Class II Division 1 Adolescent Treatment with Twin Block and Fixed Orthodontic Appliances: 3-Dimensional Changes of the Temporomandibular Joint

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Introduction: *Skeletal Class II division 1 malocclusions with a retrognathic mandible can be treated with Twin Block and fixed orthodontic appliances in growing adolescent patients.* ***Objective:*** *The aim of this case report was to show successful treatment results following step-by-step procedures determined by visualizing the changes of the temporomandibular joint (TMJ) area using cone-beam computed tomography (CBCT) images.****Case report:*** *A 10-year, 8-month-old female adolescent with skeletal Class II division 1 (ANB, 6.2°), severe overjet (8.4 mm), and overbite (7.8 mm) was treated with Twin Block and fixed orthodontic appliances. After wearing an active plate for 4 months, a Twin Block appliance for 9 months, a retainer with an inclined plane for 13 months, and fixed orthodontic treatment for 17 months, her skeletal Class II was corrected. After 39 months of posttreatment retention, good treatment results were maintained with favorable occlusion and facial balance. Acceptable 3-dimensional changes of the TMJ area were identified using cone-beam computed tomography images.****Conclusion:*** *A female adolescent patient with skeletal Class II division 1 malocclusion, severe overjet and overbite, and mandibular retrusion was treated using Twin Block and fixed orthodontic appliances. Acceptable 3-dimensional changes in the TMJ area and 2-dimensional growth of the mandible were identified using CBCT and cephalometric images.*

Keywords: *Twin Block appliance; Temporomandibular joint; Cone-beam computed tomography*

INTRODUCTION

Skeletal Class II division 1 malocclusions are characterized by a retrognathic mandible, a prognathic maxilla, or both.[1] Those patients with a retrognathic mandible can be treated with functional appliances such as Twin Block[2-13] and monoblock[6,7,14] but a patient with a prognathic maxilla can be treated with a headgear.[15,16]

When an adolescent patient has been diagnosed with skeletal Class II malocclusion, we can determine the best treatment method by evaluating the facial profile when the mandible is advanced to edge-to-edge (EtoE) bite. Functional appliances with a construction bite are a better treatment option than a headgear when the patient's facial profile is improved at EtoE bite.[17]

Clark[2,3,11] introduced a functional appliance called a Twin Block that consists of upper and lower bite blocks which interlock at a 45° or 75°, causing a functional mandibular advancement. They are designed for full-time wear to take advantage of all functional forces applied to the dentition including mastication.

Clark[2,3,11] proposed four phases of Twin Block treatment. The first stage is the active phase to correct the anteroposterior relationship and establish the correct vertical dimension using a Twin Block. At the end of the active phase, the incisors and the molars should be in correct occlusion, but an open bite will still be present in the premolar region because of the presence of the bite blocks. The second stage is the support phase which uses an upper Hawley-type removable appliance with an inclined bite plane to retain the sagittal

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position of the mandible and the corrected incisor relationship until the buccal segment occlusion is fully established. The third stage is the retention phase which can use the same appliance as in the second stage or alternatives such as a soft positioner or a monobloc or possibly no retainer at all. The fourth stage is the fixed treatment phase, in which detailing of the occlusion is achieved.

This case report shows successful treatment results following step-by-step procedures determined by visualizing the changes of the temporomandibular joint (TMJ) area using cone-beam computed tomography (CBCT) images.

Diagnosis and Etiology

A 10-year, 8-month-old female adolescent patient, presented with the chief complaint of her maxillary incisor protrusion. She had protrusive lips, acute nasolabial and mentolabial angles, and a retruded mandible. Intraoral photographs and digital models showed severe overjet (8.4 mm) and overbite (7.8 mm), Class II canine and molar relationships, slight crowding, dental midline disharmony, a V-shaped maxillary arch, and the deep curve of Spee of the mandibular arch (Figure 1).

The lateral cephalometric measurements showed a skeletal Class II (ANB, 6.2°) and hyperdivergent growth pattern (SN-MP, 41.6°), and normal inclination of the maxillary and mandibular incisors (U1 to FH, 114.5°; IMPA, 91.7°). The hand-wrist radiograph indicated the patient was in the fourth stage of the skeletal maturation indicator (SMI). A panoramic radiograph showed that all second molars were erupting and all third molar buds were forming (Figure 1; Table 1).

Figure 1. Pretreatment (T1) facial and intraoral photographs, digital model, and radiographs.

Table 1. Cephalometric measurements throughout Twin Block appliance and fixed orthodontic treatment (T1 to T5)

Measurement	Norm	T1 (10Y8M)	T2 (11Y10M)	T3 (12Y11M)	T4 (14Y6M)	T5 (17Y9M)
SNA (°)	82.0	78.5	78.3	78.1	78.9	79.1
SNB (°)	79.9	72.3	73.6	74.7	75.2	75.3
ANB (°)	2.1	6.2	4.7	3.4	3.7	3.8
Wits (mm)	1.1	2.8	-1.0	-4.5	-2.4	-1.2
SN–MP (°)	34.0	41.6	42.3	42.4	42.6	41.5
FH–MP (°)	28.2	32.2	32.5	32.4	33.0	32.0
U1–FH (°)	116.0	114.5	114.5	108.2	110.9	111.4
U1–SN (°)	104.0	107.5	107.5	101.1	103.9	104.3
U1–NA (°)	22.0	29.0	29.2	23.0	25.0	25.3
IMPA (°)	90.0	91.7	91.2	91.3	92.5	93.5
L1–NB (°)	25.0	25.6	27.1	28.4	30.3	30.3
U1/L1 (°)	124.0	119.2	119.1	125.2	121.1	120.7
Upper lip (mm)	1.2	6.1	4.1	2.0	1.9	2.0
Lower lip (mm)	2.0	7.3	5.9	2.5	3.6	4.0

T1; Pretreatment, T2; 4 months of active plate and 9 months of Twin Block treatment, T3; 13 months after modified retainer with inclined plane, T4; after 17 months of fixed orthodontic treatment, T5; 39 month-posttreatment.

