Original Article

Skeletal anteroposterior discrepancy and vertical type effects on lower incisor preoperative decompensation and postoperative compensation in skeletal Class III patients

Hyo-Won Ahn[a]; Seung-Hak Baek[b]

ABSTRACT

Objective: To determine the initial compensation, preoperative decompensation, and postoperative compensation of the lower incisors according to the skeletal anteroposterior discrepancy and vertical type in skeletal Class III patients.

Materials and Methods: The samples consisted of 68 skeletal Class III patients treated with two-jaw surgery and orthodontic treatment. Lateral cephalograms were taken before preoperative orthodontic treatment (T0) and before surgery (T1) and after debonding (T2). According to skeletal anteroposterior discrepancy/vertical type (ANB, criteria = -4°; SN-GoMe, criteria = 35°) at the T0 stage, the samples were allocated into group 1 (severe anteroposterior discrepancy/hypodivergent vertical type, N = 17), group 2 (moderate anteroposterior discrepancy/hypodivergent vertical type, N = 17), group 3 (severe anteroposterior discrepancy/hyperdivergent vertical type, N = 17), or group 4 (moderate anteroposterior discrepancy/hyperdivergent vertical type, N = 17). After measurement of variables, one-way analysis of variance with Duncan's multiple comparison test, crosstab analysis, and Pearson correlation analysis were performed.

Results: At T0, groups 3 and 2 exhibited the most and least compensated lower incisors. In group 2, good preoperative decompensation and considerable postoperative compensation resulted in different values for T0, T1, and T2 (IMPA, T0 < T2 < T1; $P < .001$). However, group 3 did not show significant changes in IMPA between stages. Therefore, groups 2 and 3 showed different decompensation achievement ratios ($P < .05$). Group 3 exhibited the worst ratios of decompensation and stability (24% and 6%, respectively, $P < .001$). Anteroposterior discrepancy/vertical type (ANB: $P < .01$ at T0 and T1, $P < .001$ at T2; SN-GoMe: $P < .01$, all stages) were strongly correlated with relative percentage ratio of IMPA to norm value.

Conclusions: Skeletal anteroposterior discrepancy/vertical type results in differences in the amount and pattern of initial compensation, preoperative decompensation, and postoperative compensation of lower incisors in Class III patients. (*Angle Orthod.* 2011;81:64–74.)

KEY WORDS: Preoperative decompensation; Postoperative compensation; Lower incisors; Skeletal Class III patients; Anteroposterior discrepancy; Vertical type

INTRODUCTION

Since Class III (CIII) patients have various skeletal anteroposterior discrepancy and vertical types (APD/VTs),[1–5] the upper and lower incisors demonstrate a diverse dentoalveolar compensation in order to maintain their occlusal function and to mask the underlying skeletal APD/VT.[2,6–9] The surgical-orthodontic approaches to skeletal CIII patients include preoperative orthodontic treatment to decompensate the malocclusion, followed by surgical correction of the skeletal discrepancy, and postoperative compensation for detailing of the occlusion.

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Table 1. Demographic Data and Criterion for Subgroups[a]

Variables	Group 1 (S-Hypo, N = 17)		Group 2 (M-Hypo, N = 17)		Group 3 (S-Hyper, N = 17)		Group 4 (M-Hyper, N = 17)		*P*-Value	Multiple Comparison
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Age, y	19.85	6.43	21.20	2.27	23.23	7.42	22.35	3.54	.2910	
Duration, mo										
Preoperative orthodontic treatment	16.41	6.89	14.35	4.72	13.53	4.77	14.00	5.89	.4648	
Postoperative orthodontic treatment	9.76	5.03	8.59	3.28	8.94	2.38	8.82	3.81	.8135	
Total treatment	26.18	9.06	22.94	5.94	22.47	6.43	22.82	6.91	.4067	
Crowding, mm										
Upper arch	−1.88	2.71	−2.89	5.24	−2.60	2.46	−1.54	1.66	.6123	
Lower arch	−2.21	2.14	−2.71	2.82	−2.40	2.75	−2.49	2.39	.9517	
Skeletal										
Anteroposterior discrepancy, ANB, °	−5.97	1.76	−1.75	1.45	−5.53	1.02	−0.92	1.38	.0000***	(groups 1, 3) < (groups 2, 4)
Vertical type, SN-GoMe, °	29.71	4.54	30.26	3.53	38.90	4.79	40.53	2.66	.0000***	(groups 1, 2) < (groups 3, 4)

[a] One-way analysis of variance (ANOVA) test and Duncan's multiple comparison test were done. SD indicates standard deviation; *** $P < .001$; Group 1, S-Hypo (severe anteroposterior [AP] discrepancy and hypodivergent type; ANB < −4°; SN-GoMe < 35°); group 2, M-Hypo (moderate AP discrepancy and hypodivergent type; ANB > −4°; SN-GoMe < 35°); group 3, S-Hyper (severe AP discrepancy and hyperdivergent type; ANB < −4°; SN-GoMe > 35°); and group 4, M-Hyper (moderate AP discrepancy and hyperdivergent type; ANB > −4°; SN-GoMe > 35°).

With regard to skeletal APD, Johnston et al.[10] reported that incisor decompensation was incomplete in 46% of CIII surgical-orthodontic patients and that only 40% of those patients had a normal ANB angle, and 52% still had an excessive SNB angle after treatment. If preoperative incisor decompensation (Pre-DC) is inadequate, the quality and quantity of the surgical outcome and postoperative incisor compensation (Post-C) can be compromised.[11]

With regard to skeletal VT, Capelozza Filho et al.[12] reported the existence of a correlation among the amount of incisor decompensation, mandibular setback surgery, postoperative mandibular excess, and lower anterior facial height. In addition, a thin alveolus, frequently encountered in patients with long lower facial height and skeletal CIII malocclusion,[13,14] can be regarded as an orthodontic wall that can affect the initial compensation (IC) as well as the Pre-DC and Post-C. Therefore, it is necessary to verify the correlation among IC, Pre-DC, Post-C, and VT.

