sciendo
DOI: 10.2478/aoj-2014-0003

Long-term results of surgically-assisted maxillary protraction

Şirin Nevzatoğlu and Nazan Küçükkeleş
Department of Orthodontics, School of Dentistry, University of Marmara, İstanbul, Turkey

Objective: The long-term treatment results of surgically-assisted facemask therapy were assessed by a comparison of the immediate protraction effects with those seen at five years review.
Materials and methods: Nine patients treated with a corticotomy-assisted maxillary protraction protocol were recalled five years following protraction. Cephalometric films taken before treatment (T0), immediately after maxillary protraction (T1) and five years after treatment (T2) were compared.
Results: The short-term results of surgically-assisted facemask therapy showed significant skeletal and soft tissue changes. After five years, the profile and dental relationships were well maintained and a cephalometric analysis revealed a stable vertical increase but only partially maintained soft tissue changes with loss of sagittal advancement. There was significant upper incisor proclination providing dental camouflage.
Conclusion: Patients who are treated with corticotomy-assisted maxillary advancement should be very carefully selected. Assessment criteria include a low mandibular plane angle Class III patients who have severe maxillary retrognathism unable to be treated by conventional orthopaedic correction alone; patients who have almost completed growth and missed the chance of earlier orthopaedic correction, as well as patients who are not willing to accept bimaxillary orthognathic surgery, may be successfully treated.
(Aust Orthod J 2014; 1: 19-31)

Received for publication: May 2013
Accepted: February 2014

Sirin Nevzatoglu: sirin2288@hotmail.com or sirin.nevzatoglu@marmara.edu.tr; Nazan Küçükkeleş: nazles@tnn.net

Introduction

Prior to the 1970s, the orthodontic literature largely portrayed a Class III malocclusion as one of mandibular prognathism and the most popular appliance used for correction was the chin cup.[1,2] However, recent studies suggest that the majority of Class III malocclusions are characterised by maxillary retrusion, rather than mandibular prognathism.[3-5] Jacobson et al.[1] found that the frequency of maxillary deficiency in Class III malocclusions was 25%, while Kapust et al.[4] and Sue et al.[5] reported the frequency as 42% to 63% respectively.

Contemporary treatment approaches used in skeletal Class III malocclusions are orthodontic camouflage, growth modification, or orthognathic surgery. If a patient presents with mandibular prognathism and a high mandibular plane angle in combination with maxillary retrognathism, orthognathic surgery is the likely treatment of choice.[6] Orthodontic camouflage or growth modification may be used for the correction of mild to moderate Class III cases presenting with a normal vertical skeletal pattern.[7] Generally, the use of a facemask is considered a common treatment protocol in growing maxillary retrognathic Class III cases.[8] Treatment results following facemask therapy are a combination of forward movement of the maxilla, a clockwise rotation of the mandible, proclination of the upper and retroclination of the lower incisors.[9,10] Although facemask therapy aims to promote forward movement of the maxilla, the reported changes are not more than 2 mm in 6 to 12 months of treatment time.[8,11,12] In addition, maxillary advancement is unlikely in patients who have ceased active growth, after which time only two options are possible. Distraction osteogenesis may be undertaken or orthognathic surgery performed.[6,13]

Figure 1. Initial (T0).

Distraction osteogenesis is a biologic process of new bone formation between the surfaces of bone segments, which are gradually separated by incremental traction. Animal and human studies have shown that it is possible to elongate the membraneous bone of the maxilla, using the distraction osteogenesis protocol, to the extent that the procedure has become an accepted treatment option for midface deficient patients.[14,15] Cohen,[16] Kessler et al.,[17] Hierl and Hemprich,[18] Polley and Figueroa[19] and Figueroa and Polley[20] have shown that it is possible to lengthen the maxilla and midface 7-11 mm by distraction osteogenesis. The studies employed rigid intra-oral and extra-oral devices, which were expensive and complex. A facemask has also been used during surgically-assisted maxillary protraction in several studies.[21,22] Molina et al.[21] and Rachmiel et al.[22-26] generated 3 to 12 mm of short-term maxillary advancement using a facemask following a Le Fort 1 osteotomy. Therefore, the aim of the present study was to evaluate the short- and long-term treatment results of facemask therapy conducted following maxillary corticotomies.

Materials and methods

Sixteen growing patients presenting with a skeletal Class III malocclusion characterised by maxillary retrognathism requiring maxillary protraction (Figure 1), were selected from the clinical referrals to the Department of Orthodontics at Marmara University. Pretreatment cephalograms were traced and the patients were selected according to the following criteria: (1) Class III skeletal and dental malocclusion, (2) maxillary retrognathism (more than 7 mm deficiency) with a normal mandible, (3) no openbite, and (4) normal/low mandibular plane angle, reflecting an acceptable vertical pattern.

An intra-oral acrylic splint was constructed and bonded according to the protocol of a previous study (T0) (Figure 2).[27] Under general anaesthesia, incomplete Le Fort 1 corticotomies were performed by the same surgeon and a facemask was applied at the 5-7th post-surgery day. A total force of 1700 - 2000 g was delivered and the patients were advised to wear the facemask for 24 hours per day except when eating. Protraction continued for approximately six to eight weeks until a Class II canine relationship was achieved (Figure 3). Patients were subsequently asked to continue the facemask, at the same force level at night for a further three months (T1), in order to retain the correction. Treatment continued with a multi-bracket system in all patients and, after initial levelling and alignment, elastics were applied to improve the dental relationships in some patients. Because of the continuing growth of the mandible, relapse occurred in four patients during fixed treatment. Additional therapy including facemask, Class III elastics and distraction osteogenesis were used, mainly in cleft patients, to complete treatments. Patients who required additional treatment were excluded from the long-term study. The remaining 12 patients were recalled five years following the protraction (T2) but only nine presented for the follow-up record and cephalometric study (two males and seven females with a mean initial age of 16 years 3 months and 11 years 3 months respectively) (Figures 4, 5). According to the hand-wrist analysis of Bjork, Grave and Brown,[28,29] the mean initial growth was prepeak (5th stage) for boys and peak growth (5th stage) for girls (Table I, Figure 6). An analysis was conducted on the lateral cephalometric films taken before treatment (T0), after maxillary protraction (T1) and at the five-year review (T2) (Figure 5).