A lateral cephalometric radiograph at EtoE bite superimposed with the pretreatment cephalometric radiograph at centric occlusion showed an improved facial profile when the mandible was advanced to EtoE bite (Figure 2).

Treatment Objectives

The initial treatment objectives were to reduce skeletal discrepancy, overjet, overbite, and curve of Spee and improve the facial profile by enhancing mandibular growth. The final treatment objectives were to align the dentition and to obtain proper occlusion.

Treatment Alternatives

The first treatment option was to plan for orthognathic surgery after the patient was finished growing. This option would depend on the growth pattern during growth. The second treatment option was to extract the premolars and perform camouflage orthodontic treatment. The third treatment option was to expand the maxillary arch and advance the mandible while the patient was still growing. After treatment with a function appliance, fixed orthodontic treatment with extraction or non-extraction would be needed depending on whether the facial profile needed to be corrected or not. The patient and parents chose the third non-extraction option.

Treatment Progress

An active plate with an expansion screw was used for 4 months to expand the maxillary arch (Figure 3A). Then a modified Twin Block appliance with expansion screws in both arches, no labial bow, jaw registration with 8.4 mm advancement of the mandible and 3 to 5 mm of posterior tooth disclusion, and steep inclined planes interlocked at about 70° to the occlusal plane was applied all-day, including meal time. The Twin Block appliance was adjusted once per month for 9 months to expand both arches and for the eruption of the mandibular molars to level the curve of Spee (Figure 3B).

The overjet, overbite, and anteroposterior occlusal relationship were overcorrected to compensate for the anticipated relapse with the condyles moving upward and backward during the retention stage (Figure 4). A maxillary modified Hawley retainer with an anterior inclined plane was applied for 13 months (Figures 5 and 6). 0.022 × 0.028-in edgewise appliances were placed in the maxillary and mandibular arches. Leveling was done with 0.014-in and 0.016-in nickel-titanium archwires and 0.018-in stainless steel (SS) archwires. Finishing was completed with a 0.018 × 0.025-in SS archwires with intermaxillary elastomers. Fixed retainers were bonded on the lingual surface of the six anterior teeth of both arches, and wraparound removable retainers were delivered to retain the treatment results. The total fixed treatment time was 17 months.

Figure 2. Pretreatment edge-to-edge bite (T1 EtoE). (A) T1 EtoE intraoral photographs.(B) T1 and T1 EtoE lateral cephalometric radiographs, tracing, and superimposition.

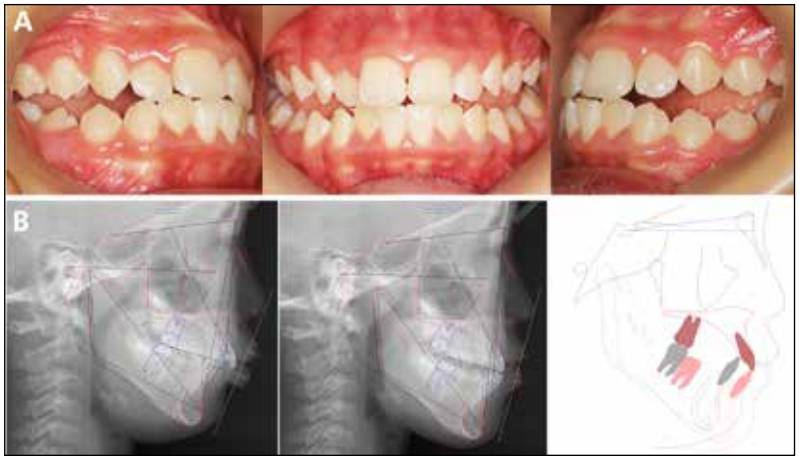


Figure 3. Treatment progress. (A) Intraoral photographs of the active plate with expansion screw. (B) Facial and intraoral photographs of Twin Block appliance with an expansion screw.

Figure 4. Facial and intraoral photographs and radiographs after 4 months of the active plate and 9 months of Twin Block appliance treatment (T2).

