Original Article

Maxillary incisor inclination of skeletal Class III patients treated with extraction of the upper first premolars and two-jaw surgery

Conventional orthognathic surgery vs surgery-first approach

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ABSTRACT

Objective: To investigate the differences in the amount and pattern of the maxillary incisor (MXI) inclination change in skeletal Class III patients treated with extraction of the maxillary first premolars (MXP1) and two-jaw surgery (TJS) between conventional orthognathic surgery (COS) and surgery-first approach (SFA).

Materials and Methods: The study included 60 skeletal Class III patients who had normal maxillary position, prognathic mandible, and mild crowding in the maxillary arch (≤4 mm). The patients were divided into group 1 (COS, n = 36) and group 2 (SFA, n = 24). Lateral cephalograms were taken before treatment (T0), 1 month before surgery (T1), within 1 month after surgery (T2), and after debonding (T3) for COS patients and at T0, T2, and T3 for SFA patients. After measurement of the skeletodental variables, statistical analyses were performed.

Results: During T0–T2, the amount of MXI inclination change (ΔU1-SN) in group 1 was significantly larger than that in group 2 (−12.8° vs −4.4°; $P < .001$). During T2–T3, ΔU1-SN in groups 1 and 2 occurred in opposite directions (3.8° vs −5.9°; $P < .001$). However, the total amount of ΔU1-SN during T0–T3 was not different between groups 1 and 2 (−9.0° vs −10.3°). At T3 the U1-SN values for groups 1 and 2, respectively, moved closer to normal according to the values of the normal range rate (all 83%), relative percentage ratio (102.4% and 100.1%), and achievement ratio (77.7% and 97.8%).

Conclusions: The results of this study might provide basic data for predicting the amount and pattern of MXI inclination change in SFA for skeletal Class III TJS patients. (*Angle Orthod.* 2014;84:720–729.)

KEY WORDS: Maxillary incisor inclination; Skeletal Class III patients; Extraction of maxillary premolar; Surgery-first approach

INTRODUCTION

The conventional surgical-orthodontic treatment for skeletal Class III patients consists of preoperative orthodontic treatment (Pre-OP-OT), orthognathic surgery, and postoperative orthodontic treatment (Post-OP-OT).[1] Although these treatment procedures generally produce satisfactory results, including appropriate dental decompensation, proper arch coordination, and accurate prediction of surgical result before orthognathic surgery, several disadvantages have been reported,[2–4] including worsening of anterior crossbite and facial profile during Pre-OP-OT and long total treatment time.

Recently, the 'surgery-first approach' (SFA) has been proposed to overcome the disadvantages of conventional surgical-orthodontic treatment procedures.[5,6] This approach has some advantages, such

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Table 1. Demographic Data of the Samples[a]

Variables	Group 1 (n = 36, COS), 16 Males and 20 Females		Group 2 (n = 24, SFA), 8 Males and 16 Females		*P*-Value
	Mean	SD	Mean	SD	
Age, y	22.43	4.37	22.35	4.55	.9535
Duration, mo					
Preoperative orthodontic treatment	17.14	3.77	NA	NA	NA
Postoperative orthodontic treatment	8.17	3.07	20.88	3.85	.0000***
Total treatment	25.31	5.43	20.88	3.85	.0005***
Amount of crowding, mm					
Maxillary arch	−1.71	1.59	−1.92	1.28	.5809
Mandibular arch	−2.72	2.92	−2.09	1.89	.3387

[a] Independent *t*-test was performed to compare the variables between the two groups. Group 1 indicates conventional orthognathic surgery (COS); Group 2, surgery-first approach (SFA); SD, standard deviation; and NA, not applicable.
*** $P < .001$.

as short total treatment duration, early improvement of the facial profile, and establishment of proper maxillomandibular relationship before orthodontic treatment.[2–4,7] The SFA can be performed successfully in cases with well-aligned or mildly crowded anterior teeth, mild to moderate curve of Spee/vertical problem, little or no transverse discrepancy, and normal to mildly proclined/retroclined incisor inclination.[2,4]

Skeletal improvement through orthognathic surgery can be compromised by inadequate preoperative decompensation of the incisors.[3,8,9] Decompensation of the maxillary incisors in skeletal Class III patients can occur either by extraction of the maxillary premolars and space closure during Pre-OP-OT or by nonextraction and superior impaction of the posterior maxilla during orthognathic surgery.[9] However, the SFA for Class III patients has been performed mainly in cases involving nonextraction and superior impaction of the posterior maxilla.[2] This approach might increase the amount of surgery as well

