A novel straight-wire edgewise system to shorten orthodontic treatment in adolescent patients: The Jiyugaoka Enjoyable Treatment system

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This report describes a patient who underwent orthodontic treatment using a novel straight-wire edgewise system (Jiyugaoka Enjoyable Treatment [JET] system; Smiledesign, Tokyo, Japan). The JET system shortened the overall treatment duration by leveling, canine distalization, and detailing simultaneously under the regional acceleratory phenomenon (RAP) induced by premolar extraction. Indirect bonding initiated the detailing from the beginning, a 3-dimensional slot self-ligating bracket system for smooth sliding mechanics, and superelastic nickel-titanium wires and coil springs to apply light continuous forces. RAP is a tissue response to noxious stimuli (eg, tooth extraction) characterized by an increased healing capacity of the affected tissues. A 13-year-old girl with Class II subdivision malocclusion, infralabioversion of the maxillary left canine, rightward deviation of the mandibular midline, and crowding of the mandibular anterior teeth underwent orthodontic treatment using the JET system. Light continuous forces were used for efficient tooth movement to reduce pain during orthodontic treatment. The orthodontic appliance was provided soon after the extraction of the maxillary first premolars and mandibular left first premolar and adjusted once a month. Active treatment was completed within 7 months, after which anterior crowding and occlusion were improved. The panoramic radiograph showed no significant reduction in alveolar crest height, but slight apical root resorption was observed. The JET system can shorten the duration of orthodontic treatment in patients during the RAP stage induced by tooth extraction. (Am J Orthod Dentofacial Orthop Clin Companion 2024;4:434-44)

Orthodontic procedures typically involve a long treatment duration. Yamazaki et al[1] reported a mean active conventional orthodontic treatment period of 29 months for patients who underwent tooth extraction. However, patients often desire rapid treatment completion. To address this issue, we invented the Jiyugaoka Enjoyable Treatment (JET; Smiledesign, Tokyo, Japan) system, a new orthodontic treatment system that decreases the treatment duration and pain associated with treatment.[2]

According to Frost,[3] the regional acceleratory phenomenon (RAP) is a sequence of events characterized by

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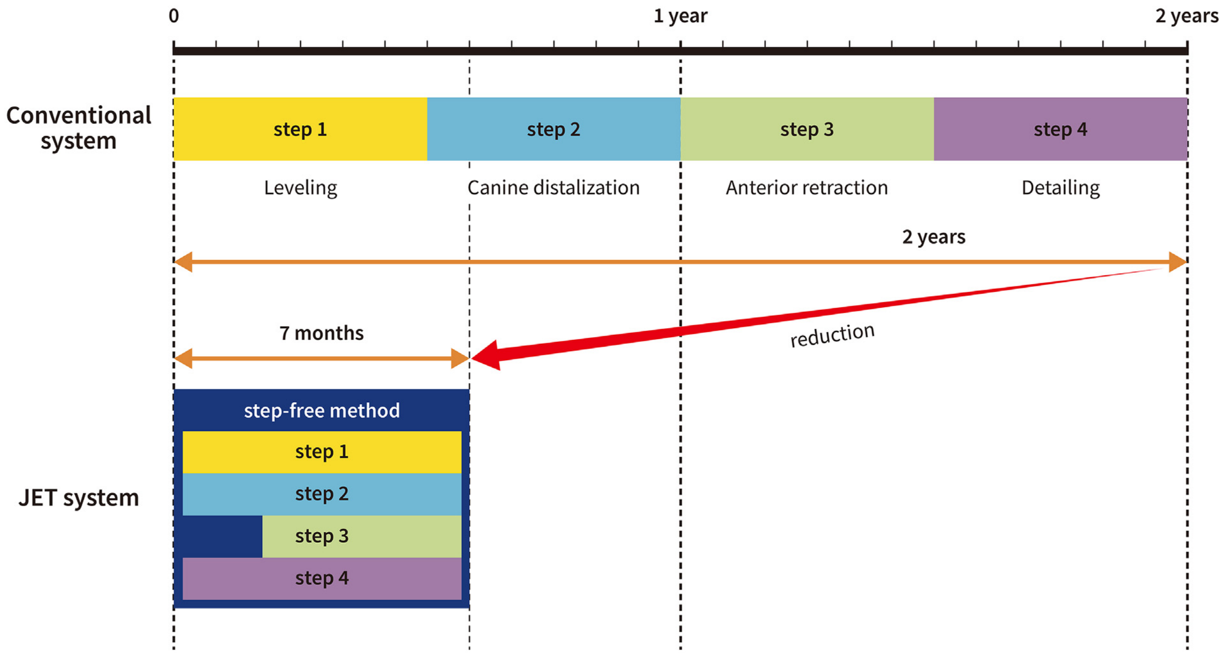

