



Long-term stability of Class III treatment: Rapid palatal expansion and protraction facemask vs LeFort I maxillary advancement osteotomy

Valmy Pangrazio-Kulbersh,^a Jeffrey L. Berger,^b Francis N. Janisse,^c and Burcu Bayirli^d

Detroit, Mich, and Windsor, Ontario, Canada

Introduction: The aim of this retrospective cephalometric study was 3-fold: (1) to compare the effects and long-term stability of protraction facemask treatment with untreated Class III controls, (2) to compare the long-term stability of early protraction facemask treatment with later surgical maxillary advancement with LeFort I osteotomy, and (3) to determine whether early intervention with protraction facemask is an effective treatment modality or whether surgical treatment after cessation of growth should be advocated. **Materials:** The sample consisted of 34 consecutively treated white patients with Class III malocclusions characterized by maxillary deficiency. The protraction sample consisted of 17 children (8 boys, 9 girls). The surgical sample consisted of 17 adults (10 men, 7 women). The protraction group was also compared with a control group of white subjects with untreated Class III malocclusions. Lateral cephalograms were taken at T1 (initial records), T2 (end of functional appliance treatment or 2 weeks postsurgery), and T3 (7 years 6 months postprotraction or 1 year 5 months postsurgery). Means and standard deviations were calculated for descriptive cephalometric measurements. ANOVA was used to assess the differences between and within the protraction and surgery groups at T1, T2, and T3. The Tukey studentized range test was performed to determine the source of the difference. In addition, paired *t* tests were used to compare the differences between the protraction group and the matched controls as well as between the surgery group and the matched controls. **Results:** In the protraction group, there was continued favorable growth of the maxilla, even after the removal of the protraction facemask. From T2 to T3, the maxilla continued to move anteriorly in the protraction patients more so than in the control groups, which had decreases in the intermaxillary measurements (ANB angle and Wits appraisal) over time. The surgical group remained stable from T2 to T3 in all measurements studied. **Conclusions:** The most striking findings of this study were the general similarity between the protraction and the surgical groups at T3 and the overall stability of both treatment modalities over time. (Am J Orthod Dentofacial Orthop 2007;131:7.e9-7.e19)

Maxillary retrusion, without mandibular prognathism, was reported to occur in 20% to 30% of adult patients with Class III malocclusions.¹ Sue et al² found that 62% of their patients had a component of maxillary skeletal retrusion. Other authors found that most patients with developing Class III malocclusions display anteroposterior and vertical

maxillary deficiencies with normal to slightly protruded mandibles and average to deep overbites.^{3,4} Therefore, it appears that early treatment of Class III dentoskeletal malocclusions should focus on correction of the maxillary deficiency and the excessive growth of the mandible when present. Björk⁵ and Björk and Skieller⁶ indicated that maxillary growth was complete in girls by 15 years of age; however, Iseri and Solow⁷ suggested that it was not complete until age 18 years. Savara and Singh⁸ and Broadbent et al⁹ found that, in adolescent boys, the maxilla stopped growing by 18 years of age. Evidence has supported treatment as early as possible to maximize maxillary anterior advancement and minimize dentoalveolar effects.¹⁰ Treatment during the early mixed dentition has been shown to improve maxillary sagittal growth when compared with treatment in the late mixed dentition.^{11,12} Also, it was shown that treatment in the late mixed dentition pro-

^aAssociate professor, School of Dentistry, Department of Orthodontics, University of Detroit Mercy, Detroit, Mich.

^bAdjunct professor, School of Dentistry, Department of Orthodontics, University of Detroit Mercy, Detroit, Mich.

^cPrivate practice, Windsor, Ontario, Canada.

^dAssociate professor, School of Dentistry, Department of Orthodontics, University of Detroit Mercy, Detroit, Mich.

Reprint requests to: Dr Jeff Berger, 600 Tecumseh Rd East, Suite 241, Windsor, Ontario, Canada N8X-4X9; e-mail, jberger@mnsi.net.

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duces increases in vertical dimensions due to the backward positional rotation of the mandible.¹²

Reyes et al¹³ examined 1091 untreated Class III white subjects and found no significant increases in maxillary length in either sex at various chronological ages. The ANB angle and the Wits appraisal showed that no skeletal improvement of the Class III malocclusion occurred during growth. Several investigators found that the growth of the maxilla after protraction treatment was not normalized.^{10,11,14-17} It returned to its original Class III growth pattern after treatment. Wisth et al¹⁸ evaluated the posttreatment growth of 22 children treated with facemasks and quad-helix appliances and compared them with Class I controls. The maxilla, the mandible, and the overjet showed no statistical differences from the Class I controls. Pangrazio-Kulbersh et al¹⁹ found that A-point moved 2.6 mm anteriorly during the retention period with a Fränkel-III appliance. Increased stability was observed with the nighttime use of the facemask and the Fränkel-III appliance.¹⁹⁻²¹ McNamara²⁰ and Turley²¹ suggested decreasing the facemask to part-time wear after 4 to 5 mm of overjet was achieved, whereas Petit²² recommended that the Fränkel-III regulator should be used for 6 months after protraction. Westwood et al²³ showed maintenance of the sagittal intermaxillary relationship in the treated group vs the untreated control group 5.5 years postprotraction. The skeletal relationship of the maxilla to the mandible remained unchanged during the retention period, whereas the Class III controls had an increased skeletal discrepancy of 3.0 mm.