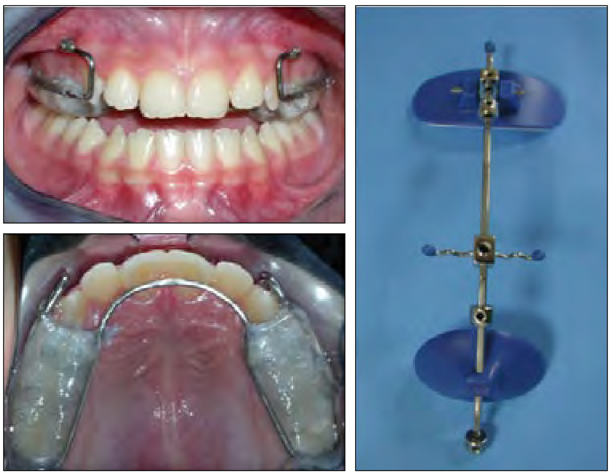

Figure 2. Intra-oral appliance and facemask.

An example of a patient treated by this protocol is shown in Figures 1, 3 and 4. At the beginning of treatment, the patient was diagnosed as having a Class III malocclusion. Although the upper incisors were slightly retroclined, maxillary deficiency (Nper-A) was found to be 8 mm and the position of the mandible was within normal limits (Table II). The malocclusion was not as severe as the skeletal discrepancy due to dental compensation.

Cephalometric method

On the initial (T0) cephalogram, a horizontal reference plane was drawn at an angle of 7° from SN plane at point S in a clockwise direction (R1). A vertical reference plane (R2) was formed by drawing a perpendicular line through S point to the horizontal reference plane. The horizontal (R1) and vertical (R2) reference planes were transferred to the post-protraction (T1) and recall (T2) cephalograms by placing the post-protraction and recall tracings over

Figure 3. Post-protraction (T1).

Figure 4. Recall (T2).

Table I. Patients' growth stage according to the hand and wrist analysis.

Patient/gender	Growth stage (hand and wrist)
ET female	6
EA female	5
HBÖ female	4
AA female	3
HG male	4
ÖÇ female	7
SA female	4
HÇ female	7
CD male	6

the initial cephalometric tracing, using the anterior cranial base (S-N plane) as a reference. All tracings were performed manually. Twenty-four linear and 11 angular parameters were subsequently measured (Figures 7, 8).

Statistical evaluation

An assessment of the findings was performed using the 'Number Cruncher' Statistical System (NCSS), 2007 and 2008 Statistical Software PASS (UT, USA) program. The differences between the measured values of the parameters at the initial, post-protraction and recall periods were evaluated, using the Friedman test, and the Wilcoxon analysis was applied to determine the period in which significant changes occurred.

To calculate the method error, 12 cephalograms (initial, post-protraction and recall) of four randomly selected patients were retraced and re-measured by the same investigator after an interval of three weeks. Intra-class correlation coefficient (ICC) was calculated to assess the reliability. Results were evaluated at the $p < 0.05$ significance level.

Results

Sagittal measurements (Table III)

Maxillary sagittal changes represented by SNA, ANB, maxillary depth angle and Nper-A, R2-A, R2-ANS, R2-PNS measurements at all time periods were found to be highly significant ($p < 0.01$).

SNB and R2-B decreased significantly during protraction ($p < 0.05$).

Dental changes represented by R2-UI and R2-UM measurements between the post-protraction and recall periods were highly significant ($p < 0.01$). There were no statistical differences between the initial and post-protraction SN-UI values ($p > 0.05$), while a significant increase was noted at the recall period. Changes in IMPA and R2-LI were not found to be statistically significant ($p > 0.05$).

Table II. Short- and long- term measurements of the patient.

Skeletal evaluation	Standard	Initial	Post-protraction	Recall
Vertical				
SN-MP (°)	32 ± 7	37	37	35.5
Maxillary height (°)	60	65	61	65
SN-UOP (°)		27	20	23
SN-PP (°)	5 - 7	13	7	16
ANSMe-NMe (%)	55	52	54	52
Sagittal				
SNA (°)	82 ± 2	76	80	77
SNB (°)	80 ± 2	77	78	77
ANB (°)	2	- 1	2	0
Nper-A (mm)	- 1/0	- 8	- 3.5	- 6
Maxillary depth (°)	90	82.5	87	85
R1-ANS (mm)		47	46	50
R1-PNS (mm)		42	44	44
R1-A (mm)		53	51	55
Dental evaluation				
SN-UI (°)	102	96	109	105
IMPA (°)	90	88	80	85
R2-UITip (mm)		59	68	65
R2-LITip (mm)		61	61.5	63
Soft tissue profile				
Nasolabial angle (°)	90 -110	116	116	110
R2-A' (mm)		73	78	74
R2-Ls (mm)		73	79	75

Vertical measurements (Table IV)

SN-PP, SN-MP angles and R1-A, ANS-Me/N-Me measurements obtained at all time periods were not found to be statistically significant ($p > 0.05$).

A statistically significant decrease of SN-UOP angle was seen at the post-protraction and recall times ($p < 0.05$).

Maxillary height angle measurements decreased at the post-protraction period and were found to increase at the recall period ($p < 0.05$).

No statistical change was noted in the R1-ANS angle measurements during protraction, while the increase gained post-protraction was found to be statistically significant ($p < 0.05$).

There were no statistically significant changes in the N-ANS measurement between T1 and T2 ($p > 0.05$). The only significant increase was noted during the follow-up period ($p < 0.05$).

