Case Report

Surgical treatment of a skeletal Class III patient using customized brackets based on the CAD/CAM virtual orthodontic system

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ABSTRACT

The computer-aided design/computer-aided manufacturing (CAD/CAM) virtual orthodontic system produces customized brackets, indirect bonding jigs, and archwires based on a three-dimensional virtual setup. In surgical cases, this system helps to visualize the final occlusion during diagnosis and to efficiently plan individualized presurgical orthodontic treatments. A 20-year-old female patient with a skeletal Class III malocclusion, maxillary protrusion, and lip protrusion was successfully treated with orthognathic surgery and orthodontic treatment with maxillary first premolar extractions. The CAD/CAM system was applied for efficient treatment, with a total active treatment time of 16 months. In this case report, the applicability of the CAD/CAM virtual orthodontic system for orthognathic surgery cases is demonstrated. Suggestions are also made to overcome the limitations and to maximize the advantages of this system during orthodontic treatment of patients undergoing orthognathic surgery. (*Angle Orthod.* 2021;91:692–704.)

KEY WORDS: CAD/CAM virtual orthodontic system; Customized brackets; Digital orthodontics; Virtual setup; Individual treatment planning; Orthognathic surgery

INTRODUCTION

Both effectiveness and efficiency are important during orthodontic treatment. In orthognathic surgery cases, the effectiveness of treatment is determined by the timing of the surgical intervention. For immediate improvement of facial appearance and a reduction in total treatment time, a surgery-first approach has gained popularity,[1] but it also has some drawbacks and contraindications in difficult cases.[2] If presurgical orthodontic treatment is unavoidable, the orthodontist should attempt to shorten the duration of preoperative treatment, as this phase can temporarily worsen the patient's facial appearance and cause discomfort to the masticatory system.[3] To effectively achieve presurgical treatment goals, an effective orthodontic plan is required, with optimal bracket placement.[4] However, because of human error and anatomic variation in each tooth, the ideal bracket positioning for individual cases can be clinically difficult to determine.[5]

To overcome these limitations, computer-aided design and computer-aided manufacturing (CAD/CAM) technology has recently been widely accepted in the orthodontic field. It can contribute to the customization of treatment plans, and the fabrication of customized brackets and indirect bonding jigs enable achievement of similar treatment results with shorter treatment times as compared with preadjusted orthodontic appliances.[6,7] Previous studies have reported the use of the system for adult camouflage treatment, although not for surgical cases.[8,9] This system may be useful in surgery cases for planning of individualized and efficient presurgical orthodontic treatment and for obtaining predictable postsurgical occlusion. This case report describes the use of the CAD/CAM virtual orthodontic system in a skeletal Class III adult patient undergoing orthognathic surgery and orthodontic treatment with maxillary first premolar extractions. The aim was to use this system to provide

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Figure 1. Pretreatment facial and intraoral photographs.

treatment effectively while reducing the number of brackets requiring rebonding and shortening the overall treatment time.

DIAGNOSIS AND ETIOLOGY

A 20-year-old female patient presented with a chief complaint of a prognathic mandible with lip protrusion. She had been treated with a removable appliance and a face mask for an anterior crossbite during her elementary school period. In the lateral view, the facial profile was concave, with protrusive upper and lower lips relative to the E-line. The nasolabial angle was acute. In the frontal view, she did not show any significant facial asymmetry, although her upper dental midline was slightly to the left in relation to the facial midline.

Intraorally, there were Class III canine and molar relationships on both sides and an edge-to-edge bite relationship between the central incisors. In cast analysis, a variable amount of crowding was found in the maxillary arch (right: 1.5 mm, left: 2.5 mm, total: 4.0 mm). There was a tooth-size discrepancy of the anterior teeth (sum of incisor = 4:2.83) because of the large maxillary incisors.

Lateral cephalometric analysis indicated a skeletal Class III jaw relationship (ANB, –2.4°; Wits, –12.2 mm; APDI, 97.6°; mandibular body length, 84.2 mm) with a normodivergent pattern (SN-MP, 37.6°). The maxillary incisors were proclined, and the mandibular incisors were retroclined (U1 to SN, 127.5°; IMPA, 74.9°). Cephalometrics for orthognathic surgery (COGS) analysis was used, and the N-A distance parallel to the horizontal plane was found to be 3.0 mm (norm, –0.9 mm), indicating anterior positioning of the maxilla. Soft-tissue analysis indicated that the distances from the upper and lower lips to the E-line were 2.4 mm and 8.4 mm, respectively. In addition, the patient was found

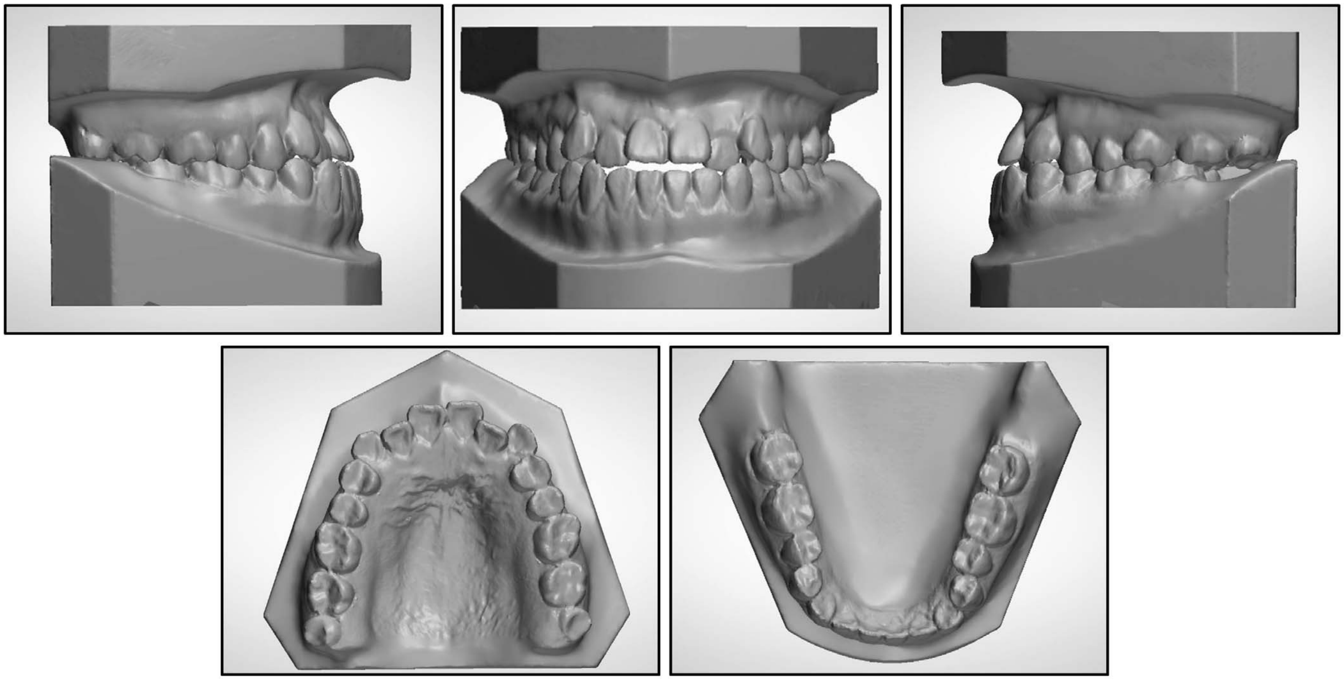

Figure 2. Pretreatment models.