Unfortunately, clinicians do not always have the chance to modify a patient's aberrant Class III growth pattern at an early age. In adults, orthognathic surgical treatment is required because growth modification is not an option. Cheever²⁴ described the first LeFort I osteotomy in 1870. One hundred years later, Obwegeser²⁵ and Bell²⁶ perfected the procedure; it is a surgical technique now routinely used for the correction of Class III skeletal imbalance.²⁴⁻²⁶ With the introduction of rigid fixation, many disadvantages associated with wire fixation have been reduced or eliminated.^{27,28} The main advantage of rigid fixation is the improvement in the stability of the results.^{28,29} Luyk and Ward-Booth²⁹ studied the relapse potential 6 months after plated LeFort I osteotomies with 6 mm of advancement and concluded that there was long-term bony stability. Investigators have demonstrated that A-point relapses less than 1 mm in the long term after surgery; this is clinically insignificant.^{29,30} Champy³¹ and Freihofer³² both stated that occlusion plays a key role in the stability of these osteotomies, and thus the

postsurgical orthodontic alignment of the dentition is an integral part of long-term stability.

Our aim in this retrospective cephalometric study was 3-fold: (1) to compare both the effects and the long-term stability of protraction facemask therapy with untreated Class III controls, (2) to compare the long-term stability of early protraction facemask treatment with later surgical maxillary advancement with the LeFort I osteotomy, and (3) to determine whether early intervention with the protraction facemask is an effective treatment modality or whether surgical treatment, after the cessation of growth, should be preferred.

MATERIAL AND METHODS

The sample consisted of 34 consecutively treated white patients with Class III malocclusions characterized by maxillary deficiencies. The protraction sample consisted of 17 children (8 boys, 9 girls). The surgical sample consisted of 17 adults (10 men, 7 women). Both the protraction and the surgical groups were treated by 1 of 2 practicing orthodontists in the same fashion, and the surgeries were performed by 1 of 2 surgeons working in close association with the orthodontists (V.P.K. and J.L.B.). For this study, the patients were carefully selected with Class III midfacial deficiencies by specific inclusion criteria that included SNA angle $\leq 80^\circ$, Wits appraisal ≤ -3 mm, A-point to nasion perpendicular ≤ -3 mm, and cervical maturation at the long-term observation point (T3) of cervical vertebrae stage (CVS) 5 or CVS 6. Dentally, these patients had exaggerated mesial steps or Class III molar relationships. Surgical patients treated only with maxillary advancement were included. The sella-nasion (SN) line was corrected to standard values when necessary for all measurements that use SN as a reference plane.

Cephalograms were taken before treatment (T1). The mean ages were 8 years 7 months (boys, 9 years; girls, 8 years 3 months) for the protraction group and 19 years 6 months for the surgical group. Progress cephalograms (T2) were taken immediately after facemask therapy and 2 weeks postsurgery. The mean ages were 9 years 10 months for the boys and 9 years 1 month for the girls. The mean treatment time with the protraction facemask was 10 months. The final cephalogram (T3) was taken 7 years 6 months after protraction (mean ages, 17 years 2 months for boys and 16 years 9 months for girls) and 1 year 5 months after surgery. Ten cephalograms were randomly selected to be retraced, redigitized, and remeasured by a second clinician (V.P.K.). Intraclass and interclass correlations were used to calculate the reliability between the 2 tracers, respectively. Intraclass correlations ranged from 0.71 to

Table I. Protraction vs Class III controls

Measurement	T1 (prot)	T1 (cont)	P value	T2 (prot)	T2 (cont)	P value	T3 (prot)	T3 (cont)	P value	T1 vs T3 (P value)
Anterior cranial base (SN) (mm)	70.41	69.44	.36	71.3	69.97	.12	75.29	74.26	.33	1
N-S-Ba (°)	128.2	121.77	<.0001 [‡]	129.47	121.95	<.0001 [‡]	130.59	122.36	<.0001 [‡]	.95
SNA (°)	79.12	80.08	.23	80.35	80.17	.88	80.71	80.98	.88	.73
Midface length (Co-A) (mm)	83.07	83.87	.34	86.53	85.04	.2	93	92.87	.95	.74
Maxillary skeletal (A-Na perp) (mm)	-2.12	-1.18	.08	0.24	-0.95	.04*	0.59	-0.58	.08	.04*
SNB (°)	77.94	79.48	.08	76.5	79.62	.001 [†]	78.94	81.5	.01*	.79
Co-Gn (mm)	107.8	109.54	.19	111.88	111.7	.83	127.59	130.11	.28	.97
IMPA (°)	90.65	87.75	.06	86.88	88.08	.44	90.59	88.11	.001 [†]	.42
U1 angulation (U1-SN) (°)	104.29	101.45	.11	103.71	102.22	.32	107.47	105.63	.23	.96
FH-SN (°)	9.82	8.68	.12	10.18	8.9	.05*	10.29	8.57	.02*	.78
N-ANS (perp HP) (mm)	49.35	48.74	.58	50.59	49.9	.32	56.19	56.22	.95	.9
LAFH (ANS-Me) (mm)	65	62.17	.05*	67.25	63.25	.008*	74.6	73.42	.62	.55
ANB (°)	1.18	0.64	.34	4	0.56	<.0001 [‡]	1.82	-0.49	.0002 [†]	.09
Wits appraisal (mm)	-4.35	-4.52	.9	-0.5	-4.62	<.0001 [‡]	-2.59	-5.48	.003*	.09