During protraction, statistically significant increases in R1-PNS, ANS-Me, N-Me, R1-UI and R1-UM measurements were observed ($p < 0.05$).

Soft tissue measurements (Table V)

Changes in NLA and R1-A', R1-Ls, R2-Li measurements were found to be insignificant. Increases in R2-A' and R2-Ls values after protraction were found to be highly significant ($p < 0.01$).

Table III. Dental and skeletal sagittal measurements: initial, post-protraction and recall means and SD values for each group (N = 9).

Sagittal measurements (N = 9)		Minimum - Maximum	Mean ± SD	Post hoc		
				T0 – T1	T0 – T2	T1 – T2
SNA (°)	T0	64 - 83	74.1 ± 5.3	**	*ns*	*
	T1	75 - 84	79.1 ± 3.5			
	T2	70 - 82	74.3 ± 4.4			
	p		**			
SNB (°)	T0	75 - 83	78.6 ± 3.0	*	*ns*	ns
	T1	71 - 82	77.1 ± 3.3			
	T2	68 - 82.5	76.3 ± 4.9			
	p		*			
ANB (°)	T0	-7 - 0	-3.6 ± 2.3	**	*ns*	*
	T1	-1.5 - 5	1.9 ± 2.3			
	T2	-7.5 - 2	-2.0 ± 3.6			
	p		**			
Maximum depth (°)	T0	65 - 95	82.3 ± 7.6	*	*ns*	**
	T1	77 - 95.5	87.4 ± 5.4			
	T2	72 - 95	83.7 ± 6.3			
	p		**			
Nper-A (mm)	T0	-21 - 0	-7.4 ± 6.5	*	*ns*	*
	T1	-14 - 5	-2.8 ± 5.5			
	T2	-21 - 5	-7.2 ± 7.3			
	p		**			
R2-A (mm)	T0	54 - 67.5	60.2 ± 4.8	**	*ns*	*
	T1	59 - 74	65.7 ± 4.6			
	T2	55 - 70	61.4 ± 5.2			
	p		**			
R2-ANS (mm)	T0	57 - 71	64.8 ± 4.8	**	*ns*	**
	T1	64 - 78	70.6 ± 4.4			
	T2	59 - 74	66.0 ± 4.4			
	p		**			
R2-PNS (mm)	T0	11 - 24	18.7 ± 4.3	*	*ns*	*
	T1	15 - 33	22.0 ± 4.9			
	T2	13 - 29	19.6 ± 4.8			
	p		**			
R2-UI (mm)	T0	51 - 71	61.1 ± 6.9	**	*ns*	**
	T1	60 - 73	68.1 ± 5.8			
	T2	57 - 78	67.7 ± 7.1			
	p		**			
SN-UI (°)	T0	85 - 110	99.8 ± 8.5	*ns*	**	*
	T1	92 - 113	102.7 ± 6.4			
	T2	93 - 113	106.2 ± 6.3			
	p		**			
R2-UM (mm)	T0	28 - 45	35.2 ± 5.9	**	**	*ns*
	T1	33 - 57	42.5 ± 7.1			
	T2	31 - 50	39.5 ± 6.6			
	p		**			
R2-B (mm)	T0	57 - 73.5	63.1 ± 5.7	*	*ns*	*ns*
	T1	51 - 73	60.4 ± 6.4			
	T2	42 - 72.5	59.5 ± 9.4			
	p		*			
IMPA (°)	T0	65 - 89	79.2 ± 7.6	*ns*	*ns*	*ns*
	T1	63 - 89	78.0 ± 7.9			
	T2	63 - 93	82.2 ± 8.6			
	p		*ns*			
R2-LI (mm)	T0	73 - 87	65.8 ± 4.1	*ns*	*ns*	*ns*
	T1	77 - 92	63.6 ± 5.1			
	T2	70 - 89	65.1 ± 6.7			
	p		*ns*			

T0, Initial; T1, Post-protraction; T2, Recall
* $p < 0.05$; ** $p < 0.01$
The differences between the measured values of the parameters of initial, post-protraction and recall periods were detected by the Friedman test; and Wilcoxon with the Bonferroni correction was applied in determining the period which caused significance (Post hoc).

Table IV. Dental and skeletal vertical measurements. Initial, post-protraction and recall means and SD values for each group (N = 9).

