Original Article

Comparison of posttreatment stability after total mandibular arch distalization with mini-implants and mandibular setback surgery

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ABSTRACT

Objectives: To compare posttreatment stability in skeletal Class III patients between those treated by total mandibular arch distalization (TMAD) with buccal mini-implants and those by mandibular setback surgery (MSS).

Materials and Methods: The samples included 40 Class III adults, 20 treated by TMAD using buccal interradicular mini-implants and 20 treated with MSS. Lateral cephalograms were taken at pretreatment, posttreatment, and at least 1-year follow-up, and 24 variables were compared using statistical analysis.

Results: Mandibular first molars moved distally 1.9 mm with intrusion of 1.1 mm after treatment in the TMAD group. The mandibular incisors moved distally by 2.3 mm. The MSS group exhibited a significant skeletal change of the mandible, whereas the TMAD group did not. During retention, there were no skeletal or dental changes other than 0.6 mm labial movement of the mandibular incisors ($P < .05$) in the MSS group. There was 1.4° of mesial tipping ($P < .01$) and 0.4 mm of mesial movement of the mandibular molars and 1.9° of labial tipping ($P < .001$) and 0.8 mm of mesial movement of the mandibular incisors in the TMAD group. These dental changes were not significantly different between the two groups.

Conclusions: The TMAD group showed a slightly decreased overjet with labial tipping of the mandibular incisors and mesial tipping of the first molars during retention. Posttreatment stability of the mandibular dentition was not significantly different between the groups. It can be useful to plan camouflage treatment by TMAD with mini-implants in mild-to-moderate Class III patients. (*Angle Orthod*. 2024;94:159–167.)

KEY WORDS: Stability; Mandibular arch distalization; Mini-implants; Mandibular setback surgery

INTRODUCTION

Mandibular setback surgery (MSS) is the primary choice of treatment to correct skeletal Class III malocclusion with mandibular prognathism. However, camouflage treatment can be considered for patients with mild-to-moderate Class III malocclusion who are reluctant to undergo surgical-orthodontic treatment. Several treatment alternatives such as extraction, Class III elastics, multiloop edgewise archwires (MEAW), mandibular lip bumper, and cervical headgear have been used.[1–7] These modalities are associated with innate problems such as tipping rather than bodily tooth movement,

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Table 1. Characteristics of Subjects in the Total Mandibular Arch Distalization (TMAD) and Mandibular Setback Surgery (MSS) Groups[a]

Characteristic	TMAD		MSS	
n (male/female)	20 (6/14)		20 (8/12)	
Age (y) at T1, mean ± SD	23.8 ± 1.9		21.0 ± 3.5	
Duration (mo)	T1–T2	T2–T3	T1–T2	T2–T3
	26.6 ± 9.7	34.4. ± 22.8	23.5 ± 7.0	33.1 ± 21.2

[a] T1 indicates pretreatment (baseline); T2, end of treatment; T3, at least 1 year posttreatment; SD, standard deviation.

unfavorable movement of anchorage teeth, and a dependence on patient compliance.

Traditionally, posterior movement of the mandibular molar in adults has been considered to be the most difficult among the various types of orthodontic tooth movement. However, the incorporation of temporary skeletal anchorage devices (TSADs) into orthodontic treatment has enabled predictable molar distalization in the mandibular dentition with minimal compliance, such as with maintaining good oral hygiene. Therefore, total mandibular arch distalization (TMAD) using interdental, buccal shelf or retromolar miniscrews,[8–14] or miniplates,[15,16] has been proposed as a camouflage treatment modality in Class III malocclusion. However, when interradicular mini-implants are used between the mandibular second premolar and first molar, potential root damage and the need for relocation to obtain additional distal movement need to be considered.[8,9]

In terms of stability after mandibular molar distalization using TSADs, Sugawara et al[15] reported that the average relapse was 0.3 mm at both the crown and root apex of the mandibular first molars. Chung et al[17] reported that, despite improvement of overjet, overbite, and facial balance after molar distalization in a Class III patient, there was a slight decrease of overbite and relapse to Class III molar and canine relationships after 8 months of retention. In contrast, some studies have reported favorable outcomes with good occlusion at retention using a combination of miniscrews inserted in the intermolar space and sliding jigs with MEAW and Class III elastics.[9,10,18] In addition, regarding the stability after MSS, long-term studies reported that the mandible remained generally stable despite a slight forward relapse.[19,20]

Few cohort studies have evaluated changes in the dentoskeletal structure during retention after TMAD using mini-implants and compared the results to those after orthognathic surgery. Therefore, the purpose of this study was to compare posttreatment stability between TMAD with buccal interradicular mini-implants and MSS in skeletal Class III patients.

MATERIALS AND METHODS

This retrospective cohort study was reviewed and approved by the Institutional Review Board at Seoul National University Bundang Hospital (B-1809-492-105).

Forty subjects were selected from skeletal Class III patients treated by orthodontic or surgical-orthodontic modalities at Seoul National University Bundang Hospital between March 2011 and August 2018 according to the following inclusion criteria: (1) $-4° < ANB < 1°$, (2) Wits appraisal less than -2 mm, (3) Angle Class III malocclusion, (4) nonextraction treatment, (5) crowding less than 2 mm in the mandibular dentition, (6) treatment modality of either TMAD using mini-implants or MSS, and (7) a minimum of 1-year posttreatment follow up. Patients were excluded if they had missing teeth, craniofacial syndromes, maxillary advancement surgery, or two-jaw surgery.