A realistic prediction of orthodontic tooth movement is essential to an accurate surgical treatment objective (STO). Therefore, clinicians should understand the envelope of the lower incisors (LI) movement for Pre-DC and Post-C in skeletal CIII patients. However, to the authors' knowledge, there have been few studies that have compared the dental and skeletal changes in CIII patients treated with surgical-orthodontic therapy according to skeletal APD/VT in the same ethnic group. The purpose of this study was to investigate the amount and pattern of IC, Pre-DC, and Post-C of LI according to the skeletal APD/VT in skeletal CIII patients. The null hypothesis was that skeletal APD/VT results in no difference in the amount and pattern of the IC, Pre-DC, and Post-C of LI in skeletal CIII patients.

MATERIALS AND METHODS

The samples comprised 68 skeletal CIII patients (mean age = 21.7 ± 5.4 years; 39 males and 29 females; SNA = 82.2° ± 3.6°; SNB = 85.7° ± 4.1°) treated with two-jaw surgery (LeFort I osteotomy and BSSRO (Bilateral saggital split ramus osteotomy)) and orthodontics (33 premolar extraction and 35 nonextraction orthodontic treatments in the upper arch; nonextraction treatments in the lower arch). This retrospective study was performed under the approval of the institutional review board of Seoul National University Dental Hospital (CRI10008).

Inclusion criteria were as follows: bilateral CIII molar relationship; ANB of less than 0° (relatively normal maxillary position combined with mandibular excess to confine skeletal APD into the mandible); lack of severe facial asymmetry (less than 3 mm of chin point deviation from the facial midline);[15] growth completion confirmed by cervical vertebral maturation status;[16] crowding in the lower arch of less than 3 mm; bracket prescription with 0.022-inch straight-wire appliance of Roth setup and fully bonded to the second molars; final archwire with 0.019 × 0.025 stainless-steel wire; and no use of Class II elastics for decompensation (Table 1).

Exclusion criteria were cleft lip/palate or other craniofacial syndrome patients, missing teeth (except for the third molars), a greater than 3-mm difference in

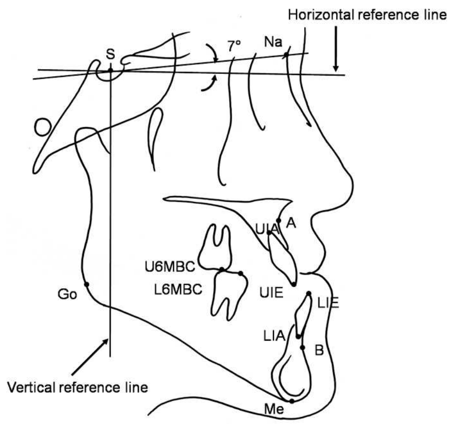

Figure 1. Reference planes and landmarks. S indicates sella; N, nasion; A, point A; B, point B; Me, menton; Go, gonion; UIE, incisal edge of the upper central incisor (UI); UIA, root apex of UI; LIE, incisal edge of the lower central incisor (LI); LIA, root apex of LI; U6MBC, mesiobuccal cusp tip (MBC) of the upper first molar; L6MBC, MBC of the lower first molar; HRL (horizontal reference line), a horizontal line angulated 7° clockwise to the SN line passing through sella; and Vertical reference line, a perpendicular line to the HRL passing through the sella.

the amount of mandibular setback between the left and right sides, spacing, or tooth size anomaly.

Lateral cephalograms were taken before preoperative orthodontic treatment (T0), 1 month before surgery (T1), and after debonding (T2). In order to exclude the influences of genioplasty or gonial reduction, the postoperative mandibular plane at T2 stage was superimposed with T0 and T1 tracings using the inner cortical outline of the upper symphysis, the inferior alveolar canal, and the intact inferior mandibular border.

Definitions for the landmarks, reference planes, and skeletal, dental, and alveolar variables are illustrated in Figures 1 and 2. Cephalometric measurements were performed by a single operator using the V-Ceph program (Version 5.5, CyberMed, Seoul, Korea).

The samples were allocated into four groups according to APD (criteria = ANB) and VT (criteria = SN-GoMe) at the T0 stage: group 1 (severe APD and hypodivergent VT, ANB $< -4°$; SN-GoMe $< 35°$, N = 17; Figure 3A), group 2 (moderate APD and hypodi-