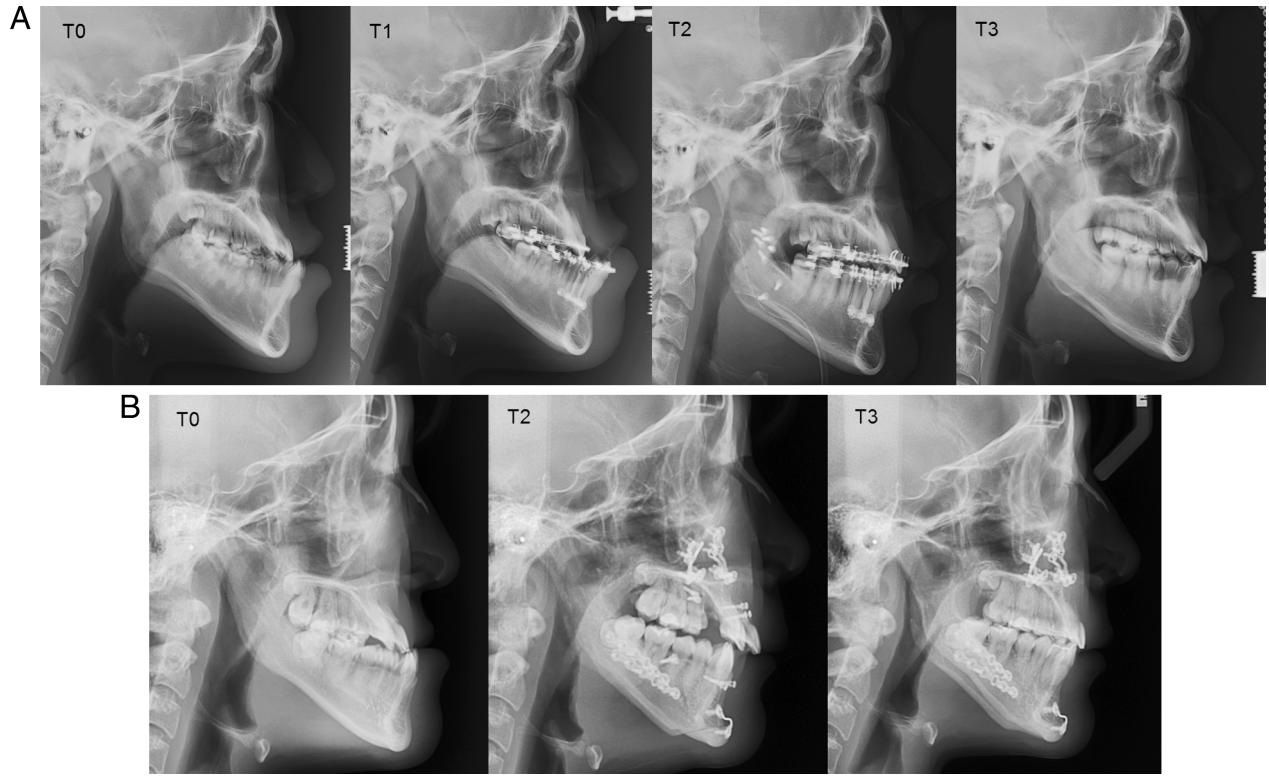

Figure 1. (A) Lateral cephalograms taken before treatment (T0), 1 month before surgery (T1), within 1 month after surgery (T2), and after debonding (T3) for group 1 (conventional orthognathic surgery, COS). (B) Lateral cephalogram at the T0, T2, and T3 stages for group 2 (surgery-first approach, SFA).

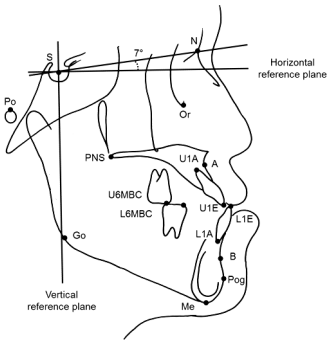

Figure 2. Landmarks and reference planes: S indicates sella; N, nasion; Or, orbitale; Po, porion; A, point A; B, point B; Pog, pogonion; Me, menton; Go, gonion; U1E, the incisal edge of the maxillary central incisor; UIA, the root apex of the maxillary central incisor; LIE, the incisal edge of the mandibular central incisor (LI); LIA, the root apex of the mandibular central incisor; U6MBC, the mesiobuccal cusp tip (MBC) of the maxillary first molar; L6MBC, the MBC of the mandibular first molar; HRP, horizontal reference plane, a horizontal plane angulated 7° clockwise to the SN-line passing through sella; and VRP, vertical reference plane, a perpendicular line to the HRP passing through sella.

as morbidity. Therefore, as an alternative, it is necessary to extract the maxillary premolars during orthognathic surgery and space closure during Post-OP-OT under the SFA concept.

The purpose of this study was to investigate the differences in the amount and pattern of maxillary incisor (MXI) inclination change in skeletal Class III patients treated with extraction of the maxillary first premolars (MXP1) and two-jaw surgery (TJS) between conventional orthognathic surgery (COS) and SFA. The null hypothesis was that there was no difference in the amount and pattern of MXI inclination change between COS and SFA.

MATERIALS AND METHODS

The sample consisted of 60 Korean skeletal Class III patients (24 males and 36 females; mean age = 22.4 ± 4.4 years) who underwent TJS (one-piece LeFort I osteotomy and bilateral sagittal split ramus osteotomy) and orthodontic treatment with MXP1 extraction. This retrospective study was approved by the Institutional Review Board of Seoul National University Dental Hospital (CRI 13007).

The patients were divided into two groups according to surgical-orthodontic treatment concept: group 1 (COS; N = 36; mean age = 22.4 ± 4.4 years) or group 2 (SFA; N = 24; mean age = 22.4 ± 4.6 years) (Table 1). Patients in group 1 were selected from Department of Orthodontics, Seoul National University Dental Hospital; patients in group 2 were selected from a private orthodontic clinic. The mandibular arch was treated with nonextraction in both groups. According to the SFA concept, none of the patients in group 2 received Pre-OP-OT, and the MXP1s were extracted during surgery for all patients in group 2. The total treatment duration for group 2 was significantly shorter than that of group 1 ($P < .001$; Table 1). There was no difference in the amount of crowding in the maxillary and mandibular arches before treatment (Table 1).

Inclusion criteria for both groups were as follows[9,10]: (1) bilateral Class III canine and molar relationships, (2) ANB of 0° or less (relatively normal anteroposterior position of the maxilla combined with a prognathic mandible), (3) lack of severe facial asymmetry (≤3 mm of menton deviation from the facial midline), (4) mild crowding in the maxillary arch (≤4 mm), and (5) growth completion confirmed by cervical vertebral maturation status.[11] Patients with cleft lip/palate or other craniofacial anomalies, missing teeth (except for third molars), and tooth size discrepancy (eg, peg lateralis) were excluded.[9,10,12]

Serial lateral cephalograms were taken during initial examination (T0), 1 month before surgery (T1), within 1 month after surgery (T2), and at debonding (T3) in COS cases (group 1) and at T0, T2, and T3 in SFA cases (group 2) (Figure 1). Definitions of the landmarks, reference planes, and skeletodental variables