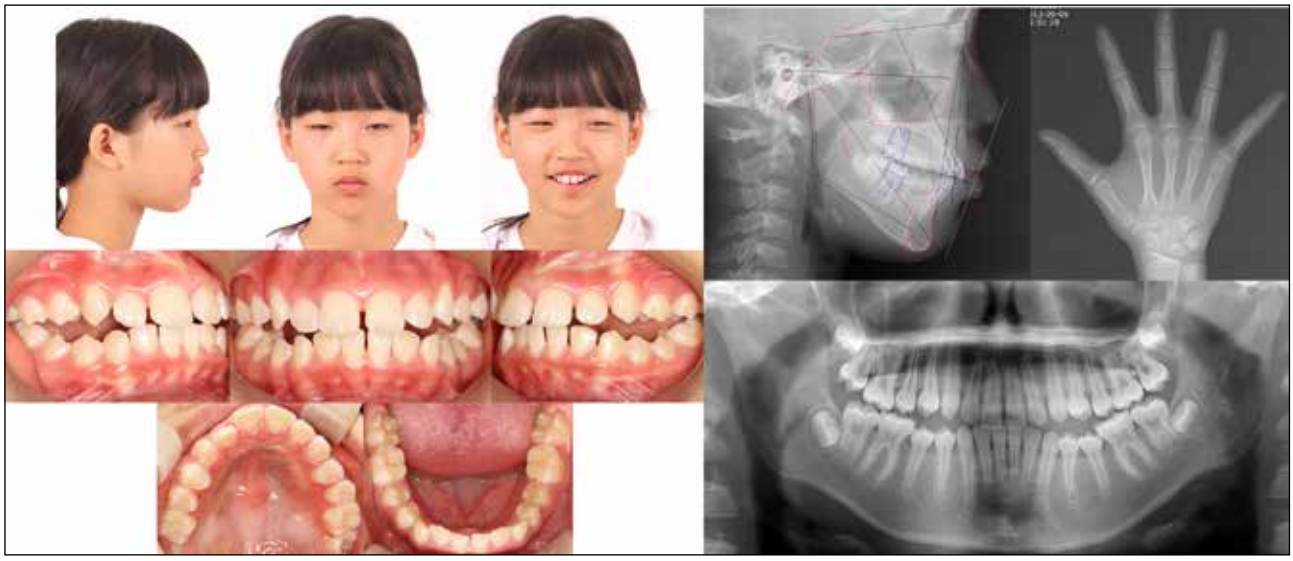
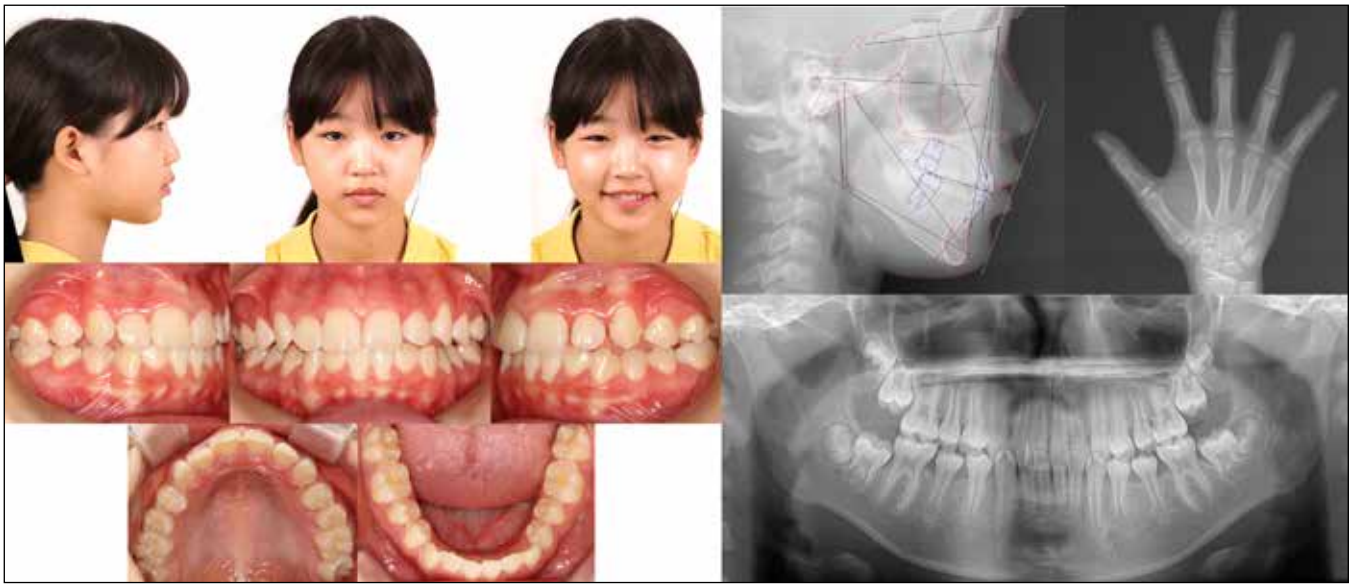


Figure 5. Intraoral photographs of a modified maxillary Hawley retainer with an anterior inclined plane.

Figure 6. Facial and intraoral photographs and radiographs after 13 months of Twin Block treatment with a modified maxillary Hawley retainer (T3).



RESULTS

Posttreatment facial photographs showed an improved profile with an acceptable smile. The posttreatment intraoral photographs and digital models showed a well-aligned dentition, Class I canine and molar relationships, proper interdigitation, proper overjet and overbite, and a flattened curve of Spee (Figure 7).

The posttreatment lateral cephalometric measurements showed improved horizontal changes (ANB, 3.8°; SNB, 75.3°), a reasonably well-maintained vertical pattern (SN-MP, 41.5°), and slightly decreased and increased inclinations of the maxillary and mandibular incisors (U1 to FH, 111.4°; IMPA, 93.5°), respectively. A hand-wrist radiograph indicated the patient was in the tenth stage of SMI. A panoramic radiograph showed acceptable root parallelism with no significant root resorption and all erupting third molars. The mandibular growth had occurred from T1 to T5 (Figure 7; Table 1).

The 39-month posttreatment photographs and radiographs showed that the treatment results were still well maintained, while the posttreatment posteroanterior cephalometric radiograph indicated no asymmetry (Figures 8). Cephalometric and 3D superimpositions from pretreatment to 39 months posttreatment showed favorable and significant treatment results and growth (Figures 9 and 10).

The 3D-volume images were automatically re-orientated using four landmarks such as the right and left fronto-zygomatic points, right porion (Po), and right orbitale (Or).[18] The serial CBCT images showed that the TMJ space between the condyle and the glenoid fossa was normalized, and condylar width had increased from T1 to T4 and was reasonably well-maintained from T4 to T5, and condylar axial angle was stable (Fig 11, Table 2).

Figure 7. Posttreatment (T4) facial and intraoral photographs, digital model, and radiographs after 17 months of fixed orthodontic treatment.