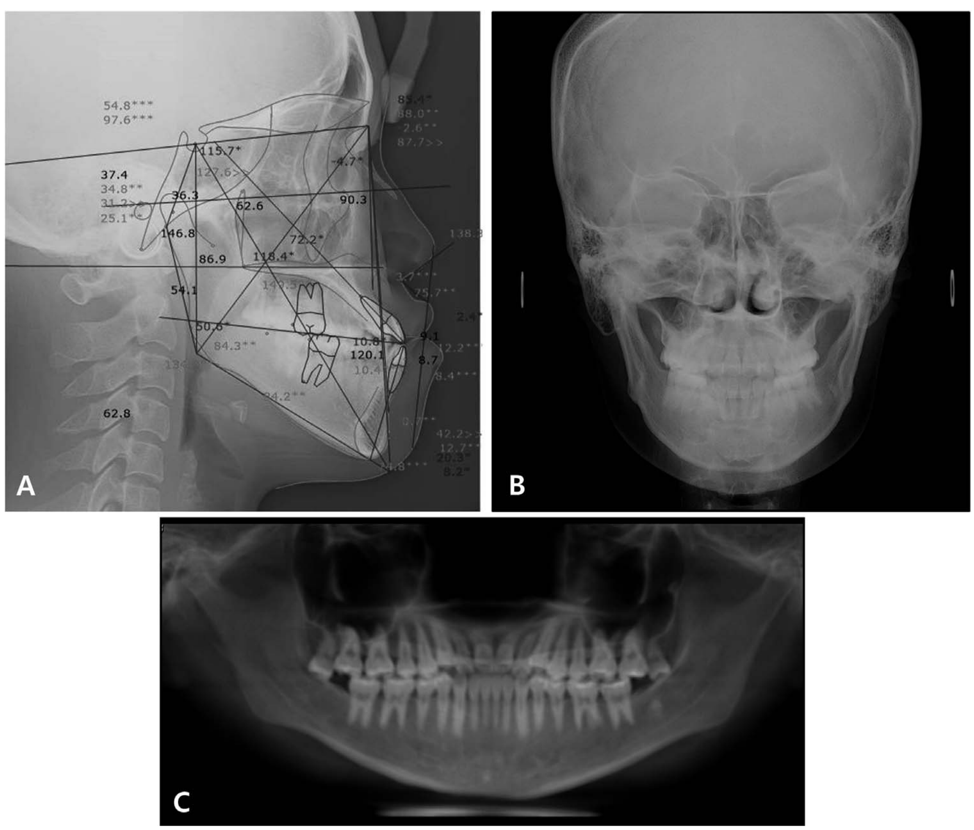

Figure 3. Pretreatment radiographs. (A) Lateral cephalogram. (B) Posteroanterior cephalogram. (C) Panoramic radiograph.

Table 1. Cephalometric Analysis

Measurement	Norm	Pretreatment	Posttreatment	2-Year Retention
Skeletal				
SNA, °	81.6 ± 3.1	85.7	85.2	85.3
SNB, °	79.1 ± 3.0	88.1	80.4	81.2
ANB, °	2.4 ± 1.8	−2.4	4.8	4.1
SN-GoMe, °	34.0 ± 5.0	37.6	42.1	41.8
Gonial angle, °	118.6 ± 5.8	134.9	135	135.3
Ramus height, mm	51.6 ± 4.2	54.1	43.8	43.3
Mn. body length, mm	76.0 ± 4.0	84.2	79.6	79.8
Wits, mm	−2.8 ± 2.5	−12.2	-2.9	-3.1
APDI, °	84.0 ± 4.0	97.6	84.6	85.6
N-A distance (// horizontal line), mm)	0.9 ± 2.2	3	1.3	1.4
Dental				
U1-SN, °	106.0 ± 5.0	127.5	106.5	106.2
U1-NA, °/mm	24.0/6.0	41.8/12.5	21.3/3.8	20.9/4.3
L1-NB, °/mm	27.0/6.1	20.5/8.3	26.1/8.9	28.3/8.5
IMPA, °	94.0 ± 5.0	74.9	83.5	85.4
Soft tissue E-line, mm				
Upper lip	−1.0 ± 2.0	2.4	0	1.4
Lower lip	1.0 ± 2.0	8.4	0.1	1.5

to have a long lower anterior facial height, especially in the lower two-thirds (G-Sn/Sn-Me′, 0.78; Sn-Stm_s/Stm_i-Me′, 0.38).

A posteroanterior cephalogram showed that the menton deviated to the right by 1.0 mm, with no other significant skeletal asymmetries. The final diagnosis was a skeletal Class III with maxillary protrusion (Figures 1–3; Table 1).

TREATMENT OBJECTIVES

The treatment objectives were (1) to correct the mandibular prognathism; (2) to improve lip protrusion; (3) to correct the anterior crossbite and relieve crowding to establish the proper overjet, overbite, and molar and canine relationships; (4) to decompensate the torque of the incisors; (5) to correct the midline deviation; and (6) to improve facial harmony.