The samples were divided into two groups according to the type of treatment: group 1 (TMAD group; n = 20; mean age, 23.8 ± 1.9 years) and group 2 (MSS group; n = 20; mean age, 21.0 ± 3.5 years) (Table 1).

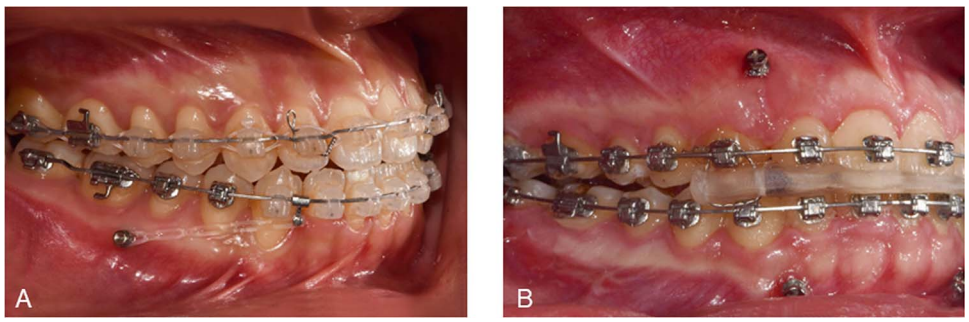

Figure 1. (A) Total mandibular arch distalization (TMAD) group. (B) Mandibular setback surgery (MSS) group. Interdental mini-implants were placed temporarily during surgery, and a surgical stent was used for intermaxillary fixation.

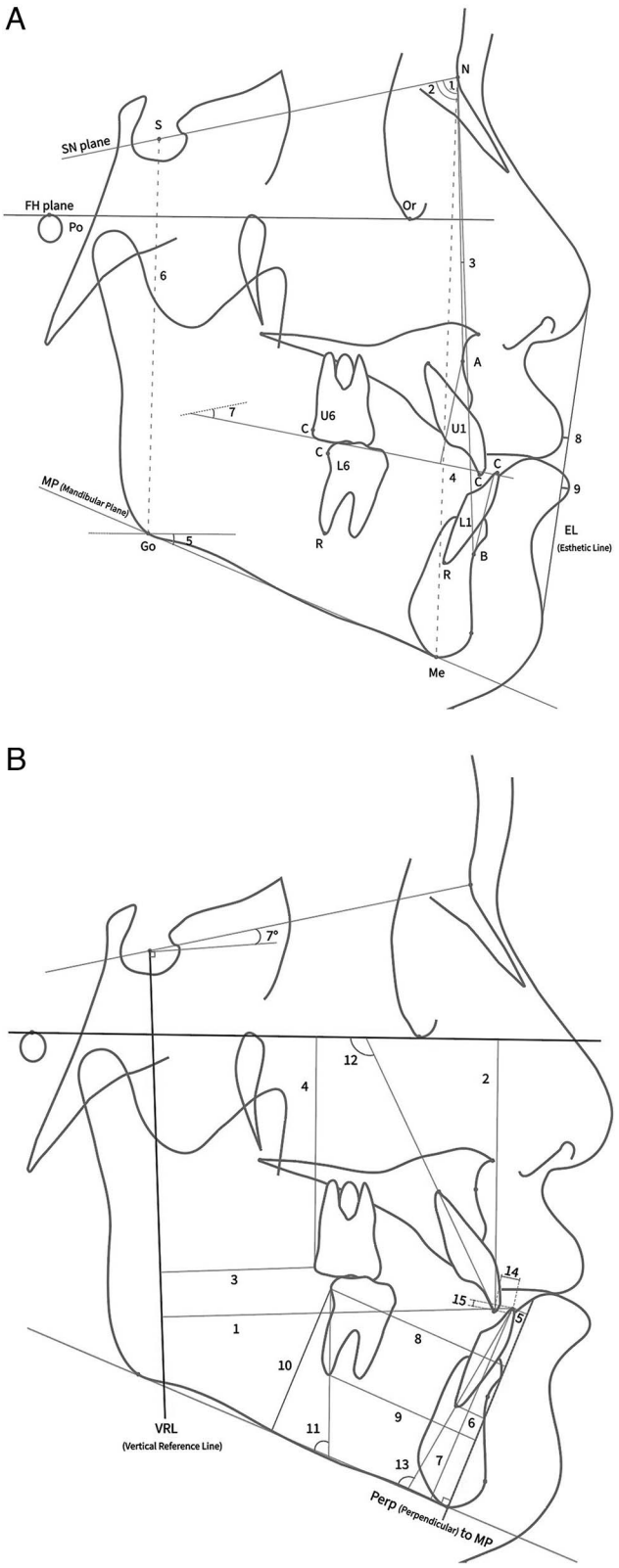

Figure 2. (A) Landmarks, skeletal and soft-tissue measurements: 1. SNA (°), 2. SNB (°), 3. ANB (°), 4. Wits appraisal (mm), 5. FMA (°), 6. PFH/AFH (%), 7. SN to occlusal plane angle (°), 8. upper lip to E-line (mm), 9. lower lip to E-line (mm). (B) Dental measurements: 1. U1C to VRL (mm), 2. U1C to FH (mm), 3. U6C to VRL (mm), 4. U6C to FH (mm), 5. L1C perp to MP (mm), 6. L1R perp to MP (mm), 7. L1C to MP (mm), 8. L6C perp to MP (mm), 9. L6R perp to MP (mm), 10. L6C to MP (mm), 11. L6 to MP (°), 12. U1 to FH (°), 13. IMPA (°), 14. overjet (mm), 15. overbite (mm).