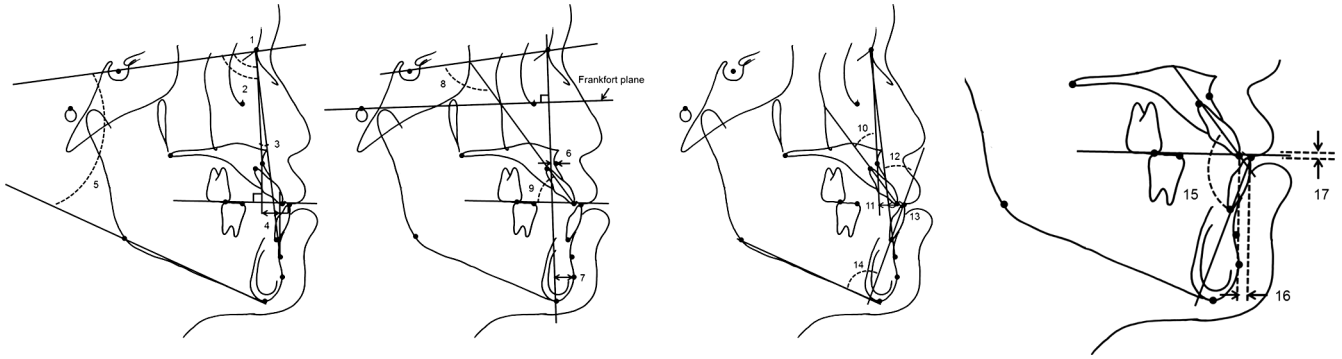

Figure 3. Cephalometric variables. 1. SNA (°); 2. SNB (°); 3. ANB (°); 4. Wits appraisal (mm); 5. SN-GoMe (°); 6. A-N perpendicular (mm); 7. Pog-N perpendicular (mm); 8. U1-SN (°); 9. U1-UOP (°); 10. U1-NA (°); 11. U1-NA (mm); 12. L1-NB (°); 13. L1-NB (mm); 14. IMPA (°); 15. Interincisal angle (°); 16. Overjet (mm); 17. Overbite (mm); U1, long axis of the maxillary central incisor; UOP, the maxillary occlusal plane; and L1, long axis of the mandibular central incisor.

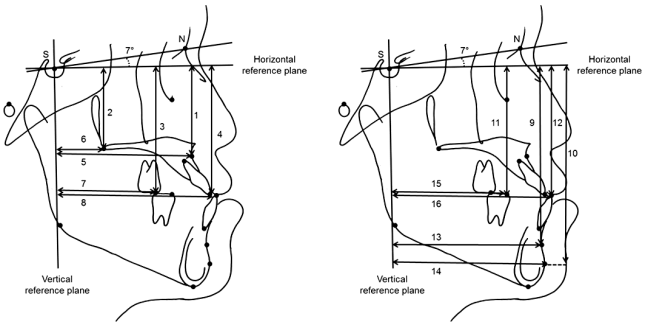

Figure 4. Surgical movement of the maxilla and mandible. 1. A-V (mm), vertical distance from A to HRP; 2. PNS-V (mm), vertical distance from PNS to HRP; 3. U6-V (mm), vertical distance from U6MBC to HRP; 4. UI-V (mm), vertical distance from UIE to HRP; 5. A-H (mm), horizontal distance from A to VRP; 6. PNS-H (mm), horizontal distance from PNS to VRP; 7. U6-H (mm), horizontal distance from U6MBC to VRP; 8. UI-H (mm), horizontal distance from UIE to VRP; 9. B-V (mm), vertical distance from B to HRP; 10. Pog-V (mm), vertical distance from Pog to HRP; 11. L6-V (mm), vertical distance from L6MBC to HRP; 12. LI-V (mm), vertical distance from LIE to HRP; 13. B-H (mm), horizontal distance from B to VRP; 14. Pog-H (mm), horizontal distance from Pog to VRP; 15. L6-H (mm), horizontal distance from L6MBC to VRP; and 16. LI-H (mm), horizontal distance from LIE to VRP.

are illustrated in Figures 2 and 3. Tracing and digitization of the lateral cephalograms were performed by a single operator (HMP) using the V-Ceph program (Version 5.5, CyberMed, Seoul, Korea). To assess the amount of surgical movement of the maxilla and mandible, the horizontal and vertical distances from eight reference points to the vertical and horizontal reference planes were measured (Figure 4). The amount and pattern of MXI inclination change were also measured and analyzed to evaluate the differences between the two groups.

All variables from 20 randomly selected subjects were measured after 2 weeks by the same operator (HMP). Differences calculated using Dahlberg's formula[13] ranged from 0.39 mm to 0.82 mm for the linear measurements and from 0.40° to 0.81° for the angular measurements. Since there were no significant differences between the first and second measurements, the first set of measurements was used.

The power analysis for sample size determination was performed using the Sample Size Determination Program, Version 2.0.1 (Seoul National University Dental Hospital, Registration number 2007-01-122-004453) using the mean and standard deviation values of U1-SN from previous studies.[8–10] The variables at each stage and the amount of change between stages were compared between COS and SFA cases, respectively. In addition, the amount and pattern of decompensation during the Pre-OP-OT and compensation during the Post-OP-OT in group 1 (COS) were compared with simultaneous decompensation and compensation during the Post-OP-OT in group 2 (SFA). Independent *t*-test, one-way analysis of variance with Duncan's multiple comparison test, chi-square test, and binomial test were performed for statistical analysis.

RESULTS

Comparison of the Variables at Each Stage and Within Each Group According to Stages and of the Amount of Change in the Variables Among T0–T2, T2–T3, and T0–T3 Stages

At T0, the two groups did not show significant differences in the values of variables, except in the case of Wits appraisal (Table 2). At T1, group 1 showed significant decompensation of the maxillary and mandibular incisors by Pre-OP-OT (Table 2).

After surgery (T2), group 2 had still more labioversed maxillary incisors and more linguoversed mandibular incisors than did group 1 (ΔU1-SN, ΔU1-UOP, ΔU1-NA angular, ΔU1-NA linear, $P < .001$; ΔL1-NB angular, ΔL1-NB linear, $P < .05$; Table 2). In addition, group 2 had a larger overjet ($P < .001$; Table 2) due to a more posteriorly positioned mandible by overcorrection (SNB, $P < .05$; Table 2).