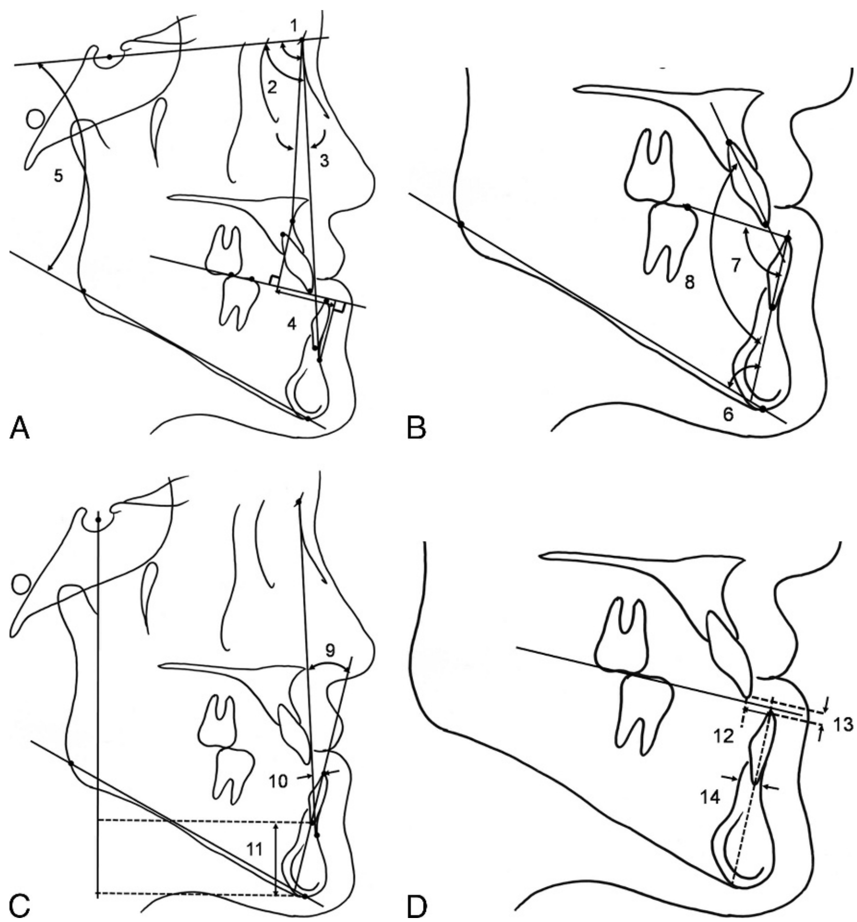

Figure 2. Cephalometric variables. A. 1. SNA; 2. SNB; 3. ANB; 4. Wits appraisal; 5. SN-GoMe; B. 6. IMPA; 7. L1-LOP (an angle formed by the lower occlusal plane and the long axis of LI); 8. Interincisal angle; C. 9. L1-NB (°); 10. L1-NB (mm); 11. L1-MP (the distance from the LI root apex to the menton parallel to the vertical reference plane); D. 12. Overjet; 13. Overbite; 14. Lower alveolar width (LAW; length of the line perpendicular to the long axis of L1 intersected with symphysis contour).

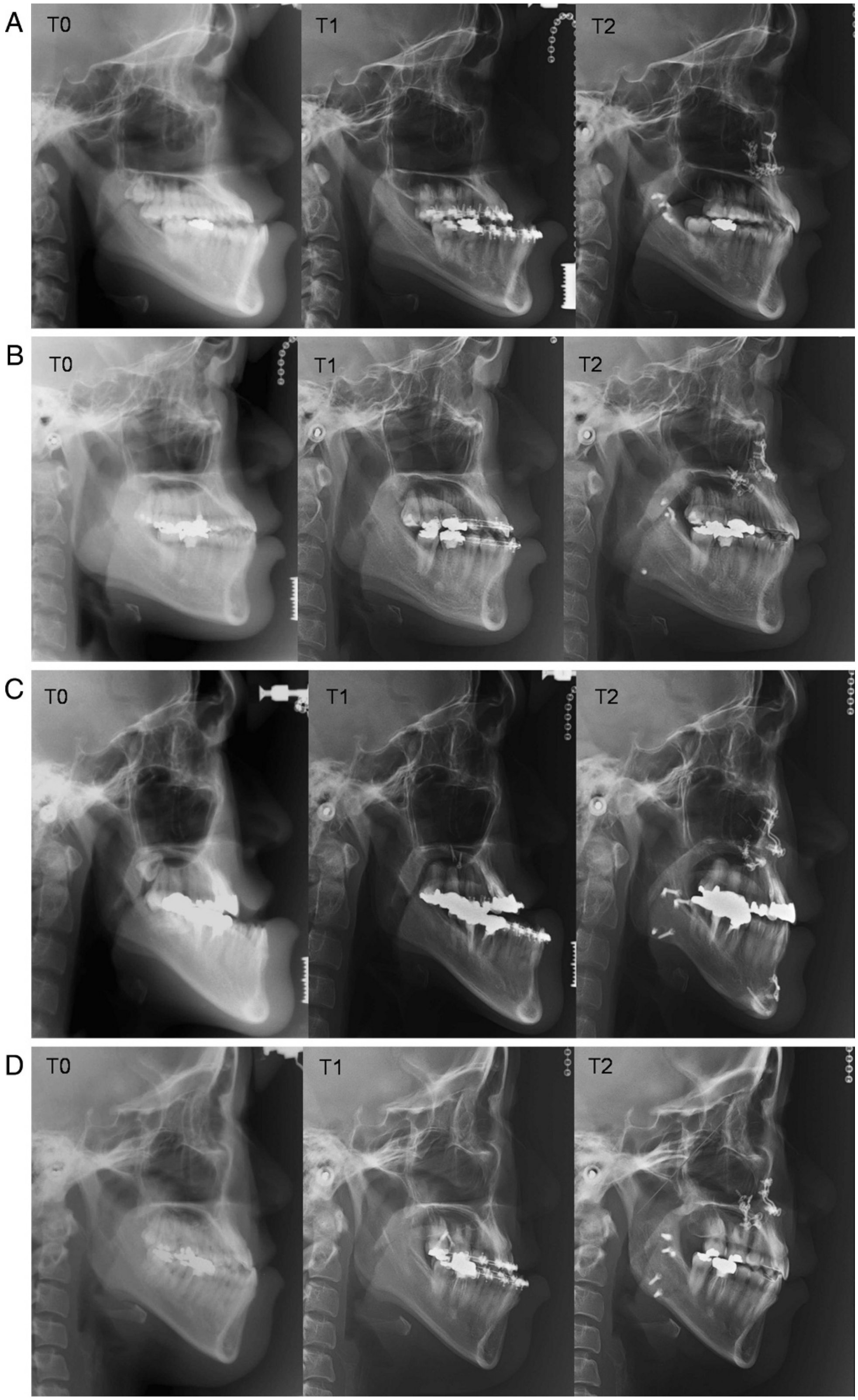

Figure 3. Lateral cephalograms at the T0, T1, and T2 stages. A. Group 1 (severe anteroposterior discrepancy [APD] and hypodivergent vertical types [VT]). B. Group 2 (moderate APD and hypodivergent VT). C. Group 3 (severe APD and hyperdivergent VT). D. Group 4 (moderate APD and hyperdivergent VT).