* $P \leq .05$; $^{\dagger}P \leq .001$; $^{\ddagger}P \leq .0001$.

Prot, Protraction; cont, control.

Table II. Surgical group vs Class III controls

Measurement	T1 (surg)	T1 (cont)	P value	T2 (surg)	T2 (cont)	P value	T3 (surg)	T3 (cont)	P value	T1 vs T3 (P value)
IMPA (°)	86.694	83.800	.068	91.800	84.000	<.0001 [‡]	91.059	84.030	<.0001 [‡]	.125
Anterior cranial base (SN) (mm)	79.418	75.240	<.0001 [‡]	79.465	75.570	<.0001 [‡]	79.412	75.410	<.0001 [‡]	.944
SNA (°)	77.488	80.680	.001 [†]	82.518	80.820	.05*	81.380	80.720	.171	.003 [†]
SNB (°)	80.635	81.710	.163	79.688	81.820	.012	79.465	81.750	.009 [†]	.620
ANB (°)	-3.118	-0.980	.0002 [†]	2.853	-0.950	<.0001 [‡]	2.377	-0.970	<.0001 [‡]	<.0001 [‡]
FH-SN (°)	8.988	8.510	.417	9.159	8.270	.239	10.029	8.210	.011	.402
U1 angulation (U1-SN) (°)	110.270	105.830	.011	106.350	106.200	.900	108.250	105.990	.190	.624
Wits appraisal (mm)	-8.006	-6.000	.015	-1.077	-5.890	<.0001 [‡]	-1.571	-6.090	<.0001 [‡]	<.0001 [‡]
N-ANS (perp HP) (mm)	55.988	57.230	.190	57.100	57.470	.663	56.882	57.690	.370	.952
LAFH (ANS-Me) (mm)	78.088	75.010	.017	77.641	75.560	.209	77.100	75.820	.549	.385
Midface length (Co-A-point) (mm)	87.906	93.960	<.001	92.582	94.630	<.047*	93.353	94.250	.412	.0002 [†]
Maxillary skeletal (A-Na perp) (mm)	-3.941	-1.000	.003 [†]	1.824	-1.120	.002 [†]	2.024	-1.280	.001 [†]	<.0001 [‡]
Co-Gn (mm)	127.650	133.400	<.0001 [‡]	128.290	134.060	<.0001 [‡]	129.350	134.130	.001 [†]	.885
N-S-Ba (°)	127.360	122.330	<.0001 [‡]	127.330	122.620	.0002 [†]	128.090	122.380	<.0001 [‡]	.900

* $P \leq .05$; $^{\dagger}P \leq .001$; $^{\ddagger}P \leq .0001$.

Surg, Surgical group; cont, controls.

0.95, and interclass correlations ranged from 0.93 to 0.99 for the various cephalometric measurements.

Each protraction patient was treated with a maxillary bonded rapid palatal expansion appliance with protraction hooks placed in the canine region. A protraction force of 400 to 600 g bilaterally was used with the anteroinferior force vector of 30° to the occlusal plane. The elastics were attached to a small or medium reverse-pull face crib (Great Lakes Orthodontics, Tonawanda, NY) according to the patient's facial dimensions. Each patient was instructed to wear the elastics 14 to 16 hours a day until an overjet of 5 mm was achieved. After active protraction, 10 patients (3 boys, 7 girls) were placed in retention with Fränkel-III

appliances (nighttime wear for 1 year before comprehensive orthodontic treatment), and 7 patients continued comprehensive treatment with fixed appliances.

To evaluate the mandibular growth potential remaining in the protraction sample at T3, the skeletal maturity was assessed by using the cervical vertebral maturation method.³³⁻³⁶ All long-term cephalograms measured in this study were at least at CVS 5, indicating that the patients were beyond the pubertal growth spurt, with little or no growth remaining in the mandible.