When comparing the preoperative and surgical changes from T0 to T2, improvements in the intermaxillary relationship (ΔANB, ΔWits appraisal) and the anteroposterior position of the mandible (ΔSNB, ΔPog-N perp) were not significantly different between the two groups (Table 3).

At T3, although there were no significant differences in the dental variables between the two groups, group 2 showed deeper overbite than group 1 ($P < .05$; Table 2). The maxilla and mandible were more backward positioned in group 2 (SNA, SNB, Pog-N perp, all $P < .05$; Table 2).

When comparing the postoperative changes from T2 to T3, group 1 showed less relapse of the intermaxillary relationship than did group 2 (ΔANB, $P < .05$; ΔWits appraisal, $P < .001$; Table 3). Because group 2 showed extraction space closure of the MXP1 and labioversion of the mandibular incisors during Post-OP-OT, groups 1 and 2 showed opposite directions of the inclination change (postoperative compensation) of the maxillary and mandibular incisors (ΔU1-SN, ΔU1-UOP, ΔU1-NA angular, ΔU1-NA linear, ΔL1-NB angular, and ΔIMPA, all $P < .001$; Table 3), resulting in different amounts of change in the overjet (Δoverjet, $P < .001$; Table 3).

Comparing the total amounts of change from T0 to T3, there were no significant differences in dental variables, except for ΔL1-NB linear (Table 3). However, the maxilla of group 2 was more backward positioned than that of group 1 (ΔSNA, ΔA-N perp;

Table 2. Comparison of the Cephalometric Variables at Each Stage and Within Each Group According to Stages[a]

		T0 Stage					T1 Stage					T2 Stage	
		Group 1, COS (n = 36)		Group 2, SFA (n = 24)		*P*-	Group 1, COS (n = 36)		Group 2, SFA (n = 24)		*P*-	Group 1, COS (n = 36)	
Variables	Norm[¶]	Mean	SD	Mean	SD	Value[b]	Mean	SD	Mean	SD	Value[b]	Mean	SD
SNA, °	81.31	82.15	3.33	81.56	3.28	.4960	82.07	3.13	NA	NA	NA	83.05	3.21
SNB, °	78.92	85.71	3.73	83.96	3.57	.0690	85.70	3.88	NA	NA	NA	79.67	3.41
ANB, °	2.62	−3.57	2.30	−2.40	3.12	.1182	−3.63	2.64	NA	NA	NA	3.37	1.77
Wits appraisal, mm	−1.72	−10.85	3.99	−7.64	4.38	.0053**	−11.76	3.68	NA	NA	NA	−2.03	2.84
SN-GoMe, °	33.77	35.31	4.83	36.71	7.48	.4163	35.09	5.09	NA	NA	NA	37.19	4.92
A-N perpendicular, mm	−0.79	1.17	2.91	0.56	3.50	.4742	1.05	2.76	NA	NA	NA	2.21	3.06
Pog-N perpendicular, mm	−2.26	10.22	7.19	7.57	6.91	.1542	10.39	7.44	NA	NA	NA	−0.12	6.61
U1-SN, °	106.55	118.24	5.59	117.25	6.88	.5572	108.29	7.29	NA	NA	NA	105.40	7.00
U1-UOP, °	55.16	48.27	4.96	48.38	6.81	.9425	54.27	6.70	NA	NA	NA	55.60	5.44
U1-NA angular, °	29.07	36.09	4.99	35.70	6.85	.8081	26.22	7.23	NA	NA	NA	22.35	7.04
U1-NA linear, mm	6.32	9.15	2.07	9.06	2.27	.8783	5.27	2.03	NA	NA	NA	4.04	1.82
L1-NB angular, °	25.27	21.96	5.50	23.45	7.29	.3916	26.50	6.37	NA	NA	NA	22.54	5.42
L1-NB linear, mm	6.01	5.94	2.13	6.47	3.45	.5028	7.09	2.28	NA	NA	NA	5.50	2.02
IMPA, °	95.39	80.93	6.38	82.78	8.87	.3762	85.70	6.79	NA	NA	NA	85.68	6.96
Interincisal angle, °	127.09	125.24	7.65	123.70	12.10	.5760	130.92	7.66	NA	NA	NA	131.74	8.50
Overjet, mm	3.55	−1.94	2.65	−0.68	2.60	.0693	−7.03	3.23	NA	NA	NA	3.27	0.88
Overbite, mm	1.52	−0.52	1.75	−0.06	2.51	.4314	0.22	1.93	NA	NA	NA	1.29	0.84

[a] SD indicates standard deviation; NA, not applicable; COS, conventional orthognathic surgery; and SFA, surgery-first approach. The ethnic norms (¶) are cited from Kim and Baek,[9] Baek and Yang,[15] and Choi et al.[16]

[b] Independent *t*-test was performed to compare the variables between the two groups at each stage.

[c] One-way analysis of variance (ANOVA) test was performed to compare the variables among stages in each group and the results were verified with Duncan's multiple comparison test. For multiple comparisons at each stage, a indicates T0 stage; b, T1 stage; c, T2 stage; and d, T3 stage.

* $P < .05$; ** $P < .01$; *** $P < .001$.

all $P < .01$; ΔWits appraisal, $P < .001$; Table 3). Changes in the MXI inclination had a different pattern between the two groups, as follows: group 1 showed that U1-SN and U1-NA angular decreased by both Pre-OP-OT and surgery and increased by Post-OP-OT (T3 < [T2,T4] < T0, all $P < .001$; Table 2; Figure 5A). However, group 2 showed gradual decreases in U1-SN and U1-NA angular by both surgery and extraction space closure during Post-OP-OT (T3 < T2 < T0, all $P < .001$; Table 2; Figure 5A).