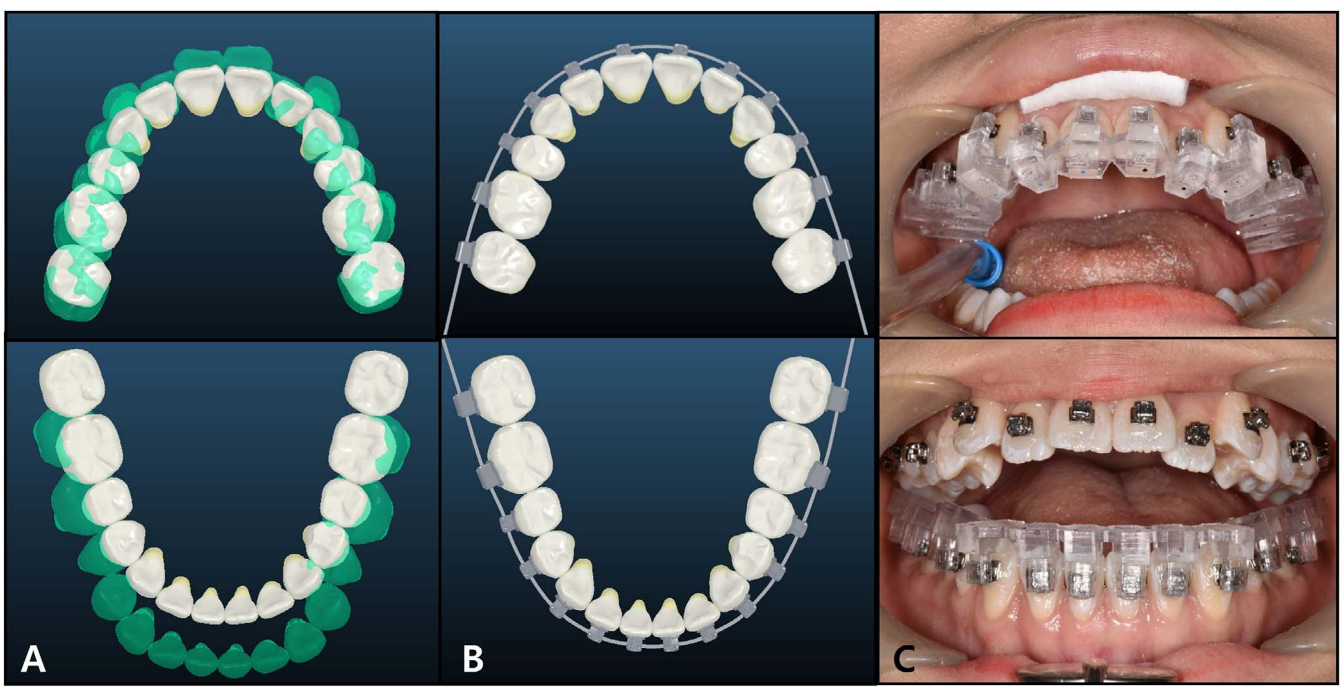

Figure 4. (A) Diagnostic setup using digital models to simulate maxillary dentition space closure with first premolar extraction and setback of the mandible, adjusted to the maxilla. Green, pretreatment; white, simulation. (B) Final setup and customized brackets and archwire combinations. (C) Customized brackets combined with transfer tray.

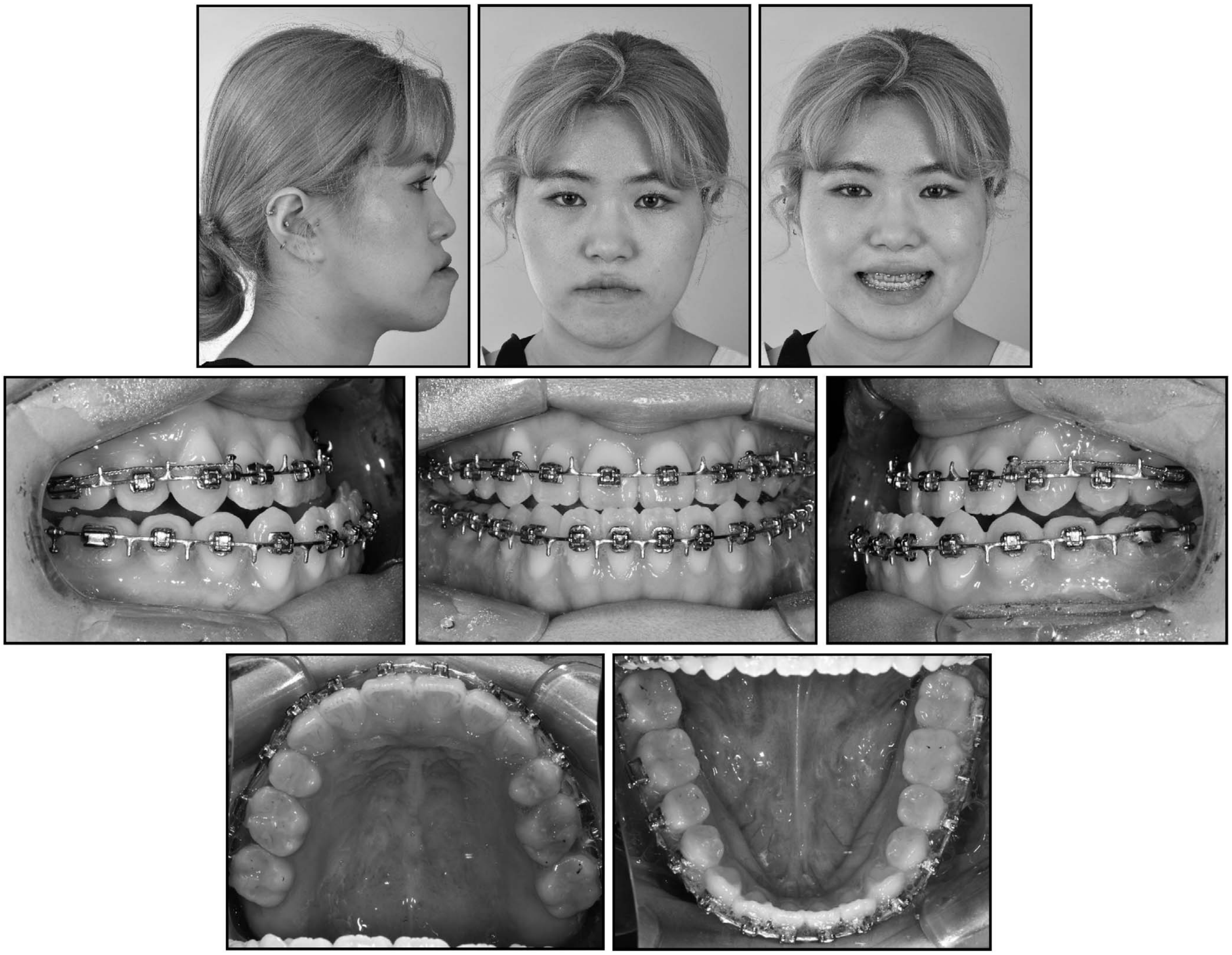

Figure 5. Presurgery facial and intraoral photographs.

Treatment Alternatives

Three treatment options were presented to the patient. The first treatment option was camouflage orthodontic treatment with nonextraction, involving protraction of the maxillary posterior teeth and distalization of the mandibular posterior teeth. However, this option was rejected by the patient because she had a strong desire to improve her facial esthetics, especially her prognathic mandible. The second option was a combination of orthodontic treatment with nonextraction and orthognathic surgery. This treatment method would have limited the improvement of the lip protrusion and the decompensation of the labial torque of the maxillary incisors. Therefore, orthodontic treatment with extraction of the maxillary first premolars along with orthognathic surgery was adopted as the plan.

Treatment Progress

Virtual setup for presurgical orthodontic treatment. The patient's initial model was scanned (Insignia Approver, Ormco, Orange, Calif). A customized arch form based on the patient's arch form was created as a reference to move the teeth. It was planned to relieve the maxillary crowding by extracting the first premolars and closing the space reciprocally. During space closure, the upper dental midline was corrected to the right side by about 0.5 mm. Maxillary incisors were planned for controlled tipping, with a 10° decrease of U1 to SN during space closure. Because the patient had thin mandibular labial cortical bone, only a 10° increase of IMPA and buccal tipping of the mandibular incisors were planned. By simulating the arch coordination during the virtual setup, the mandibular arch was expanded by about 2.5 mm, and the maxillary

