ORIGINAL ARTICLE

Long-term comparison of treatment outcome and stability of Class II patients treated with functional appliances versus bilateral sagittal split ramus osteotomy

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Purpose: The objective of this study was to compare the treatment outcomes and stability of patients with Class II malocclusion treated with either functional appliances or surgical mandibular advancement. **Material:** The early-treatment group consisted of 30 patients (15 girls, 15 boys), with a mean age of 10 years 4 months (range, 7 years 5 months to 12 years 5 months), who received either Fränkel II (15 patients) or Herbst appliances (15 patients). The surgical group consisted of 30 patients (23 female, 7 male), with a mean age of 27 years 2 months (range, 13 years 0 months to 53 years 10 months). They were treated with bilateral sagittal split ramus osteotomies with rigid fixation. Lateral cephalograms were taken for the early-treatment group at T1 (initial records), T2 (completion of functional appliance treatment), and Tf (completion of comprehensive treatment). In the surgical group, lateral cephalograms were taken at T1 (initial records), T2 (presurgery), T3 (postsurgery), and Tf (completion of comprehensive treatment). The average times from the completion of functional appliance treatment or surgery to the final cephalograms were 35.8 months and 34.9 months, respectively. A mixed-design analysis of variance was used to compare changes within and between groups. **Results:** In the functional appliance group, the mandible continued to grow in a favorable direction even after discontinuation of the functional appliance. Both groups had stable results over time. Both groups finished treatment with the same cephalometric measurements. Significant skeletal and soft tissue changes were noted in the treatment groups due to either functional or surgical advancement of the mandible. More vertical relapse was noted in the surgical group than in the functional group. **Conclusions:** This study suggests that early correction of Class II dentoskeletal malocclusions with functional appliances yields favorable results without the possible deleterious effects of surgery. (Am J Orthod Dentofacial Orthop 2005;127:451-64)

The treatment of Class II malocclusions can be rendered by dentoalveolar changes, orthopedic forces to stimulate mandibular growth or inhibit maxillary growth, or surgical repositioning of the mandible in nongrowing patients.[1] Various types of functional appliances have been used to stimulate or enhance mandibular growth, and the effectiveness of these appliances has been documented in numerous studies.[2-13] McNamara et al[2] studied 45 patients treated with either Herbst or Fränkel II appliances and found that both appliances significantly influenced growth of the craniofacial complex and that skeletal changes increased mandibular length and lower facial height. Creekmore and Radney[5] noted that the Fränkel appliance produced a significant increase in mandibular length and suggested that this was the result of increased backward direction of condylar growth and decreased forward growth of the maxilla. Owen[6] indicated that patients treated with a Fränkel II appliance demonstrated condylar growth, maxillary retraction, lateral expansion, and improved facial esthetics. Croft et al[1] performed a cephalometric and tomographic study of the Herbst appliance and found similar results to those of the Fränkel II appliance. They found no significant joint space changes at the end of treatment and rejected the idea of mandibular posturing and condylar repositioning as a factor in relapse. Long-term change in the posterior joint space showed that the

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functional appliance has a long-term affect on the morphologic change of the condyle and the glenoid fossa, creating a more ideal skeletal and facial balance.[1] Gultan and Uner[13] found that the results of functional appliance treatment were sustained and improved during retention, indicating their stability.

The bilateral sagittal split ramus osteotomy (BSSRO) was developed to anteriorly reposition the mandible into a more ideal position and enhance the dental, skeletal, and soft tissue relationships. The introduction of the rigid fixation technique has increased the stability of the results.[14-26] A 3-year study by Kierl et al[14] showed a 14% relapse with rigid internal fixation, in contrast to a 10% to 80% relapse in the nonrigid fixation group. Dolce et al[19] reported no sagittal relapse of the mandibular symphysis in the rigid fixation group as opposed to the wire fixation group. Ellis and Gallo[27] used dentoskeletal fixation and found a statistically insignificant horizontal mean relapse of 8.9% during the fixation period. They also reported that an increase in the gonial arc and a decrease in the mandibular plane angle were associated with relapse. These 2 variables, along with the amount of advancement, accounted for 84.9% of relapse in the study of Gassman et al[28] and were postulated to be due to the stretch on the surrounding tissues. Duoma et al[29] suggested that the dental and skeletal relapse was due to the adaptation to the altered functional equilibrium and was affected by individual variability. The positional change of the proximal segment was found to be an important parameter in determining stability of the advanced mandible.[30,31] It has also been noted that there was a proportional relationship between the amount of advancement and relapse, which could be attributed to different degrees of neuromuscular adaption.[32,33]

This study was designed to compare the treatment outcomes and stability of patients with Class II malocclusions treated with either a functional appliance (Herbst or Fränkel II) or surgical mandibular advancement by BSSRO.

MATERIAL AND METHODS

Sixty consecutively treated patients were selected for this study, each with a Class II malocclusion characterized by mandibular retrognathia and a normal maxilla. The mean values used in this study were SNA angle, 81.7°; SNB angle, 76.7°; ANB angle, 5.1°; and Wits appraisal, 2.6 mm for the functional appliance treatment group, and SNA angle, 80.4°; SNB angle, 75.6°; ANB angle, 4.9°; and Wits appraisal, 2.3 mm for the surgical group. The patients (all white) were divided into 2 equal groups of 30 growing and nongrowing patients, selected from 2 private orthodontic practices. All functional appliance treatments were performed by 1 orthodontist. The cephalograms were standardized for magnification and manually traced by the same operator (C.G.) and checked by a separate clinician (V.P-K.) to ensure consistency of cephalometric points. Twenty-eight cephalometric measurements were recorded for each time point.

The functional appliance treatment group of 30 young patients consisted of equal numbers of boys and girls. Fifteen of these patients were treated with the Fränkel II appliance and the remaining 15 with the acrylic, removable Herbst appliance. The 2 types of appliances were combined as 1 functional appliance group because the treatment effects of both the Fränkel II and Herbst were very similar, as outlined in a previous study.[2] The initial mean age for these patients was 10 years 4 months (range, 7 years 5 months to 14 years 5 months). For the girls, the initial mean age was 10 years 2 months (range, 7 years 5 months to12 years 5 months), and, for the boys, the initial mean age was 10 years 6 months (range, 7 years 9 months to 14 years 5 months). The following cephalograms were taken in the functional appliance group: pretreatment (T1), progress (T2) (when the patient finished functional appliance therapy and before comprehensive treatment), and after comprehensive treatment (Tf). The mean treatment time with functional appliances was 19.8 months (range, 6-36 months). The mean time from the completion of functional therapy to the final records was 35.8 months (range, 19-64 months). The mean age at the final cephalogram was 15 years 11 months (range, 12 years 8 months to 18 years 10 months); the mean ages were 15 years 5 months for the girls and 16 years 4 months for the boys. All patients wore the functional appliances until full eruption of the permanent dentition, when the second phase of comprehensive treatment was begun.