In the TMAD group, buccal mini-implants (diameter, 1.5 mm; length, 7 mm; BioMaterials Inc., Seoul, South Korea) were placed between the mandibular second premolar and first molar bilaterally by an experienced orthodontist (Dr Lee). Elastomeric chains were engaged with a force of approximately 250 g per side between mini-implants and hooks positioned between the canine and lateral incisor on 0.019 × 0.025-inch stainless steel archwire (Figure 1A). In the MSS group, bilateral sagittal split ramus osteotomy was conducted by one surgeon. After the mandible was fixated with metal plates and monocortical screws, the interdental mini-implants placed at surgery were used with a surgical stent for intermaxillary fixation for 2 weeks (Figure 1B). Functional jaw exercises were followed for the next 2 weeks.

Lateral cephalograms were obtained before (T1) and after treatment (T2) and at least 1 year after posttreatment (T3). All cephalograms were traced and analyzed by an orthodontist (Dr Kim) using V-ceph software (version 6.0; Osstem, Seoul, South Korea). To evaluate intraexaminer reliability, lateral cephalograms of 10 randomly selected cases were retraced and remeasured after 2 weeks by the same examiner. The intraclass correlation coefficient for all cephalometric variables ranged between 0.99 and 0.91. The cephalometric landmarks, reference planes, and measurements are shown in Figure 2.

Sample Size Estimation

Sample size estimation was based on studies that evaluated overjet changes during retention after mandibular arch distalization using miniscrews and MSS.[18,21] The sample size calculation showed that at least 13 patients were required in each group to identify an effect size of 1.1 units, provided that alpha was .05 and beta was .2 (G*Power v. 3.1.9.7; Heinrich Heine Universität, Düsseldorf, Germany).[22]

Statistical Analysis

Statistical analysis was performed using SPSS Statistics 22.0 (IBM, Armonk, NY, USA). Independent *t*-test and Mann-Whitney *U* test were used to evaluate intergroup differences in cephalometric variables, while paired *t*-test and Wilcoxon signed-rank test were used to evaluate intragroup differences. The level of significance was set at $P < .05$.

Table 2. Comparison of Changes in Cephalometric Variables at T1 and After Treatment (T1–T2) in the TMAD and MSS Groups and Between Groups[a]

Variable	Group	T1	T1–T2	
		Mean ± SD	Mean ± SD	*P* Value[b]
SNA, °	TMAD	80.19 ± 3.55	0.03 ± 0.44	1.000
	Surgery	80.63 ± 3.40	−0.04 ± 0.84	1.000
	P value[c]	.691		.742
SNB, °	TMAD	79.89 ± 4.16	0.04 ± 0.48	1.000
	Surgery	81.71 ± 3.60	2.56 ± 1.31	<.001
	P value[c]	.146		<.001
ANB, °	TMAD	0.30 ± 2.52	0.00 ± 0.61	1.000
	Surgery	−1.08 ± 1.38	−2.60 ± 1.11	<.001
	P value[c]	.038		<.001
Wits appraisal, mm	TMAD	−6.38 ± 3.08	−1.19 ± 1.57	.009
	Surgery	−10.32 ± 3.41	−5.87 ± 2.19	<.001
	P value[c]	<.001		<.001
FMA, °	TMAD	27.24 ± 4.38	0.19 ± 0.16	.691
	Surgery	27.16 ± 5.05	−0.22 ± 3.02	1.000
	P value[c]	.976		.789
PFH/AFH, %	TMAD	63.24 ± 4.35	−0.20 ± 0.16	.612
	Surgery	63.82 ± 4.16	−0.20 ± 1.77	1.000
	P value[c]	.703		.632
Occlusal plane angle (to SN), °	TMAD	18.23 ± 4.59	1.25 ± 1.93	.013
	Surgery	17.34 ± 4.67	0.22 ± 3.57	1.000
	P value[c]	.671		.004
U1C to VRL, mm	TMAD	71.77 ± 6.00	1.90 ± 1.34	.246
	Surgery	74.42 ± 6.98	0.39 ± 1.43	.697
	P value[c]	.205		.034
U1C to FH, mm	TMAD	58.45 ± 4.74	−0.48 ± 1.54	.532
	Surgery	60.80 ± 5.33	−0.12 ± 1.49	1.000
	P value[c]	.149		.454
U6C to VRL, mm	TMAD	32.41 ± 5.67	0.31 ± 0.84	.331
	Surgery	34.05 ± 5.90	0.60 ± 1.38	.196
	P value[c]	.376		.157
U6C to FH, mm	TMAD	49.19 ± 4.46	−0.62 ± 1.32	.151
	Surgery	51.58 ± 4.21	0.62 ± 1.08	.057
	P value[c]	.090		.002
L1C perp to MP, mm	TMAD	11.68 ± 11.04	−2.26 ± 1.64	<.001
	Surgery	11.68 ± 4.11	0.35 ± 3.23	1.000
	P value[c]	.086		.003
L1C to MP, mm	TMAD	45.17 ± 2.41	−0.34 ± 1.38	.840
	Surgery	46.8 ± 3.85	0.65 ± 1.83	.389
	P value[c]	.103		.056
L1R perp to MP, mm	TMAD	12.58 ± 12.21	−1.66 ± 1.34	<.001
	Surgery	10.11 ± 2.35	−0.21 ± 2.46	1.000
	P value[c]	.076		.046
L6C perp to MP, mm	TMAD	36.53 ± 12.80	−1.87 ± 1.20	<.001
	Surgery	45.16 ± 4.36	−0.03 ± 3.23	1.000
	P value[c]	.001		.038
L6C to MP, mm	TMAD	30.49 ± 2.37	1.10 ± 0.79	<.001
	Surgery	32.26 ± 3.54	1.37 ± 1.21	<.001
	P value[c]	.218		.194
L6R perp to MP, mm	TMAD	31.38 ± 12.42	−1.42 ± 1.56	.002
	Surgery	41.09 ± 4.19	0.88 ± 3.46	.817
	P value[c]	<.001		.017
U1 to FH, °	TMAD	119.55 ± 5.58	−1.62 ± 5.64	.648
	Surgery	118.90 ± 7.01	0.54 ± 3.42	1.000
	P value[c]	.747		.153
IMPA, °	TMAD	89.80 ± 6.24	4.15 ± 4.46	.002
	Surgery	85.18 ± 8.01	−1.78 ± 5.89	.579
	P value[c]	.068		.001
L6 to MP, °	TMAD	73.22 ± 3.28	4.65 ± 3.21	<.001
	Surgery	75.63 ± 5.23	3.05 ± 4.54	.022
	P value[c]	.089		.205