Vertical measurements (N = 9)		Minimum - Maximum	Mean ± SD	Post hoc		
				T0-T1	T0-T2	T1-T2
SN-PP (°)	T0	2 - 23	10.6 ± 6.1	*ns*	*ns*	*ns*
	T1	4 - 15	8.8 ± 3.8			
	T2	4 - 18	10.9 ± 4.7			
	p		*ns*			
SN-UOP (°)	T0	15 - 29	22.1 ± 5.1	*	*	*ns*
	T1	5 - 29	17.7 ± 7.6			
	T2	12 - 27	19.7 ± 4.4			
	p		*			
SN-MP (°)	T0	31 - 42	36.7 ± 3.0	*ns*	*ns*	*ns*
	T1	33 - 44	38.6 ± 3.0			
	T2	32 - 51	39.8 ± 5.6			
	p		*ns*			
Maximum height (°)	T0	59 - 72	63.9 ± 4.0	*	*ns*	*
	T1	58 - 69	61.6 ± 3.2			
	T2	59 - 73	65.0 ± 4.6			
	p		**			
R1-A (mm)	T0	47 - 55	50.1 ± 2.8	*ns*	*ns*	*ns*
	T1	48.5 - 56	51.7 ± 3.1			
	T2	49 - 55	51.7 ± 2.9			
	p		*ns*			
R1-ANS (mm)	T0	41 - 50	44.8 ± 2.8	*ns*	*	*
	T1	43 - 50	45.7 ± 2.4			
	T2	44 - 50	47.3 ± 3.3			
	p		**			
R1-PNS (mm)	T0	38 - 45	42.7 ± 2.6	*	*	*ns*
	T1	41 - 50	44.7 ± 3.3			
	T2	41 - 48	44.2 ± 2.4			
	p		*			
N-ANS (mm)	T0	51 - 60	54.3 ± 2.8	*ns*	*ns*	*
	T1	51.5 - 60	54.7 ± 3.0			
	T2	54 - 60.5	56.4 ± 2.5			
	p		*			
ANS-Me (mm)	T0	53 - 77	63.6 ± 7.1	*	**	*ns*
	T1	57 - 78.5	67.8 ± 7.4			
	T2	59 - 79	69.8 ± 7.3			
	p		**			
N-Me (mm)	T0	109 - 128	117.8 ± 6.2	*	**	*ns*
	T1	112 - 137	122.5 ± 9.2			
	T2	115 - 140	125.6 ± 8.3			
	p		**			
ANS-Me/N-Me (ratio)	T0	49 - 60	53.9 ± 3.4	*ns*	*ns*	*ns*
	T1	51 - 58	55.2 ± 2.3			
	T2	51 - 59	55.4 ± 2.7			
	p		*ns*			
R1-UI (mm)	T0	67 - 75	70.7 ± 3.3	**	**	*ns*
	T1	71 - 78	78.8 ± 2.6			
	T2	69 - 79	74.5 ± 2.9			
	p		**			
R1-UM (mm)	T0	56 - 71	63.6 ± 4.2	*	*	*ns*
	T1	64 - 76	68.4 ± 5.1			
	T2	61.5 - 73	68.6 ± 3.8			
	p		**			

T0, Initial; T1, Post-protraction; T2, Recall
* $p < 0.05$; ** $p < 0.01$
The differences between the measured values of the parameters of initial, post-protraction and recall periods were detected by the Friedman test; and Wilcoxon with the Bonferroni correction was applied in determining the period which caused significance (Post hoc).

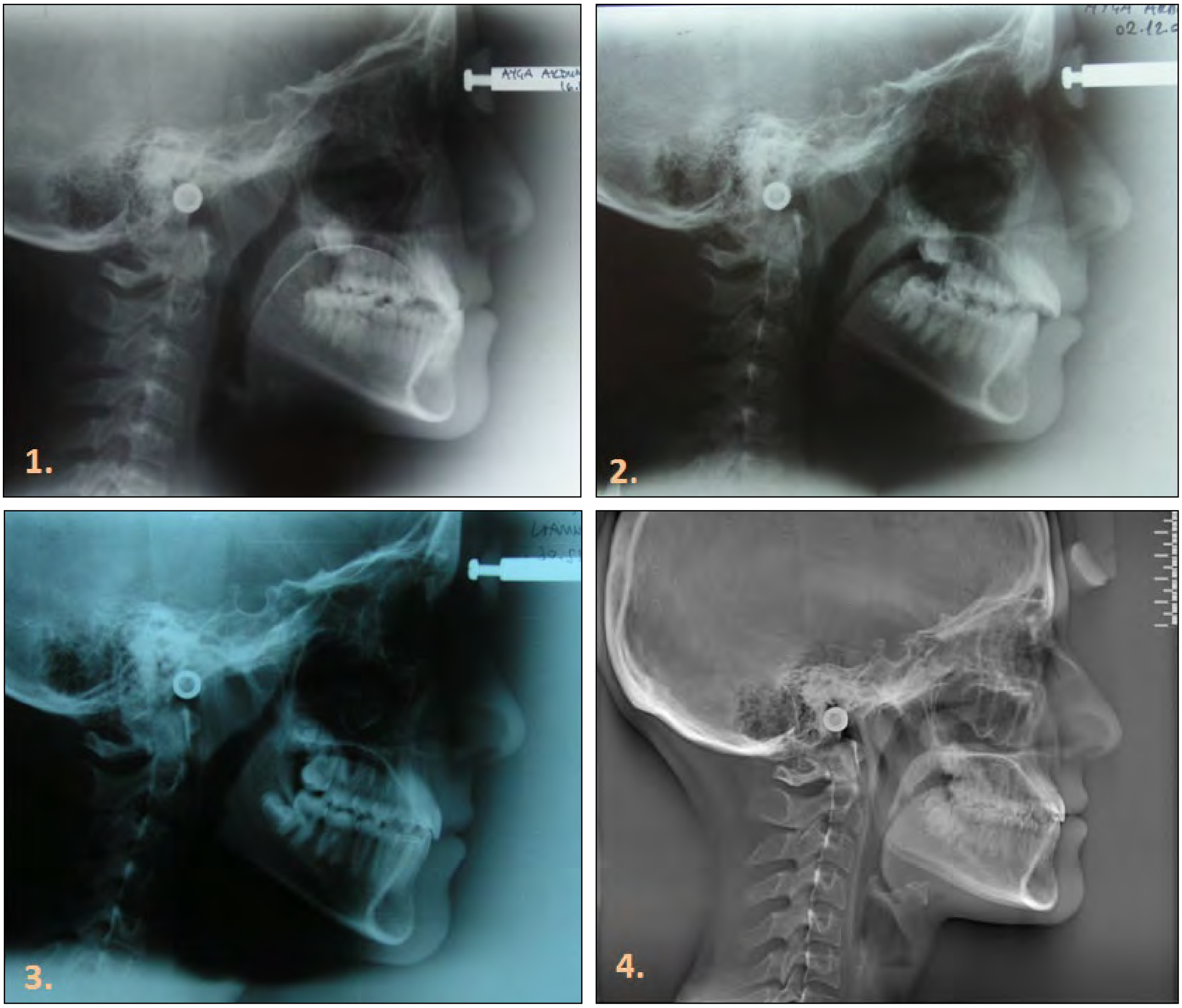

Figure 5. Initial (T0), post-protraction (T1), final and recall (T2) cephalograms.