The BSSRO group consisted of 23 female patients and 7 male patients, who were treated by 1 orthodontist and 1 surgeon. The BSSRO group was stabilized with internal rigid fixation. The mean age of these patients was 27 years 2 months (range, 13 years 0 months to 53 years 10 months). The following cephalograms of the surgical patients were taken: pretreatment (T1), presurgery (T2), postsurgery (T3, 10 days after surgery), and postorthodontic treatment (Tf). The mean time from postsurgical to final records was 34.9 months (range, 15-69 months). For the long-term treatment evaluation of the surgical patients, the cephalograms at T1, T2, T3, and Tf were used. For the comparison between the surgical and functional appliance treatment patients, the cephalograms at T1, T3, and Tf were used for the surgical group, and the cephalograms at T1, T2, and Tf

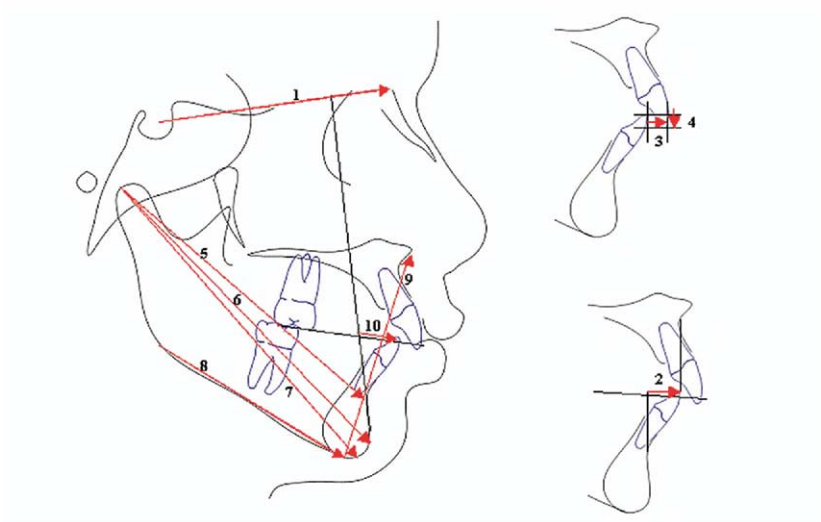

Fig 1. Linear measurements. *1*, SN (sella to nasion); *2*, Wits (perpendicular line from A point [A pt]/B point [B pt] to occlusal plane and measure difference); *3*, overjet (OJ) (incisal edge of maxillary incisor to incisal edge of mandibular incisor [horizontal]); *4*, overbite (OB) (incisal edge of maxillary incisor to incisal edge of mandibular incisor [vertical]); *5*, Co-B pt (condylion to B pt); *6*, Co-Pog (condylion to pogonion); *7*, Co-Gn (condylion to gnathion); *8*, Go-Me (gonion to menton); *9*, ANS-Me (anterior nasal spine to menton); *10*, PM perp (SN) L1 (perpendicular line from SN to PM, along occlusal plane to most anterior point of mandibular incisor).

for the functional treatment group. The longer observation time for the functional group was chosen to ensure that there was limited, if any, growth remaining in these patients and to evaluate cephalograms when any remaining limited growth could not influence the final outcome. The linear measurements used in this study are noted in Figure 1, angular measurements are recorded in Figure 2, and the soft tissue measurements are shown in Figure 3.

Mixed-design analysis of variance statistical analysis was used to test globally for mean differences between each group and over time. Significance was set at $P < .05$. To adjust for experiment-wide alpha error associated with multiple tests, the P value for individual results was set at $P < .05$. Post hoc analysis was conducted with t tests to compare specific pairs of observations, both between groups (functional versus surgical at T2) and within groups (functional from T1 to T2). All measurements demonstrated a correlation of 0.8 or higher for intra- and interjudge reliability.

RESULTS

Cephalometric measurements were compared between the 2 groups at 3 time points. The changes in the functional group were compared at 3 time points (T1, T2, and Tf), and the changes in the surgical group were compared at 4 time points (T1, T2, T3, and Tf). The mean value changes between these groups as well as within each group are listed in Tables I-VI.

Functional group

The SN length changed between T1 and T2 by 1.8 mm ($P < .001$) and from T2 to Tf by 2 mm ($P < .001$), with an overall change of 3.8 mm due to normal anterior cranial base growth. The Wits appraisal was reduced from T1 to T2 by 3.1 mm ($P < .001$) as B point (B pt) was moved more anteriorly with functional appliance treatment. The Wits increased insignificantly from T2 to Tf, by 0.4 mm, for an overall change of 2.7 mm ($P < .001$), indicating a reduction of Class II malocclusion. The overjet was reduced by 4 mm ($P < .001$) from T1 to T2 after the use of the functional appliance and was reduced even further from T2 to Tf (0.8 mm, $P < .001$), for an overall change of −4.8 mm, indicating that the growth continued in a positive direction after the removal of the functional appliance.

This continued growth was noted also by the changes of Co-Pog, Co-B pt, Co-Gn, and Go-Me. All measurements associated with mandibular growth showed continuation in a positive direction, with no relapse after the functional appliance was discontinued. PM perp L1 had an overall increase of 0.7 mm ($P < .001$), indicating a slight forward movement of the mandibular incisors. The vertical dimension increased