Table 2. Continued.

Variable	Group	T1	T1–T2	
		Mean ± SD	Mean ± SD	*P* Value[b]
Overjet, mm	TMAD	0.65 ± 1.76	−2.80 ± 1.82	<.001
	Surgery	−0.59 ± 2.25	−4.35 ± 2.31	<.001
	P value[c]	.062		.024
Overbite, mm	TMAD	0.63 ± 2.04	−0.91 ± 1.57	.055
	Surgery	−0.10 ± 1.14	−2.02 ± 1.12	<.001
	P value[c]	.081		.007
Upper lip to EL, mm	TMAD	−1.46 ± 2.47	0.03 ± 0.97	1.000
	Surgery	−2.39 ± 1.86	−0.99 ± 1.49	.023
	P value[c]	.183		.014
Lower lip to EL, mm	TMAD	1.42 ± 2.91	1.38 ± 1.48	.002
	Surgery	1.15 ± 2.60	1.47 ± 2.11	.017
	P value[c]	.761		.871

[a] T1 indicates pretreatment (baseline); T2, end of treatment; SD, standard deviation. Refer to the legends of Figure 2 for a definition of each measurement. Significance level at $P < .05$.

[b] Independent *t* test and Mann-Whitney *U* test.

[c] Paired *t* test and Wilcoxon signed-rank test.

RESULTS

The mean treatment periods in the TMAD and MSS group were 26.6 ± 9.7 months and 23.5 ± 7.0 months, respectively. The mean retention periods were 34.4 ± 22.8 months and 33.1 ± 21.2 months, respectively (Table 1).

The two groups showed similar cephalometric characteristics at baseline (T1). However, the MSS group had a lower (more negative) ANB ($P < .05$) and Class III Wits appraisal ($P < .001$) than the TMAD group did (Table 2), confirming that the MSS group had a more severe skeletal Class III relationship than did the TMAD group.

The TMAD group showed significant distal tipping of 4.7° and intrusion of 1.1 mm of the mandibular first molars ($P < .001$) after treatment (T1–T2). Distalization of the first molar crown and root were 1.9 mm ($P < .001$) and 1.4 mm ($P < .01$), respectively (Table 2). The mandibular incisors showed a lingual inclination of 4.2° ($P < .01$). Distalization of the incisor crown and root were 2.3 mm and 1.7 mm, respectively ($P < .001$). Overjet increased by 2.8 mm ($P < .001$), and the lower lip was retracted by 1.4 mm ($P < .01$). In addition, the Wits appraisal increased by 1.2 mm ($P < .01$) and occlusal plane angle decreased by 1.3° ($P < .05$), respectively.

The MSS group showed a significant decrease in SNB of 2.6°, an increase in ANB of 2.6°, and an increase in the Wits appraisal of 5.9 mm ($P < .001$) after treatment. The overjet and overbite increased by 4.4 mm and 2.0 mm ($P < .001$), respectively. In addition, the upper lip to E-line increased by 1.0 mm and lower lip to E-line decreased by 1.5 mm ($P < .05$).