Table 2. Comparison of the Variables Among the Four Groups According to Each Stage and Within Each Group According to Stages[a]

		T0 Stage						T1 Stage					
		Group 1 (S-Hypo)	Group 2 (M-Hypo)	Group 3 (S-Hyper)	Group 4 (M-Hyper)		Multiple Comparison, Group Nos.	Group 1 (S-Hypo)	Group 2 (M-Hypo)	Group 3 (S-Hyper)	Group 4 (M-Hyper)		Multiple Comparison, Group Nos.
Valuables	Norm+	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	*P*-Value		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	*P*-Value	
Skeletal AP													
SNA, °	81.31	82.57 (3.30)	84.39 (3.61)	80.26 (3.00)	81.55 (3.52)	.0059**	(3, 4, 1) < (1, 2)	82.44 (3.03)	83.96 (3.46)	80.05 (2.74)	81.21 (3.40)	.0049**	(3, 4) < (4, 1) < (1, 2)
SNB, °	78.92	88.54 (3.74)	86.14 (4.04)	85.80 (3.15)	82.47 (3.35)	.0001***	4 < (3, 2) < (2, 1)	88.56 (3.61)	85.77 (4.14)	85.82 (3.29)	82.13 (3.44)	.0000***	4 < (2, 3) < 1
ANB, °	2.62	−5.97 (1.76)	−1.75 (1.45)	−5.53 (1.02)	−0.92 (1.38)	.0000***	(1, 3) < (2, 4)	−6.13 (1.94)	−1.81 (1.68)	−5.76 (1.48)	−0.92 (2.02)	.0000***	(1, 3) < (2, 4)
Wits, mm	−1.72	−14.91 (3.18)	−10.03 (3.37)	−17.76 (4.94)	−11.20 (3.25)	.0000***	3 < 1 < (4, 2)						
Skeletal vertical													
SN-GoMe, °	33.77	29.71 (4.54)	30.26 (3.53)	38.90 (4.79)	40.53 (2.66)	.0000***	(1, 2) < (3, 4)	29.38 (4.71)	30.46 (3.72)	38.78 (4.56)	40.99 (2.69)	.0000***	(1, 2) < (3, 4)
Dental													
IMPA, °	95.39	77.95 (7.66)	84.61 (3.57)	72.35 (10.93)	81.06 (5.48)	.0001***	3 < (1, 4) < (4, 2)	85.87 (5.81)	91.86 (3.54)	79.31 (7.99)	86.49 (5.30)	.0000***	3 < (1, 4) < 2
L1-LOP, °	65.9	81.02 (8.78)	79.39 (5.66)	88.33 (13.12)	78.32 (6.37)	.0079**	(4, 2, 1) < 3	75.01 (5.90)	71.94 (5.40)	79.92 (8.20)	71.69 (4.62)	.0006***	(4, 2, 1) < 3
L1-NB, °	25.27	16.20 (6.15)	21.01 (4.21)	17.05 (8.37)	24.06 (4.73)	.0010**	(1, 3) < (3, 2) < (2, 4)	23.82 (4.46)	28.09 (5.46)	23.90 (4.58)	29.61 (4.81)	.0008***	(1, 3) < (2, 4)
L1-NB, mm	6.01	4.03 (2.37)	5.53 (2.33)	5.24 (2.57)	7.31 (2.24)	.0020**	(1, 3, 2) < 4	5.94 (1.95)	7.21 (2.56)	6.86 (1.80)	9.26 (2.29)	.0003***	(1, 3, 2) < 4
L1-MP, mm	NA	26.73 (3.04)	26.84 (2.33)	28.11 (3.03)	28.50 (3.08)	.2631		27.25 (3.14)	27.54 (3.33)	29.39 (3.25)	29.88 (2.69)	.0361*	(1, 2, 3) < (3, 4)
IIA, °	127.09	135.34 (11.58)	131.42 (7.27)	135.39 (14.59)	129.36 (6.63)	.2587		130.43 (6.85)	128.83 (5.58)	130.06 (9.68)	125.76 (7.13)	.2587	
Overjet, mm	3.55	−4.80 (2.60)	−1.02 (3.04)	−4.73 (3.74)	−1.32 (2.27)	.0001***	(1, 3) < (4, 2)	−8.57 (2.94)	−4.61 (4.55)	−8.10 (3.48)	−4.08 (3.00)	.0003***	(1, 3) < (2, 4)
Overbite, mm	1.52	1.41 (2.74)	−0.69 (1.58)	−3.10 (2.53)	−1.30 (1.84)	.0000***	3 < (4, 2) < 1	0.77 (2.24)	−0.64 (1.26)	−2.43 (2.83)	−1.20 (1.86)	.0006***	(3, 4) < (4, 2) < (2, 1)
Alveolar													
LAW, mm	NA	6.60 (1.33)	7.30 (2.32)	5.11 (1.23)	5.91 (1.19)	.0012**	(3, 4) < (4, 1) < (1, 2)	6.29 (1.66)	7.01 (2.13)	4.65 (1.71)	5.55 (1.17)	.0011**	(3, 4) < (4, 1) < (1, 2)

[a] One-way analysis of variance (ANOVA) test was done for statistical analysis, and the results were verified with Duncan's multiple comparison test. SD indicates standard deviation; LOP, lower occlusal plane; MP, menton parallel; and LAW, lower alveolar width; * $P < .05$; ** $P < .01$; *** $P < .001$. Group 1, severe anteroposterior (AP) discrepancy and hypodivergent type; group 2, moderate AP discrepancy and hypodivergent type; group 3, severe AP discrepancy and hyperdivergent type; and group 4, moderate AP discrepancy and hyperdivergent type. In multiple comparisons in each stage, 1 indicates group 1; 2, group 2; 3, group 3; and 4, group 4. In multiple comparisons within each group, a indicates T0 stage; b, T1 stage; and c, T2 stage. Korean norms (+) are cited from Baek and Yang[18] and Choi et al.[19] NA indicates nonapplicable as a result of genioplasty at the T2 stage.

vergent VT, ANB $> -4°$; SN-GoMe $< 35°$, N $= 17$; Figure 3B), group 3 (severe APD and hyperdivergent VT, ANB $< -4°$; SN-GoMe $> 35°$, N $= 17$; Figure 3C), and group 4 (moderate APD and hyperdivergent VT, ANB $> -4°$; SN-GoMe $> 35°$, N $= 17$; Figure 3D).