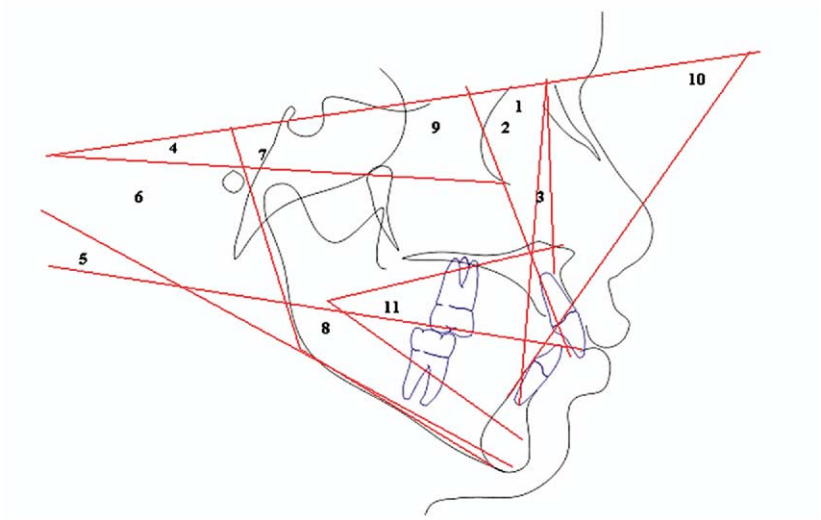

Fig 2. Angular measurements. *1*, SNA (sella-nasion-A pt); *2*, SNB (sella-nasion-B pt); *3*, ANB (A pt-nasion-B pt); *4*, SNFH (sella-nasion line angle to Frankfort horizontal); *5*, SN-Occl (sella-nasion line angle to occlusal plane); *6*, SN-GoGn (sella-nasion line angle to gonion-gnathion line); *7*, SN-Ar-Go (sella-nasion line angle to articulare-gonion line); *8*, Ar-Go-Me (articulare-gonion-menton); *9*, SN-U1 (sella-nasion line to long axis of maxillary incisor); *10*, Sn-L1 (sella-nasion line to long axis of mandibular incisor); *11*, ANS-Xi-PM (anterior nasal spine-Xi point-PM).

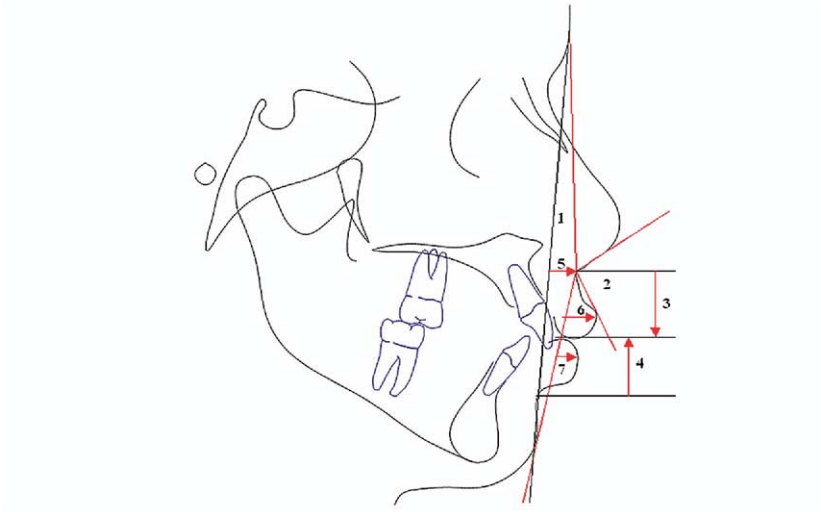

Fig 3. Soft tissue measurements. *1*, facial contour angle (soft tissue glabella-subnasale-soft tissue pogonion); *2*, NLA (nasolabial angle); *3*, ULL (upper lip length; subnasale-maxillary stomion, in millimeters); *4*, LLL (lower lip length; mandibular stomion-soft tissue B-point, in millimeters); *5*, GLPG-Sn, subnasale from soft tissue line glabella to pogonion, in millimeters); *6*, ULP (upper lip protrusion; upper lip from subnasale-soft tissue pogonion, in millimeters); *7*, LLP (lower lip protrusion; lower lip from line subnasale-soft tissue pogonion, in millimeters).

as the mandible continued to grow downward and forward, as noted by the increase in ANS-Me from T1 to T2 by 2.7 mm ($P < .001$) and from T2 to Tf by 3.5 mm ($P < .001$), for an overall increase of 6.2 mm ($P < .001$). OB decreased from T2 to Tf by 0.8 mm ($P < .006$), for an overall decrease of 1.4 mm ($P < .001$). These results are shown in Table I. The SNA angle remained stable from T1 to T2, indicating little or no

headgear effect from the functional appliance; it became smaller from T2 to Tf (1.3°, $P < .008$), indicating possible remodeling at A point (A pt) during fixed appliance therapy. The SNB angle increased 1.1° ($P < .008$) from T1 to Tf, whereas the ANB angle decreased 2.8° ($P < .001$) from T1 to Tf. Ar-Go-Me decreased 1.4° ($P < .007$) from T1 to Tf, and SN-Ar-Go increased 2.6° ($P < .001$) overall. SN-Go-Gn and SNFH remained relatively stable over time. The maxillary incisors uprighted from T1 to T2 ($P < .001$), for an insignificant overall change ($P < .189$). The mandibular incisor flared 4° from T1 to Tf, for a significant change over time ($P < .015$). Angular measurements are illustrated in Table II. The differences in the soft tissue values support the linear and angular changes noted above (Table III).

Surgical group

The length of the cranial base (SN measurement) did not change at any time because this surgical group was composed of nongrowing patients. The Wits decreased by 3 mm ($P < .001$) from T2 to T3, with an overall decrease of 3.5 mm ($P < .001$) due to mandibular advancement. OJ increased from T1 to T2 by 1.4 mm ($P < .012$) during the presurgical orthodontic preparation but decreased from T2 to T3 by 4.7 mm ($P < .001$) due to surgical advancement of the mandible. From T3 to Tf, there was a slight increase (0.5 mm, $P < .034$), with an overall decrease in OJ of 2.8 mm ($P < .001$). From T1 to T2, OB decreased by 2.1 mm ($P < .001$); from T2 to T3, it continued to decrease, by 2.2 mm ($P < .001$); and it increased 1.7 mm from T3 to Tf, for an overall decrease of 2.6 mm ($P < .001$). The postsurgery increase in mandibular length was confirmed by changes in the measurements Co-Pog, Co-B pt, and Co-Gn ($P < .001$). These measurements remained stable over time, with no significant change from immediately after surgery (T3) to after treatment (Tf). Go-Me increased from T2 to T3 by 3.2 mm ($P < .001$), for an overall change of 3.7 mm ($P < .001$). ANS-Me increased from T1 to T2 by 2 mm ($P < .001$) and from T2 to T3 by 2.1 mm ($P < .001$), with a slight relapse from T3 to Tf of 1.5 mm ($P < .001$). The overall increase in lower anterior face height was statistically significant at 2.6 mm ($P < .001$). PM perp L1 increased 0.8 mm ($P < .186$) from T1 to T2 during the orthodontic presurgical preparation. The mandibular incisors remained relatively stable from T2 to T3. From T3 to Tf, the mandibular incisors uprighted 1 mm ($P < .006$). Results are shown in Table I.

