	0.109
	Steiner	0.30	2.56	−0.09	2.13	0.616
Ay	Björk	−0.91	2.35	−1.53	2.62	0.298
	Steiner	−0.67	1.97	−1.47	2.31	0.096
Bx	Björk	0.76	4.02	−0.81	3.60	0.143
	Steiner	0.91	3.25	−0.13	3.47	0.419
By	Björk	−2.47	3.51	−2.91	2.96	0.489
	Steiner	−2.51	3.29	−2.33	2.54	0.902
Pox	Björk	0.89	4.29	−0.69	3.91	0.130
	Steiner	1.44	3.61	−0.07	3.71	0.103
Poy	Björk	−3.33	3.89	−3.59	3.02	0.773
	Steiner	−3.44	3.43	−3.51	2.96	0.773
Gnx	Björk	0.96	4.68	−0.77	4.02	0.111
	Steiner	1.50	3.98	−0.13	3.74	0.177
Gny	Björk	−4.10	3.98	−3.49	3.10	0.448
	Steiner	−3.97	3.76	−3.40	3.00	0.625
Mex	Björk	0.90	4.39	−0.67	4.12	0.155
	Steiner	1.51	3.69	0.13	3.92	0.282
Mey	Björk	−4.24	4.18	−3.31	3.25	0.230
	Steiner	−3.93	3.97	−3.17	3.03	0.506
Gox	Björk	−0.74	2.81	−1.43	3.06	0.451
	Steiner	−0.53	3.15	−2.10	5.64	0.287
Goy	Björk	−3.86	3.46	−2.27	2.48	0.066
	Steiner	−3.69	3.49	−4.11	9.55	0.312
Cox	Björk	−1.19	2.05	−1.03	2.06	0.818
	Steiner	−0.71	1.95	−1.60	4.68	0.319
Coy	Björk	0.51	2.01	−0.17	2.35	0.176
	Steiner	0.41	2.22	−0.21	2.13	0.226
Maxillary rotation	Björk	−0.45	2.95	1.00	3.60	0.132
	Steiner	−0.10	1.50	0.57	1.90	0.113
Mandibulary rotation	Björk	−0.05	2.70	−0.33	1.94	0.915
	Steiner	−0.73	1.96	0.07	1.99	0.464

*P < 0.05.

risk of increased registration error of structural superimposition.

Statistically significant downward movements of points B, Po, Gn, Me, and Go were observed in both groups using both methods. This may be related to growth as no significant difference was found between the groups. Kocadereli (1999) reported that there was no difference in N–Me and ANS–Me measurements between 40 extraction and 40 non-extraction patients treated with fixed appliances. However, that author observed differences between pre- and post-treatment measurements of vertical dimensions and attributed this difference to downward and forward growth of the mandible. Chua *et al.* (1993) evaluated the effects of extraction and non-extraction therapy on LAFH of 174 skeletal Class I and II patients. An increase in LAFH was observed in the non-extraction group, while there was no significant difference in the extraction group. Those authors concluded that the mandible showed posterior rotation as a result of the increase in LAFH in the non-extraction group. The increase in this measurement may be related to downward and forward growth of the mandible. When the non-extraction group is considered in the present study, anterior mandibular rotation was observed with Björk's method, whereas Steiner's method revealed posterior rotation. Nevertheless, the difference between the groups was not statistically significant.

Staggers (1994), who studied 45 extraction and 38 non-extraction skeletal Class I subjects, found no significant difference in the measurements of N–Me, N–ANS/ANS–Me between the two groups. In another study, Staggers (1990) observed extrusion of the first molars in all groups when the effects of first premolar and second molar extractions were evaluated. Significant anterior movement of the first molars was observed in the premolar but not in the second molar extraction group. This data shows that, even if first molars move anteriorly, the effects of extrusion inhibit anterior rotation of the mandible.

Cusimano *et al.* (1993) investigated the effects of four first premolar extractions in high-angle cases and recorded occlusal movement of both the anterior and posterior groups of teeth. They claimed that this movement prevented closing rotation of the mandible and reported an insignificant increase of 0.4 degrees for SN/Go–Gn.

Some authors (Gültan, 1990; Staggers, 1990, 1994; Cusimano *et al.*, 1993; Kocadereli, 1999) do not support the idea that extraction therapy has a decreasing effect on the vertical dimensions. Many space closing mechanics have an extrusive effect, and intermaxillary elastics have a growth stimulating effect on the dentoalveolar region. In the present study, no closing rotation of the mandible was observed. Even if the mandible showed anterior rotation in the extraction group, the average rotation was less than 1 degree and not significant. Rotation of the maxilla was anterior in the extraction group but posterior in the non-extraction group for both superimposition methods, but the difference between the groups was not significant.

Conclusions

Extraction therapy did not result in anterior rotation of the mandible and with non-extraction therapy posterior rotation did not occur. No difference was found between groups or methods. The methods of Steiner and Björk did not show any statistically significant difference, but the short evaluation time and absence of intensive growth must be considered.