ANB and SN-GoMe exhibited significant differences between severe and moderate APD groups ([groups 1, 3] < [groups 2, 4], $P < .001$; Table 1) and between hypo- and hyperdivergent VD groups ([groups 1, 2] < [groups 3, 4], $P < .001$; Table 1). Since there were no significant

Table 2. Extended

T2 Stage						Comparison According to Stages Within Each Group			
Group 1 (S-Hypo)	Group 2 (M-Hypo)	Group 3 (S-Hyper)	Group 4 (M-Hyper)		Multiple Comparison, Group Nos.	*P*-Value/Multiple Comparison, Stage Nos.			
Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	*P*-Value		Group 1 (S-Hypo)	Group 2 (M-Hypo)	Group 3 (S-Hyper)	Group 4 (M-Hyper)
83.47 (3.34)	85.51 (3.11)	82.17 (3.22)	82.77 (3.34)	.0229*	(3, 4, 1) < (1, 2)	.6003	.3942	.0862	.3848
82.52 (3.41)	82.86 (3.34)	81.04 (3.02)	79.53 (3.46)	.0181*	(4, 3) < (3, 1, 2)	.0000*** c < (a, b)	.0322* c < (b, a)	.0000*** c < (a, b)	.0301* c < (b, a)
0.96 (1.15)	2.66 (1.90)	1.13 (1.65)	3.24 (2.18)	.0004***	(1, 3) < (2, 4)	.0000*** (b, a) < c	.0000*** (b, a) < c	.0000*** (b, a) < c	.0000*** (a, b) < c
36.58 (6.65)	32.39 (4.21)	40.76 (4.82)	42.36 (4.12)	.0000***	2 < 1 < (3, 4)	.0003*** (b, a) < c	.2132	.3981	.2370
82.79 (6.21)	87.47 (3.78)	75.86 (6.64)	84.27 (5.41)	.0000***	3 < (1, 4) < (4, 2)	.0034** a < (c, b)	.0000*** a < c < b	.0799	.0137* (a, c) < (c, b)
76.45 (5.42)	74.86 (4.48)	81.16 (5.97)	74.39 (4.94)	.0012**	(4, 2, 1) < 3	.0361* (b, c) < (c, a)	.0005*** (b, c) < a	.0288* (b, c) < a	.0030** (b, c) < a
20.71 (5.26)	21.86 (4.05)	17.51 (4.13)	24.72 (5.00)	.0004***	3 < (1, 2) < (2, 4)	.0006*** a < (c, b)	.0001*** (a, c) < b	.0023** (a, c) < b	.0028** (a, c) < b
4.99 (2.01)	5.57 (1.58)	5.17 (1.50)	7.70 (1.98)	.0001***	(1, 3, 2) < 4	.0396* (a, c) < (c, b)	.0482* (a, c) < b	.0280* (c, a) < b	.0280* (a, c) < b
NA	NA	NA	NA	NA		NA	NA	NA	NA
128.76 (9.83)	132.76 (6.56)	134.87 (8.40)	129.05 (6.93)	.0842		.1276	.2114	.3194	.2514
3.22 (0.64)	3.28 (0.51)	3.35 (0.71)	3.10 (0.68)	.7273		.0000*** b < a < c	.0000*** b < a < c	.0000*** b < a < c	.0000*** b < a < c
1.78 (0.96)	1.83 (0.57)	1.80 (1.09)	1.89 (0.70)	.9824		.3763	.0000*** (a, b) < c	.0000*** (a, b) < c	.0000*** (a, b) < c
6.20 (1.71)	6.35 (2.04)	4.58 (1.24)	4.89 (1.32)	.0025**	(3, 4) < (1, 2)	.7434	.4293	.5060	.0569

differences in age, treatment duration, or the amount of crowding in the upper and lower arches among the four groups (Table 1), these intergroup differences can be considered to represent the results of skeletal APD/VT.

All variables from 20 randomly selected subjects (five per group) were reassessed at 2-week intervals by the same operator. The differences that were calculated using Dahlberg's formula[17] ranged from 0.43 mm to 0.66 mm for the linear measurements and from 0.51° to 0.78° for the angular measurements. Therefore, the first set of measurements was used for this study. One-way analysis of variance (ANOVA) with Duncan's multiple comparison test, crosstab analysis, and Pearson correlation analysis was performed for statistical analysis.

RESULTS

Comparison of the Variables Among Four Groups According to Each Stage (Table 2)

At the T0 stage, LI was significantly compensated according to IMPA and L1–lower occlusal plane (LOP) compared to those of the Korean norms (95.4° and 65.9°, respectively).[18,19] Groups 3 and 2 exhibited the most and the least compensated LI (IMPA, 72° and 85°, respectively, $P < .001$) and the narrowest and the widest lower alveolar width (LAW; 5.1 mm and 7.3 mm, respectively, $P < .01$). Although the L1–menton parallel (MP) to the vertical reference plane (mm) indicated that hyperdivergent groups had longer distances than the hypodivergent groups, there were no significant differences.