The SNA angle remained stable throughout all time periods studied. The SNB angle increased by 2.8° ($P < .001$) from T2 to T3, with a slight, nonsignificant relapse from T3 to Tf of 0.3° ($P < .365$), for an overall increase of 2.1° ($P < .001$). As a sequelae of the latter, ANB decreased 2.5° ($P \leq .001$) from T2 to T3 ($P < .001$), for an overall decrease of 2.4° ($P < .001$). ANB remained stable from T3 to Tf, indicating the stability of the surgical results. ANS-Xi-PM increased by 1.3° ($P < .001$) from T1 to T2 and continued to change from T2 to T3 and from T3 to Tf, by 1.6° and 1.4°, respectively ($P < .001$), for an overall change of 1.5° ($P < .001$). The Ar-Go-Me showed vertical increases from T2 to T3 of 3.7° ($P < .001$) and from T3 to Tf of 1.1° ($P < .027$), for an overall increase of 5° ($P < .001$). SN-Ar-Go decreased from T2 to T3 by 2.6° ($P < .001$) and remained stable from T3 to Tf. The SN-GoGn increased by 1° ($P < .003$) from T1 to T2 and 1.3° ($P < .017$) from T2 to T3, with an overall change from T1 to Tf of 3° ($P < .001$). SN-U1 increased 7.4° ($P < .004$), indicating flaring of the maxillary incisor from T1 to T2, with an overall increase of 6.4° ($P < .022$) from T1 to Tf. The position of the maxillary incisors remained stable from T2 to T3 and from T3 to Tf, indicating that most of the changes occurred during the presurgical orthodontic preparation. SN-L1 did not show statistically significant changes, although there was a slight uprighting of the mandibular incisors, by 0.7° as indicated previously by the PM perp L1 measurement. SNFH and SN-Occl measurements did not change significantly at any time points. Results are shown in Table II.

The soft tissue changes are summarized in Table III. In most instances, the changes in the soft tissues reflected those observed in the underlying skeletal structures.

Difference between the groups

Most of the initial linear measurements for the functional treatment group were significantly smaller than in the surgical group, with the exception of OJ, which was larger in the functional treatment group. For most measurements, both groups finished with the same range of values, whether treated with surgery or a functional appliance. Results are shown in Table IV.

Unlike the initial linear measurements, the angular values for the 2 groups were very similar at the start of treatment, with the exception of Ar-Go-Me and SN-L1, which were larger in the functional group, and SN-Ar-Go and SN-Occl, which were larger in the surgical sample (Table V). At the end of treatment, all angular measurements remained the same except for SN-L1 and SN-Occl. The mandibular incisors were significantly flared in the functional group ($P < .012$), whereas the

Table I. Linear difference (in millimeters) within functional and surgical groups over time

			T1-T2 (F-S)				*T2-Tf (F) T2-T3 (S)*		
Measurement	*Group*	*T1*	*Mean diff*	t *value*	P *value*	*T2*	*Mean diff*	t *value*	P *value*
SN	Functional	73.3	1.8	6.6	<.001*	75.1	2.0	6.8	<.001*
	Surgical	75.6	0.0	−0.2	<.833	75.6	−0.2	−0.8	<.419
ANS-Me	Functional	64.9	2.7	5.9	<.001*	67.6	3.5	6.5	<.001*
	Surgical	66.6	2.0	5.7	<.001*	68.6	2.1	4.0	<.001*
Co-B pt	Functional	101.6	6.2	10.2	<.001*	107.8	3.0	4.7	<.001*
	Surgical	106.0	0.1	0.3	<.759	106.0	5.2	9.8	<.001*
Co-Gn	Functional	112.0	7.5	12.5	<.001*	119.5	5.4	6.9	<.001*
	Surgical	117.0	3.9	1.1	<.262	121.0	4.9	9.5	<.001*
Co-Pog	Functional	109.5	7.4	11.8	<.001*	116.9	5.3	6.4	<.001*
	Surgical	117.0	0.8	1.9	<.069	118.0	4.6	8.2	<.001*
Go-Me	Functional	69.3	3.2	6.5	<.001*	72.5	3.5	6.3	<.001*
	Surgical	74.6	0.2	0.5	<.590	74.8	3.2	7.3	<.001*
Wits	Functional	2.6	−3.1	−5.4	<.001*	−0.5	0.4	1.3	<.216
	Surgical	2.3	0.4	1.0	<.326	2.7	−3.0	−7.8	<.001*
PM perp L1	Functional	9.2	0.5	1.9	<.063	9.7	0.2	0.8	<.429
	Surgical	8.5	0.8	1.4	<.186	9.3	0.4	0.9	<.376
OB	Functional	3.7	−0.6	−1.8	<.079	3.1	−0.8	−3.0	<.006**
	Surgical	5.6	−2.1	−5.2	<.001*	3.5	−2.2	−5.2	<.001*
OJ	Functional	8.4	−4.0	−9.7	<.001*	−4.4	−0.8	−3.0	<.006**
	Surgical	6.8	1.4	2.7	<.012**	8.2	−4.7	−11.0	<.001*

F, functional group; *S,* surgical group; *Mean diff,* mean difference.
*$P \leq .001$; **$P \leq .05$.

Table II. Angular differences (in degrees) within functional and surgical groups over time