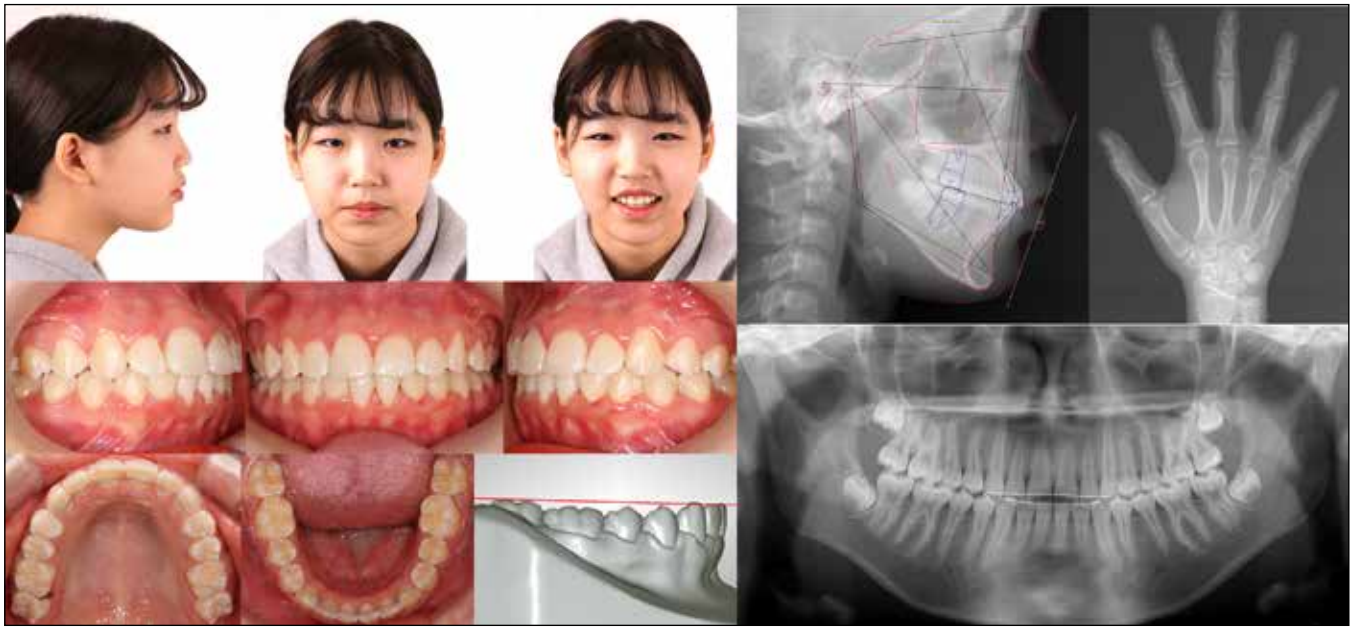


Figure 8. Facial and intraoral photographs and radiographs at 39 month-posttreatment (T5).

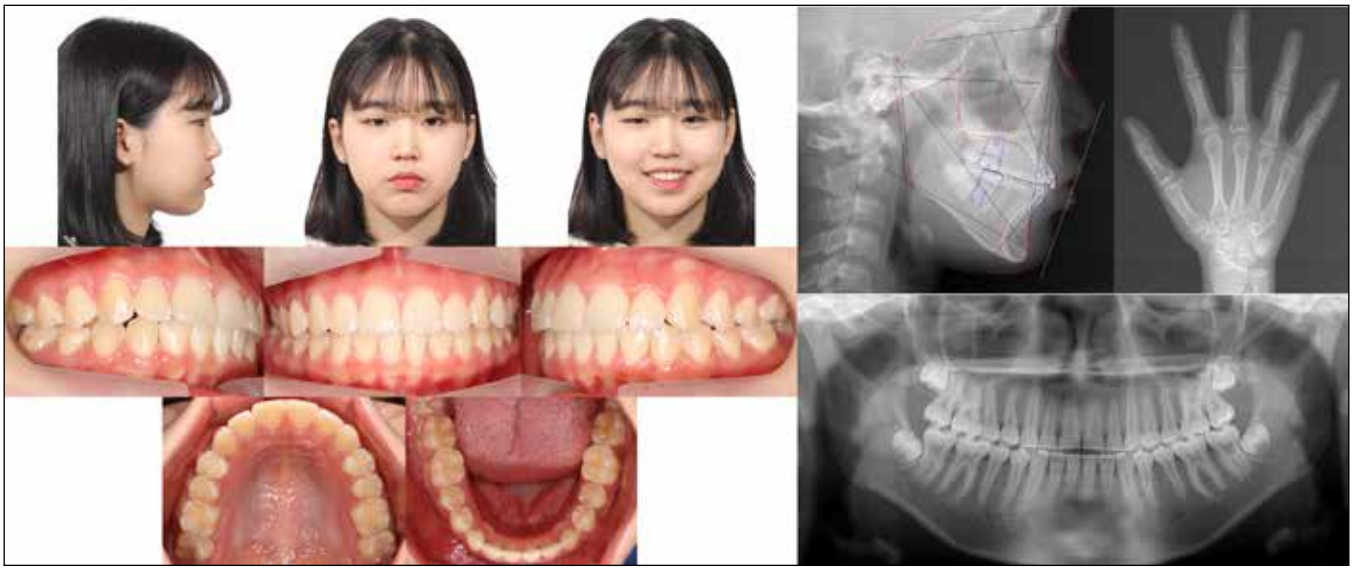


Figure 9. Cephalometric superimpositions. (A) T1-T2-T3-T4-T5. (B) T1-T2. (C) T2-T3. (D) T3-T4. (E) T4-T5. (F) T1-T5. T1, Pretreatment; T2, 4 months of active plate treatment and 9 months of Twin Block treatment; T3, 13 months after Twin Block treatment; T4, after 17 months of fixed orthodontic treatment; T5, 39 month-posttreatment.