References

Arat Z M, Rubenduz M, Akgul A A 2003 The displacement of craniofacial reference landmarks during puberty: a comparison of three superimposition methods. Angle Orthodontist 73: 374–380

Baumrind S, Ben-Bassat Y, Korn E L, Bravo L A, Curry S 1992a Mandibular remodeling measured on cephalograms. 1. Osseous changes relative to superimposition on metallic implants. American Journal of Orthodontics and Dentofacial Orthopedics 102: 134–142

Baumrind S, Ben-Bassat Y, Korn E L, Bravo L A, Curry S 1992b Mandibular remodeling measured on cephalograms: 2. A comparison of information from implant and anatomic best-fit superimpositions. American Journal of Orthodontics and Dentofacial Orthopedics 102: 227–238

Baumrind S, Frantz R C 1971a The reliability of head film measurements. 1. Landmark identification. American Journal of Orthodontics 60: 111–127

Baumrind S, Frantz R C 1971b The reliability of head film measurements. 2. Conventional angular and linear measures. American Journal of Orthodontics 60: 505–517

Baumrind S, Korn E L, Ben-Bassat Y, West E E 1987 Quantitation of maxillary remodeling. 1. A description of osseous changes relative to superimposition on metallic implants. American Journal of Orthodontics and Dentofacial Orthopedics 91: 29–41

Björk A 1969 Prediction of mandibular growth rotation. American Journal of Orthodontics 55: 585–599

Björk A, Sarnas K V, Rune B 1995 Intramatrix rotation—the frontal bone. European Journal of Orthodontics 17: 3–7

Björk A, Skieller V 1972 Facial development and tooth eruption. An implant study at the age of puberty. American Journal of Orthodontics 62: 339–383

Björk A, Skieller V 1977 Growth of the maxilla in three dimensions as revealed radiographically by the implant method. British Journal of Orthodontics 4: 53–64

Björk A, Skieller V 1983 Normal and abnormal growth of the mandible. A synthesis of longitudinal cephalometric implant studies over a period of 25 years. European Journal of Orthodontics 5: 1–46

Chen Y J, Chen S K, Chang H F, Chen K C 2000 Comparison of landmark identification in traditional versus computer-aided digital cephalometry. Angle Orthodontist 70: 387–392

Chen Y J, Chen S K, Yao J C, Chang H F 2004 The effects of differences in landmark identification on the cephalometric measurements in traditional versus digitized cephalometry. Angle Orthodontist 74: 155–161

Chua A L, Lim J Y, Lubit E C 1993 The effects of extraction versus nonextraction orthodontic treatment on the growth of the lower anterior face height. American Journal of Orthodontics and Dentofacial Orthopedics 104: 361–368

Cusimano C, McLaughlin R P, Zernik J H 1993 Effects of first bicuspid extractions on facial height in high-angle cases. Journal of Clinical Orthodontics 27: 594–598

Erbay E, Ülgen M 1995 An investigation of profile changes in Angle Class I anomalies treated with extraction and nonextraction. Türk Ortodonti Dergisi 8: 232–242

Ghafari J, Efstratiadis S S 1989 Mandibular displacement and dentitional changes during orthodontic treatment and growth. American Journal of Orthodontics and Dentofacial Orthopedics 95: 12–19

Ghafari J, Engel F E, Laster L L 1987 Cephalometric superimposition on the cranial base: a review and a comparison of four methods. American Journal of Orthodontics and Dentofacial Orthopedics 91: 403–413

Graber T M 1968 Orthodontics, principle and practice. W B Saunders, Philadelphia

Gültan A S 1990 The evaluation of the upper and upper-lower first premolars extraction alternatives for Class II, 1 malocclusions treatment. Türk Ortodonti Dergisi 3: 56–62

Hahn von Dorsche S, Fanghänel J, Kubein-Meesenburg D, Nägerl H, Hanschke M 1999 Interpretation of the vertical and longitudinal growth of the human skull. Annals of Anatomy 181: 99–103

Karlsen A T 1997 Association between facial height development and mandibular growth rotation in low and high MP-SN angle faces: a longitudinal study. Angle Orthodontist 67: 103–110

Kocadereli I 1999 The effect of first premolar extraction on vertical dimension. American Journal of Orthodontics and Dentofacial Orthopedics 116: 41–45

Midtgård J, Björk G, Linder-Aronson S 1974 Reproducibility of cephalometric landmarks and errors of measurements of cephalometric cranial distances. Angle Orthodontist 44: 56–61

Nielsen I L 1989 Maxillary superimposition: a comparison of three methods for cephalometric evaluation of growth and treatment change. American Journal of Orthodontics 95: 422–431

Pancherz H 1982 The mechanism of Class II correction in Herbst appliance treatment. A cephalometric investigation. American Journal of Orthodontics 82: 104–113

Pancherz H, Hansen K 1984 The nasion-sella reference line in cephalometry: a methodologic study. American Journal of Orthodontics 86: 427–434

Pearson L E 1978 Vertical control in treatment of patients having backward-rotational growth tendencies. Angle Orthodontist 48: 132–140

Proffit W R 1994 Forty-year review of extraction frequencies at a university orthodontic clinic. Angle Orthodontist 64: 407–414

Richardson A 1966 An investigation into the reproducibility of some points, planes, and lines used in cephalometric analysis. American Journal of Orthodontics 52: 637–651

Ricketts R M 1975 A four-step method to distinguish orthodontic changes from natural growth. Journal of Clinical Orthodontics 9: 208–228

Sassouni V, Nanda S 1964 Analysis of dentofacial vertical proportions. American Journal of Orthodontics 50: 801–823

Schendel S A, Eisenfeld J, Bell W H, Epker B N, Mishelevich D J 1976 The long face syndrome: vertical maxillary excess. American Journal of Orthodontics 70: 398–408

Schudy F F 1965 The rotation of the mandible resulting from growth: its implications in orthodontic treatment. Angle Orthodontist 35: 36–50

Staggers J A 1990 A comparison of results of second molar and first premolar extraction treatment. American Journal of Orthodontics and Dentofacial Orthopedics 98: 430–436

Staggers J A 1994 Vertical changes following first premolar extractions. American Journal of Orthodontics and Dentofacial Orthopedics 105: 19–24

Steiner C C 1953 Cephalometrics for you and me. American Journal of Orthodontics 39: 729–755

You Q L, Hägg U 1999 A comparison of three superimposition methods. European Journal of Orthodontics 21: 717–725