Fig 1. Principle of the JET system.

stimulated bone remodeling that occurs in response to a noxious stimulus. Yaffe et al[4] demonstrated that the reflection of a full flap alone induced a transitory period of osseous demineralization in a rat model. Melsen[5,6] reported RAP involvement in orthodontic tooth movement (OTM) and stimulation by surgical procedures, which may translate to faster tooth movement in clinical settings. Previous studies have described techniques such as corticotomy, wherein the bone is surgically injured to induce the RAP, thereby shortening the duration of orthodontic treatment.[7-10] The RAP is induced by tooth extraction,[11] and the JET system uses this phenomenon caused by premolar extraction.[2]

The JET system is designed to reduce orthodontic treatment pain, increase OTM efficiency with minimal invasion, and shorten the treatment duration.

Passive self-ligating brackets (PSLBs) and heat activated nickel-titanium (HANT) wires are used to reduce pain.[12,13] The frictional and binding forces of the PSLBs are lower than those of the conventional brackets. Light continuous forces (LCF) using a superelastic nickel-titanium (NiTi) coil spring are used for canine distalization.

In the JET system, extraction creates a space and induces the RAP.[2,11] Furthermore, canine distalization with leveling under the RAP increases the efficiency of OTM. The treatment duration is shortened by indirect bonding from the beginning of treatment instead of detailing, which is usually performed at the end of the treatment duration.

Panoramic radiographs are taken several months after the start of treatment to confirm bracket position and additional RAP is performed when necessary to shorten the duration of orthodontic treatment. Anterior retraction is performed after 1-3 months, but with further improvements, this will be implemented earlier in the future.

The features and concepts of the JET system are illustrated in Figure 1.

The JET system incorporates the following 3 key elements:

1. Under RAP induced by simultaneous premolar extraction (Fig 2), the goal is to perform all steps (leveling, canine distalization, anterior retraction, and detailing) simultaneously (ie, the step-free method) rather than step-by-step as done previously to maximize OTM. However, currently, 3 steps (leveling, canine distalization, and detailing) are performed simultaneously from the beginning, followed by anterior retraction a few months later.
2. The Shirasuka-Watanabe method[14,15] is used for the accurate positioning and indirect bonding of brackets (Fig 3). The method of indirect bonding of brackets was as follows:
   a. The line of the root axis to the center of the crown was drawn while viewing the panoramic radiograph.
   b. A Kalange line (a line connecting the marginal ridges of the molars)[16] on the first mandibular and maxillary molar and the remaining premolars and molars was drawn.
   c. The bracket height of the mandibular and maxillary first molar was determined, and a line perpendicular to the tooth axis was drawn.

Fig 2. The RAP in simultaneous premolar extraction.