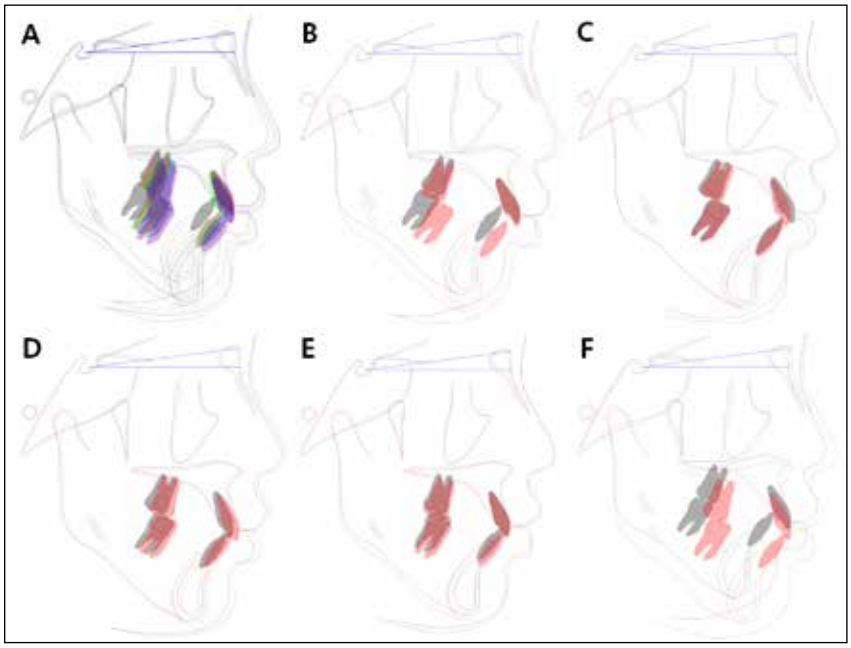


Figure 10. 3-dimensional superimpositions of pretreatment (T1, orange) and 39 month-posttreatment (T5, green). (A) Sagittal view. (B) Coronal view. (C) Axial view.

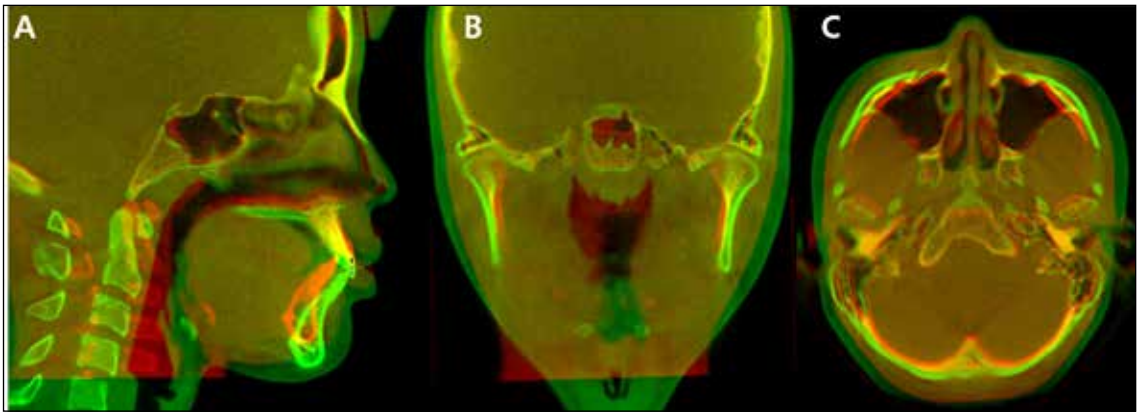


Table 2. Temporomandibular joint space (mm), condylar width (mm), and condylar angle (°) throughout Twin Block appliance and fixed orthodontic treatment (T1 to T5)

	Coronal view						Sagittal view				Axial view			
	Right TMJS			Left TMJS			Right TMJS		Left TMJS		Condylar width		Condylar angle	
	MS	SS	LS	MS	SS	LS	AS	PS	AS	PS	Right	Left	Right	Left
T1	2.50	3.66	1.89	2.58	2.96	2.96	2.11	1.82	1.68	3.23	17.24	17.91	24.74	22.95
T2	3.30	4.34	2.68	2.76	3.75	2.67	1.37	3.04	1.69	3.43	18.51	18.42	26.92	21.40
T3	1.93	3.37	2.16	2.29	2.88	2.40	1.42	1.43	1.53	2.26	19.36	19.23	20.87	23.42
T4	2.01	2.42	2.01	2.15	2.46	1.93	1.73	1.27	2.14	1.94	20.30	19.96	21.16	22.68
T5	2.31	3.08	2.09	1.90	2.69	2.25	1.91	1.67	1.43	2.04	20.38	20.29	23.39	23.50

T1; Pretreatment, T2; 4 months of active plate and 9 months of Twin Block treatment, T3; 13 months after modified retainer with inclined plane, T4; after 17 months of fixed orthodontic treatment, T5; 39 month-posttreatment. MS, medial space; SS, superior space; LS, lateral space; AS, anterior space; PS, posterior space.

Figure 11. Reorientation of cone-beam computed tomography (CBCT) images (right and left fronto-zygomatic points, right porion, and right orbitale) and measurements of the temporomandibular joint spaces, condylar axial angle (AA), and condylar width (CW) (T1-T2-T3-T4-T5). T1, Pretreatment; T2, 4 months of active plate treatment and 9 months of Twin Block treatment; T3, 13 months after Twin Block treatment; T4, after 17 months of fixed orthodontic treatment; T5, 39 month-posttreatment. SF, superior fossa; AF, anterior fossa; PF, posterior fossa; MF, medial fossa; LF, lateral fossa; AS, anterior space; SS, superior space; PS, posterior space; MS, medial space; LS, lateral space; AC, anterior condyle; SC, superior condyle; PC, posterior condyle; MC, medial condyle; LC, lateral condyle, MH, medial head; LH, lateral head; CW, the distance between MH and LH; AA, the angle between MH-LH line and coronal plane.