Comparing the two groups, the MSS group exhibited a greater decrease in SNB and an increase in ANB and the Wits appraisal ($P < .001$) and a greater increase in overbite ($P < .01$), overjet, and upper lip to E-line ($P < .05$) compared with the TMAD group.

During the retention period (T2–T3), the TMAD group showed mesial tipping and movement of the mandibular first molars by 1.4° ($P < .01$) and 0.4 mm ($P < .05$), respectively, and extrusion of 0.6 mm ($P < .05$; Table 3). The incisors showed labial inclination and movement of 1.9° ($P < .001$) and 0.8 mm ($P < .01$), respectively. The overjet showed a decrease of 0.5 mm ($P < .001$).

In the MSS group, the mandibular incisors moved labially at the crown by 0.6 mm ($P < .05$) and at the root by 0.5 mm ($P < .01$) during retention.

The comparison between the two groups showed a significant difference in ANB, PFH/AFH, L1C to MP, and overbite during retention. However, there was no significant changes in these variables within the groups.

DISCUSSION

MSS is commonly used to enhance facial esthetics and improve occlusion in skeletal Class III cases with mandibular prognathism. However, camouflage treatment can be considered in patients with mild-to-moderate Class III malocclusion who refuse surgical-orthodontic treatment, but the procedure is difficult and challenging.[18,23] Since the introduction of miniscrews and miniplates, at least six studies have been published reporting the treatment results when these anchorage devices were used for TMAD in Class III malocclusion,[10–17] but only three case reports have documented posttreatment stability.[9,11,17] Therefore, this study was designed to compare posttreatment stability between TMAD with buccal interradicular mini-implants and MSS in skeletal Class III patients.

Dental changes after treatment (T1–T2) in the TMAD group showed significant changes of 1.9 mm posterior

Table 3. Comparison of Changes in Cephalometric Variables at T2 and During Retention (T2–T3) in Each TMAD and MSS Group and Between Groups[a]

Variable	Group	T2	T2–T3	
		Mean ± SD	Mean ± SD	*P* Value[b]
SNA, °	TMAD	80.16 ± 3.57	−0.06 ± 0.27	.871
	Surgery	80.67 ± 3.73	0.02 ± 0.61	1.000
	P value[c]	.661		.718
SNB, °	TMAD	79.85 ± 4.11	0.21 ± 0.42	.108
	Surgery	79.15 ± 4.15	−0.09 ± 0.15	1.000
	P value[c]	.594		.115
ANB, °	TMAD	0.31 ± 2.42	−0.27 ± 0.31	.103
	Surgery	1.52 ± 1.14	0.10 ± 0.54	.208
	P value[c]	.053		< .001
Wits appraisal, mm	TMAD	−5.19 ± 2.48	0.20 ± 0.72	.685
	Surgery	−4.45 ± 2.49	−0.02 ± 1.31	.938
	P value[c]	.358		.509
FMA, °	TMAD	27.05 ± 4.56	0.23 ± 0.13	.278
	Surgery	27.38 ± 5.47	−0.33 ± 0.22	.471
	P value[c]	.927		.060
PFH/AFH, %	TMAD	63.45 ± 4.18	−0.24 ± 0.15	.389
	Surgery	64.01 ± 4.31	0.36 ± 0.20	.257
	P value[c]	.591		.040
Occlusal plane angle (to SN), °	TMAD	16.98 ± 4.59	−0.41 ± 1.11	.136
	Surgery	17.11 ± 5.40	−0.27 ± 2.06	.573
	P value[c]	.936		.722
U1C to VRL, mm	TMAD	72.43 ± 6.33	−0.11 ± 0.40	.225
	Surgery	74.03 ± 7.54	0.23 ± 2.72	.526
	P value[c]	.473		.398
U1C to FH, mm	TMAD	58.93 ± 4.55	−0.22 ± 0.54	.079
	Surgery	60.92 ± 5.66	−0.22 ± 0.54	.911
	P value[c]	.228		.640
U6C to VRL, mm	TMAD	32.09 ± 5.95	−0.20 ± 0.37	.026
	Surgery	33.45 ± 6.55	0.25 ± 1.96	.580
	P value[c]	.499		.328
U6C to FH, mm	TMAD	49.81 ± 3.71	−0.15 ± 0.75	.395
	Surgery	50.96 ± 4.68	0.28 ± 1.91	.823
	P value[c]	.396		.461
L1C perp to MP, mm	TMAD	13.94 ± 10.15	0.79 ± 1.17	.007
	Surgery	11.33 ± 4.31	0.59 ± 0.93	.011
	P value[c]	.841		.560
L1C to MP, mm	TMAD	45.51 ± 2.65	−0.13 ± 0.58	.550
	Surgery	46.23 ± 3.94	−0.28 ± 2.10	.563
	P value[c]	.506		.038
L1R perp to MP, mm	TMAD	14.24 ± 12.53	0.28 ± 0.71	.090
	Surgery	10.32 ± 2.60	0.46 ± 0.67	.006
	P value[c]	.678		.420
L6C perp to MP, mm	TMAD	38.40 ± 13.23	0.44 ± 0.77	.019
	Surgery	45.19 ± 4.14	0.70 ± 2.01	.133
	P value[c]	.072		.820
L6C to MP, mm	TMAD	29.39 ± 2.33	−0.56 ± 0.90	.035
	Surgery	30.05 ± 3.40	0.01 ± 1.68	.976
	P value[c]	.718		.242
L6R perp to MP, mm	TMAD	32.8 ± 11.54	0.19 ± 0.64	.268
	Surgery	40.21 ± 4.16	0.58 ± 1.57	.232
	P value[c]	.012		.799
U1 to FH, °	TMAD	121.17 ± 6.4	0.25 ± 1.33	.407
	Surgery	118.36 ± 7.95	0.32 ± 2.25	.575
	P value[c]	.226		.947
IMPA, °	TMAD	85.65 ± 7.59	−1.90 ± 1.54	< .001
	Surgery	86.96 ± 8.14	−0.47 ± 2.58	.247
	P value[c]	.603		.052