			T1-T2 (F-S)				*T2-Tf (F) T2-T3 (S)*		
Measurement	*Group*	*T1*	*Mean diff*	t *value*	P *value*	*T2*	*Mean diff*	t *value*	P *value*
SNFH	Functional	10.4	0.3	1.1	<.286	10.7	−0.5	−2.2	<.038**
	Surgical	10.5	0.5	1.8	<.087	11.0	−0.4	−2.2	<.039**
SNA	Functional	81.7	−0.3	−0.7	<.467	81.4	−1.3	−2.8	<.008**
	Surgical	80.4	−0.2	−0.9	<.372	80.2	0.3	1.0	<.295
SNB	Functional	76.7	1.3	4.3	<.001*	78.0	−0.2	−0.8	<.430
	Surgical	75.6	−0.4	−1.7	<.101	75.2	2.8	7.8	<.001*
ANB	Functional	5.1	−1.7	−4.3	<.001*	3.4	−1.1	−4.1	<.001*
	Surgical	4.9	0.1	0.8	<.437	5.0	−2.5	−8.7	<.001*
ANS-Xi-PM	Functional	42.2	0.7	0.5	<.140	42.9	0.4	0.5	<.001*
	Surgical	40.5	1.3	4.8	<.001*	41.8	1.6	4.0	<.001*
Ar-Go-Me	Functional	128.3	0.6	1.7	<.109	128.9	−2.0	−4.4	<.001*
	Surgical	122.4	0.2	0.8	<.439	123.0	3.7	5.4	<.001*
SN-Ar-Go	Functional	84.0	0.4	0.5	<.657	84.4	2.2	2.6	<.013**
	Surgical	88.7	0.4	0.8	<.404	89.1	−2.6	−6.7	<.001*
Sn-GoGn	Functional	30.4	−0.1	−0.4	<.691	30.3	−0.5	−1.5	<.155
	Surgical	28.7	1.0	3.2	<.003**	29.7	1.3	2.5	<.017**
SN-U1	Functional	107.0	−4.4	−3.6	<.001*	102.6	2.7	2.4	<.025**
	Surgical	95.6	7.4	3.1	<.004**	103.0	−0.7	−1.7	<.103
SN-L1	Functional	50.8	−2.1	−2.1	<.047**	48.7	−2.0	−1.7	<.103
	Surgical	52.5	−2.7	−1.8	<.090	49.8	0.8	1.0	<.315
Sn-Occl	Functional	16.2	0.3	0.4	<.659	16.5	−0.8	−1.5	<.140
	Surgical	18.7	−0.2	−0.5	<.606	18.5	−0.4	−0.8	<.410

*$P \leq .001$; **$P \leq .05$.

Table I. Continued

	T3-Tf (S)				T1-Tf (F-S)			Overall change
T3	*Mean diff*	t *value*	P *value*	*Tf*	*Mean diff*	t *value*	P *value*	(P *value*)
				77.1	3.8	9.1	<.001*	<.001*
75.0	0.1	0.6	<.588	75.5	−0.1	−0.5	<.630	<.752
				71.1	6.2	10.4	<.001*	<.001*
71.0	−1.5	−4.3	<.001*	69.2	2.6	6.6	<.001*	<.001*
				110.8	9.2	11.6	<.001*	<.001*
112.0	−0.6	−1.5	<.147	111.0	4.7	8.9	<.001*	<.001*
				124.9	12.9	13.0	<.001*	<.001*
125.0	−0.6	−1.4	<.184	125.0	8.2	2.4	<.022**	<.001*
				122.2	12.7	12.3	<.001*	<.001*
123.0	−0.6	−1.5	<.142	122.0	4.8	9.1	<.001*	<.001*
				76.0	6.7	10.1	<.001*	<.001*
78.0	0.3	1.0	<.361	78.3	3.7	6.8	<.001*	<.001*
				−0.1	−2.7	−4.8	<.001*	<.001*
−1.7	0.5	1.3	<.182	−1.2	−3.5	−6.5	<.001*	<.001*
				9.9	0.7	2.3	<.028**	<.040*
9.7	−1.0	−2.9	<.006**	8.7	0.2	0.5	<.611	<.055
				2.3	−1.4	−3.8	<.001*	<.001*
1.3	1.7	6.3	<.001*	3.0	−2.6	−6.9	<.001*	<.001*
				3.6	−4.8	−11.5	<.001*	<.001*
3.5	0.5	2.2	<.034**	4.0	−2.8	−6.3	<.001*	<.001*
								df = 29

Table II. Continued

	T3-Tf (S)				T1-Tf (F-S)			Overall change
T3	*Mean diff*	t *value*	P *value*	*Tf*	*Mean diff*	t *value*	P *value*	(P *value*)
				10.2	−0.2	−0.6	<.585	<.527
10.6	0.3	1.0	<.310	10.9	0.4	1.4	<.171	<.182
				80.1	−1.6	−3.0	<.005**	<.002**
80.5	−0.4	−1.1	<.267	80.1	−0.4	−1.1	<.293	<.494
				77.8	1.1	2.9	<.008**	<.001*
78.0	−0.3	−0.9	<.365	77.7	2.1	8.1	<.001*	<.001*
				2.3	−2.8	−5.7	<.001*	<.001*
2.5	0.0	−0.1	<.900	2.5	−2.4	−7.2	<.001*	<.001*
				43.3	1.1	1.3	<.202	<.001*
43.4	−1.4	−3.9	<.001*	42.0	1.5	5.6	<.001*	<.001*
				126.9	−1.4	−2.9	<.007**	<.001*
126.3	1.1	2.3	<.027**	127.4	5.0	7.4	<.001*	<.001*
				86.6	2.6	2.6	<.013**	<.001*
86.5	0.2	0.5	<.644	86.7	−2.0	−2.7	<.011**	<.001*
				29.8	−0.6	−1.5	<.145	<.054
31.0	0.7	1.9	<.065	31.7	3.0	7.7	<.001*	<.001*
				105.3	−1.7	−1.1	<.264	<.189
102.3	−0.3	−0.4	<.710	102.0	6.4	2.4	<.022**	<.001*
				46.7	−4.1	−3.0	<.005**	<.015**
50.6	1.2	1.6	<.118	51.8	−0.7	−0.5	<.599	<.101
				15.7	−0.5	−1.0	<.337	<.345
18.1	0.0	0.1	<.947	18.1	−0.6	−1.2	<.243	<.471
								df = 29

Table III. Soft tissue differences within functional and surgical groups over time

			T1-T2 (F-S)				*T2-Tf (F) T2-T3 (S)*		
Measurement	*Group*	*T1*	*Mean diff*	t *value*	P *value*	*T2*	*Mean diff*	t *value*	P *value*
Facial contour (°)	Functional	166.4	1.9	3.0	<.006**	168.3	−0.2	−0.3	<.745
	Surgical	164.6	−0.3	−0.9	<.393	164.3	4.0	6.1	<.001*
NLA (°)	Functional	103.1	1.7	1.2	<.234	104.8	2.8	2.4	<.025**
	Surgical	101.8	0.5	0.5	<.650	102.3	0.2	0.1	<.886
GLPG-Sn (mm)	Functional	6.9	−0.6	−1.6	<.113	6.3	0.2	0.7	<.493
	Surgical	8.3	0.2	1.1	<.276	8.5	−2.0	−5.4	<.001*
ULL (mm)	Functional	20.7	0.3	0.9	<.400	21.0	0.8	2.4	<.021**
	Surgical	22.6	0.2	0.7	<.461	22.8	−0.1	−0.6	<.531
LLL (mm)	Functional	16.2	2.0	6.9	<.001*	18.2	0.6	1.8	<.089
	Surgical	16.1	0.2	0.6	<.569	16.3	2.2	5.1	<.001*
ULP (mm)	Functional	5.4	−0.8	−3.3	<.003**	4.6	−1.1	−4.0	<.001*
	Surgical	4.3	0.0	−0.1	<.957	4.3	−1.1	−3.7	<.001*
LLP (mm)	Functional	3.2	0.4	1.0	<.312	3.6	−1.2	−3.1	<.004**
	Surgical	1.9	0.9	2.5	<.019**	2.8	0.3	0.9	<.404

*$P \leq .001$; **$P \leq .05$.