The protraction group was compared with a control group of similar age, ethnicity, and geographic location at each time interval.¹³ The surgical patients treated

Table III. Protraction vs surgery: maxilla/mandible

Measurement	Group	T1-T2			
		T1	Mean difference	t value	P value
SNA (°)	Protraction	79.12	1.24	-1.04	.90
	Surgical	77.49	5.03	-4.25	.001 [†]
	P vs S (P value)	.74			.001 [†]
Midface length (Co-A) (mm)	Protraction	83.07	3.46	-1.95	.38
	Surgical	87.91	4.68	-2.73	.08
	P vs S (P value)	.08			.004*
Maxillary skeletal (A-Na perp) (mm)	Protraction	-2.12	2.35	-2.11	.29
	Surgical	-3.94	5.77	-5.18	<.0001 [‡]
	P vs S (P value)	.58			<.0001 [‡]
SA (mm)	Protraction	80.65	2.71	-1.68	.55
	Surgical	91.47	4.12	-2.55	.12
	P vs S (P value)	<.0001 [‡]			.01*
SNB (°)	Protraction	77.94	-1.44	1.20	.84
	Surgical	80.64	-0.95	0.80	.97
	P vs S (P value)	.21			.34
Facial plane to SN (SN-NPog) (°)	Protraction	78.24	-1.24	0.98	.92
	Surgical	81.58	-0.56	0.45	1.00
	P vs S (P value)	.09			.57
Co-B-point total mandible (mm)	Protraction	99.07	2.82	-1.20	.84
	Surgical	125.41	-1.83	.81	.97
	P vs S (P value)	<.0001 [‡]			.95
Ar-Gn (mm)	Protraction	102.13	2.88	-1.14	.86
	Surgical	129.21	-1.32	0.53	1.00
	P vs S (P value)	<.0001 [‡]			.90
Co-Gn (mm)	Protraction	107.80	4.08	-1.57	.62
	Surgical	127.65	0.65	-0.26	1.00
	P vs S (P value)	<.0001 [‡]			.39
ANB (°)	Protraction	1.18	2.82	-3.68	.005*
	Surgical	-3.12	5.97	-7.91	<.0001 [‡]
	P vs S (P value)	<.0001 [‡]			<.0001 [‡]
Wits appraisal (mm)	Protraction	-4.35	3.85	-3.65	.006*
	Surgical	-8.01	6.93	-6.67	<.0001 [‡]
	P vs S (P value)	.006*			<.0001 [‡]

* $P \leq .05$; [†] $P \leq .001$; [‡] $P \leq .0001$.

P, Protraction; S, surgical.

with LeFort I maxillary advancement with rigid fixation and comprehensive orthodontics were compared with a control group of similar age, ethnicity, and geographic location. The measurements selected for comparison between the protraction, surgical, and control samples were based on the availability of similar data in the control group. The protraction and surgical subjects were compared to determine treatment effectiveness and stability in both groups.

Means and standard deviations were calculated for the descriptive cephalometric measurements. ANOVA was used to assess the differences between and within the protraction and surgical groups at T1, T2, and T3. Because of a significant ANOVA, the Tukey studentized range test was performed to determine the source of the difference. In addition, paired *t* tests were used to

compare the differences between the protraction group and the matched controls as well as between the surgery group and the matched controls. A *z* score and paired *t* tests were calculated to express the differences between the protraction group and the controls and between the surgical group and the controls.

RESULTS

Protraction and surgical treatment groups vs Class III controls

Tables I and II show the comparisons of skeletal and dental changes over time between the protraction and surgical samples and the Class III controls. The samples were matched by age with the controls at each time interval. Anterior cranial base length showed no statistical differences between the groups at any time

Table III. Continued

T2-T3				T1-T3			
T2	Mean difference	t value	P value	T3	Mean difference	t value	P value
80.35	0.35	−0.30	1.00	80.71	1.59	−1.34	.76
82.52	−1.14	0.96	.93	81.38	3.89	−3.29	.02*
.45			.89	.99			.004*
86.53	6.47	−3.77	.004*	93.00	9.93	−5.61	<.0001*
92.58	0.77	−0.45	1.00	93.35	5.45	−3.18	.02*
.008*			.01*	1.00			<.0001*
0.24	0.35	−0.32	1.00	0.59	2.71	−2.43	.16
1.82	0.20	−0.18	1.00	2.02	5.97	−5.35	<.0001*
.71			.93	.79			<.0001*
83.35	6.47	−4.01	.002*	89.82	9.18	−5.69	<.0001*
95.59	−0.59	0.36	1.00	95.00	3.53	−2.19	.25
<.0001*			.03*	.02*			<.0001*
76.50	2.44	−2.04	.33	78.94	1.00	−0.85	.96
79.69	−0.22	0.19	1.00	79.47	−1.17	0.99	.92
.09			.39	1.00			.99
77.00	3.00	−2.37	.18	80.00	1.77	−1.42	.72
81.02	−0.11	0.09	1.00	80.92	−0.67	0.53	1.00
.02*			.24	.98			.81
101.88	11.65	−5.12	<.0001*	113.53	14.46	−6.16	<.0001*
123.58	0.13	−0.06	1.00	123.71	−1.70	0.75	.98
<.0001*			.001†	.00			.001†
105.00	16.24	−9.23	<.0001*	121.24	19.11	−7.57	<.0001*
127.88	0.05	−0.02	1.00	127.94	−1.27	0.51	1.00
<.0001*			<.0001*	.09			<.0001*
111.88	15.71	−6.25	<.0001*	127.59	19.79	−7.63	<.0001*
128.29	1.06	−0.42	1.00	129.35	1.71	−0.68	.98
<.0001*			<.0001*	.98			<.0001*
4.00	−2.18	2.84	.06	1.82	0.65	−0.86	.96
2.85	−0.48	0.63	.99	2.38	5.49	−7.28	<.0001*
.67			.041*	.98			<.0001*
−0.50	−2.09	1.98	.36	−2.59	1.77	−1.70	.54
−1.08	−0.50	0.48	1.00	−1.57	6.44	−6.19	<.0001*
.99			.19	.92			<.0001*