The mandibular incisor inclination of group 1 at T3 was not improved compared to T0 (IMPA, [T0,T3] < [T1,T2], $P < .01$; Table 2). Similarly, group 2 did not show a significant change in IMPA from T0 to T3 stages (Table 2).

Comparison of the Amounts of Surgical Movement of the Maxilla and Mandible (Table 4)

Group 2 showed less advancement (ΔPNS-H, $P < .001$; ΔU6-H and ΔU1-H, $P < .01$; ΔA-H, $P < .05$) and more superior impaction of the maxilla (ΔA-V, $P < .01$; ΔU6-V, $P < .05$) than group 1. Although the amounts of the mandibular setback were not different between the two groups, group 2 showed more superior movement of the mandible (ΔB-V, $P < .001$; ΔL6-V, $P < .01$; ΔPog-V and ΔL1-V, $P < .05$).

Distribution of Samples According to MXI Inclination in Each Group and Between Groups at the T0, T1, T2, and T3 Stages (Table 5)

At T0, groups 1 and 2 had lower values of the normal range rate (NRR) for U1-SN. In group 1, NRR for U1-SN sequentially increased by Pre-OP-OT and superior impaction of the posterior maxilla during surgery; then it decreased slightly by Post-OP-OT. On the other hand, group 2 showed a sequential increase in NRR for U1-SN by superior impaction of the posterior maxilla during surgery and extraction space closure of MXP1 during Post-OP-OT. Although the level of contribution to U1-SN normalization by orthodontic treatment and surgery was slightly different between the two groups, NRRs for U1-SN at T3 were not significantly different between the two groups (all 83%; Figure 5).

Relative Percentage Ratio (Table 6)

In group 1, U1-SN mainly came close to the ethnic norm by Pre-OP-OT, was slightly overcorrected by surgery, and was then labially compensated by Post-OP-OT. In group 2, U1-SN was sequentially normalized into the ethnic norm by both surgery and Post-OP-OT. However, there was no significant difference in the relative percentage ratio (RPR) for U1-SN at T3

Table 2. Extended.

T2 Stage			T3 Stage					Comparison According to Stages Within Each Group			
Group 2, SFA (n = 24)		*P*-Value[b]	Group 1, COS (n = 36)		Group 2, SFA (n = 24)			Group 1, COS (n = 36)		Group 2, SFA (n = 24)	
Mean	SD		Mean	SD	Mean	SD	*P*-Value[b]	*P*-Value[c]	Multiple Comparison	*P*-Value[c]	Multiple Comparison
81.71	2.90	.0962	83.06	3.15	80.85	3.61	.0169*	0.3753		.6125	
77.62	3.00	.0162*	80.83	3.40	78.55	3.37	.0126*	0.0000***	(c,d) < (a,b)	.0000***	(d,c) < a
4.09	2.02	.1600	2.23	2.19	2.30	2.18	.9113	0.0000***	(a,b) < d<c	.0000***	a < d < c
0.70	4.24	.0077**	−2.72	2.91	−3.29	3.82	.5322	0.0000***	(a,b) < (c,d)	.0000***	a < d < c
38.60	5.93	.3340	38.23	5.21	39.12	6.85	.5871	0.0232*	(a,b) < (c,d)	.3778	
0.59	3.78	.0822	2.02	2.73	−0.31	3.26	.0053	0.2130		.5922	
−3.29	6.08	.0590	1.66	6.68	−1.62	5.09	.0347*	0.0339	(c,d) < (a,b)	.0000***	(c,d) < a
112.91	6.90	.0001***	109.20	6.65	106.72	7.40	.1873	0.0000***	c < (b,d) < a	.0000***	d < c < a
48.65	3.97	.0000***	52.60	5.43	50.97	4.33	.2003	0.0000***	a < d < (b,c)	.1751	
31.20	6.91	.0000***	26.11	6.89	25.87	7.59	.9023	0.0000***	c < (d,b) < a	.0001***	d < c < a
6.91	2.94	.0001***	5.20	2.20	4.83	2.27	.5287	0.0000***	c < (d,b) < a	.0000***	d < c < a
18.39	6.38	.0108*	20.92	5.30	22.47	5.49	.2755	0.0003***	(a,d,c) < b	.0295*	c < (d,a)
4.19	2.46	.0327*	5.47	1.87	4.82	2.33	.2486	0.0034**	(d,c,a) < b	.0258*	c < (d,a)
82.16	8.60	.0972	81.86	7.19	84.81	7.19	.1220	0.0031**	(a,d) < (c,b)	.5772	
126.46	10.58	.0441*	130.82	7.93	129.52	5.72	.4592	0.0023**	a < (d,b,c)	.1598	
9.25	2.30	.0000***	2.91	0.73	3.14	0.95	.3163	0.0000***	b < a < (d,c)	.0000***	a < d < c
2.09	1.79	.0456*	1.60	0.82	2.15	0.84	.0128*	0.0000***	a < b < (c,d)	.0001***	a < (c,d)

between groups 1 and 2 (102.4% and 100.1%, respectively).

Achievement Ratio (Table 6)

The achievement ratio (AR) showed similar patterns of changes in RPR. Group 1 had the same direction of change in U1-SN during Pre-OP-OT and surgery and the opposite directional change in U1-SN during Post-OP-OT, resulting in 77.7% of total AR. However, group 2 exhibited the same direction of change in U1-SN during surgery and Post-OP-OT, resulting in 97.8% of the total AR.