At the T1 stage, initial differences in ANB, SN-GoMe, IMPA, and LAW among the four groups were maintained (ANB, SN-GoMe, IMPA: $P < .001$; LAW: $P < .01$). Despite Pre-DC of the LI, none of the groups reached the normal values. Groups 3 and 2 exhibited the least and the most decompensated LI (IMPA, 79° and 92°, respectively, $P < .001$) and the narrowest and the widest LAW (4.7 mm and 7.0 mm, respectively, $P < .01$). Overjet was aggravated as a result of Pre-DC according to the severity of skeletal APD (groups 1 and 3 < groups 2 and 4, $P < .001$).

At the T2 stage, although there were significant improvements in ANB and Wits appraisal and an increase in SN-GoMe, skeletal APD/VT was maintained among the four groups (ANB: $P < .001$; Wits: $P < .05$; SN-GoMe: $P < .001$). In spite of Post-C of LI, differences in IMPA ($P < .001$), L1-LOP ($P < .01$), and L1-NB (mm) ($P < .001$) among the four groups were maintained, as was the case during the T0 and T1 stages. The LAW of all groups decreased compared to that of the T0 and T1 stages. However, groups 3 and 2 still showed the narrowest and the widest LAW (4.6 mm and 6.4 mm, respectively, $P < .01$). Overbite and overjet were normalized without significant difference among the four groups.

Comparison of the Variables According to Stage Within Each Group (Table 2)

The pattern of IMPA change in each group was different according to skeletal APD/VT. Group 1 showed considerable Pre-DC and negligible Post-C, which produced a significant difference from the T0 stage (IMPA, T0 < [T2, T1], $P < .01$; Figure 4A). In group 2, good Pre-DC and considerable Post-C resulted in different values for T0, T1, and T2 (IMPA, T0 < T2 < T1; $P < .001$; Figure 4B). Although group 3 also had Pre-DC and Post-C, the changes were not sufficient to separate into three parts (IMPA, $P > .05$; Figure 4C). Group 4 showed considerable Pre-DC, but the T2 value was not different from the T0 or T1 values (IMPA, [T0, T2] < [T2, T1], $P < .05$; Figure 4D).

Although LAW decreased during Pre-DC and Post-C, there were no significant changes in any of the groups. Overbite was also increased during treatment, significantly at T2 compared to T1 or T0, except for in the case of group 1 ($P < .001$).

Correlation Between the Relative Percentage Ratios and Cephalometric Valuables (Table 3)

The relative percentage ratio (RPR) indicates how close the IMPA comes to the Korean norm (95°).[18] RPR at each stage showed a significant correlation with skeletal APD/VT. The IMPA came close to the Korean norm at the larger ANB ($P < .01$ at T0 and T1, $P < .001$ at T2), the larger Wits appraisal ($P < .001$, all stages), and the smaller SN-GoMe ($P < .01$, all stages). In addition, IMPA was also increased when overjet and overbite were larger (overjet $P < .01$ at T1 and T2; overbite $P < .05$ at T0; $P < .01$ at T1 and T2) and when LAW was wider ($P < .001$, all stages).

Comparison of RPR and Achievement Ratio Among the Four Groups (Table 4)

The values of RPR were increased by Pre-DC and were decreased by Post-C in all of the groups. The differences among the four groups at the T0 stage were maintained through T1 and T2 stages ($P < .001$). Although groups 1, 2, and 4 achieved more than 90% of the normal value after Pre-DC, group 3 did not. Interestingly, group 3 showed the most prominent IC at the T0 stage, the least Pre-DC at the T1 stage, and the greatest Post-C at the T2 stage (76%, 83%, and 80%, respectively).

Decompensation achievement ratio revealed significant difference between groups 2 and 3 (70% and 29%, respectively, $P < .05$). Although group 3 showed the lowest value in total achievement ratio (8%), there were no significant differences among the four groups.

Good Decompensation Ratio and Good Stability Ratio Among the Four Groups (Table 5)

Group 2 showed the best ratios for decompensation and stability of LI (100% and 88%, respectively, $P < .001$). However, group 3 exhibited the worst ratios for decompensation and stability of LI (24% and 6%, respectively, $P < .001$).

DISCUSSION

This study focused on the pre- and postoperative orthodontic movements of the LI because decompensation of the LI is more easily achieved than that of the upper incisors.[11,12] Troy et al.[11] used the NB line for evaluation of LI change. However, B point can be influenced by rotation of the mandible and the dimension of the anterior cranial base,[12] and eventually it was not appropriate for evaluation of real LI change. In addition, L1-LOP can be changed by intrusion or extrusion of the lower teeth.[19] Since IMPA is not affected by rotation of the mandible or vertical