An increase in upper lip strain after protraction was significant ($p < 0.05$).

A statistically significant decrease of lower lip strain was seen after the protraction ($p < 0.05$).

Superimpositions of the initial, post-protraction and recall cephalograms represent the total skeletal, dental and soft tissue changes obtained during the protraction and follow-up periods (Figure 9).

Reliability of the measurements

The reliability of the measurements was calculated for each parameter separately. In all samples, the intra-class correlation coefficient (ICC) was found

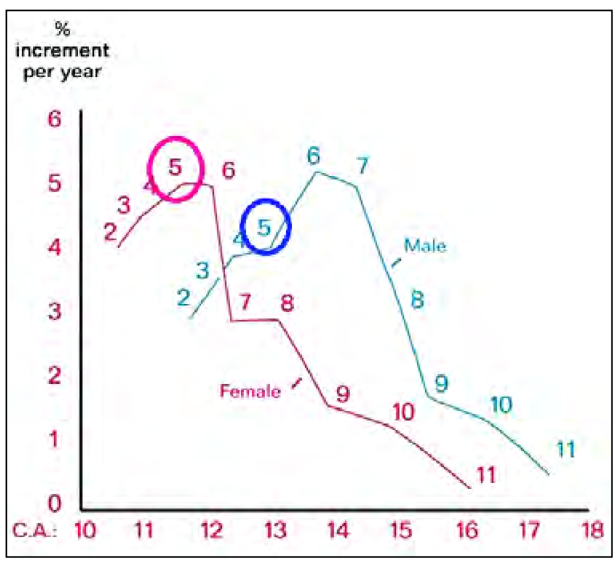

Figure 6. Growth chart, representing the average increment per year for females and males.

Table V. Soft tissue measurements. Initial, postprotraction and recall means and SD values for each group (N = 9).

Soft tissue measurements measurements (N = 9)		Minimum - Maximum	Mean ± SD	Post hoc		
				T0 – T1	T0 – T2	T1 – T2
R2-A' (mm)	T0	69.5 - 83	75.5 ± 5.4	**	*	*
	T1	74 - 92	81.6 ± 5.9			
	T2	74 - 89	79.1 ± 6.3			
	p		**			
R2-Ls (mm)	T0	70 - 88	77.6 ± 6.6	**	*	*
	T1	76 - 95	83.8 ± 6.7			
	T2	69 - 91	80.7 ± 7.2			
	p		**			
R1-A' (mm)	T0	49 - 59	54.0 ± 3.0	*ns*	*ns*	*ns*
	T1	49 - 62	54.1 ± 4.4			
	T2	50 - 60	53.6 ± 3.7			
	p		*ns*			
R1-Ls (mm)	T0	59 - 68	64.1 ± 3.1	*ns*	*ns*	*ns*
	T1	59.5 - 71	65.7 ± 4.0			
	T2	61.5 - 74	66.2 ± 4.3			
	p		*ns*			
R2-Li (mm)	T0	73 - 87	80.6 ± 4.9	*ns*	*ns*	*ns*
	T1	74.5 - 92	81.1 ± 5.6			
	T2	70 - 89	78.6 ± 7.0			
	p		*ns*			
ULS (mm)	T0	-4 - 7	1.1 ± 3.2	*ns*	*	*
	T1	0 - 6	1.7 ± 2.1			
	T2	2 - 8	5.4 ± 2.3			
	p		*			
LLS (mm)	T0	-4 - 2	-0.7 ± 1.8	*	*ns*	*ns*
	T1	-7 - 1	-3.2 ± 2.6			
	T2	-4 - 0	-1.6 ± 1.1			
	p		*			
NLA (°)	T0	64 - 116	95.6 ± 16.0	*ns*	*ns*	*ns*
	T1	97 - 116	106.6 ± 9.1			
	T2	93 - 110	98.1 ± 7.0			
	p		*ns*			

T0, Initial; T1, Post-protraction; T2, Recall
* $p < 0.05$; ** $p < 0.01$
The differences between the measured values of the parameters of initial, post-protraction and recall periods were detected by the Friedman test; and Wilcoxon with the Bonferroni correction was applied in determining the period which caused significance (Post hoc).

Legends for abbreviations in tables:
R1, Horizontal reference line
R2, Vertical reference line
UI, Upper incisor tip
UM, Upper molar cusp
LI, Lower incisor tip
UOP, Upper occlusal plane
PP, Palatal plane
NLA, Nasolabial angle
Ls, Labiale superior
Li, Labiale inferior
A', Soft tissue A point
ULS, Upper lip strain
LLS, Lower lip strain

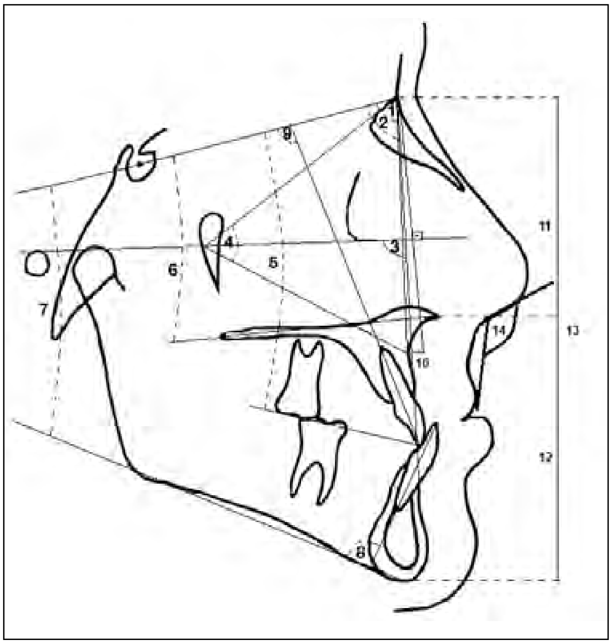

Figure 7. Skeletal, dental and soft tissue variables used in this study: 1, SNA (°); 2, SNB (°); 3, Maxillary depth (°); 4, Maxillary height (°); 5, SN-UOP (°); 6, SN-PP (°); 7, SN-MP (°); 8, IMPA (°); 9, SN-UI (°); 10, Nper-A (mm); 11, N-ANS; 12, ANS-Me (mm); 13, N-Me (mm) 14, NLA (°).