point. The surgical patients had significantly longer anterior cranial bases than did the controls ($P \leq .001$). There were significant statistical differences ($P \leq .0001$) between the 2 groups in the nasion-sella-basion angles at all time points, indicating acute cranial base angles in the control group. The cranial base flexure increased in the protraction group, although this increase was statistically insignificant.

The maxillary measurements showed more retrusive maxillae in the protraction and surgical groups as indicated by SNA angle, condylion-A-point and A-point-nasion perpendicular at T1. At T2 and T3, A-point in both groups was significantly farther forward than in the controls (A-point-nasion perpendicular: T2, $P \leq .04$, and T1-T3, $P \leq .04$ for the protraction sample; T2, $P \leq .002$, and T1-T3, $P \leq .0001$ for the surgical group).

The mandibular measurements indicated significantly smaller values for SNB angle and condylion-gnathion in both treatment groups at all observation points, depicting more prognathic mandibles in the controls (SNB angle: T2, $P \leq .001$, and T3, $P \leq .01$ for the protraction group; T2, $P \leq .001$, and T3, $P \leq .009$ for the surgical group).

The U1-SN measurement increased over time in the control sample, whereas the maxillary incisors uprighted in the protraction and surgical groups at T2. The IMPA showed more flared mandibular incisors in the treatment groups than in the controls at T1 and T3 ($P \leq .001$). The IMPA in the control group did not change over time, indicating stable mandibular incisor positions.

Upper anterior face height (N-ANS) was similar in both treatment groups and the controls at all time intervals. Lower anterior face height (ANS-Me) was

Table IV. Protraction vs surgery: vertical/cranial base

Measurement	Group	T1-T2			
		T1	Mean difference	t value	P value
SN-MP (°)	Protraction	36.00	1.19	−0.61	.99
	Surgical	36.77	0.16	−0.08	1.00
	P vs S (<i>P</i> value)	1.00			.87
Occlusal plane to SN (°)	Protraction	19.94	−1.65	1.24	.82
	Surgical	14.95	0.75	−0.57	.99
	P vs S (<i>P</i> value)	.004*			.88
FH-SN (°)	Protraction	9.82	0.35	−0.37	1.00
	Surgical	8.99	0.17	−0.18	1.00
	P vs S (<i>P</i> value)	.95			.92
N-ANS (perp HP) (mm)	Protraction	49.35	1.24	−0.83	.96
	Surgical	55.99	1.11	−0.75	.98
	P vs S (<i>P</i> value)	.0003†			.51
LAFH (ANS-Me) (mm)	Protraction	65.00	2.25	−1.03	.91
	Surgical	78.09	−0.45	0.21	1.00
	P vs S (<i>P</i> value)	<.0001‡			.83
Co-Go (mm)	Protraction	48.67	3.39	−1.74	.51
	Surgical	60.31	0.17	−0.09	1.00
	P vs S (<i>P</i> value)	<.0001‡			.39
Total face height (N-Gn) (mm)	Protraction	110.82	3.55	−1.24	.82
	Surgical	137.51	−0.04	0.01	1.00
	P vs S (<i>P</i> value)	<.0001‡			.66
Anterior cranial base (SN) (mm)	Protraction	70.41	0.88	−0.60	.99
	Surgical	79.42	0.05	−0.03	1.00
	P vs S (<i>P</i> value)	<.0001‡			.90
N-S-Ba (°)	Protraction	128.20	1.27	−0.72	.98
	Surgical	127.36	−0.03	0.02	1.00
	P vs S (<i>P</i> value)	1.00			.87
N-S-Ar (°)	Protraction	121.88	1.89	−1.08	.89
	Surgical	120.46	−0.49	0.29	1.00
	P vs S (<i>P</i> value)	.97			.84

**P* ≤ .05; †*P* ≤ .001; ‡*P* ≤ .0001.*P*, Protraction; *S*, surgical.

statistically different between the groups, with the protraction group having a greater lower anterior face height than the controls at T1 (*P* ≤ .05) and T2 (*P* ≤ .008). Both had similar values at T3 (*P* ≤ .62). Lower anterior face height was not significantly different between the surgical and control samples.

The relative sagittal intermaxillary discrepancies were similar between the groups as measured by the ANB angle and Wits appraisal. Both measurements showed more negative changes at each time point in the control group, but, in the protraction and surgical groups, they increased significantly (*P* ≤ .0001) between T1 and T3.