Table 3. Continued.

Variable	Group	T2	T2–T3	
		Mean ± SD	Mean ± SD	*P* Value[b]
L6 to MP, °	TMAD	68.57 ± 3.93	−1.37 ± 2.04	.007
	Surgery	72.59 ± 3.98	−0.47 ± 2.67	.881
	P value[c]	.003		.108
Overjet, mm	TMAD	3.44 ± 0.96	0.52 ± 0.49	<.001
	Surgery	3.77 ± 0.82	0.21 ± 0.74	.220
	P value[c]	.264		.130
Overbite, mm	TMAD	1.54 ± 1.01	0.14 ± 0.38	.332
	Surgery	1.91 ± 0.87	−0.25 ± 0.68	.135
	P value[c]	.213		.021
Upper lip to EL, mm	TMAD	−1.49 ± 2.4	0.26 ± 0.66	.097
	Surgery	−1.4 ± 1.99	0.36 ± 0.64	.022
	P value[c]	.678		.630
Lower lip to EL, mm	TMAD	0.04 ± 2.34	0.22 ± 0.68	.163
	Surgery	−0.32 ± 2.84	0.12 ± 1.06	.604
	P value[c]	.663		.735

[a] T2 indicates at the end of treatment; T3, at least 1 year posttreatment; SD, standard deviation. Refer to the legends of Figure 2 for a definition of each measurement. Significance level at $P < .05$.

[b] Paired *t* test and Wilcoxon signed-rank test.

[c] Independent *t*-test and Mann-Whitney *U* test.

movement and 1.1 mm intrusion of the mandibular first molars and 2.3 mm of retraction and 4.2° of lingual tipping of the incisors. In contrast, there were no significant dental changes in the MSS group. In agreement with the results observed in the TMAD group, Yu et al.[16] reported that the first molars at the crown were distalized by 2.1 mm. However, previous studies showed greater molar distalization ranging from 2.5 mm to 4.9 mm and lingual movement of 2.6 mm to 3.4 mm with 2.2 mm to 2.4 mm extrusion of mandibular incisors.[12,15,18,23–25] Variations among study results might be attributed to multiple factors such as the placement location and types of TSADs used, the force vectors, application of Class III elastics, and severity of the Class III patients.[15,16,23–27]

In the TMAD group, there was a counterclockwise rotation of the occlusal plane, which might have occurred because the line of force between the miniimplant and anterior retraction hook on the archwire passed above the center of resistance of the mandibular dentition.[26,27] In comparison, there was no change in the occlusal plane angle in the MSS group, which indicated that the setback movement did not affect the occlusal plane.

With regard to the skeletal change after treatment, there was a significant sagittal change in the MSS group due to the posterior movement of the mandible, whereas no changes occurred in the TMAD group. Therefore, the MSS group had a greater improvement

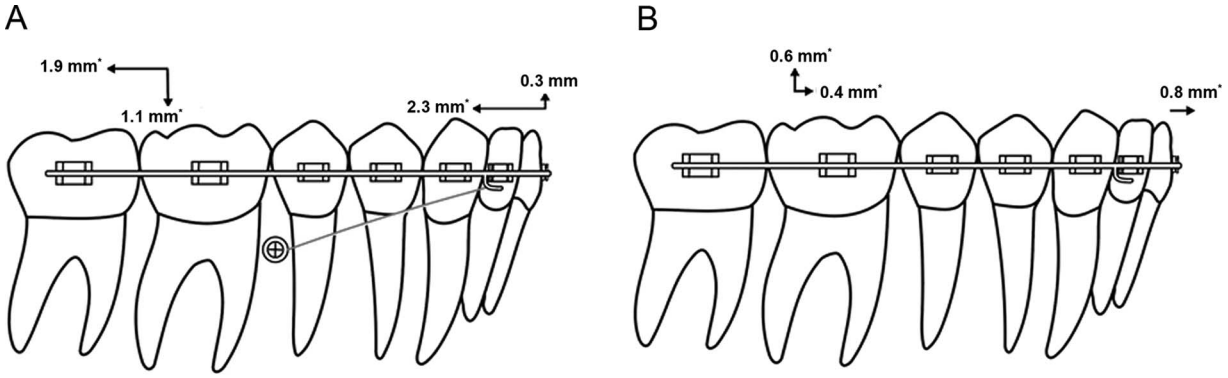

Figure 3. Schematic drawings showing the changes in mandibular dentition after treatment and during retention in the TMAD group. (A) At the end of treatment, the mandibular first molars displayed 1.9 mm of distalization and 1.1 mm intrusion with distal tipping of 4.7°. The mandibular incisors showed 2.3 mm of distalization and 0.3 mm of extrusion with lingual tipping of 4.2°. (B) During posttreatment retention, the mandibular first molars displayed mesial movement of 0.4 mm and extrusion of 0.6 mm with mesial tipping of 1.4°. The mandibular incisors showed labial movement of 0.8 mm with 1.9° of labial tipping. *Significant change.

in overjet, overbite, and Wits appraisal compared with the TMAD group (Table 2).