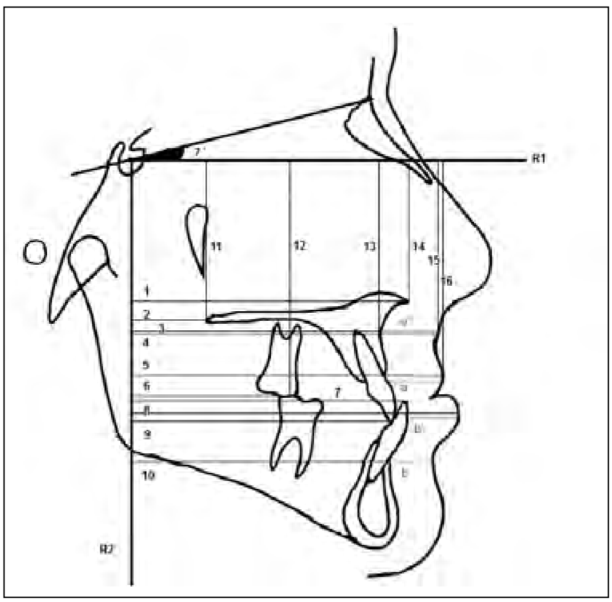

Figure 8. Linear variables according to reference planes used in this study: 1, R2-ANS; 2, R2-PNS; 3, R2-A; 4, R2-A'; 5, R2-Ls; 6, R2-UM; 7, 2-LI; 8, R2-Li; 9, R2-UI; 10, R2-B; 11, R1-PNS; 12, R1-UM; 13, R1-A; 14, R1-ANS; 15, R1-A'; 16, R1-Ls; 17, Upper lip strain: a-a' Arithmetic difference between upper lip thickness (horizontal thickness of upper lip overlying the incisor crowns at the level of vermilion border) and basic upper lip thickness (lip thickness near the base of the alveolar process, about 3 mm below point A). 18, Lower lip strain: b-b' Arithmetic difference between lower lip thickness (horizontal thickness of lower lip overlying the incisor crowns at the level of vermilion border) and basic lower lip thickness (lip thickness near the base of the alveolar process, at about point B).

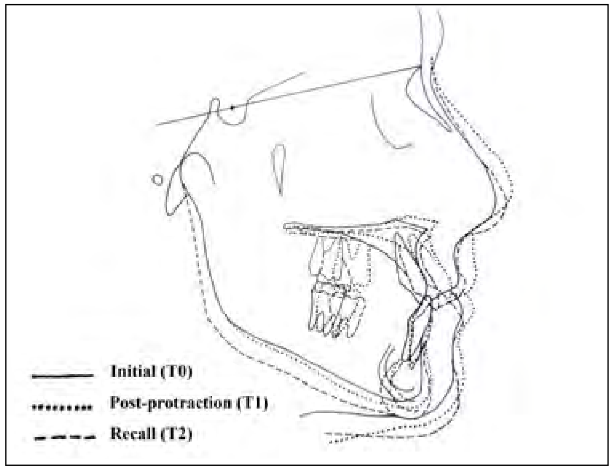

Figure 9. Superimpositions.

to be close to the value of 1.00. The results of the method analysis showed that all measurements could be reproduced with non-fatal errors.

Discussion

Despite considerable improvement in maxillary sagittal position during protraction, significant relapse was noted in the follow-up period. However, the decrease in SNB angle and R2-B distance remained unchanged after treatment. Figueroa et al.[30] reported maxillary sagittal stability after advancement with rigid external distraction osteogenesis. Harada et al.[31] also reported long-term skeletal and dental stability following maxillary distraction osteogenesis. Kanno et al.[32] showed that distraction osteogenesis of the maxilla ensured a stable midface, which offered a promising treatment alternative for patients with maxillary hypoplasia. Conversely, Gürsoy et al.[33] stated that, even though the overall treatment results were stable, the dento-skeletal treatment outcome was partly diminishing in time. Although corticotomy-assisted facemask therapy is described as a 'distraction osteogenesis protocol', its long-term stability is not comparable with that of rigid distraction osteogenesis cases.[30,31] In addition, the stability of corticotomy-assisted facemask therapy is lower compared with the long-term stability of traditional facemask cases.[34-36]

In order to explain the difference in relapse, the protraction retention protocols required examination. The current method aimed to overcorrect by advancing the maxilla until the canines were in a Class II relationship. Once achieved, patients reverted from full-time facemask wear to three months nighttime wear, without a change in force magnitude. Because reorganisation of newly formed bone takes time after distraction osteogenesis, it would be appropriate to decrease the force value and to continue facemask wear for 24 hours during the entire retention period.