Table IV. Linear differences (in millimeters) between groups over time

			T1-T2(F) *T1-T3(S)*			*T2(F)* *T3(S)*	*T2-Tf(F)* *T3-Tf(S)*		
Measurement	*Group*	*T1*	*Mean diff*	t *value*	P *value*		*Mean diff*	t *value*	P *value*
SN	Functional	73.3	2.3	2.1	<.038**	75.1	0.4	0.4	<.730
	Surgical	75.6				75.4			
ANS-Me	Functional	64.9	1.7	1.1	<.264	67.6	3.0	2.1	<.035**
	Surgical	66.6				70.7			
Co-B pt	Functional	101.6	4.7	3.3	<.002**	107.8	3.7	2.5	<.015**
	Surgical	106.3				111.6			
Co-Gn	Functional	112.0	4.7	1.2	<.254	119.5	5.9	3.2	<.003**
	Surgical	116.6				125.4			
Co-Pog	Functional	109.5	7.8	4.3	<.001*	116.9	5.6	3.0	<.004**
	Surgical	117.2				122.6			
Go-Me	Functional	69.3	5.3	4.3	<.001*	72.5	5.5	4.2	<.001*
	Surgical	74.6				78.0			
Wits	Functional	2.6	0.4	−0.5	<.627	−0.5	1.2	−1.8	<.076
	Surgical	2.3				−1.7			
PM perp L1	Functional	9.2	0.8	−0.7	<.514	9.7	0.0	0.0	<.973
	Surgical	8.5				9.7			
OB	Functional	3.7	1.9	2.9	<.005**	3.1	1.8	−4.8	<.001*
	Surgical	5.6				1.3			
OJ	Functional	8.4	1.5	−2.5	<.014**	4.4	0.9	−2.8	<.006**
	Surgical	6.8				3.5			

*$P \leq .001$; **$P \leq .05$.

occlusal plane was steeper in the surgical sample ($P < .038$).

The soft tissue measurement demonstrated that there were no statistically significant differences between the 2 groups at T1, with the exception of ULL and ULP ($P < .05$). At the end of the observation period (Tf), only LLL and NLA were statistically different between the 2 groups ($P < .05$). Results are shown in Table VI.

DISCUSSION

This study demonstrated that, for most cephalometric measurements, there were no differences in the final

Table III. Continued

	T3-Tf (S)				T1-Tf (F-S)			Overall changes
T3	Mean diff	t value	P value	Tf	Mean diff	t value	P value	(P value)
				168.1	1.7	2.6	<.013**	<.001*
168.3	0.6	1.1	<.273	169.0	4.3	8.2	<.001*	<.001*
				107.6	4.5	2.0	<.054	<.028**
102.5	0.5	0.6	<.580	103.0	1.2	0.8	<.432	<.810
				6.5	−0.4	−1.2	<.253	<.001*
6.5	−0.5	−1.4	<.171	6.0	−2.3	−7.5	<.001*	<.001*
				21.8	1.1	3.1	<.004**	<.014**
22.7	0.1	0.6	<.538	22.8	0.2	0.9	<.383	<.775
				18.8	2.6	7.0	<.001*	<.001*
18.5	−1.0	−2.2	<.038**	17.5	1.4	4.3	<.001*	<.001*
				3.5	−1.9	−5.7	<.001*	<.001*
3.2	−0.3	−1.5	<.133	2.9	−1.4	−4.9	<.001*	<.001*
				2.4	−0.8	1.8	<.076	<.001*
3.1	−1.0	−3.0	<.006**	2.1	0.2	0.4	<.673	<.003**
								df = 29

Table IV. Continued

	T1-Tf (F-S)				
Tf	Mean diff	t value	P value	Group difference	Group interaction
77.1	1.6	−1.5	<.135	<.741	<.001*
75.3					
71.1	2.0	−1.2	<.222	<.536	<.001*
69.2					
110.8	0.2	0.1	<.919	<.051	<.001*
111.0					
124.9	0.1	0.0	<.987	<.130	<.130
124.8					
122.2	0.3	−0.1	<.896	<.020**	<.001*
121.9					
76.0	2.4	1.6	<.109	<.001*	<.001*
78.3					
−0.1	1.1	−1.7	<.093	<.120	<.477
−1.2					
9.9	1.2	−1.1	<.259	<.510	<.170
8.7					
2.3	0.7	2.7	<.010**	<.457	<.001*
3.0					
3.6	0.4	2.0	<.050**	<.014	<.002**
4.0					

result between early treatment with functional appliances and surgical treatment to advance the mandible by BSSRO.

The changes that occurred within the groups are considered to be primarily due to the effect of treatment and growth because both samples were closely matched at the onset of treatment. The results indicate that the correction of a Class II malocclusion can be successful with functional appliances or orthognathic surgery, with a great degree of stability.