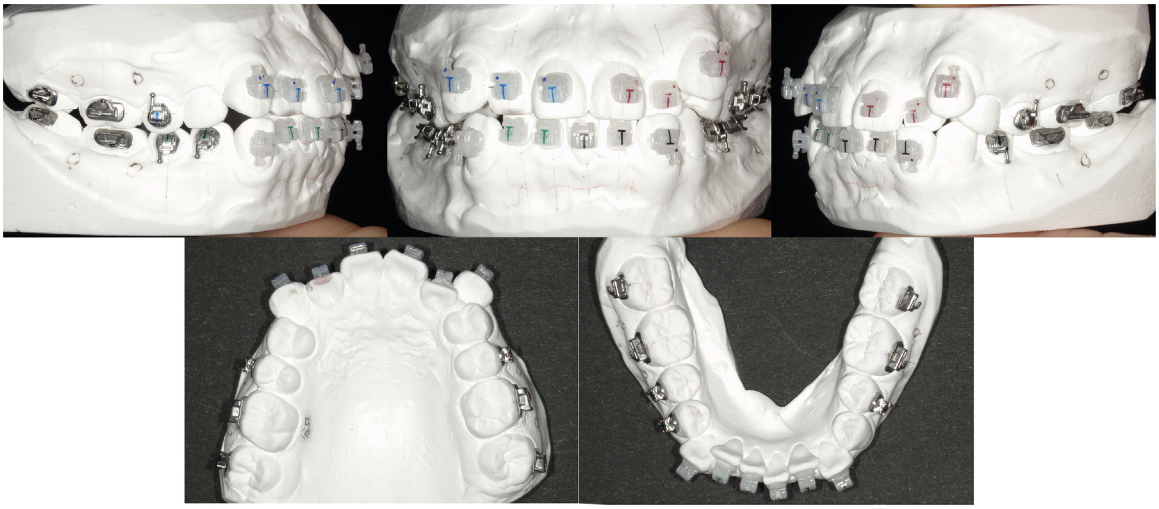

Fig 3. Shirasuka-Watanabe positioning.

d. The difference between the bracket height of the mandibular and maxillary first molar and the Kalange line was measured. The difference on the other molars was measured to determine the bracket height.
e. The standard anterior teeth bracket heights were as follows: maxillary central incisor, 5.0 mm; maxillary lateral incisor, 4.75 mm; maxillary canine, 5.5 mm; mandibular central and lateral incisors, 4.25 mm; and mandibular canine, 5.0 mm. However, adjustments were made so that the marginal ridges of the canine and premolar teeth were met.
f. The bracket guidelines to the root axis rather than the Andrews clinical crown axis were aligned.

3. A three-dimensional (3D) slot (anterior, 0.018 × 0.025-in; premolar, 0.021 × 0.026-in; molar, 0.022 × 0.028-in) PSLB system was used for anterior torque control and smoother sliding with superelastic light-force NiTi wires along with closed coils. This technique allows for greater control of the premolars than the bidimensional technique without the loss of sliding efficiency (Fig 4).

DIAGNOSIS AND ETIOLOGY

A 13-year-old Japanese girl presented with infralabioversion of the maxillary canines and irregular alignment of the maxillary and mandibular anterior teeth. She had no allergies or notable medical concerns, with no evidence of temporomandibular dysfunction.

Pretreatment facial photographs showed a symmetrical convex shape, wherein the maxillary dental midline was aligned to the facial midline; however, the mandibular incisor midline was deviated 3.5 mm to the right of the facial midline. The patient exhibited Class I malocclusion on the left side, Class II tendency on the right side, 4.0 mm overjet, and 3.0 mm overbite. The maxillary and mandibular arches were irregularly aligned, with arch length

Fig 4. Three-dimensional slot self-ligating bracket system.

Fig 5. Pretreatment facial and intraoral photographs.

discrepancies of −10.0 and −4.0 mm, respectively (Figs 5–7). Panoramic radiograph examination revealed the absence of all third molars. The lateral cephalometric analysis indicated a mild-to-moderate skeletal Class II relationship (ANB, 5.5°), high mandibular plane angle (FMA, 36.6°), and the labial inclination of the maxillary and mandibular incisors (FH-U1,112.0°; FMIA,44.4°; IMPA,99.0°), resulting in a smaller interincisal angle (U1-L1, 112.5°) (Table). The patient was diagnosed with Class I malocclusion on the left side, Class II tendency on the right side, a slight skeletal Class II relationship, and severe crowding of the anterior teeth.

TREATMENT OBJECTIVES

The main treatment objectives included correction of (1) maxillary canine infralabioversions, (2) mandibular anterior tooth crowding, (3) slight labial inclination of the maxillary and mandibular incisors, and (4) lip protrusion.

Fig 6. Pretreatment study models.