Table 3. Comparison of the Amounts of Change in the Variables Between the T0–T2, T2–T3, and T0–T3 Stages[a]

	To-T2 Stage					T2–T3 Stage					T0–T3 Stage				
	Group 1, COS (n = 36)		Group 2, SFA (n = 24)			Group 1, COS (n = 36)		Group 2, SFA (n = 2 4)			Group 1, COS (n = 36)		Group 2, SFA (n = 24)		
Variables	Mean	SD	Mean	SD	*P*-Value	Mean	SD	Mean	SD	*P*-Value	Mean	SD	Mean	SD	*P*-Value
ΔSNA, °	0.90	2.04	0.22	2.32	.2515	0.01	1.38	−0.90	1.83	.0428	0.91	1.94	−0.68	2.06	.0043**
ΔSNB, °	−6.04	1.97	−6.37	2.02	.5325	1.15	1.07	0.92	1.66	.5532	−4.89	1.71	−5.45	2.12	.2843
ΔANB, °	6.94	2.05	6.60	2.42	.5701	−1.14	1.08	−1.83	1.24	.0320*	5.80	2.04	4.77	2.48	.0979
ΔWits appraisal, mm	8.82	4.05	8.44	2.62	.1486	−0.69	2.42	−3.77	3.52	.0003***	8.13	3.40	4.66	4.09	.0007***
ΔSN-GoMe, °	1.88	3.30	2.12	4.98	.8339	1.04	1.83	0.47	2.71	.3756	2.92	4.07	2.60	4.81	.7892
ΔA-N perpendicular, mm	1.04	2.55	0.09	2.84	.1537	−0.19	1.19	−0.95	2.31	.1608	0.85	1.99	−0.85	2.72	.0091**
ΔPog-N perpendicular, mm	−10.34	4.24	−10.98	6.40	.7844	1.78	2.21	1.65	4.41	.9042	−8.56	3.27	−9.32	5.17	.5871
ΔU1-SN, °	−12.84	5.73	−4.43	3.53	.0000***	3.80	3.22	−5.89	8.30	.0000***	−9.04	5.86	−10.32	7.58	.4880
ΔU1-UOP, °	7.34	5.77	0.35	5.87	.0000***	−3.01	3.55	2.31	4.69	.0000***	4.33	4.80	2.66	7.01	.3137
ΔU1-NA angular, °	−13.74	6.58	−4.66	3.83	.0000***	3.76	3.64	−4.98	8.11	.0000***	−9.98	6.54	−9.64	7.74	.8611
ΔU1-NA linear, mm	−5.11	2.77	−2.25	2.51	.0000***	1.16	1.51	−1.93	2.94	.0000***	−3.95	2.80	−4.18	4.21	.6740
ΔL1-NB angular, °	0.58	5.47	−4.88	4.21	.0001***	−1.62	2.58	3.84	5.39	.0001***	−1.04	5.15	−1.05	5.67	.9948
ΔL1-NB linear, mm	−0.44	1.51	−2.16	1.84	.0006***	−0.03	0.58	0.53	1.60	.0644	−0.47	1.46	−1.63	1.98	.0135*
ΔIMPA, °	4.75	6.76	−0.64	4.44	.0004***	−3.81	2.92	2.44	5.02	.0000***	0.93	6.58	1.81	7.26	.6378
ΔInterincisal angle, °	6.49	9.01	2.62	3.82	.0265*	−0.91	3.51	3.00	8.58	.0429*	5.58	9.14	5.63	10.17	.9848
ΔOverjet, mm	5.21	2.89	9.91	2.85	.0000***	−0.36	0.82	−5.96	2.42	.0000***	4.85	2.75	3.95	2.61	.1454
ΔOverbite, mm	1.81	1.83	2.14	2.77	.8219	0.30	0.99	0.08	1.82	.5391	2.11	1.75	2.22	2.59	.8694

[a] Independent *t*-test was performed to compare the variables between the two groups during T0–T2, T2–T3, and T0–T3 stage, respectively. SD indicates standard deviation; COS, conventional orthognathic surgery; and SFA, surgery-first approach.

* $P < .05$; ** $P < .01$; *** $P < .001$.

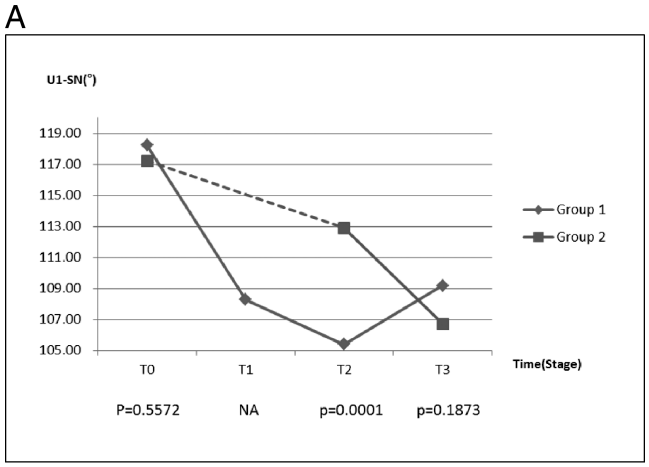

Figure 5. Comparison of the changing pattern between the two groups. (A) The maxillary incisor inclination (U1-SN). (B) Normal range rate (NRR).

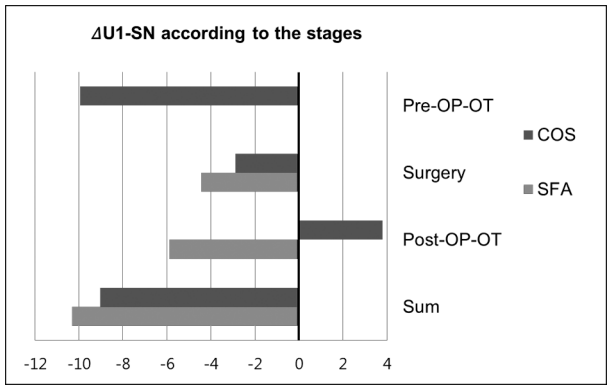

Figure 6. The amounts of inclination change in the U1-SN between the two groups.

DISCUSSION

Although several previous studies[3,8,9] have reported on the inclination change of MXI during surgical-orthodontic treatment of skeletal Class III patients, these studies have compared the inclination change of MXI between COS and orthodontic camouflage, between COS and SFA with nonextraction cases, or between extraction and nonextraction of MXP1 cases only in COS. On the contrary, this study was designed to compare the inclination change of MXI between COS and SFA with MXP1 extraction cases.