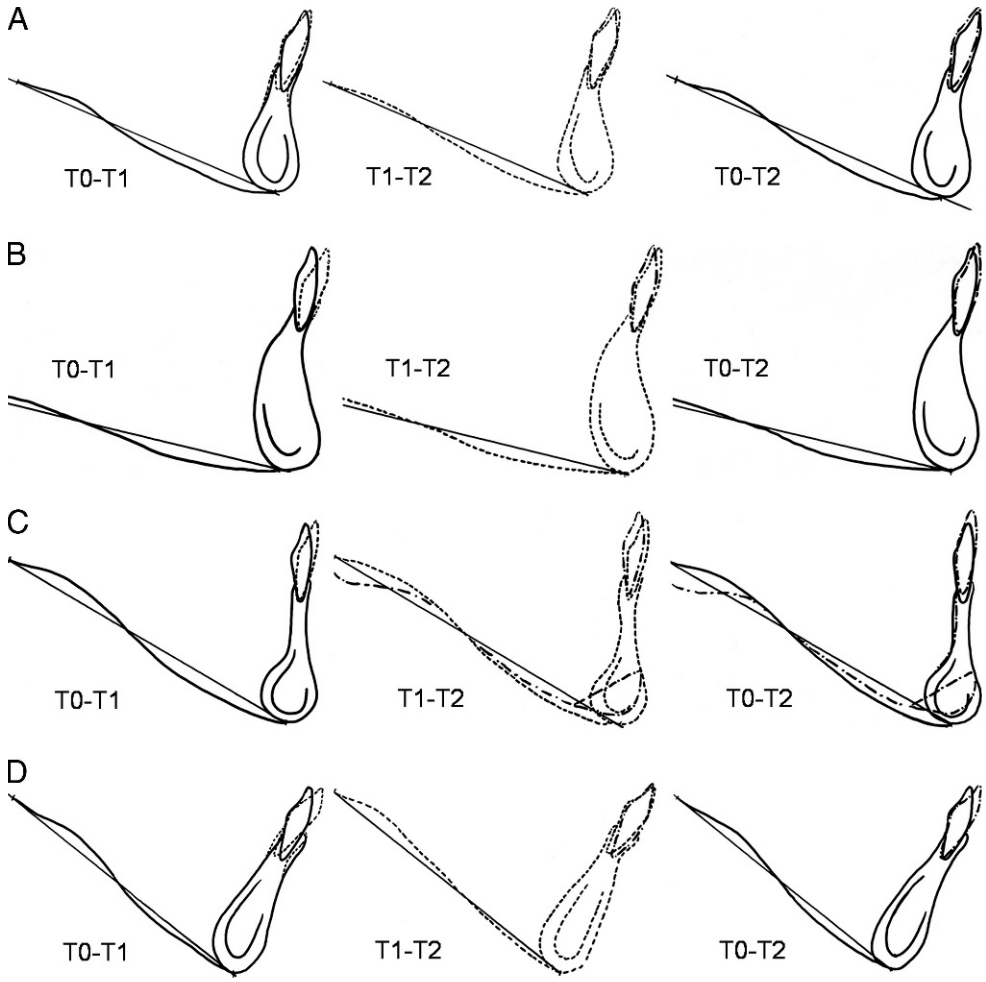

Figure 4. Superimpositions of the LI during preoperative decompensation (T0–T1), during postoperative compensation (T1–T2), and during total treatment period (T0–T2). A. Group 1. B. Group 2. C. Group 3. D. Group 4.

Table 3. Correlation Between the Relative Percentage Ratio and Cephalometric Valuables[a]

	Relative Percent Ratio					
	T0 Stage		T1 Stage		T2 Stage	
Variables	*r*	*P*-Value	*r*	*P*-Value	*r*	*P*-Value
Skeletal anteroposterior						
ANB, °	0.3525	.0032**	0.3728	.0017**	0.4513	.0001***
Wits, mm	0.6185	.0000***	0.6075	.0000***	0.6393	.0000***
Skeletal vertical						
SN-GoMe, °	−0.3572	.0028**	−0.3946	.0009***	−0.3412	.0044**
Dental						
L1-NB, mm	0.5765	.0000***	0.3441	.0041**	0.3309	.0059**
L1-MP, mm	−0.0341	.7822	−0.1542	.2092	−0.1854	.1301
IIA, °	−0.7487	.0000***	−0.5231	.0000***	−0.4507	.0001***
Overjet, mm	0.2125	.0819	0.3471	.0037**	0.4080	.0006***
Overbite, mm	0.2823	.0197*	0.3824	.0013**	0.3667	.0021**
Alveolar						
LAW, mm	0.5396	.0000***	0.5531	.0000***	0.4719	.0000***

[a] Pearson correlation test was done. Negative values indicate the inverse nature of the relationship. Relative percentage ratio to Korean norm of IMPA (95°)[18] indicates (actual value of IMPA/95°) × 100; MP, menton parallel; and LAW, lower alveolar width; * $P < .05$; ** $P < .01$; *** $P < .001$. Angular measurements related to the mandibular incisors were excluded.

Table 4. Comparison of the Efficacy in Relative Percentage Ratio and Achievement Ratio of the Lower Incisors Among the Four Groups[a]

Variables	Group 1 (S-Hypo) Mean	SD	Group 2 (M-Hypo) Mean	SD	Group 3 (S-Hyper) Mean	SD	Group 4 (M-Hyper) Mean	SD	*P*-Value	Multiple Comparison, Group Nos.
Relative percentage ratio, %										
T0	82.05	8.07	89.06	3.76	76.16	11.50	85.33	5.77	.0001***	3 < (1, 4) < (4, 2)
T1	90.39	6.12	96.69	3.73	83.48	8.41	91.05	5.57	.0000***	3 < (1, 4) < 2
T2	87.15	6.54	92.07	3.98	79.85	6.99	88.70	5.70	.0000***	3 < (1, 4) < (4, 2)
Achievement ratio, %										
Decompensation	55.97	58.90	70.43	40.33	28.80	24.64	42.37	29.58	.0257*	(3, 4, 1) < (4, 1, 2)
Total	23.55	48.31	23.37	40.17	7.83	27.32	22.49	32.19	.5572	

[a] One-way analysis of variance (ANOVA) test and Duncan's multiple comparison test were done. SD indicates standard deviation; * $P < .05$; *** $P < .001$. Relative percentage ratio to Korean norm of IMPA (95°)[18] indicates (actual value of IMPA/95°) × 100; Decompensation achievement ratio (actual amount of preoperative orthodontic movement/expected amount of preoperative orthodontic movement in surgical treatment objective [STO]) × 100; Total achievement ratio, (actual amount of orthodontic movement/expected amount of preoperative orthodontic movement in STO) × 100.

movement of the lower dentition, it was primarily used to evaluate the LI inclination in this study.