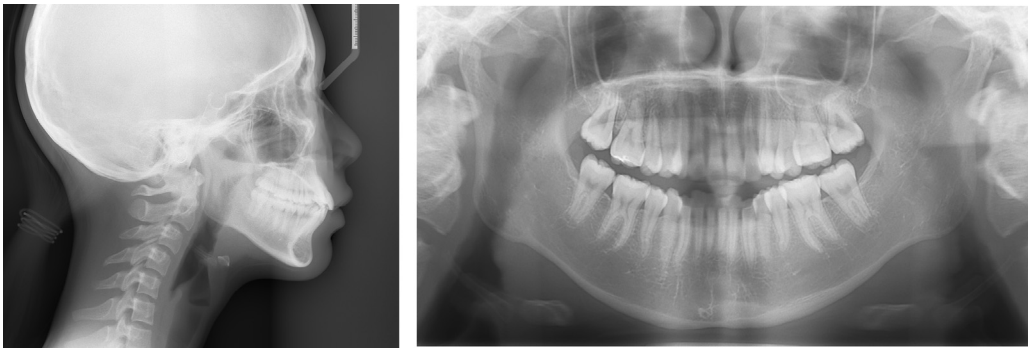

Fig 7. Pretreatment lateral cephalogram and panoramic radiograph (patient aged 13 years 8 months).

TREATMENT ALTERNATIVES

As the maxillary incisor midline was aligned and the mandibular incisor midline was deviated by 3.5 mm to the right of the facial midline, tooth movement simulation was performed with the extraction of the maxillary left and right and mandibular left first premolars (Fig 8). The findings revealed mesial shifting of the maxillary left first molar by 0.1 mm, maxillary right first molar by 4.0 mm, mandibular right first molar by 0.2 mm, and mandibular left first molar by 2.0 mm. Therefore, we planned to use orthodontic anchor screws as the treatment progressed, but ultimately, they were not used. The maxillary anterior teeth were fitted with 0.018 × 0.025-in high-torque PSLBs; in the mandibular incisors, the brackets were positioned upside down to prevent excessive lingual tipping.

TREATMENT PROGRESS

The JET system uses PSLBs (GeniusTM CristalTM and GeniusTM Metal; MEM, Tainan, Taiwan) with a 3D slot. The maxillary left and right first premolars and mandibular left first premolars were extracted the day before the placement of the orthodontic appliance to enable correction of the maxillary and mandibular anterior crowding and lip protrusion.

Following the Shirasuka-Watanabe method (straight-wire positioning), the brackets were first positioned on a plaster model and then bonded using an indirect tray (Fig 9).[14,15] Distal movement of the maxillary left and right canines and mandibular left canines was initiated immediately after placing brackets using superelastic NiTi closed coil springs (SENTS; 50 g of force) and maintained for up to 2 months. One side of the SENTS (50 g of force) was ligated to the bracket base of the canine, and the other was hooked onto the first molar. Initially, 0.014-in HANT archwires were used. The main archwires were replaced with 0.016 × 0.016-in HANT after 1 month, and in the following month, maxillary and mandibular anterior retractions were initiated using SENTS (100 g of force) and 0.016 × 0.022-in NiTi with a reverse curve from 2-4

Table. Cephalometric measurements

Analysis	Japanese norms*	Pretreatment	Posttreatment
Skeletal			
SNA (°)	81.3 ± 2.7	76.6	76.2
SNB (°)	78.6 ± 2.7	71.1	71.0
ANB (°)	2.6 ± 1.1	5.5	5.2
FMA (°)	26.3 ± 4.1	36.6	36.8
Dental			
FMIA (°)	56.9 ± 6.4	44.4	45.9
IMPA (°)	96.8 ± 6.4	99.0	97.3
FH-U1 (°)	111.1 ± 5.5	112.0	108.5
U1-L1 (°)	123.5 ± 5.5	112.5	117.5
Facial			
UL/E-line (mm)	1.4 ± 2.0	2.8	1.0
LL/E-line (mm)	1.4 ± 2.0	2.0	1.5

*Values are presented as mean ± standard deviation.