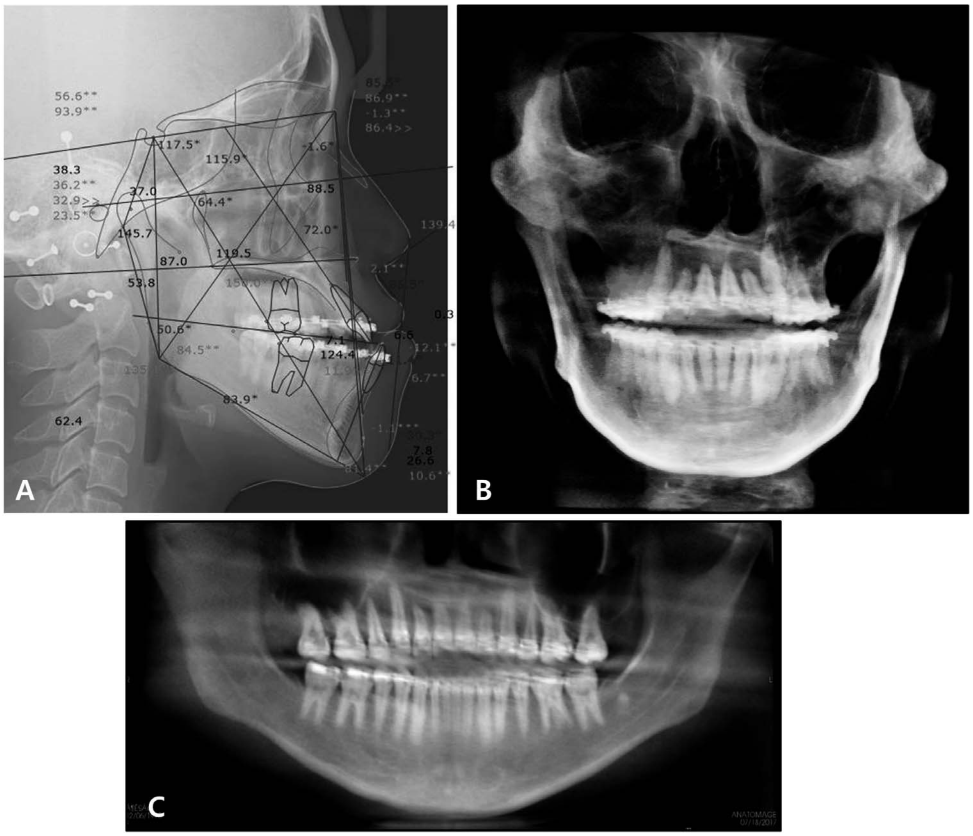

Figure 6. Presurgery radiographs. (A) Lateral cephalogram. (B) Posteroanterior cephalogram. (C) Panoramic radiograph.

arch was constricted by about 2.5 mm. The maxillary and mandibular arches were then positioned in the desired occlusion following surgical treatment objectives.

The maxillomandibular complex was repositioned horizontally considering normal values of N perpendicular to the A point and N perpendicular to Pogonion, parallel to the horizontal plane based on COGS. Even though the initial occlusal plane angle was steep (23.5°; norm, 15.0°), posterior impaction of the maxilla was planned to avoid limitations of the pterygomasseteric sling: for the maxilla, a Le Fort I osteotomy with posterior impaction of 5.0 mm and backward translation of 2.0 mm; for the mandible, bilateral intraoral vertical ramus osteotomy with setback of 9.0 mm; and for the chin, a genioplasty with a 4.0-mm advancement was planned.

Finally, postsurgical occlusion was visualized and virtual collisions were evaluated to eliminate occlusal interferences. Meanwhile, marginal ridge discrepancies and rotations of the teeth were corrected, and an interproximal reduction of the four maxillary incisors (0.2-mm reduction on the mesial and distal sides) was planned to obtain ideal overjet and canine relationships. After confirmation of the virtual alignment and final occlusion (Figure 4A), customized brackets with an optimal prescription were designed and placed on a virtual model. Then, indirect bonding jigs and archwires were fabricated (Figure 4B).

Table 2. Treatment Progress and Sequencing Details

Appointment	Archwire	Note
1 (0 mo)	0.016-inch CuNiTi	Initial leveling and alignment
2 (1 mo)	0.016 × 0.025-inch CuNiTi	
3 (2 mo)	0.018 × 0.025-inch CuNiTi	
4 (3 mo)	0.019 × 0.025-inch low-friction TMA	
5–10 (4–9 mo)	0.019 × 0.025-inch stainless steel	Space closure
Surgery (10 mo)	0.019 × 0.025-inch stainless steel surgical arch wire	
11–16 (11–16 mo)	0.019 × 0.025-inch low-friction TMA	Finishing
17 (16 mo)		Debonded

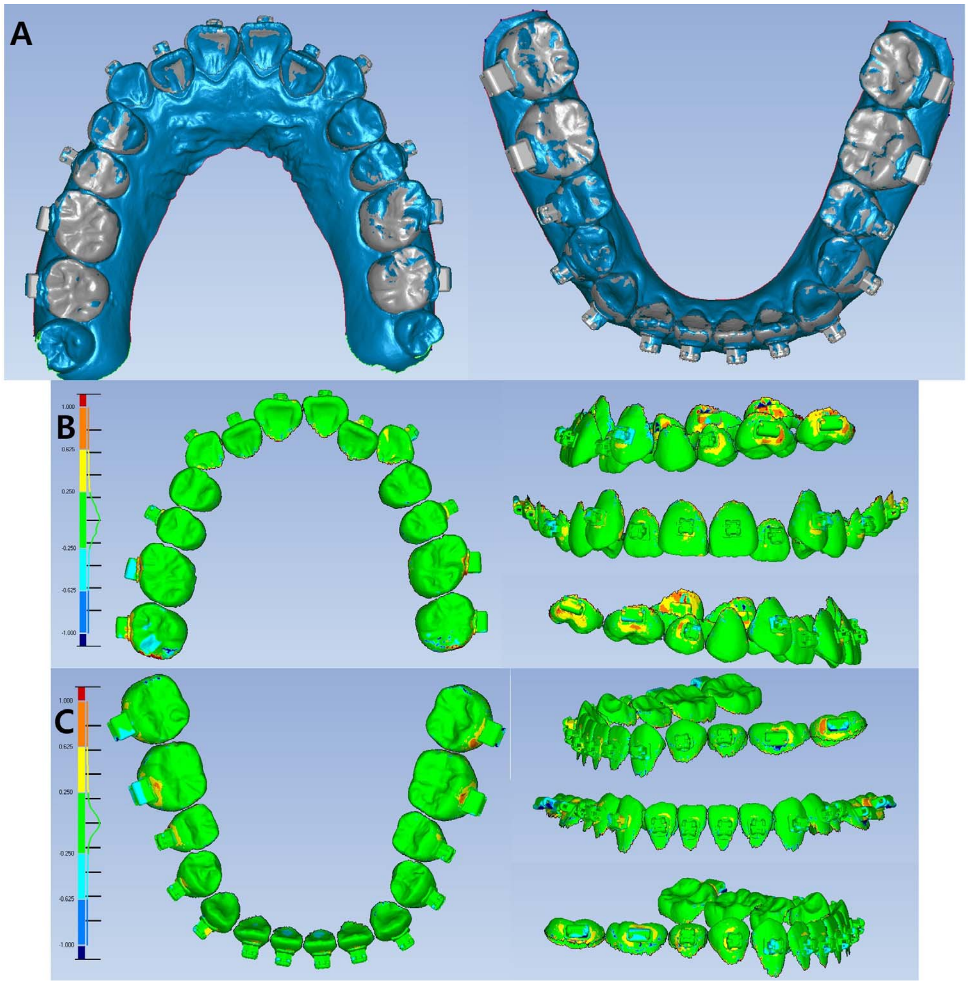

Figure 7. (A) Superimposition between proposed and actual bracket placement. Blue, proposed; gray, actual, B and C. Superimposed images with different color scales, maxillary and mandibular dentition.