The major surgical movement of the maxilla of the samples comprised superior and posterior impaction as a result of the normal anteroposterior position of the maxilla at T0 (Table 2). Improvement of ANB ($P <$ .001 for all groups; Table 2) was obtained by mandibular setback (SNB, $P < .001$ for groups 1 and 3; $P <$ .05 for groups 2 and 4; Table 2). Although final ANB improved to within the normal range in groups 2 and 4 (moderate APD groups), groups 1 and 3 (severe APD groups) were undercorrected (ANB, 1.0° and 1.1°, respectively). These findings are in accordance with those of Troy et al.,[11] who reported that over 90% of the subjects improved skeletally with surgery but attained only 65% of the normal position by ANB. They also reported that 82% of subjects improved in Wits appraisal, but only 56% to 59% of the norm was achieved.[11] Capelozza Filho et al.[12] insisted that the inadequately treated group had greater IC than did the adequately treated group before surgery.

At the T0 stage, LI tend to erupt to maintain overbite, and the alveolus elongates and attenuates labiolingually in hyperdivergent groups (groups 3 and 4). Since there was no significant change in LAW during the entire treatment period, the initial difference in LAW between the hyperdivergent and hypodivergent groups (groups 1 and 2) was maintained (Table 2; $P <$ .01). Therefore, VT might be related to the alveolus width and morphology, which could have an effect on the amounts of IC of the LI.

The IMPA change in each group showed a different pattern according to the skeletal APD/VT (Table 2; Figure 4). Lim et al.[20] reported that they could not predict the Pre-DC of LI in relation to the projected postoperative maxillo-mandibular plane angle. However, in this study there was a significant association between APD/VT and RPR at each stage ($P < .01$; Table 3).

Table 5. Comparison of the Distribution of Good Decompensation Ratio at the T1 Stage and of the Distribution of Good Stability Ratio at the T2 Stage of the Lower Incisors Among the Four Groups[a]

IMPA	Distribution of Decompensation: Good Decompensation (less than ±10° compared to norm)	Distribution of Decompensation: Poor Decompensation (more than ±10° compared to norm)	Good Decompensation Ratio, %	*P*-Value	Distribution of Stability: Good Stability (less than ±10° compared to norm)	Distribution of Stability: Poor Stability (more than ±10° compared to norm)	Good Stability Ratio, %	*P*-Value
Group 1 (S-Hypo)	10	7	58.82	.0001***	7	10	41.18	.0000***
Group 2 (M-Hypo)	17	0	100.00		15	2	88.24	
Group 3 (S-Hyper)	4	13	23.53		1	16	5.88	
Group 4 (M-Hyper)	11	6	64.71		7	10	41.18	

[a] Crosstab analysis was done. SD indicates standard deviation; * $P < .05$; ** $P < .01$; *** $P < .001$. Any angular change between Korean norm of IMPA (95°)[18] and the decompensation result (T1) of less than ±10° was regarded as good decompensation, while the others were regarded as poor decompensation. Good decompensation ratio indicates (number of the good decompensation sample/number of the total sample) × 100. Any angular change between Korean norm of IMPA (95°)[18] and the final result (T2) of less than ±10° was regarded as indicating good stability, while the others were regarded as indicating poor stability. Good stability ratio indicates (number of the good stability sample/number of the total sample) × 100.

Figure 5. An example of use of the miniplate for preoperative decompensation of the lower incisors.

Although group 2 showed significant changes in Pre-DC and Post-C ($P < .001$, T0 < T2 < T1; Table 2; Figure 4B), group 3 did not exhibit significant changes ($P > .05$; Table 2; Figure 4C). Differences among groups was more obvious at decompensation achievement ratio ($P < .05$; Table 4) and good decompensation ratio ($P < .001$; Table 5). Johnston et al.[10] also reported that the duration of preoperative orthodontic treatment was not related to the amount of Pre-DC. Therefore, impractical efforts to decompensate the LI up to normal values of IMPA can only prolong preoperative orthodontic treatment and cause unexpected side effects, especially in group 3. Pre-DC using TADs (temporary anchorage devices) might be considered to overcome poor Pre-DC (Figure 5), although there is still a risk of periodontal problems in the lower anteriors. However, in group 2, good Pre-DC alone can produce a satisfactory surgical outcome.

During postoperative orthodontic treatment, LI were "round tripped" back to their original position[11] because of a 'less-than-optimal amount' of the mandibular setback and resultant 'more-than-usual amount' of Post-C. Troy et al.[11] reported that 75% of the LI were retroclined at the T2 stage and that 75% moved more lingually compared to the T1 stage. In this study, total achievement ratio dropped to around 23% of the expected decompensation amount in groups 1, 2, and 4 (Table 4). However, group 3 achieved only 7.8% (Table 4). This finding is in accordance with that of Troy et al.,[11] who reported that half of the retroclined LI were aggravated.

Although intergroup differences in IMPA at the T0 stage were maintained during the T1 and T2 stages (Table 2), the amounts of IMPA change during Pre-DC (T1–T0), Post-C (T2–T1), and total treatment (T2–T0) were 5° to 8°, 2° to 4°, and 3° to 4°, respectively (Table 2). These values can be a guideline for the setup of STO.

In terms of Post-C and total change, Årtun et al.[21] and Johnston et al.[10] reported results (2.2° and 5°, respectively) that are similar to ours (2° to 4° and 3° to 4°, respectively). However, for the amounts of Pre-DC, Årtun et al.[21] and Capelozza Filho et al.[12] reported a value of around 10°, which was different from our values (5° to 8°). The reason why our results showed a smaller amount of Pre-DC seems to involve the different sample selection criteria, skeletal APD/VT, and biomechanics for Pre-DC. Further studies are needed to investigate the IC, Pre-DC, and Post-C of the upper incisors (with regard to extraction and nonextraction approaches) using large sample sizes in order to secure more accurate statistical validity.

CONCLUSIONS

- The null hypothesis that skeletal APD/VT results in no differences in the amount and pattern of IC, Pre-DC, and Post-C of LI in skeletal Class III patients was rejected.
- Moderate APD and hypodivergent VT could produce good Pre-DC and eventually a satisfactory surgical outcome. However, in cases involving severe APD and hyperdivergent VT, Pre-DC using TADs might be considered to overcome poor Pre-DC.

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