	UR8	UR7	UR6	UR5	UR4	UR3	UR2	UR1	UL1	UL2	UL3	UL4	UL5	UL6	UL7	UL8
Extrusion/Intrusion(mm).	-	0.1 I	0.5 I	0.1 I	-	0.5 I	1.1 E	0.5 I	0.6 I	0.7 E	0.1 I	-	0.1 E	0	0.1 I	-
Relative Ext./Int.(mm).	-	1.5 E	0	0.1 I	-	2.4 E	1.5 E	1.0 E	0.5 E	0.3 E	3.8 E	-	0.1 I	0.2 I	0.3 E	-
Translation Buccal/Lingual(mm)	-	1.2 L	0.1 L	0.1 B	-	3.8 L	0.8 L	2.0 L	1.7 L	0.5 B	4.6 L	-	0.6 B	0.3 B	0.4 L	-
Translation Mesial/Distal(mm)	-	3.9 M	4.0 M	4.0 M	-	2.4 D	1.1 D	0.7 D	0	0.8 D	5.6 D	-	0	0.1 M	0.2 M	-
Rotation Mesial/Distal	-	1.4 D	6.7 D	9.8 D	-	21.9 D	10.9 D	4.4 M	15.6 M	17.5 D	18.5 D	-	3.1 M	4.7 D	10.5 M	-
Angulation Mesial/Distal	-	0.9 D	7.2 M	1.2 D	-	10.5 D	2.2 D	0.9 M	4.9 M	5.8 D	14.3 D	-	1.9 D	1.9 D	5.0 M	-
Inclination Buccal/Lingual	-	1.3 L	0.2 L	0.9 L	-	9.7 L	4.0 L	5.9 L	3.7 L	6.9 B	11.3 L	-	2.8 B	1.6 B	0.6 L	-

	LR8	LR7	LR6	LR5	LR4	LR3	LR2	LR1	LL1	LL2	LL3	LL4	LL5	LL6	LL7	LL8
Extrusion/Intrusion(mm).	-	0.5 E	0.3 E	0.9 E	0.3 I	2.0 I	2.2 I	2.2 I	2.1 I	1.5 I	1.6 I	-	0.2 E	0.3 I	0.1 E	-
Relative Ext./Int.(mm).	-	0.1 E	0.3 E	1.0 E	0.4 I	1.1 I	2.7 I	2.4 I	1.8 I	2.1 I	0.2 I	-	0.1 I	0.3 I	0.2 I	-
Translation Buccal/Lingual(mm)	-	0.7 L	0.1 B	0.2 L	0.1 B	1.8 L	2.5 B	1.0 B	0.4 L	1.3 B	1.2 L	-	0.8 B	0.8 B	0.2 B	-
Translation Mesial/Distal(mm)	-	0.1 M	0.2 M	0.2 M	0.1 M	1.1 M	2.5 M	2.6 M	3.5 D	3.7 D	5.5 D	-	1.8 M	2.0 M	1.9 M	-
Rotation Mesial/Distal	-	2.1 M	1.2 D	8.7 D	8.8 M	8.0 D	12.6 M	7.2 M	3.5 M	10.4 D	24.7 D	-	14.6 D	3.1 D	9.2 D	-
Angulation Mesial/Distal	-	2.5 M	0.6 D	6.3 D	1.2 D	3.0 M	1.0 M	3.1 D	0.1 D	1.9 M	3.3 D	-	2.9 D	2.7 M	2.8 M	-
Inclination Buccal/Lingual	-	0.5 L	0.1 L	0.3 B	0.3 B	7.2 L	16.2 B	7.0 B	1.4 L	7.9 B	3.0 L	-	4.0 B	0.6 B	2.5 B	-

Fig 8. Three-dimensional simulation of a tooth movement.