ORTHODONTIC TREATMENT AND SURGICAL PROCEDURE

Treatment was initiated using transfer trays to bond customized, stainless steel, passive self-ligating brackets with 0.022 × 0.028-inch slots (Insignia System, Ormco), except on the maxillary first premolars (Figure 4C). On the same day, the maxillary first premolars were extracted, and a 0.016-inch copper nickel titanium archwire was used for initial leveling and alignment.

After initial leveling and alignment, the wires were changed sequentially up to 0.019 × 0.025-inch stainless steel archwires and used as working wires. Elastomeric chains were positioned between the first molar and the hook between the lateral incisor and the canine to close the maxillary extraction spaces reciprocally. To disarticulate the arches during space closure, posterior bite blocks were constructed on the occlusal surfaces of the mandibular second molars with light-cured core buildup composite (Light-Core, BISCO Dental, Schaumburg, Ill). After 5 months of active space closure, all spaces were closed, and surgical archwires were placed 30 days before surgery (Figures 5 and 6). The presurgical treatment time was 9 months. To obtain ideal facial esthetics, a virtual surgical plan based on the surgical treatment objective was performed after the preoperative treatment, which was similar to the initial plan.

The patient was evaluated 1 month after surgery, and the final splint was removed. Finishing and detailing was started on a 0.019 × 0.025-inch low-friction beta-titanium (TMA) archwire, and rotations in the maxillary canines were corrected by bending the archwire. In addition, the patient was instructed to wear settling elastics during the entire day and to perform therapeutic exercises to restore normal functioning of the jaw muscles and to finalize the occlusion. The patient was debonded 7 months after surgery, and lingual-fixed and circumferential removable retainers were provided to secure the stability of the arches. The total treatment time for this patient was 16 months. The

Figure 8. Posttreatment facial and intraoral photographs.

treatment progress and sequencing details are shown in Table 2.

Evaluation of Bracket Rebonding

An intraoral scan (Trios, 3Shape, Copenhagen, Denmark) was taken immediately after the indirect bonding procedure to evaluate the bonding accuracy of the customized brackets. Subsequently, the intended bracket positioning was compared with the actual positioning by digital model superimposition. Most of the brackets were bonded within a 0.25-mm error range, but the maxillary right first and second molars showed 0.5 mm of vertical and labiolingual positioning errors (Figure 7). After confirmation of accuracy, rebonding of these two brackets was performed during leveling and alignment, and one additional bracket (mandibular left second molar) was rebonded because of bond failure. In total, three brackets required rebonding procedures during the entire treatment period.

Treatment Results

Posttreatment records showed that the treatment objectives were achieved, and the patient was satisfied with the esthetic facial profile. Favorable interdigitation, Class I canine and Class II molar relationships, and ideal overjet and overbite were established. The upper and lower dental midline aligned with the patient's facial midline, and the patient's smile esthetics were significantly improved (Figures 8–10).

The final lateral cephalometric analysis showed that both the inclination of the maxillary and mandibular incisors and the lip profile were improved during treatment (Figure 10; Table 1). The final panoramic radiograph documented adequate root parallelism and showed slight root resorption of the mandibular incisors. Cephalometric superimposition between pre-

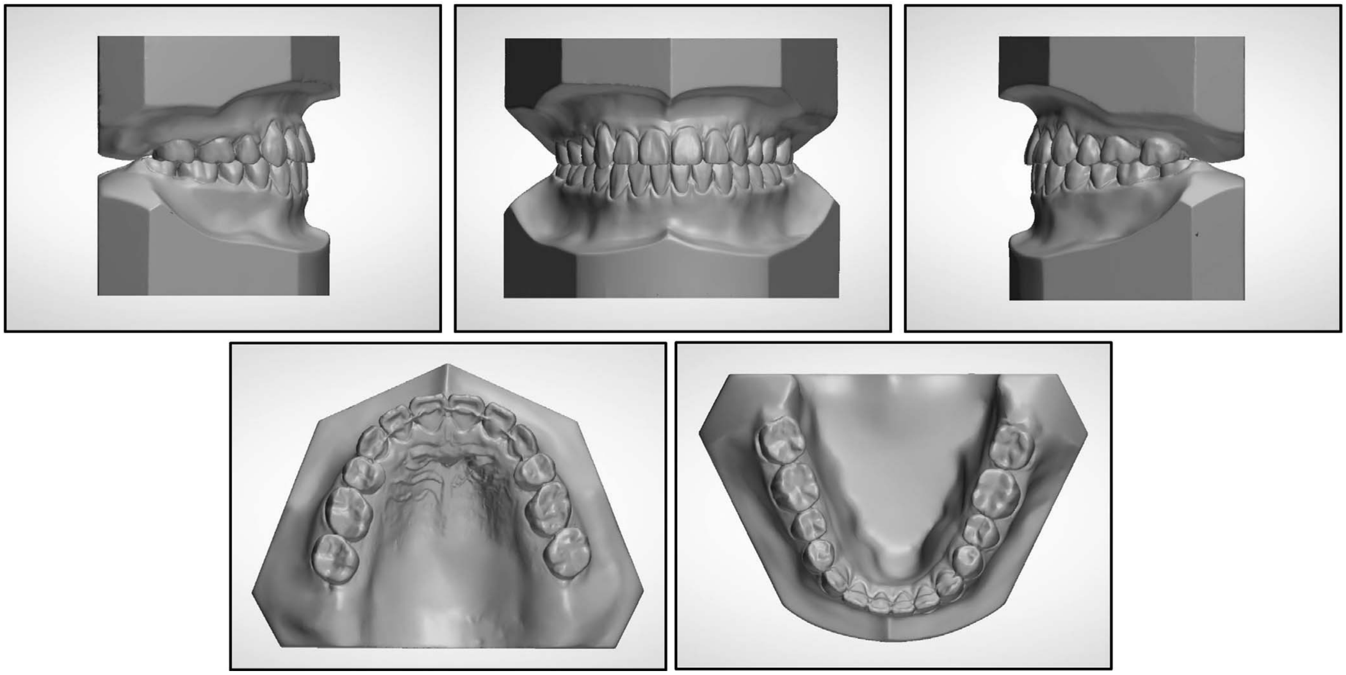

Figure 9. Posttreatment models.