After Pre-OP-OT in group 1, the U1-SN values decreased by about 10° and came close to normal range (Tables 3, 5, and 6). This finding was similar to the result of Kim and Baek.[9] Similar patterns of change in both groups were observed in NRR, RPR, and AR (Tables 5 and 6). Our findings for group 1 also agree with those of Kim and Baek,[9] who reported that Pre-OP-OT played an important role in the normalization of MXI inclination compared to surgical impaction of the posterior maxilla and that a 48% of achievement ratio was decreased during Post-OP-OT. In group 2, sequentially normalizing pattern of change by surgery and Post-OP-OT allowed for the avoidance of opposite directional changes in U1-SN that occurred during Post-OP-OT in group 1. These findings are in accordance with those of Ko et al.,[3] who reported that patients treated with COS exhibited a round-tripping movement in the maxillary and mandibular incisors.

When we compared total changes during T0–T3, there was no significant difference in terms of the MXI inclination between the two groups (Table 3). This finding disagrees with that of Ko et al.,[3] who reported that MXI inclination after treatment was different between COS and SFA (5.4° in SFA, −1.8° in COS, $P < .01$). Since they did not define the amount of crowding before treatment and also did not distinguish MXP1 extraction cases from nonextraction cases in the COS group,[3] the amounts of MXI inclination change could be different from those of this study.

Although there was no significant difference in the anteroposterior and vertical skeletal variables between the two groups at T0 (Table 2), surgical movements of the maxilla in group 2 exhibited less advancement and more superior impaction of the posterior maxilla compared to group 1 (Table 4). Therefore, changes in the sagittal position of the maxilla during T0–T3 were different between the two groups (ΔSNA, ΔA-N perp, all $P < .01$; Table 3). Also, since group 2 requires the improvement of MXI inclination by surgery, significant superior impaction of the posterior maxilla was performed in group 2. This finding also agrees with that of Baek et al.,[2] who reported that the MXI were significantly lingually inclined as a result of superior impaction of the posterior maxilla after surgery.

Table 4. Comparison of the Amounts of Surgical Movement of the Maxilla and Mandible[a]

	Group 1, COS (n = 36)		Group 2, SFA (n = 24)		
	Mean	SD	Mean	SD	*P*-Value
Anteroposterior movement, mm					
Maxilla					
ΔA-H	1.43	1.99	0.07	2.39	.0238*
ΔPNS-H	2.28	2.70	−0.58	2.30	.0000***
ΔU6-H	0.75	2.18	−1.08	2.40	.0038**
ΔUI-H	0.42	2.07	−1.67	2.68	.0021**
Mandible					
ΔB-H	−10.57	3.41	−11.38	3.60	.3783
ΔPog-H	−10.38	3.69	−10.73	4.98	.7642
ΔL6-H	−9.22	3.18	−11.03	3.68	.0524
ΔLI-H	−9.79	3.22	−11.20	3.67	.1258
Vertical movement, mm					
Maxilla					
ΔA-V	−0.41	1.54	−1.63	1.79	.0079**
ΔPNS-V	−3.02	1.90	−4.13	2.47	.0665
ΔU6-V	−1.35	1.49	−2.63	2.31	.0187*
ΔUI-V	0.28	1.79	−0.78	2.24	.0557
Mandible					
ΔB-V	0.22	3.18	−3.87	4.38	.0003***
ΔPog-V	−1.76	3.57	−4.26	4.07	.0167*
ΔL6-V	−1.94	2.02	−3.48	2.20	.0077**
ΔLI-V	−1.21	2.86	−3.20	3.39	.0205*

[a] Independent *t*-test was performed to compare the variables between the two groups. For the anteroposterior movement: (−) indicates setback; (+), advancement. For the vertical movement: (−) indicates superior impaction; (+), elongation. SD indicates standard deviation; COS, conventional orthognathic surgery; and SFA, surgery-first approach.

* $P < .05$; ** $P < .01$; *** $P < .001$.

The total amount of ΔU1-SN in group 1 (−9.0°; Pre-OP-OT, −10.0°; surgery, −2.9°; and Post-OP-OT, 3.8°) nearly coincided with that of ΔU1-SN in group 2 (−10.3°; surgery, −4.4°; and Post-OP-OT, −5.9°) (Table 3; Figure 6). These findings suggest that inclination change of MXI during Post-OP-OT in SFA is due to the combination of extraction space closure of the MXP1 and compensation of the MXI inclination to maintain normal overjet and overbite while skeletal relapse occurred during Post-OP-OT. Therefore, surgical treatment objective (STO) and model surgery in SFA cases have to reflect the amounts of expected inclination change in MXI after surgery.[14] In addition, the amounts of superior impaction of the posterior

Table 5. Distribution of Samples According to Upper Incisor Inclination in Each Group and Between the Two Groups at the T0, T1, T2, and T3 Stages[a]

	Distribution at T0 Stage		Distribution at T1 Stage		Distribution at T2 Stage		Distribution at T3 Stage	
U1-SN, °	Group 1, COS (n = 36)	Group 2, SFA (n = 24)	Group 1, COS (n = 36)	Group 2, SFA (n = 24)	Group 1, COS (n = 36)	Group 2, SFA (n = 24)	Group 1, COS (n = 36)	Group 2, SFA (n = 24)
Normal range (less than ±10° compared to norm)	13	10	28	NA	31	16	30	20
Beyond normal range (more than ±10° compared to norm)	23	14	8	NA	5	8	6	4
P-value[b]	.1325	.5413	.0012**	NA	.0000***	.1516	.0001***	.0003***
Normal range rate, %	36	42	78	NA	86	67	83	83
P-value[c]	.6672		NA		.076		1.000	

[a] NA indicates not applicable; COS, conventional orthognathic surgery; and SFA, surgery-first approach.

[b] Binomial test was performed to analyze the distribution of groups 1 and 2.

Normal range indicates the U1-SN value less than ±10° compared to the ethnic norm.[9,15,16]

Normal range rate, [(the number of subjects who were within normal range/total number of sample in each group) × 100].