Protraction vs LeFort I maxillary advancement surgery

Tables III through V show the comparisons of treatment between the 2 groups. There was a significant difference in SN length at T1 and T2 because of the age differences (*P* ≤ .0001). At T3, the protraction group

was not statistically different from the surgical group as the result of growth in the anterior cranial base. N-S-Ba and N-S-Ar had similar measurements in both groups at the onset. A statistically significant difference at T3 in N-S-Ar (*P* ≤ .04) was observed between the 2 groups. The protraction group also experienced a statistically insignificant increase in cranial base flexure as shown by the N-S-Ba angle.

The surgical group started with a more retrusive maxilla as depicted by SNA angle and A-point–N perp. In the long term, the 2 groups did not differ significantly in these measurements. The protraction and surgical groups had significant increases of 9.9 and 5.4 mm, respectively, in Co–A-point between T1 and T3 (*P* ≤ .0001, *P* ≤ .02). At T3, they both had similar maxillary length measurements (*P* ≤ 1.0). Between T2 and T3, the surgical group remained stable over time, but the protraction group continued to increase by a total of 6.47 mm (*P* ≤ .004) during the 7 years 6 months

Table IV. Continued

T2-T3				T1-T3			
T2	Mean difference	t value	P value	T3	Mean difference	t value	P value
37.19	-2.84	1.46	.69	34.35	-1.65	0.86	.95
36.92	-0.25	0.13	1.00	36.68	-0.09	0.05	1.00
1.00			.50	.83			.80
18.29	-1.94	1.46	.69	16.35	-3.59	2.70	.08
15.71	-0.12	-0.09	1.00	15.83	0.88	-0.66	.99
.38			.60	1.00			.32
10.18	0.12	-0.12	1.00	10.29	0.47	-0.50	1.00
9.16	1.07	-1.14	.87	10.23	1.24	-1.32	.78
.89			.65	1.00			.41
50.59	5.60	-3.72	.005*	56.19	6.84	-4.54	.0002†
57.10	-0.22	0.15	1.00	56.88	0.89	-0.60	.99
.0004†			.03*	1.00			.001†
67.25	7.35	-3.26	.02*	74.60	9.60	-4.31	.001†
77.64	-0.54	0.25	1.00	77.10	-0.99	0.46	1.00
.0001‡			.08	0.87			.02*
52.06	10.65	-5.63	<.0001‡	62.71	14.04	-7.19	<.0001‡
60.48	0.37	-0.20	1.00	60.85	0.54	-0.28	1.00
.0003†			.0002†	.92			<.0001‡
114.38	15.27	-5.33	<.0001‡	129.65	18.82	-6.68	<.0001‡
137.47	-1.02	0.36	1.00	136.45	-1.05	0.37	1.00
<.0001‡			.002*	.16			<.0001‡
71.29	4.00	-2.71	.08	75.29	4.88	-3.31	.02*
79.47	-0.05	0.04	1.00	79.41	-0.01	0.00	1.00
<.0001‡			.15	.07			.06
129.47	1.12	-0.66	.99	130.69	2.39	-1.36	.75
127.33	0.77	-0.45	1.00	128.09	0.74	-0.43	1.00
.81			.72	.69			.41
123.76	1.71	-0.99	.92	125.47	3.60	-2.05	.32
119.97	0.31	-0.18	1.00	120.28	-0.19	0.11	1.00
.25			.69	.04*			.35

of follow-up. The protraction group had a significant increase of 6.5 mm ($P \leq .002$) in S-A-point distance between T2 and T3.

There were similar patterns for all mandibular measurements in both groups. The surgical group had slightly more prognathic mandibles than the protraction group at all 3 times as depicted by SNB, SN-Pog, Co-B-point, Ar-Gn, and Co-Gn. All measurements indicating mandibular length (Co-B-point, Ar-Gn, and Co-Gn) had significant increases from T1 to T3 in the protraction group ($P \leq .001$), whereas the surgical patients had no significant difference over time.

The mandibular incisors (IMPA) started more upright in the surgical group due to dental compensation associated with the skeletal problem. At T2, presurgical orthodontic treatment proclined the mandibular incisors, and, at T3, both groups finished with the mandibular incisors well positioned over the basal bone with

an IMPA of 90° ($P = 1.00$). The maxillary incisors (U1-SN) were more flared in the surgical group at the onset. At T2, uprighting of the maxillary incisors occurred in the protraction and surgical groups because of the presurgical orthodontic treatment. At T3, the maxillary incisors had similar angulations in both groups ($P \leq 1.0$). The overbite changes were minimal and not significant between the groups at all time intervals. Both groups finished with larger overbites at T3. The overjet in both groups increased significantly between T1 and T2; this was expected with treatment. There was a statistically significant ($P \leq .01$) decrease in overjet in the protraction group between T2 and T3 compared with the surgical group. The protraction group had a total increase (T1-T3) in overjet of 1.11 mm, whereas the surgical patients had an overjet increase of 3.8 mm. There were also significant improvements in molar relationships in both groups (SNpM). The maxillary molars moved forward 5 mm in