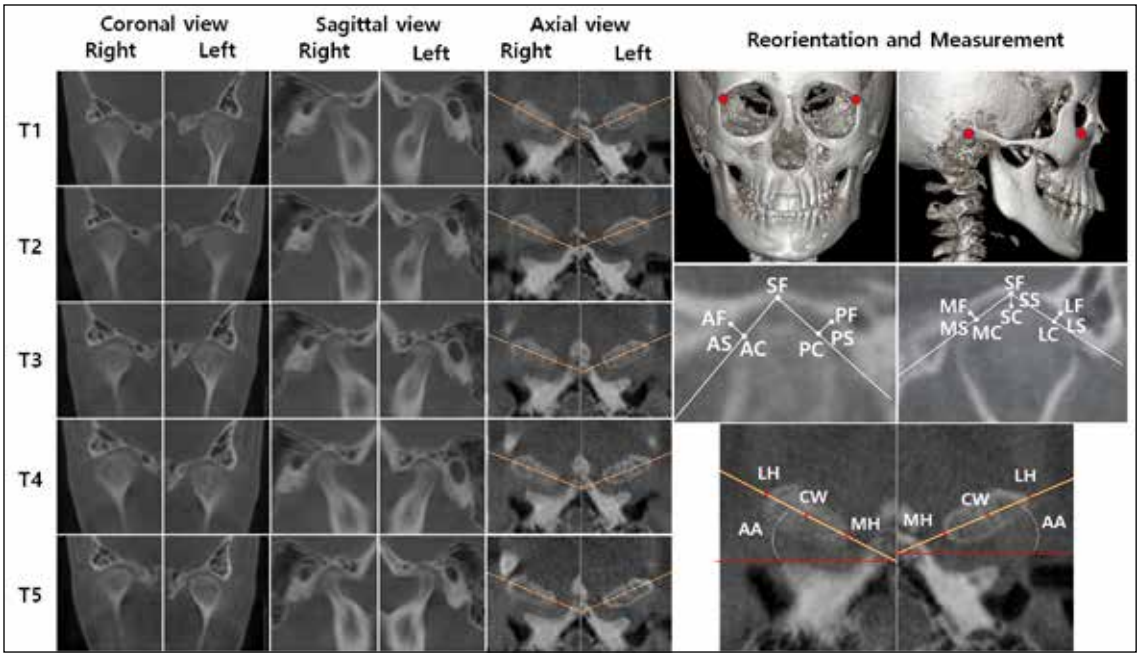


Fig 12. Growth velocity curve and stages of the skeletal maturation index (SMI)[22]: T1, Pretreatment (SMI 4); T2, 4 months of active plate treatment and 9 months of Twin Block treatment (SMI 6); T3, 13 months after Twin Block treatment (SMI 8); T4, after 17 months of fixed orthodontic treatment (SMI 10); T5, 39 month-posttreatment (SMI 11).

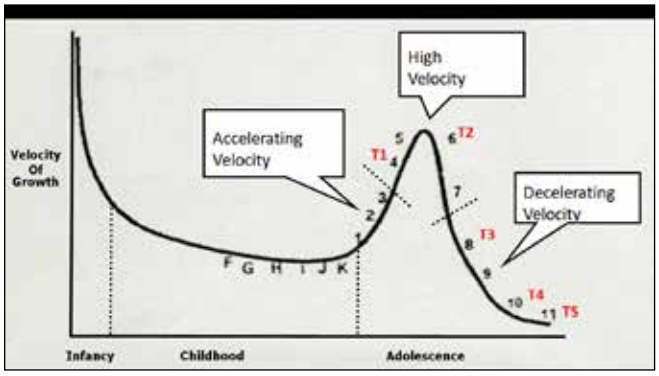


Table 3. Cephalometric measurements (mandibular growth) throughout Twin Block appliance and fixed orthodontic treatment (T1 to T5) according to SMI and CVMI

Measurement	T1 (10Y8M)	T2 (T2-T1) (11Y10M)	T3 (T3-T2) (12Y11M)	T4 (T4-T3) (14Y6M)	T5 (T5-T4) (17Y9M)
Co-Pog (mm)	110.9	116.0 (+5.1)	116.6 (+0.6)	120.3 (+3.7)	120.6 (0.3)
Co-Go (mm)	52.1	55.6 (+3.5)	55.8 (+0.2)	58.0 (+2.2)	59.2 (+1.2)
Go-Pog (mm)	73.2	75.1 (+1.9)	77.0 (+1.9)	77.0 (+0.0)	77.9 (+0.9)
SMI	4	6	8	10	11
CVMI	2	3	4	5	6

T1; Pretreatment, T2; 4 months of active plate and 9 months of Twin Block treatment, T3; 13 months after modified retainer with inclined plane, T4; after 17 months of fixed orthodontic treatment, T5; 39 month-posttreatment. T1-T2, 13 months; T2-T3, 13 months; T3-T4, 17 months; T4-T5, 39 months. SMI, skeletal maturation indicator; CVMI, cervical vertebrae maturation indicator.

Figure 13. Cervical vertebrae maturation indicator (CVMI): T1, Pretreatment (CVMI 2); T2, 4 months of active plate treatment and 9 months of Twin Block treatment (CVMI 3); T3, 13 months after Twin Block treatment (CVMI 4); T4, after 17 months of fixed orthodontic treatment (CVMI 5); T5, 39 month-posttreatment (CVMI 6).