Changes in the functional group

This study demonstrated increased mandibular growth during and after the discontinuation of functional appliance treatment, as shown by the statistically significant

Table V. Angular difference (in degrees) between groups over time

Measurement	*Group*	*T1*	*T1-T2(F) T1-T3(S)*			*T2(F) T3(S)*	*T2-Tf(F) T3-Tf(S)*		
			Mean diff	t *value*	P *value*		*Mean diff*	t *value*	P *value*
SNFH	Functional	10.4	0.1	0.1	<.844	10.7	0.2	−0.2	<.818
	Surgical	10.5				10.6			
SNA	Functional	81.7	1.3	−1.3	<.209	81.4	0.9	−1.0	<.302
	Surgical	80.4				80.5			
SNB	Functional	76.7	1.1	−1.2	<.233	78.0	0.1	−0.1	<.951
	Surgical	75.6				78.0			
ANB	Functional	5.1	0.2	−0.3	<.740	3.4	0.9	−2.0	<.056
	Surgical	4.9				2.5			
ANS-Xi-PM	Functional	42.2	1.7	−1.4	<.172	42.9	0.5	0.4	<.693
	Surgical	40.5				43.4			
Ar-Go-Me	Functional	128.3	5.9	−4.2	<.001*	128.9	2.6	−1.9	<.060
	Surgical	122.4				126.3			
SN-Ar-Go	Functional	84.0	4.7	3.7	<.001*	84.4	2.1	1.7	<.100
	Surgical	88.7				86.5			
Sn-GoGn	Functional	30.4	1.8	−1.2	<.239	30.3	0.7	0.5	<.627
	Surgical	28.7				31.0			
SN-U1	Functional	107.0	11.4	−4.2	<.001*	102.6	0.3	−0.2	<.847
	Surgical	95.6				102.3			
SN-L1	Functional	50.8	1.8	0.8	<.435	48.7	1.9	1.0	<.313
	Surgical	52.6				50.6			
Sn-Occl	Functional	16.2	2.6	2.1	<.037**	16.5	1.5	1.2	<.232
	Surgical	18.7				18.1			

*$P \leq .001$; **$P \leq .05$.

Table VI. Soft tissue difference between groups over time

Measurement	*Group*	*T1*	*T1-T2(F) T1-T3(S)*			*T2(F) T3(S)*	*T2-Tf(F) T3-Tf(S)*		
			Mean diff	t *value*	P *value*		*Mean diff*	t *value*	P *value*
Facial contour (°)	Functional	166.4	1.8	−1.5	<.139	168.3	0.02	0.0	<.990
	Surgical	164.6				168.3			
NLA (°)	Functional	103.1	1.3	−0.5	<.618	104.8	2.3	−1.0	<.306
	Surgical	101.8				102.5			
GLPG-Sn (mm)	Functional	6.9	1.4	2.1	<.042**	6.3	0.2	0.3	<.786
	Surgical	8.3				6.5			
ULL (mm)	Functional	20.7	1.9	2.4	<.019**	21.0	1.7	2.0	<.047**
	Surgical	22.6				22.7			
LLL (mm)	Functional	16.2	0.1	−0.2	<.866	18.2	0.4	0.7	<.471
	Surgical	16.1				18.5			
ULP (mm)	Functional	5.4	1.1	−2.2	<.033**	4.6	1.3	−2.8	<.007**
	Surgical	4.3				3.2			
LLP (mm)	Functional	3.2	1.3	−1.9	<.058	3.6	0.4	−0.7	<.507
	Surgical	1.9				3.1			

*$P \leq .001$; **$P \leq .05$.

changes in Co-Pog, Co-B pt, Co-Gn, Go-Me, OJ, SNB, and ANB. Each of these measurements significantly increased at each time point, with no relapse noted. Co-Pog started at 109.5 mm, which is below the norm value of 111.3 mm.[34] At T2, the measurement was 116.9 mm, which is above the norm value of 116 mm.[34] At final records, Co-Pog was 122.2 mm, which is within the normal value of 125 mm ± 5.4 mm.[34] Co-B pt started at 101.6 mm, which is below the norm of 102.7 mm. At T2, Co-B pt was 107.8 mm, which was greater than the norm value of 106.6 mm.[34] At T3, Co-B pt was 110.8 mm, approaching the normal value of 113.7 mm ± 4.9 mm.

Table V. Continued

	T1-Tf (F-S)				
Tf	*Mean diff*	t *value*	P *value*	*Group difference*	*Group interaction*
10.2 10.9	0.7	1.0	<.340	<.764	<.115
80.1 80.1	0.0	0.0	<.972	<.408	<.075
77.8 77.7	0.1	−0.1	<.904	<.626	<.041**
2.3 2.5	0.1	0.2	<.844	<.493	<.085
43.3 42.1	1.2	−0.9	<.360	<.500	<.001*
126.9 127.1	0.4	0.3	<.762	<0.043**	<.001*
86.6 86.7	0.2	0.1	<.910	<.053	<.001*
29.8 31.7	1.9	1.2	<.245	<.855	<.001*
105.3 102.0	3.3	−1.9	<.062	<.002**	<.001*
46.7 51.8	5.2	2.5	<.012**	<.102	<.084
15.7 18.1	2.4	2.1	<.038**	<.054	<.400

Table VI. Continued

	T1-Tf (F-S)				
Tf	*Mean diff*	t *value*	P *value*	*Group difference*	*Group interaction*
168.1 168.9	0.8	0.6	<.563	<.795	<.007
107.6 103.0	4.7	−2.2	<.034**	<.172	<.271
6.5 6.0	0.5	−0.6	<.547	<.585	<.001*
21.8 22.8	1.1	1.3	<.212	<.050**	<.173
18.8 17.5	1.3	−2.1	<.036**	<.504	<.008**
3.5 2.9	0.6	−1.3	<.206	<.019**	<.167
2.4 2.1	0.3	−0.6	<.571	<.216	<.183

Co-Gn started at 112.0 mm, which is below the norm value of 112.9 mm. This measurement was 119.5 mm at T2, which is above the average of 117.7 mm, and reached 124.9 mm at Tf, which is within the normal value of 125.5 mm ± 5.2 mm. The total amount of growth was 12 mm during the 35.9 months of observation, which is double the amount of approximately 2 mm per year expected for these measurements.[34] A similar trend was noted by Pangrazio-Kulbersh and Berger.[35] McNamara et al[2,3] found an 8-mm increase in Co-Gn over a 24-month period with the Fränkel II appliance and a 4.8-mm increase over 18 months with the Herbst appliance. However, several studies[36,37] do not support the long-term stability of functional appliance treatment. Weislander[38] and Pan-