Table V. Protraction vs surgery: dental

Measurement	Group	T1-T2				T2-T3				T1-T3			
		T1	Mean difference	t value	P value	T2	Mean difference	t value	P value	T3	Mean difference	t value	P value
IMPA (°)	Protraction	90.65	−3.77	1.72	.52	86.88	3.71	−1.70	.54	90.59	−0.06	0.03	1.00
	Surgical	86.69	5.11	−2.34	.19	91.80	−0.74	0.34	1.00	91.06	4.37	−2.00	.35
	P vs S	.46			.90	.22			.60	1.00			.35
	(P value)												
U1 ang (U1-SN) (°)	Protraction	104.29	−0.59	0.26	1.00	103.71	3.77	−1.67	.55	107.47	3.18	−1.41	.72
	Surgical	110.27	−3.92	1.74	.51	106.35	1.91	−0.85	.96	108.25	−2.02	0.90	.95
	P vs S	.10			.34	.85			.18	1.00			.93
	(P value)												
Overbite (mm)	Protraction	1.00	−0.13	1.34	1.00	0.88	0.83	−1.13	.87	1.71	0.71	−0.94	.94
	Surgical	−1.38	1.38	−1.89	.41	−0.01	0.28	−0.38	1.00	0.27	1.65	−2.27	.22
	P vs S	.02*			.46	.84			.54	.37			.07
	(P value)												
Overjet (mm)	Protraction	0.53	3.15	−5.05	<.0001*	3.69	−2.04	3.37	.01*	1.65	1.11	−1.81	.47
	Surgical	−0.85	3.27	−5.48	<.0001*	2.42	0.11	−0.19	1.00	2.53	3.38	−5.67	<.0001*
	P vs S	.23			<.0001*	.30			.07	.68			<.0001*
	(P value)												
SNpM (mm)	Protraction	20.59	2.41	−1.60	.60	23.00	2.59	−1.71	.53	25.59	5.00	−3.31	.02*
	Surgical	26.53	4.18	−2.76	.07	30.71	1.00	−0.66	.99	31.71	5.18	−3.42	.01*
	P vs S	.00			.01*	<.0001*			.22	.001†			<.0001*
	(P value)												

* $P \leq .05$; † $P \leq .001$; ‡ $P \leq .0001$.

P, Protraction; S, surgical.

the protraction group and moved mesially 5.17 mm in the surgical group.

The mandibular plane angle (SN-MP) was similar between the groups at T1 and remained stable over time. The protraction group increased slightly from T1 to T2. Between T2 and T3, there was closure of SN-MP due possibly to an increase in posterior face height (Co-Go). The occlusal plane was significantly different between the groups at T1, with the protraction group having a steeper occlusal plane. The occlusal plane in the protraction group showed a decrease over time, whereas the surgical group increased slightly. There was no statistical difference between the groups at T3. Upper and lower anterior face heights (N-ANS, ANS-Me) were similar between the groups at T3 even though they were statistically different at T1 and T2 ($P \leq .0001$). There were increases in posterior face height (Co-Go) and total face height (N-Gn) in the protraction group from T1 to T2 ($P \leq .0001$). The surgical group had no changes in these parameters. There were statistically significant differences between the 2 groups at T1 and T2, but, at T3, the protraction subjects had larger posterior face heights than the surgical subjects without reaching statistical significance.

The ANB angle and Wits appraisal increased significantly in the surgical group from T1 to T2 and

remained stable at T3 for an overall significant change of 5.49° and 6.44 mm, respectively, from T1 to T3 ($P \leq .0001$). The protraction group had a significant increase from T1 to T2 ($P \leq .005$) but failed to maintain this difference over time.

DISCUSSION

Protraction and surgical groups vs Class III controls

The protraction group did not reflect the overall growth pattern of the control group, which was characterized by a more prognathic mandible. Research showed that cranial base flexure dictates the anteroposterior position of the mandible. In this study, the control group had a predisposition toward mandibular prognathism as shown by N-S-Ba. The increase in cranial base flexure in the protraction patients was the opposite of what was reported by Ritucci and Nanda,³⁷ who found closure of N-S-Ba with chinup therapy.

The maxillary measurements depicted normal values in the control group at all time points. The protraction group was more retrognathic at the onset but was similar to the controls at T2 and T3 due to the normalization of SNA angle and Co-A-point after protraction. A-point continued to advance 0.35 mm from T2 to T3. This finding is consistent with those of other investigators.^{11,23} The use of the Fränkel-III

appliance during the retention phase in the protraction sample could have aided in the long-term forward movement of A-point.