Chen et al.[37] found no significant difference in sagittal intermaxillary relationship in Class III malocclusion patients from age 8 to 14. The results suggested that the sagittal intermaxillary relationships in Class III malocclusions were established before 8 years of age and remained the same throughout puberty. The findings were consistent with those of Sugawara and Mitani.[38] According to the Ochoa and Nanda,[39] maxillary length increased significantly from ages 6 to 12 and 14 to 20 in female and male Class I subjects, respectively. It was reported that female subjects tended to have the greatest skeletal change between the ages of 10 and 14, while the male sample experienced the greatest change from ages 12 to 16 and even up to age 18 if the mandible was considered. It was further stated that, compared with the maxilla, the mandible grows more than twice as much in length between ages 6 and 20. The data supported the results of Nanda and Ghosh,[40] who found that the highest rate of growth in the maxilla occurred from ages 6 to 12 in female and 12 to 18 in male Class I subjects. The female sample demonstrated a relative deceleration in growth in maxillary length after age 12 and in mandibular length after age 14, whereas the male sample continued to grow significantly until age 16. Although the initial chronological age of the females and males was not comparable, according to the initial hand-wrist analysis all were in the 5th stage of growth and development (prepeak for boys and peak for girls). All were near the end of their sagittal growth spurt and therefore unlikely to exhibit significant horizontal growth after the protraction treatment. However, during treatment the upper incisors moved bodily without proclination, a distance commensurate with maxillary skeletal base advancement (referring to the stable SN-UI angle and increased R2-UI distance during protraction). During the follow-up period, a significant increase in upper incisor proclination was observed (increased SN-UI angle), while the position of the tip of the incisors remained stable (unchanged R2-UI distance). This suggested that dental camouflage occurred. During protraction, the upper molars moved forward and in the long term maintained their position, which indicated that the molars followed the forward skeletal movement of the upper jaw. There were no recorded significant statistical changes related to IMPA and R2-LI values, which represented a stable lower incisor position. Clinically, there were no obvious discrepancies between the final and recall occlusions.

During protraction, the posterior part of the maxilla extruded and was found to be stable at review. A statistically significant increase of R1-ANS distance took place during the follow-up period. The values for lower facial height (ANS-Me) and total facial height (N-Me) increased during treatment.

According to Ochoa and Nanda,[39] vertical displacement of ANS decreases in girls after 8 years of age and shows an insignificant increase in girls and decelerative growth in boys after the age of 14 years. Significant vertical displacement was not expected in the present samples due to the higher mean age of the female and male patients. Significant vertical displacement of ANS was observed during the follow-up period. Vertical movement of ANS was nearly 1 mm during protraction, following which, 6 mm of vertical movement of ANS was measured after protraction (R1-ANS, Table IV). The remaining growth in the examined samples was altered from the sagittal to a vertical direction in both jaws during the follow-up period.

The advancement of soft tissue A point and upper lip position achieved during protraction was maintained throughout the follow-up period even after relapse of the maxillary base. This might be explained by the simultaneous expansion of the surrounding soft tissues after rapid maxillary protraction and the surgical assistance similar to distraction osteogenesis protocols.[41] Upper lip strain did not change during treatment, even though an increase was noted during the post-treatment period and explained by a backward movement of A point and proclination of the upper incisors. Lower lip strain decreased and remained stable, which was due to the downward and backward position of the mandible during protraction and also its stable position during the recall period.

Conclusion

In the short term, a significant improvement in skeletal and soft tissue profile was obtained through corticotomy-assisted maxillary protraction. This approach was found to be more rapid and effective compared with conventional treatment methods. However, clinicians should be careful in case selection. The ideal patient, for whom surgically-assisted maxillary protraction would be beneficial, is a Class III patient characterised by a low mandibular plane angle and maxillary retrognathism in the post-peak growth stage. Patients indicate unwillingness to accept orthognathic surgery and the malocclusions are generally too severe for conventional orthodontic/orthopaedic correction.

Acknowledgments

This study was supported by Marmara University's Scientific Research Projects Committee (Project No: SAG-D-090512-0147).

Corresponding author

Dr Şirin Nevzatoğlu
Department of Orthodontics, School of Dentistry
Marmara University
3rd Floor, 6 Teşvikiye mah Büyükçiftlik sok 34365
Nişantaşı, Şişli, İstanbul
Turkey