DISCUSSION

It is essential to predict the treatment effects when selecting the most acceptable treatment option for Class II malocclusion correction. Evaluating the facial profile at EtoE bite with mandibular advancement is a rational way to select the treatment method. A functional appliance is recommended when the facial appearance is improved at EtoE bite to enhance the mandibular growth. If the facial profile becomes worse at EtoE bite, headgear or combined activator should be considered to correct the abnormalities.[17]

Optimal treatment timing is essential to stimulate the condylar growth or retard the maxillary growth efficiently. Fishman developed an SMI to evaluate the skeletal maturity using four stages of bone maturation at six anatomic sites on the hand-wrist radiographs.[19] Hassel and Farman defined six categories of cervical vertebrae maturation (CVM) and developed a reliable ranking according to growth potential using a CVM indicator (CVMI).[20] Some authors have suggested that there is a high correlation between SMI and CVMI.[20,21]

Baccetti et al.[9] concluded that the optimal timing for Twin Block therapy of Class II malocclusion is in CVMI 3 to 5 (SMI 5 to10) rather than in CVMI 1 to 2 (SMI 1 to 4). This means that the treatment should be performed during or slightly after the onset of the pubertal peak in growth velocity. In our patient, Twin Block treatment and retention were performed in SMI 4 to 8 or CVMI 2 to 4 (Figs 12 and 13), which showed a similarity to the optimal treatment timing for Twin Block appliances in a previous article.[9,21,22] Before application of Twin block appliance, we used an active plate to make an available space to level the maxillary anterior teeth and get the patient be familiar to intraoral appliance.

Clark[2] suggested that the bite registration rule with Twin Block should be such that initial activation reduces the overjet by 5-7 mm, leaving approximately 4-5 mm of inter-occlusal space in the first premolar region. However, an overjet of up to 10 mm can be corrected without reactivating the bite blocks if the rate and direction of mandibular growth are favorable.[3] In this case report, initial activation of about 8 mm to EtoE bite and 3 to 4 mm apart in the buccal segment were performed. Further studies are recommended to predict the accurate mandibular growth pattern and determine a better approach.

Mills and McCulloch[4] reported that their Twin Block group showed an increased mandibular unit length (condylion to gnathion), of which two-thirds was attributed to an increase in ramus height (condylion to gonion) and the remaining one-third was the result of an increase in the mandibular body length (gonion to gnathion), which was similar to our treatment results (Table 3). Yildrim *et al* [23] also concluded the Twin Block appliance increased intercondylar distance by stimulating the growth of the condyle in an upward and backward direction as seen in our patient (Figure 10). Chintakanon *et al* [24] reported that the condylar axial angle was stable in their Twin Block appliance group, similar to that of our patient. However, it is still not certain how much condylar growth can be increased by growth modification.[25] Therefore, further studies might be necessary.

Profitt *et al*.[26] showed a diagrammatic representation of the difference between temporary mandibular growth acceleration and true stimulation of the mandibular growth.

They concluded that functional appliances could accelerate the rate of forward mandibular growth before and during adolescence. They also concluded that growth acceleration would be possible. Still, the period of growth acceleration is followed by a diminished growth later, so if there is any increase in mandibular length in the long-term, it would be quite small. But our patient showed acceptable treatment results with growth acceleration during Twin Block treatment and true stimulation thereafter (Table 3). To achieve the best favorable growth curve for true stimulation, a good growth potential is essential. Therefore, future studies are recommended to predict an individual's growth potential.

Dentoalveolar responses in both arches, such as uprighting of the maxillary incisors and labial tipping of the mandibular incisors, were observed with Twin Block treatment.[2,4,8] These responses contribute to an overjet correction, but in some Class II cases, they are considered to be inevitable side effects of the functional appliance because these effects could inhibit the forward movement of the mandible. Therefore, many attempts have been made to reduce these side effects. A Twin Block appliance without a labial bow was used to prevent uprighting of the maxillary anterior teeth.[4] And a Twin Block appliance with acrylic capping[12] or supported by mini-implants[13] was used to prevent labial tipping of the mandibular anterior teeth. These approaches can increase the envelope for orthopedic correction in Class II myofunctional therapy. In our patient, a Twin Block appliance without a labial bow was used to reduce the side effects.

Twin Block appliances are simple bite blocks with the advantage that they can be worn full-time. They offer rapid functional correction with occlusal inclined planes and transverse maxillary expansion and allow greater freedom of movement in the anterior and lateral excursion.[2-6,11] Aggarwal *et al* [5] reaffirmed the importance of full-time wear for functional appliances to exert their maximum therapeutic effect through neuromuscular adaptation. However, Parekh *et al* [10] concluded that part-time wearing (12 hours a day) could be a viable alternative to the full-time wearing of a Twin Block appliance. Therefore, further studies are needed to resolve this conflict.

Clark[11] suggested that the best treatment results can be obtained by combining orthopedic and orthodontic techniques. After achieving optimal temporomandibular joint space (TMJS),[27] with growth modification possible, Class II malocclusion could be corrected by fixed orthodontic treatment with either extraction or non-extraction. Therefore, the condyle-fossa relationship should be evaluated using serial CBCT images, and it will depend on condylar growth and glenoid fossa modification during Twin Block appliance treatment and retention. Our patient showed normalized TMJS at T3 (Table 2) and started fixed orthodontic treatment with non-extraction because the patient and parents did not want extraction to reduce lip protrusion.

CONCLUSION

A female adolescent patient with skeletal Class II division 1 malocclusion, severe overjet and overbite, and mandibular retrusion was treated using Twin Block and fixed orthodontic appliances. Acceptable 3D changes in the TMJ area and 2-dimensional growth of the mandible were identified using CBCT and cephalometric images.