In addition, similar to changes in the lower lips reported in previous studies,[11,12,16,18] there was retraction of the lower lip (1.4 mm) in the TMAD group without any vertical or sagittal changes in the upper lips and teeth. This indicated that the lip posture was improved via distal movement of the mandibular dentition without mesial movement of the maxillary incisors and molars. Both lips were changed due to the setback of the mandible in the MSS group, and there was a significant intergroup difference in the upper lip ($P < .05$).

During the 34-month average duration of retention, the TMAD group showed mesial tipping of the mandibular incisors and molars, resulting in a decrease in overjet (Table 3). Regarding this posttreatment relapse, He et al.[18] reported that the mandibular first molars moved 0.2 mm and tipped 0.3° mesially, while the incisors moved 0.1 mm labially due to MEAW treatment and modified Class III elastics from the maxillary miniscrews. Interestingly, there were a couple of reports of cases that showed good occlusion and facial esthetics at the 2-year follow-up after miniscrew-assisted mandibular arch distalization with sliding jigs or with second molar extractions.[9,11] It should be noted that Chen et al.[11] and Chung et al.[17] stated the importance of preventing tipping of the mandibular molars for better stability after distalization. Despite mesial tipping and extrusion of the mandibular first molars during the retention period in the TMAD group, the counterclockwise rotation of the occlusal plane was well maintained.

As previously stated, the MSS group experienced no significant posttreatment skeletal or dental changes except for positional change of the mandibular incisors over an average of 33 months of retention. Similarly, Eggensperger et al.[19] reported that the mandible remained stable over the long term after mandibular setback in Class III patients. Some studies, however, showed anterior relapse of 0.24 mm or 26% of the initial setback over long-term follow-up after mandibular surgery.[20,28]

In comparing the TMAD and MSS groups during retention (Table 3), there were no differences in stability of the mandibular dentition between the two groups, although the TMAD group did show some dental relapse such as slight flaring of the mandibular incisors and mesial tipping of the molars and decreased overjet. This suggested that the results after TMAD showed posttreatment stability over the course of this study (Figure 3).

This study had some limitations including a small sample size, short follow-up, sagittal discrepancy at baseline between the groups, the lack of an untreated Class III control group and a three-dimensional radiographic evaluation.[29] A prospective comparative randomized study would be needed to evaluate the efficacy and long-term stability of various mini-implant- or miniplate-assisted TMAD techniques compared with bimaxillary surgery in similar Class III malocclusions.

Clinicians must carefully evaluate the dental and skeletal characteristics of each patient and also consider treatment stability when planning TMAD using skeletal anchorage as an alternative treatment for mild-to-moderate Class III patients.

CONCLUSIONS

- The MSS group showed a significant skeletal change of the mandible, whereas the TMAD group did not exhibit a skeletal improvement at the end of treatment.
- The TMAD group presented slightly decreased overjet with flaring of the mandibular incisors and mesial tipping of the first molars during retention.
- The MSS group showed no significant skeletal or dental changes except for labial movement of the mandibular incisors during retention.
- Posttreatment stability of the mandibular dentition was not significantly different between the TMAD and MSS group.

REFERENCES

1. Saito I, Yamaki M, Hanada K. Nonsurgical treatment of adult open bite using edgewise appliance combined with high-pull headgear and class III elastics. *Angle Orthod*. 2005;75:277–283.
2. Kim YH, Han UK, Lim DD, Serraon ML. Stability of anterior openbite correction with multiloop edgewise archwire therapy: a cephalometric follow-up study. *Am J Orthod Dentofacial Orthop*. 2000;118:43–54.
3. Janson G, de Souza JE, Alves Fde A, Andrade P Jr, Nakamura A, de Freitas MR, Henriques JF. Extreme dentoalveolar compensation in the treatment of Class III malocclusion. *Am J Orthod Dentofacial Orthop.* 2005;128:787–794.
4. Mora DR, Oberti G, Ealo M, Baccetti T. Camouflage of moderate Class III malocclusions with extraction of lower second molars and mandibular cervical headgear. *Prog Orthod*. 2007;8:300–307.
5. Kuroda Y, Kuroda S, Alexander RG, Tanaka E. Adult Class III treatment using a J-hook headgear to the mandibular arch. *Angle Orthod*. 2010;80:336–343.
6. O'Donnell S, Nanda RS, Ghosh J. Perioral forces and dental changes resulting from mandibular lip bumper treatment. *Am J Orthod Dentofacial Orthop*. 1998;113:247–255.
7. Hu H, Chen J, Guo J, Li F, Liu Z, He S, Zou S. Distalization of the mandibular dentition of an adult with a skeletal Class III malocclusion. *Am J Orthod Dentofacial Orthop.* 2012; 142:854–862.
8. Lim JK, Jeon HJ, Kim JH. Molar distalization with a miniscrew-anchored sliding jig. *J Clin Orthod*. 2011;45:368–377.
9. Tai K, Park JH, Tatamiya M, Kojima Y. Distal movement of the mandibular dentition with temporary skeletal anchorage devices to correct a Class III malocclusion. *Am J Orthod Dentofacial Orthop*. 2013;144:715–725.
10. Jing Y, Han X, Guo Y, Li J, Bai D. Nonsurgical correction of a Class III malocclusion in an adult by miniscrew-assisted