Email: sirin2288@hotmail.com

sirin.nevzatoglu@marmara.edu.tr

References

1. Armstrong CJ. A clinical evaluation of the chin cup. Aust Dent J 1961;6:338-46.
2. Graber TM, Chung B, Aoba TJ. Dentofacial orthopedics versus orthodontics. Aust Orthod J 1968;1:84-105.
3. Jacobson A, Evans WG, Preston CB, Sadowsky PL. Mandibular prognathism. Am J Orthod 1974;66:140-71.
4. Kapust AJ, Sinclair PM, Turley PK. Cephalometric effects of face mask/expansion therapy in Class III children: a comparison of three age groups. Am J Orthod Dentofacial Orthop 1998;113:204-12.
5. Sue G, Chanoca SJ, Turley PK, Itoh J. Indicators of skeletal Class III growth. J Dent Res 1987;66:343.
6. Proffit WR, Fields HW Jr. Section VIII, Chapter 22, Combined surgical and orthodontic treatment. In: Rudolph P, Everding J, editors. Contemporary Orthodontics 3rd ed. St. Louis: Mosby; 2000;674-709.
7. Proffit WR, Fields HW Jr. Section VIII, Chapter 15, Treatment of skeletal problems in preadolescent children. In: Rudolph P, Everding J, editors. Contemporary Orthodontics 3rd ed. St.Louis: Mosby; 2000;478-523.
8. Baccetti T, McGill JS, Franchi L, McNamara JA Jr, Tollaro I. Skeletal effects of early treatment of Class III malocclusion with maxillary expansion and face-mask therapy. Am J Orthod Dentofacial Orthop 1998;113:333-43.
9. McNamara JA Jr. An orthopedic approach to the treatment of Class III malocclusion in young patients. J Clin Orthod 1987;21:598-608.
10. Turley PK. Orthopedic correction of Class III malocclusion with palatal expansion and custom protraction headgear. J Clin Orthod 1988;22:314-25.
11. da Silva Filho OG, Magro AC, Capelozza Filho L. Early treatment of the Class III malocclusion with rapid maxillary expansion and maxillary protraction. Am J Orthod Dentofacial Orthop 1998;113:196-203.
12. Alcan T, Keles A, Erverdi N. The effect of a modified protraction headgear on maxilla. Am J Orthod Dentofacial Orthop 2000;117:27-38.
13. Suh J, Choi TH, Baek SH, Kim JC, Kim S. Mandibular distraction in unilateral craniofacial microsomia: longitudinal results until the completion of growth. Plast Reconstructr Surg 2013;132:1244-52.
14. Hierl T, Klöppel R, Hemprich A. Midfacial distraction osteogenesis without major osteotomies: a report on the first clinical application. Plast Reconstr Surg 2001;108:1667-72.
15. Altuna G, Walker DA, Freeman E. Surgically assisted rapid orthodontic lengthening of the maxilla in primates-a pilot study. Am J Orthod Dentofacial Orthop 1995;107:531-6.
16. Cohen SR. Craniofacial distraction with a modular internal distraction system: evolution of design and surgical techniques. Plast Reconstr Surg 1999;103:1592-607.
17. Kessler P, Wiltfang J, Schultze-Mosgau S, Hirschfelder U, Neukam FW. Distraction osteogenesis of the maxilla and midface using a subcutaneous device: report of four cases. Br J Oral Maxillofac Surg 2001;39:13-21.
18. Hierl T, Hemprich A. A novel modular retention system for midfacial distraction osteogenesis. Br J Oral Maxillofac Surg 2000;38:623-6.
19. Polley JW, Figueroa AA: Rigid external distraction: its applacation in cleft maxillary deformities. Plast Reconstr Surg. 1998;102:1360-72.
20. Figueroa AA, Polley JW. Management of severe cleft maxillary deficiency with distraction osteogenesis: procedure and results. Am J Orthod Dentofacial Orthop 1999;115:1-12.
21. Molina F, Ortiz Monasterio F, de la Paz Aguilar M, Barrera J. Maxillary distraction: aesthetic and functional benefits in cleft lip-palate and prognathic patients during mixed dentition. Plast Reconst Surg 1998;101:951-63.
22. Rachmiel A, Aizenbud D, Ardekian L, Peled M, Laufer D. Surgically-assisted orthopedic protraction of the maxilla in cleft lip and palate patients. Int J Oral Maxillofac Surg 1999;28:9-14.
23. Rachmiel A, Potparic Z, Jackson IT, Sugihara T, Clayman L, Topf JS, Forté RA. Midface advancement by gradual distraction. Br J Plast Surg 1993;46:201-7.
24. Rachmiel A, Levy M, Laufer D, Clayman L, Jackson IT. Multiple segmental gradual distraction of facial skeleton: an experimental study. Ann Plastic Surg 1996;36:52-9.
25. Rachmiel A, Lewinson D, Eizenbud D, Rosen D, Laufer D. Distraction osteogenesis for hypoplastic facial bones. Harefuah 1997;132:833-6.
26. Rachmiel A, Aizenbud D, Peled M. Application of Ilizarov method in maxillofacial treatment. Harefuah 2003;142:359-63.
27. Küçükkeleş N, Nevzatoğlu S, Koldaş T. Rapid maxillary expansion compared to surgery for assistance in maxillary face mask protraction. Angle Orthod 2011;81:42-49.
28. Björk A. Timing of interceptive orthodontic measures based on stages of maturation. Trans Eur Orthod Soc 1972;61-74.
29. Grave KC, Brown T. Skeletal ossification and the adolescent growth spurt. Am J Orthod 1976;69:611-19.
30. Figueroa AA, Polley JW, Friede H, Ko EW. Long-term skeletal stability after maxillary advancement with distraction osteogenesis using a rigid external distraction device in cleft maxillary deformities. Plast Reconstr Surg 2004;114:1382-92.
31. Harada K, Sato M, Omura K. Long-term skeletal and dental changes in patients with cleft lip and palate after maxillary distraction: a report of three cases treated with a rigid external distraction device. Cranio 2005;23:152-7.

32. Kanno T, Mitsugi M, Hosoe M, Sukegawa S, Yamauchi K, Furuki Y. Long-term skeletal stability after maxillary advancement with distraction osteogenesis in nongrowing patients. J Oral Maxillofac Surg 2008;66:1833-46.
33. Gürsoy S, Hukki J, Hurmerinta K. Five-year follow-up of maxillary distraction osteogenesis on the dentofacial structures of children with cleft lip and palate. J Oral Maxillofac Surg 2010;68:744-50.
34. Chen L, Chen R, Yang Y, Ji G, Shen G. The effects of maxillary protraction and its long-term stability-a clinical trial in Chinese adolescents. Eur J Orthod 2012;34:88-95.
35. Ngan PW, Hagg U, Yiu C, Wei SH. Treatment response and long-term dentofacial adaptations to maxillary expansion and protraction. Semin Orthod 1997;3:255-64.
36. Westwood PV, McNamara JA Jr, Baccetti T, Franchi L, Sarver DM. Long-term effects of Class III treatment with rapid maxillary expansion and facemask therapy followed by fixed appliances. Am J Orthod Dentofacial Orthop 2003;123:306-20.
37. Chen F, Terada K, Wu L, Saito I. Longitudinal evaluation of the intermaxillary relationship in Class III malocclusions. Angle Orthod 2006;76:955-61.
38. Sugawara J, Mitani H. Facial growth of skeletal Class III malocclusion and the effects, limitations and long-term dentofacial adaptations to chincap therapy. Semin Orthod 1997;3:244-54.
39. Ochoa BK, Nanda RS. Comparison of maxillary and mandibular growth. Am J Orthod Dentofacial Orthop 2004;125:148-59.
40. Nanda RS, Ghosh J. Longitudinal growth changes in the sagittal relationship of maxilla and mandible. Am J Orthod Dentofacial Orthop 1995;107:79-90.
41. Jayade CV, Ayoub AF, Khambay BS, Walker FS, Gopalakrishnan K, Malik NA, Srivastava D, Pradhan R. Skeletal stability after correction of maxillary hypoplasia by the Glasgow extra-oral distraction (GED) device. Br J Oral Maxillofac Surg 2006;44:301-7.