[c] Chi-square test was performed to analyze the difference in distribution between two groups.

** $P < .01$; *** $P < .001$.

Table 6. Efficacy in Terms of Relative Percentage Ratio and Achievement Ratio of the Maxillary Incisor (MXI) Inclination[a]

	Group 1, COS (n = 36)		Group 2, SFA (n = 24)		
	Mean	SD	Mean	SD	*P*-Value
Relative percentage ratio, %					
T0	110.92	5.25	109.99	6.46	.5228
T1	101.59	6.84	NA	NA	NA
T2	98.87	6.56	105.92	6.47	.0002***
T3	102.44	6.24	100.11	6.95	.2122
Achievement ratio, %					
Preoperative decompensation	85.79	85.88	NA	NA	NA
Surgical	28.02	52.58	41.93	35.12	.2783
Postoperative compensation	−36.16	42.63	55.88	72.89	.0001***
Total	77.65	57.35	97.81	79.61	.3561

[a] Independent *t*-test was performed to compare the variables between the two groups. SD indicates standard deviation; NA, not applicable; COS, conventional orthognathic surgery; and SFA, surgery-first approach. Relative percentage ratio to the ethnic norm of U1-SN (106.6°)[9,15,16] means (actual value of U1-SN/106.6°) × 100. For the achievement ratio, preoperative decompensation achievement ratio indicates (actual amount of preoperative orthodontic movement/expected amount of changes in U1-SN for surgical treatment objective [STO]) × 100; Surgical achievement ratio, (the amount of changes in U1-SN by surgical movement of the maxilla/expected amount of changes in U1-SN for STO) × 100; Postoperative compensation achievement ratio, (actual amount of postoperative orthodontic movement/expected amount of changes in U1-SN for STO) × 100; Total achievement ratio, (actual amount of changes in U1-SN with orthodontic treatment/expected amount of changes in U1-SN for STO) × 100.

*** $P < .001$.

maxilla should be determined according to the MXI inclination and the amount of crowding in the maxillary arch before treatment.[15] Postoperative visual treatment objective (VTO) representing the expected outcome after treatment also needs to contain these findings.[16] Therefore, accurate STO and postoperative VTO for changes in the MXI inclination are crucial in SFA.

This study focused on the inclination change of the maxillary incisors during surgical-orthodontic treatment. However, further studies with follow-up data and categorized surgical movement of the maxilla (amounts and direction) are needed to investigate the long-term stability of SFA.

CONCLUSIONS

- The null hypothesis was rejected.
- The results of this study might provide basic data for predicting the amount and pattern of MXI inclination change in SFA for skeletal Class III TJS patients.

REFERENCES

1. Bell WH, Creekmore TD. Surgical-orthodontic correction of mandibular prognathism. *Am J Orthod*. 1973;63:256–270.
2. Baek SH, Ahn HW, Kwon YH, Choi JY. Surgery-first approach in skeletal Class III malocclusion treated with 2-jaw surgery: evaluation of surgical movement and postoperative orthodontic treatment. *J Craniofac Surg*. 2010;21:332–338.
3. Ko EW, Hsu SS, Hsieh HY, Wang YC, Huang CS, Chen YR. Comparison of progressive cephalometric changes and postsurgical stability of skeletal Class III correction with and without presurgical orthodontic treatment. *J Oral Maxillofac Surg*. 2011;69:1469–1477.
4. Liou EJ, Chen PH, Wang YC, Yu CC, Huang CS, Chen YR. Surgery-first accelerated orthognathic surgery: orthodontic guidelines and setup for model surgery. *J Oral Maxillofac Surg*. 2011;69:771–780.
5. Hong KG, Lee JG. 2-phase treatment without preoperative orthodontics in skeletal Class III malocclusion. *J Korean Assoc Oral Maxillofac Surg*. 1999;25:48–53.
6. Nagasaka H, Sugawara J, Kawamura H, Nanda R. "Surgery first" skeletal Class III correction using the Skeletal Anchorage System. *J Clin Orthod*. 2009;43:97–105.
7. Liao YF, Chiu YT, Huang CS, Ko EW, Chen YR. Presurgical orthodontics versus no presurgical orthodontics: treatment outcome of surgical-orthodontic correction for skeletal Class III open bite. *Plast Reconstr Surg*. 2010;126:2074–2083.
8. Troy BA, Shanker S, Fields HW, Vig K, Johnston W. Comparison of incisor inclination in patients with Class III malocclusion treated with orthognathic surgery or orthodontic camouflage. *Am J Orthod Dentofacial Orthop*. 2009;135:146.e1–146.e9.
9. Kim DK, Baek SH. Change in maxillary incisor inclination during surgical-orthodontic treatment of skeletal Class III malocclusion: comparison of extraction and nonextraction of the maxillary first premolars. *Am J Orthod Dentofacial Orthop*. 2013;143:324–335.
10. Ahn HW, Baek SH. Skeletal anteroposterior discrepancy and vertical type effects on lower incisor preoperative decompensation and postoperative compensation in skeletal Class III patients. *Angle Orthod*. 2011;81:64–74.
11. Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. *Am J Orthod Dentofacial Orthop*. 1995;107:58–66.
12. Johnston C, Burden D, Kennedy D, Harradine N, Stevenson M. Class III surgical-orthodontic treatment: a cephalometric study. *Am J Orthod Dentofacial Orthop*. 2006;130:300–309.
13. Dahlburg G. *Statistical Methods for Medical and Biological Students*. New York, NY: Interscience Publication; 1940.

14. Oh JY, Park JW, Baek SH. Surgery-first approach in Class III open-bite. *J Craniofac Surg*. 2012;23:e283–e287.
15. Baek SH, Yang WS. A soft tissue analysis on facial esthetics of Korean young adults. *Korean J Orthod*. 1991;21:131–170.
16. Choi B, Baek SH, Yang WS, Kim S. Assessment of the relationships among posture, maxillomandibular denture complex, and soft tissue profile of aesthetic adult Korean women. *J Craniofac Surg*. 2000;11:586–594.