The SNA and SNB angles did not show statistically significant changes between T1 and T3 in the protraction sample. Horizontal mandibular growth excesses in the control group were, for the most part, not matched by the maxilla, thus causing the Class III relationship to worsen with age; this finding supports the findings of Graber³⁸ and Bjork.³⁹

The Wits appraisal continued to decrease at each time point in the control group due to the underlying increase in skeletal discrepancy. In the protraction group, the Wits appraisal increased significantly from T1 to T3. The increase in Wits appraisal could be explained by the forward movement of A-point produced by the horizontal protraction forces and the counterclockwise rotation in the occlusal plane due to extrusion of the maxillary molars.^{40,41}

There were no statistical differences between the groups in upper and lower anterior face heights at T3. However, the protraction group had a significant increase at T2. Two reasons could account for this: molar tipping during expansion, and downward and forward movement of the maxilla after expansion and protraction.⁴²

The maxillary incisors in the protraction group experienced uprighting at T2 because of the expansion before protraction. The maxillary incisors proclined in both groups between T2 and T3; this supports the “dentoalveolar compensatory mechanism”^{43,44} of the dentition to compensate for an underlying skeletal imbalance. The IMPA showed that the mandibular incisors were well positioned over basal bone at T1 and T3. At T2, pressure from the chincup portion of the facemask against the labial surface of the dentoalveolar process could have had an uprighting effect. The IMPA in the control group did not change over time, indicating a stable mandibular incisor position maintaining the compensatory uprighted position. The forward movement of the maxillary molars could be due to not only the anterior repositioning of the maxilla but also their mesial migration into the leeway space during comprehensive orthodontic treatment. The changes observed in the surgical patients were similar to those of the protraction group in relation to the controls. However, SNA angle and A-point to Na perpendicular had relative more significant changes in the surgical patients due not only to the advancement of A-point but also to the lack of forward growth at N in these nongrowing subjects.

Protraction vs LeFort I maxillary advancement surgery

The surgical sample at the onset had a more retrognathic maxilla than did the protraction group. When comparing the 2 groups at T3 (7 years 6 months for the protraction group and 1 year 5 months for the surgical group), we found that growth played a larger role in the changes in certain measurements in the protraction group than it did in the surgical group.

The cranial base flexure and articulare angle were larger at T1 and at all time intervals in the protraction group, making the mandible more orthognathic.³⁶ These measurements remained stable in the surgical patients, whereas the protraction group showed a continued increase, which could be attributed to the force generated by the chincup portion of the facemask on the mandible as observed by Graber.³⁸ The increase in the cranial base flexure and articulare angle has not been previously reported with facemask treatment.

The longer cranial base due to growth in the surgical group could explain the difference in SNA and A-point–Na perp between the protraction and surgical groups at T1. Although this difference was not significant at the onset, at T2, a significant difference was seen due to the need for more maxillary advancement in the surgical group. At T3, there were no statistically significant differences between the 2 samples due to an insignificant relapse in the surgical group between T2 and T3^{29,30} and the maintenance of the protraction effects in the orthopedic sample. When growth of the cranial base is not considered, the protraction group had a more retrusive maxilla (Co–A-point and S–A-point) than did the surgical group at T1. Both groups had statistically significant differences between T1 and T3 at Co–A-point. There was a statistically significant increase during the 7 years 6 months in the protraction group, showing continued forward movement of 6.47 mm in both Co–A-point and S–A-point. Since S to A-point normally increases 0.8 mm per year (measured along the SA vector),⁴⁵ one could expect an increase of approximately 6.64 mm from normal growth, if the age difference from T1 and T3 was 8.3 years in the protraction group. The results indicated a total of 9.18 mm after 8.3 years, giving an increase of 2.6 mm. Therefore, one could suggest that most of the effects of protraction mechanics were maintained and that continued forward and downward growth of the maxilla occurred in the long term. When we compared our S–A-point results with those of Pangrazio-Kulbersh et al,¹⁹ an identical growth increment of 2.6 mm postprotraction was found.

There was a statistically significant ($P \leq .01$) decrease in overjet in the protraction group between T2 and T3 due to the continued forward growth of the mandible when compared with the surgical group that did not change over time. The protraction group had a total increase in overjet from T1 to T3 of 1.11 mm. There were also significant improvements in molar relationships in both groups (SNpM). In the surgical and protraction groups, the molars moved mesially approximately 5 mm. Since the protraction group had growth remaining, 2.6 mm of the 5 mm movement was due to favorable maxillary anterior displacement (T2-T3). In the surgical patients, the molars moved mesially 4 mm of which 2 mm could be attributed to the forward maxillary repositioning of 6 mm at A-point.

The surgical group had greater changes in ANB angle and the Wits appraisal from T1 to T3 than did the protraction sample. This difference could be explained by the forward growth of the mandible that contributed to the decrease of these measurements over time. Therefore, 0.65° of total increase in the ANB angle and 1.8 mm of increase in the Wits appraisal is of clinical significance, since these measurements remained stable over the long term.

CONCLUSIONS

This 2-part study compared the long-term treatment effects produced by protraction facemask therapy, followed later by a second phase of comprehensive fixed appliance therapy, with untreated Class III controls and with subjects surgically treated with LeFort I maxillary advancement. The investigation demonstrated that:

1. Orthodontic and surgical treatments both produced positive changes in the anteroposterior position of the maxilla, and these changes remained stable over time.
2. Both treatment modalities produced acceptable clinical improvements and stable long-term results.
3. Early treatment with orthopedic forces to advance the maxilla might reduce altogether the need for surgical intervention later. If surgery becomes necessary, it might be restricted to only 1 jaw, thereby minimizing complications and increasing the stability.

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