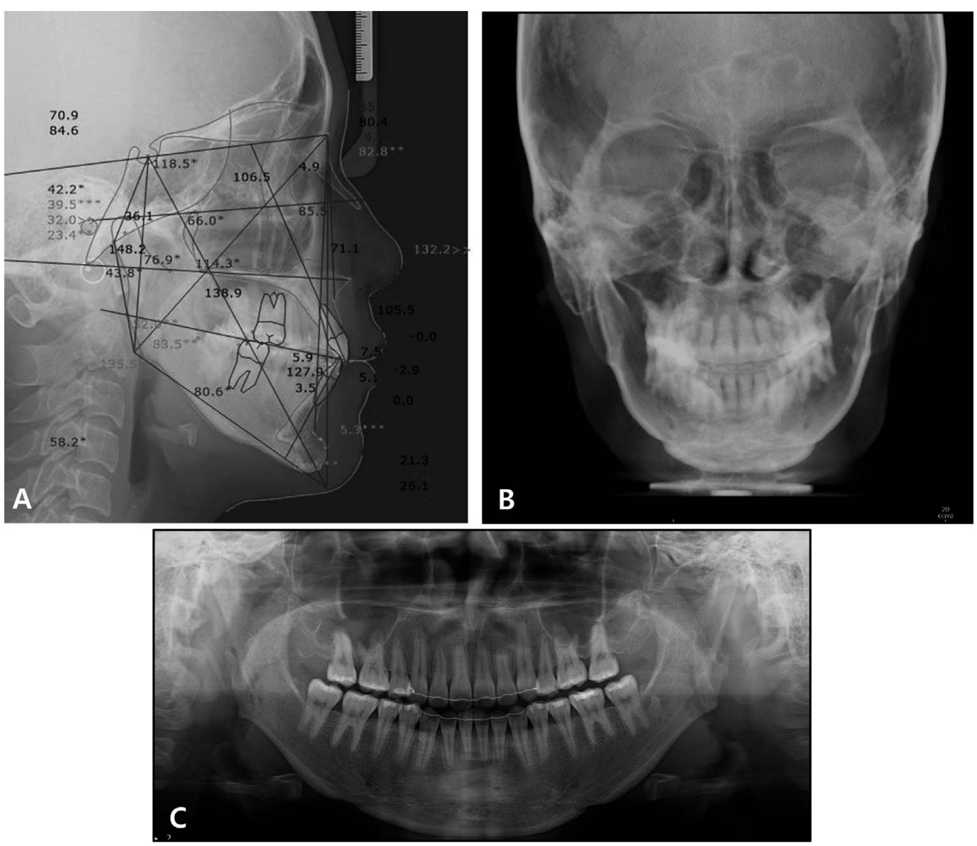

Figure 10. Posttreatment radiographs. (A) Lateral cephalogram. (B) Posteroanterior cephalogram. (C) Panoramic radiograph.

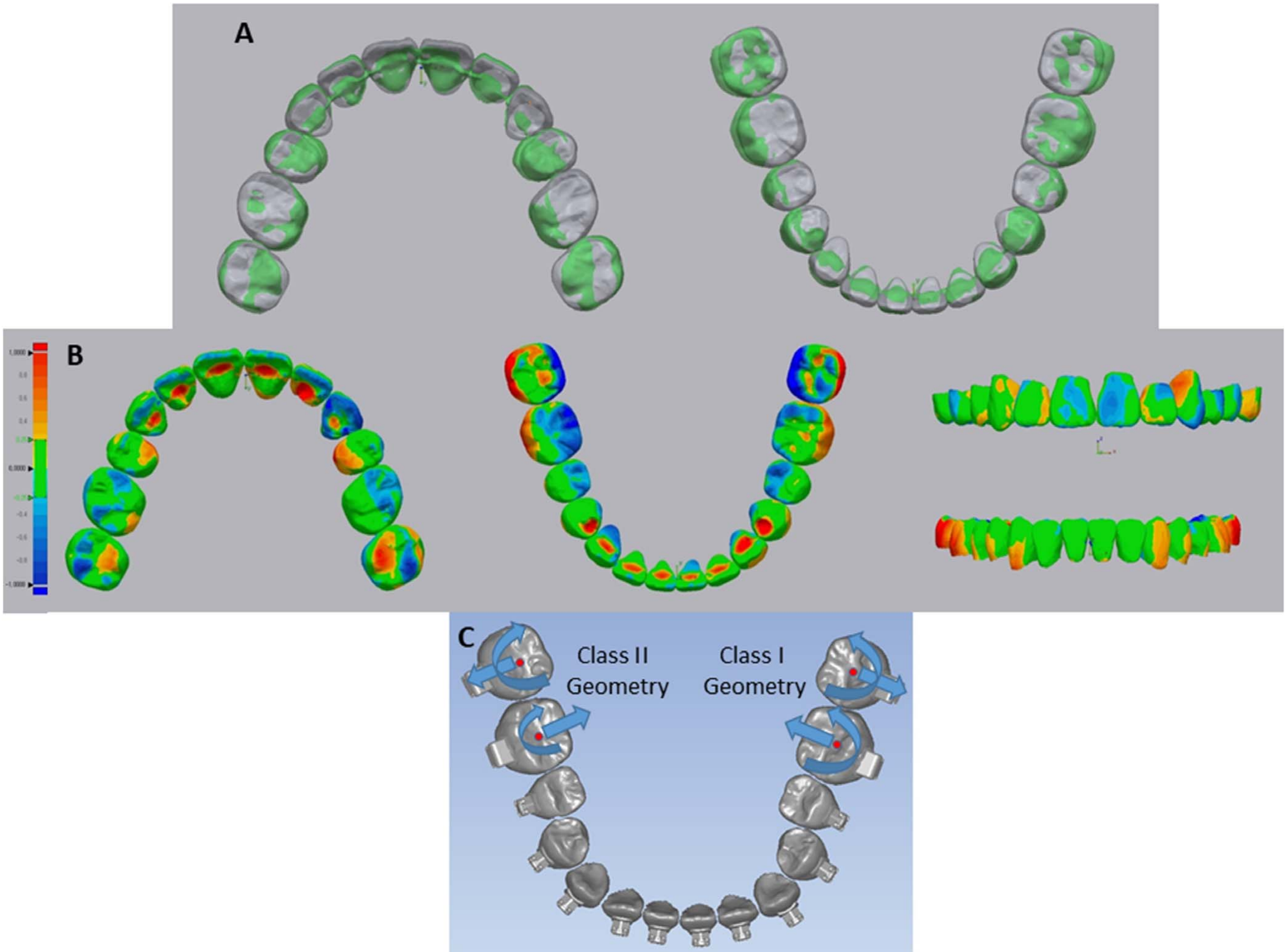

Figure 11. (A) Superimposition between initial setup and final outcome. Gray, setup; green, final model. (B) Superimposition images with different color scales, maxillary and mandibular dentition. (C) Force diagram of mandibular first and second molars.

and posttreatment showed clockwise rotation and setback of the maxillomandibular complex during surgery, which helped to improve the patient's protrusive mandible and lip profile and shortened her lower third anterior facial height. Her American Board of Orthodontics Cast-Radiograph Evaluation score was 10.

Superimposition between the initial digital setup and final outcome was performed (Figure 11). Discrepancies in position between the setup and outcome were small for all teeth (less than 1 mm), except for the mandibular molars, especially the mandibular second molars. Mandibular molars were expanded more than planned, but buccal overjet in the molar area was clinically acceptable.