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REFERENCES

1. Moyers RE, Riolo ML, Guire KE, Wainright RL, Bookstein FL. Differential diagnosis of class II malocclusions. Part 1. Facial types associated with class II malocclusions. Am J Orthod. 1980 Nov;78(5):477-94.
2. Clark WJ. The twin block traction technique. Eur J Orthod. 1982 May;4(2):129-38.
3. Clark WJ. The twin block technique. A functional orthopedic appliance system. Am J Orthod Dentofacial Orthop. 1988 Jan;93(1):1-18.
4. Mills CM, McCulloch KJ. Treatment effects of the twin block appliance: a cephalometric study. Am J Orthod Dentofacial Orthop. 1998 Jul;114(1):15-24.
5. Aggarwal P, Kharbanda OP, Mathur R, Duggal R, Parkash H. Muscle response to the twin-block appliance: an electromyographic study of the masseter and anterior temporal muscles. Am J Orthod Dentofacial Orthop. 1999 Oct;116(4):405-14.
6. Tümer N, Gültan AS. Comparison of the effects of monoblock and twin-block appliances on the skeletal and dentoalveolar structures. Am J Orthod Dentofacial Orthop. 1999 Oct;116(4):460-8.
7. Toth LR, McNamara JA Jr. Treatment effects produced by the twin-block appliance and the FR-2 appliance of Fränkel compared with an untreated Class II sample. Am J Orthod Dentofacial Orthop. 1999 Dec;116(6):597-609.
8. Lee KY, Park JH, Tai K, Chae JM. Treatment with Twin-block appliance followed by fixed appliance therapy in a growing Class II patient. Am J Orthod Dentofacial Orthop. 2016 Nov;150(5):847-63.
9. Baccetti T, Franchi L, Toth LR, McNamara JA Jr. Treatment timing for Twin-block therapy. Am J Orthod Dentofacial Orthop. 2000 Aug;118(2):159-70.
10. Parekh J, Counihan K, Fleming PS, Pandis N, Sharma PK. Effectiveness of part-time vs full-time wear protocols of Twin-block appliance on dental and skeletal changes: A randomized controlled trial. Am J Orthod Dentofacial Orthop. 2019 Feb;155(2):165-72.
11. Clark WJ. Twin Block Functional Therapy: Applications in Dentofacial Orthopaedics: Mosby; 2002.
12. van der Plas MC, Janssen KI, Pandis N, Livas C. Twin Block appliance with acrylic capping does not have a significant inhibitory effect on lower incisor proclination. Angle Orthod. 2017 Jul;87(4):513-8.
13. Tripathi T, Singh N, Rai P, Gupta P. Mini-implant-supported twin-block appliance: An innovative modification. Niger J Clin Pract. 2019 Mar;22(3):432-8.
14. Idris G, Hajeer MY, Al-Jundi A. Soft- and hard-tissue changes following treatment of Class II division 1 malocclusion with Activator versus Trainer: a randomized controlled trial. Eur J Orthod. 2019 Jan 23;41(1):21-8.
15. Papageorgiou SN, Kutschera E, Memmert S, Gölz L, Jäger A, Bourauel C, Eliades T. Effectiveness of early orthopaedic treatment with headgear: a systematic review and meta-analysis. Eur J Orthod. 2017 Apr 1;39(2):176-187.
16. Kopecky GR, Fishman LS. Timing of cervical headgear treatment based on skeletal maturation. Am J Orthod Dentofacial Orthop. 1993 Aug;104(2):162-9.
17. Chae JM, Park JH, Kim SH, Mangal U, Seo HY. Prognostic Indicators for Anterior Mandibular Repositioning in Adolescents with Class II Malocclusion: A Cross-Sectional Cephalometric Study. J Clin Pediatr Dent. 2020 Aug 1;44(4):274-82.
18. Hong M, Kim MJ, Shin HJ, Cho HJ, Baek SH. Three-dimensional surgical accuracy between virtually planned and actual surgical movements of the maxilla in two-jaw orthognathic surgery. Korean J Orthod. 2020 Sep 25;50(5):293-303.
19. Fishman LS. Radiographic evaluation of skeletal maturation. A clinically oriented method based on hand-wrist films. Angle Orthod. 1982 Apr;52(2):88-112.
20. Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. Am J Orthod Dentofacial Orthop. 1995 Jan;107(1):58-66.
21. Morris JM, Park JH. Correlation of dental maturity with skeletal maturity from radiographic assessment: a review. J Clin Pediatr Dent. 2012 Spring;36(3):309-14.
22. MarshallWA, Tanner JM. Puberty. In: Falkner F, Tanner JM, editors. Human growth, volume 2. 2nd ed. New York: Plenum; 1986.
23. Yildirim E, Karacay S, Erkan M. Condylar response to functional therapy with Twin-Block as shown by cone-beam computed tomography. Angle Orthod. 2014 Nov;84(6):1018-25.
24. Chintakanon K, Sampson W, Wilkinson T, Townsend G. A prospective study of Twin-block appliance therapy assessed by magnetic resonance imaging. Am J Orthod Dentofacial Orthop. 2000 Nov;118(5):494-504.
25. Owtad P, Park JH, Shen G, Potres Z, Darendeliler MA. The biology of TMJ growth modification: a review. J Dent Res. 2013 Apr;92(4):315-21.
26. Proffit WR, Fields HW Jr, Sarver DM. Contemporary orthodontics. 5th ed. Philadelphia: Elsevier; 2013.
27. Ikeda K, Kawamura A, Ikeda R. Assessment of optimal condylar position in the coronal and axial planes with limited cone-beam computed tomography. J Prosthodont. 2011 Aug;20(6):432-8.