mandibular dentition distalization. *Am J Orthod Dentofacial Orthop*. 2013;143:877–887.

11. Chen K, Cao Y. Class III malocclusion treated with distalization of the mandibular dentition with miniscrew anchorage: A 2-year follow-up. *Am J Orthod Dentofacial Orthop*. 2015; 148:1043–1053.
12. Ye C, Zhihe Z, Zhao Q, Ye J. Treatment effects of distal movement of lower arch with miniscrews in the retromolar area compared with miniscrews in the posterior area of the maxillary. *J Craniofac Surg.* 2013;24:1974–1979.
13. Chang C, Liu SS, Roberts WE. Primary failure rate for 1680 extra-alveolar mandibular buccal shelf mini-screws placed in movable mucosa or attached gingiva. *Angle Orthod*. 2015; 85:905–910.
14. Nucera R, Lo Giudice A, Bellocchio AM, Spinuzza P, Caprioglio A, Perillo L, Matarese G, Cordasco G. Bone and cortical bone thickness of mandibular buccal shelf for mini-screw insertion in adults. *Angle Orthod*. 2017;87:745–751.
15. Sugawara J, Daimaruya T, Umemori M, Nagasaka H, Takahashi I, Kawamura H, Mitani H. Distal movement of mandibular molars in adult patients with the skeletal anchorage system. *Am J Orthod Dentofacial Orthop.* 2004; 125:130–138.
16. Yu J, Park JH, Bayome M, Kim S, Kook YA, Kim Y, Kim CH. Treatment effects of mandibular total arch distalization using a ramal plate. *Korean J Orthod*. 2016;46:212–219.
17. Chung KR, Kim SH, Choo H, Kook YA, Cope JB. Distalization of the mandibular dentition with mini-implants to correct a Class III malocclusion with a midline deviation. *Am J Orthod Dentofacial Orthop*. 2010;137:135–146.
18. He S, Gao J, Wamalwa P, Wang Y, Zou S, Chen S. Camouflage treatment of skeletal Class III malocclusion with multiloop edgewise arch wire and modified Class III elastics by maxillary mini-implant anchorage. *Angle Orthod*. 2013;83:630–640.
19. Eggensperger N, Raditsch T, Taghizadeh F, Iizuka T. Mandibular setback by sagittal split ramus osteotomy: a 12-year follow-up. *Acta Odontol Scand.* 2005;63:183–188.
20. Mobarak KA, Krogstad O, Espeland L, Lyberg T. Long-term stability of mandibular setback surgery: a follow-up of 80 bilateral sagittal split osteotomy patients. *Int J Adult Orthodon Orthognath Surg*. 2000;15:83–95.
21. Larson BE, Lee NK, Jang MJ, Yun PY, Kim JW, Kim YK. Comparing stability of mandibular setback versus 2-Jaw surgery in Class III patients with minimal presurgical orthodontics. *J Oral Maxillofac Surg*. 2017;75:1240–1248.
22. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behav Res Methods.* 2009;41:1149–1160.
23. Sato S. Case report: developmental characterization of skeletal Class III malocclusion. *Angle Orthod*. 1994;64:105–111.
24. Oh YH, Park HS, Kwon TG. Treatment effects of microimplant-aided sliding mechanics on distal retraction of posterior teeth. *Am J Orthod Dentofacial Orthop*. 2011;139:470–481.
25. Park HS, Lee SK, Kwon OW. Group distal movement of teeth using microscrew implant anchorage. *Angle Orthod*. 2005;75:602–609.
26. Roberts WE, Viecilli RF, Chang C, Katona TR, Paydar NH. Biology of biomechanics: Finite element analysis of a statically determinate system to rotate the occlusal plane for correction of a skeletal Class III open-bite malocclusion. *Am J Orthod Dentofacial Orthop*. 2015;148:943–955.
27. Park JH, Heo S, Tai K, Kojima Y, Kook YA, Chae JM. Biomechanical considerations for total distalization of the mandibular dentition in the treatment of Class III malocclusion. *Semin Orthod*. 2020;26:148–156.
28. Joss CU, Thüer UW. Stability of hard tissue profile after mandibular setback in sagittal split osteotomies: a longitudinal and long-term follow-up study. *Eur J Orthod*. 2008;30:352–358.
29. Choi YT, Kim YJ, Yang KS, Lee DY. Bone availability for mandibular molar distalization in adults with mandibular prognathism. *Angle Orthod*. 2018;88:52–57.