Photographs, radiographs, and cephalometric superimpositions obtained at a 2-year follow-up showed stable results (Figures 12–14; Table 1).

DISCUSSION

Here, the CAD/CAM virtual orthodontic system was used in an adult patient undergoing orthognathic surgery and orthodontic treatment with premolar extractions for the first time. The aim was to objectively evaluate the effectiveness of the treatment and accuracy of the treatment results.

In surgical cases, the effectiveness and duration of treatment are influenced by the severity of the pretreatment skeletal discrepancy.[10,11] To overcome a patient's individual characteristics and to shorten treatment time, different approaches have been introduced, including a surgery-first approach, accelerating tooth movement methods, and so forth.[1,4] Among the many different methods, the focus for this patient was on an individualized treatment plan based on the virtual setup, fabrication, and precise placement of customized brackets to improve the efficiency of treatment.

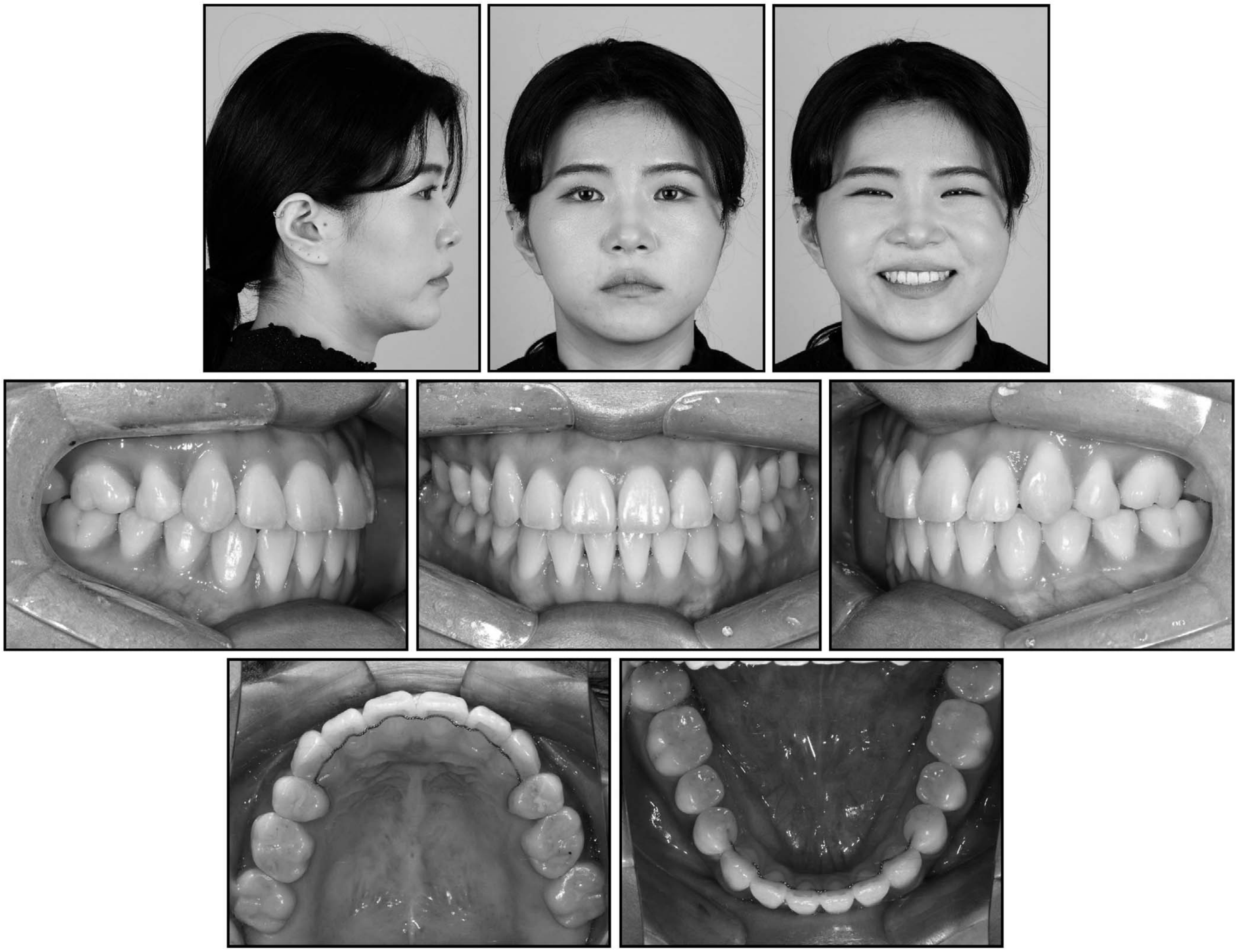

Figure 12. Two-year retention facial and intraoral photographs.

The digital diagnostic setup of orthodontic treatment is helpful for determining the amount of tooth movement needed. Checking the final incisal and occlusal relationship can result in a substantial change in the treatment plan.[11,12] When combined with the CAD/CAM system, it helps to manufacture customized appliances that achieve ideal alignment at the end of treatment with the final full-sized archwires. Despite contradictory opinions, the CAD/CAM system with customized brackets has been reported to produce similar treatment results in shorter treatment times compared with preadjusted orthodontic appliances.[6] In surgical cases, clinicians cannot determine the postsurgical occlusion of the patient before surgery, and additional procedures, including taking impressions and intraoral scanning, are needed, which can be time-consuming and may delay the timing of surgical interventions. Therefore, applying the CAD/CAM virtual orthodontic system can improve the efficiency of surgical orthodontic treatment by simulating presurgical treatment and visualizing postsurgical occlusion during treatment planning.

In this patient, presurgical treatment was planned, including construction of a customized arch form, decompensation of the anterior tooth inclination, and arch coordination related to the transverse discrepancy. It was confirmed that these treatment objectives were successfully accomplished through model superimposition between the initial setup and final outcome (Figure 11). However, the mandibular intermolar width increased by about 3.5 mm, which was larger than expected, and the second molars were even more greatly expanded. Large transverse discrepancies in the mandibular molar area could be explained by two factors. First, when using Class II elastics for presurgical dental decompensation, the force application is buccal to the center of resistance of the mandibular posterior teeth and could have a tendency to cause expansion. The second factor that might have introduced greater discrepancy in the second molar region