cherz[37] reported that good occlusal intercuspation was necessary to prevent skeletal and dental relapse. All subjects in the present study were retained with the functional appliance until the full eruption of the permanent dentition and the initiation of fixed appliance therapy. This could have positively influenced the stability of the results. SNB had a statistically significant increase due to functional appliance wear. The patients started with an SNB angle of 76.7°. At T2 and T3, it was 78°, which falls within the normal measurement of 78.5° ± 3.9°.[34] This increase supports the changes in the linear measurements. Ar-Go-Me significantly decreased with functional appliance treatment. This finding agrees with those of Pancherz,[36] who found a larger closure of the gonial angle in the Herbst than in the control subjects and in contrast to the findings of Manfredi et al,[39] who found no changes in their sample. In this study, SN-Ar-Go increased, possibly because of remodeling of the posterior and anterior border of the ramus and the lower border of the mandible. The increase in ramus height and body length in the present study is supported by the findings of others.[2,3,36,40] Pangrazio-Kulbersh and Berger[35] reported that the posteroanterior face height ratio remained relatively stable in the Herbst subject, as a result of the increase in ramus height, whereas the Fränkel subject showed a slight increase in this ratio, as a result of a smaller increase in ramus height. The Wits significantly decreased with the functional appliance and remained stable over time. This could be explained by the forward movement of B pt and the stability of the occlusal plane throughout treatment. Pancherz[36] found that the occlusal plane tipped downward anteriorly in 82% of the Herbst patients, with a maximum value of 7.5°, but some relapse was noted during the posttreatment time. The difference in the behavior of the occlusal plane could be explained by the difference in the design of the banded versus the acrylic Herbst. OB decreased significantly at the end of functional appliance treatment and at the end of full treatment. This is to be expected as the mandible migrates forward along the lingual inclines of the maxillary incisors. As the result of this downward and forward mandibular repositioning, a significant increase in the vertical dimension (ANS-Me) was noticed. This is consistent with other studies[2,36] in which a greater lower anterior face height increase was noted in the Herbst and Fränkel groups compared with controls. Gultan and Uner[13] also observed a greater facial height increase at the end of the retention period as compared with controls. Initially, the mandibular incisors flared significantly with use of the functional appliance, as reported in the literature.[2,3,5,6,12,37] The maxillary incisors were retracted lingually with functional therapy and then flared out to proper torque once the braces were placed. The initial retraction of the maxillary incisor and the possible headgear effect of the functional appliances have been previously reported.[5,6] The SN measurement increased significantly at each time point because of growth.[34] The soft tissue changes followed the positive growth changes that were found in the skeletal and dental changes. The facial contour had a significant change with treatment as the result of the forward posturing of the mandible and thus a better profile. The NLA changed significantly once the braces were placed and correct torque was applied to the maxillary incisors, which in turn significantly affected the protrusion of the upper lip. The ULP significantly decreased overall because of the retraction of the maxillary incisors as a result of the headgear effect of the functional appliance. Pancherz and Anehus-Pancherz[41] found that the ULP became more retrusive in the Herbst patients, by an average of 4.5 mm. The ULL change was most likely due to growth. Owen[6] reported an increase in the NLA as the result of improved muscle tone. The LLL significantly increased during functional therapy, with an overall increase due to the reduction of the lower lip curl and continued growth.[42] The LLP decreased after full expression of the mandibular incisor brackets. The GLPG-Sn measurements did not change significantly at any time points. Overall, the changes were both significant and stable over the 3-year follow-up; this is consistent with the results reported by Gultan and Uner.[13]

Changes in the surgical group

Because all patients in the surgical group were nongrowing, the changes recorded were solely due to treatment. Co-Pog, Co-B pt, and Co-Gn improved significantly immediately after surgery and had a statistically significant overall change. SNB and ANB had significant postsurgery and long-term changes due to the mandibular advancement. OJ initially increased, because of decompensation of the incisors before surgery; then it had a significant reduction postsurgery, with only a minor relapse over the long term (Tf). There was a significant increase in vertical dimension both presurgery and postsurgery, as shown by a decrease in overbite and an increase in ANS-Me, ANS-Xi-PM, and SN-GoGn; this supports previous findings by Berger et al.[16] SN-Ar-Go decreased, indicating forward movement of the gonion as a result of surgery. Berger et al[16] also found a decrease in the SN-Ar-Go and a significant relapse in ANS-Me, ANS-Xi-PM, OJ, and OB. This study found significant relapse in those measurements from postsurgery to final measurements, except in SN-GoGn. Ar-Go-Me increased by 5°, indicating again the change in the relationship between the ramus and the body as a result of the BSSRO. The ANS-Me increased postsurgically, with a slight relapse

at the final observation point, possibly because of the settling of the occlusion. The soft tissue changes, as indicated earlier, produced a more esthetic profile. The forward movement of the mandible, combined with a stable position of the maxilla, helped to improve the profile, as shown by the significant esthetic changes in the facial contour and GLPG-Sn both postsurgery and overall. The LLL increased postsurgically, with a 1-mm relapse from postsurgery to final measurements. The LLP decreased by 1 mm from postsurgery to final measurements, because of the reduction of swelling of the lower lip postsurgically. Pangrazio-Kulbersh et al[43] reported that the lower lip advanced 60% to the incisor movement, and soft tissue pogonion advanced 90% in relation to the hard tissue landmark. Overall, the results of the surgical mandibular advancement with rigid fixation in this study were very stable and mirrored those reported by Kirkpatrick et al.[15]

Comparison between the 2 groups

All initial measurements that were associated with growth were smaller in the functional appliance treatment group. Athough this difference existed at the beginning of treatment, the measurements were very much the same at the end in both groups. This indicated that the functional appliance patients finished with similar maxillomandibular relationships after treatment. The only measurements that remained significantly different were OB, SN-L1, and SN-Occl. The surgical group started with steeper SN-Occl, and, as with the functional group, it maintained its dimensions throughout treatment. All changes that took place either by functional appliance treatment or mandibular advancement surgery remained relatively stable over the 3-year period. The soft tissue changes behaved similarly to the hard tissue landmarks, and the initial differences were eliminated by Tf, with the exception of NLA, which was more obtuse in the functional appliance treatment group, possibly because of the retraction of the maxillary incisors. The LLL was longer in the functional treatment group, possibly because of the perioral muscle retraining and growth associated with functional appliance treatment.[42] The results of this study suggest that the early correction of Class II dentoskeletal malocclusions with functional appliances yields favorable results without the possible deleterious effects of surgery.

CONCLUSIONS

1. The functional appliance patients continued to grow in favorable directions even after the appliances were discontinued.
2. Both the functional appliance patients and the surgical patients showed stable results over time.
3. The functional appliance patients and the surgical patients finished treatment with the same cephalometric measurements. Their differences were considered not statistically significant.
4. Significant skeletal and soft tissue changes were noticed within the treatment groups due to the advancement of the mandible by either functional appliance or by surgery.
5. There was more vertical relapse in the surgical group than in the functional appliance treatment group.

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