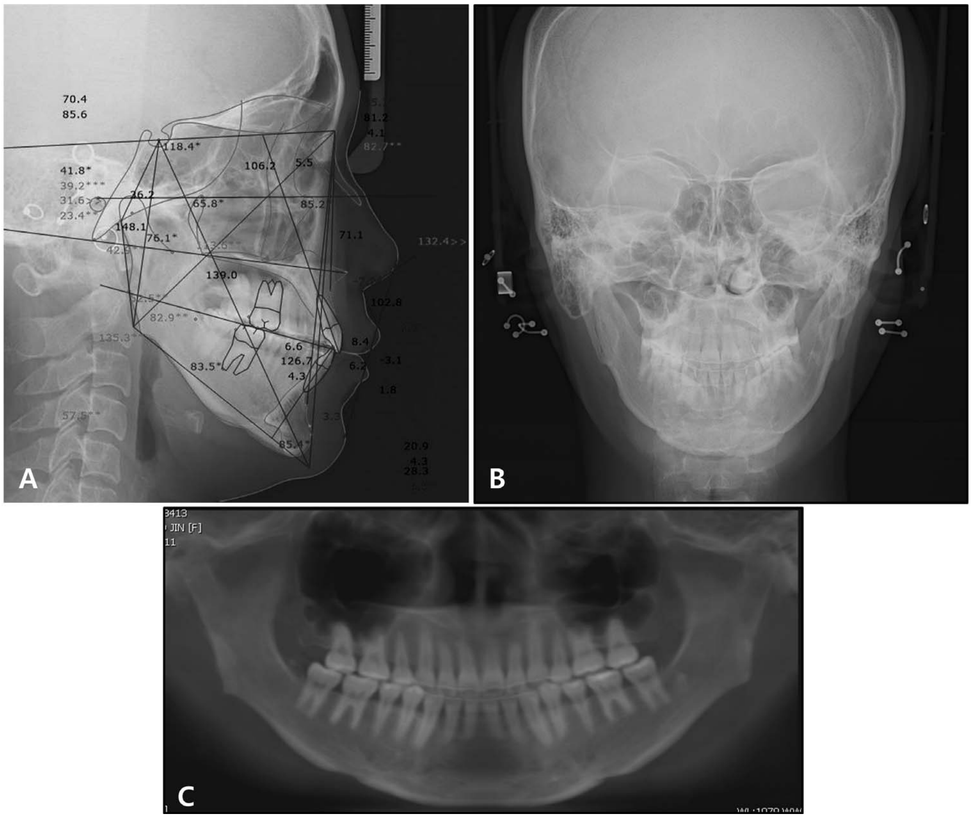

Figure 13. Two-year retention radiographs. (A) Lateral cephalogram. (B) Posteroanterior cephalogram. (C) Panoramic radiograph.

was the geometry of the brackets. The force system caused by Class I and II geometries is demonstrated in Figure 11C. Both systems help derotation of the second molars but also produced buccal expansion forces. These forces are additive, because the buccal expansion force was planned to be produced by the mandibular molar bracket's customized prescription with overdone buccal torque at the coronal aspect.

Customized brackets need to be placed precisely at the planned positions because bracket rebonding due

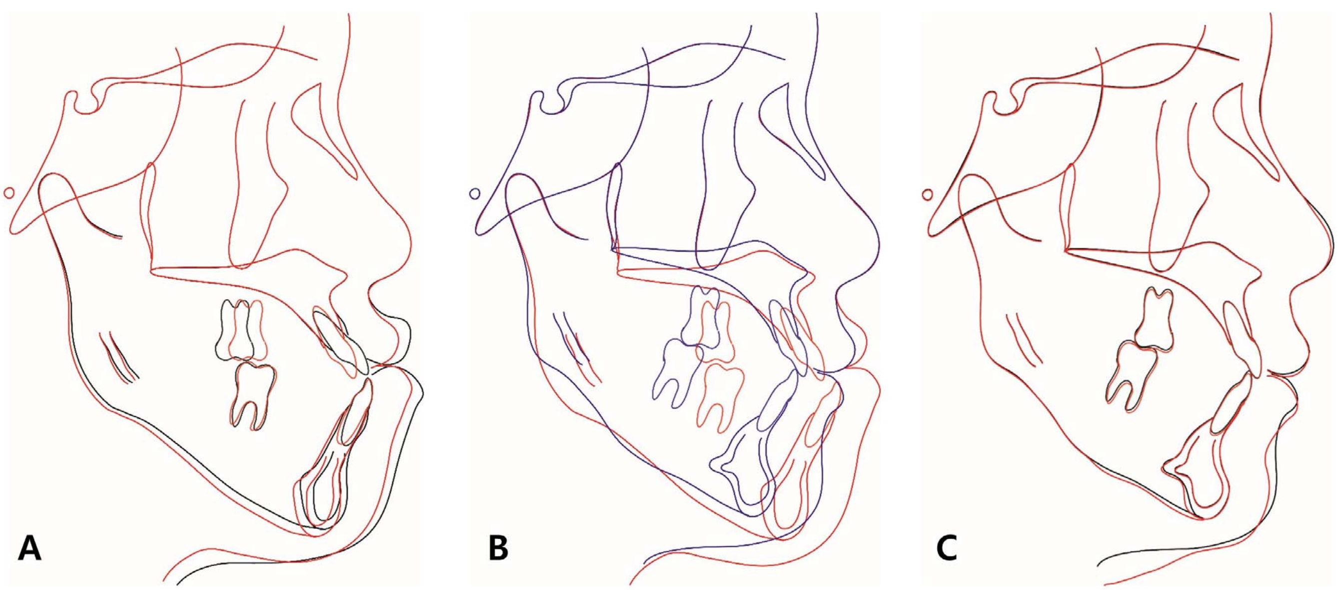

Figure 14. Cephalometric superimposition. (A) Pretreatment and presurgery. Black, pretreatment; red, presurgery. (B) Presurgery and posttreatment. Red, presurgery; blue, posttreatment. (C) Posttreatment and 2-year retention. Black, posttreatment; red, 2-year retention.

to positional errors has been associated with longer treatment times. Rebonding three or more brackets has been shown to increase the treatment time by an additional 2.5 months.[13] In this patient, most of the brackets were bonded within a 0.25-mm error range, although there were approximately 0.5-mm positioning errors on the maxillary right first and second molars. This error was considered a positioning error of the transfer tray. The positional error value was large compared with previous research that studied linear errors of indirect bonding with 3D-printed transfer trays (0.04 mm to 0.42 mm).[14] However, based on a literature review, linear differences not exceeding 0.5 mm are considered clinically acceptable.[15] Thus, the two brackets that showed large errors were rebonded during leveling and alignment, and an additional rebonding procedure was required only once more during treatment.

The total treatment time was 16 months (presurgical, 9 months; postsurgical, 7 months), which was a relatively short time frame compared with previous reports of conventional orthodontics-first surgical cases.[16,17] When using the conventional method, the duration of postsurgical treatment is known to be 6 to 12 months, with little or no relationship between the treatment duration and the patient's age, gender, preoperative treatment duration, and so on.[17] Therefore, it was believed that the CAD/CAM virtual orthodontic system can be applied to improve the efficiency of treatment by strategic presurgical orthodontic treatment. However, there may still be some limitations to the full expression of the individual prescription of the customized brackets because of a gap between the wire and the bracket slots. Therefore, additional torqueing or bending of the wire may be needed. In addition, a clinician's knowledge and skills are needed for the duration of treatment for maximizing the advantages of the CAD/CAM–based customized orthodontic treatment system.

CONCLUSIONS

- Ideal tooth alignment and occlusion can be achieved by an individualized orthodontic treatment plan and optimal prescriptions of customized brackets using the CAD/CAM virtual orthodontic system. In addition, this system can contribute to efficient orthodontic treatment in surgical cases.
- However, the evaluation of customized bracket bonding accuracy and additional detailing procedures related to functional occlusion are needed to maximize the advantages of the system.

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