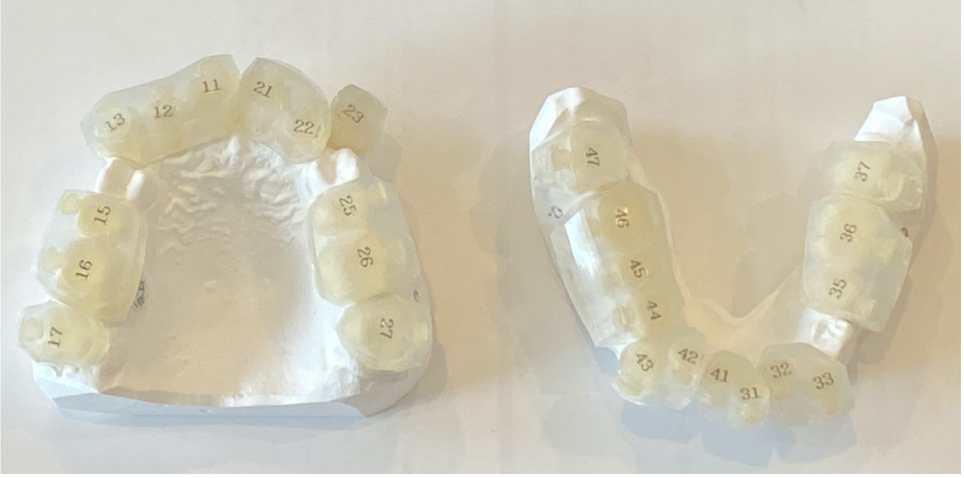

Fig 9. Indirect bonding system.

months. The second molar brackets were placed 4 months after the initial bracket placement. After 4 months, SENTS (100 g of force) were removed, and an elastomeric chain was used. The extraction space was closed 5 months after the bracket placement. For the mandibular teeth, 0.016 × 0.022-in a reverse curved NiTi wire (reverse curve of Spee straight leg; American Orthodontics, Sheboygan, Wis) was used for only 1 month after the 5 months, after which the previous wire was used.

The total duration of the active treatment was 7 months (Fig 10, *A* and *B*), after which the patient exhibited retrusion of the upper and lower lips and considerable improvements in her facial profile. Panoramic radiographs revealed no apparent root resorption. Although there appeared to be a problem with the axis of the maxillary right second premolar, which was distally inclined on the posttreatment panoramic radiograph, the bracket was not repositioned because no issue with the intraoral occlusal condition was noted. In case of any further discrepancy, a panoramic radiograph was obtained, and the bracket was repositioned 3-4 months after the bracket placement. Postoperative cephalometric analyses in the lateral view showed changes in Frankfurt mandibular incisor angle (44.4-45.9°) and interincisal angle (112.5-117.5°), indicating an improvement in her facial profile (Table).

After treatment was completed, the preadjusted edgewise appliance was removed, and circumferential retainers were placed on the maxillary and mandibular arches.

TREATMENT RESULTS

The patient exhibited acceptable occlusion and a good facial profile (ie, balanced lip line) owing to the successful retraction of the maxillary canines and anterior teeth. The dental arches were aligned and leveled, and ideal overjet and overbite were achieved (Fig 11, *A-D*). Cephalometric superimpositions before and after the treatment revealed mesial movement of the maxillary right molars (Fig 12).

DISCUSSION

This report demonstrates the successful fixed orthodontic treatment of a patient with severely crowded anterior teeth using the novel JET system invented by our research team. The JET system shortened the overall treatment duration to 7 months and yielded predictable outcomes. At the end of the treatment, a Class I relationship of the canines and left molar and a full-cusp Class II molar relationship of the right molar were achieved. Maxillary and mandibular crowding was corrected, and an optimal overjet and overbite were established. No scar tissues were observed in the gingival region.

The JET system encompasses 3 elements: the RAP, Shirasuka-Watanabe positioning,[14,15] and indirect bonding, and a 3D slot PSLB system. The JET system uses the RAP to accelerate tooth movement induced by premolar extraction. The current understanding of the acceleration of OTM after surgery is based on the notion that the surgical procedure induces RAP. This phenomenon is characterized by an enhanced process of demineralization and mineralization in the vicinity of the surgical area.[9,17] As the RAP represents a brief healing period, the early postoperative period must be fully used to maximize OTM. Yaffe et al[4] documented the onset of the RAP within a few days after surgery and peaks within 1-2 months. Although this effect typically persists for 4 months, complete subsidence may require more than 6-24 months. In this patient, the JET system benefited from the effects of the RAP during the treatment period (7 months). Furthermore, Hu and Li[18] stated that accelerated OTM was positively modulated by various elements, including cells (eg, macrophages, osteoclasts, and osteoblasts), cytokines (eg, macrophage colony-stimulating factor, receptor activator of nuclear factor-kappa B ligand [RANKL], tumor necrosis factor-α, and transforming growth factor-β), and signaling pathways (eg, NF-κB, JAK/STAT3, MAPK, RANKL/RANK/OPG, and Wnt). Accelerated OTM involves a distinctive biological mechanism centered on the RANKL/RANK/OPG signaling pathway, in

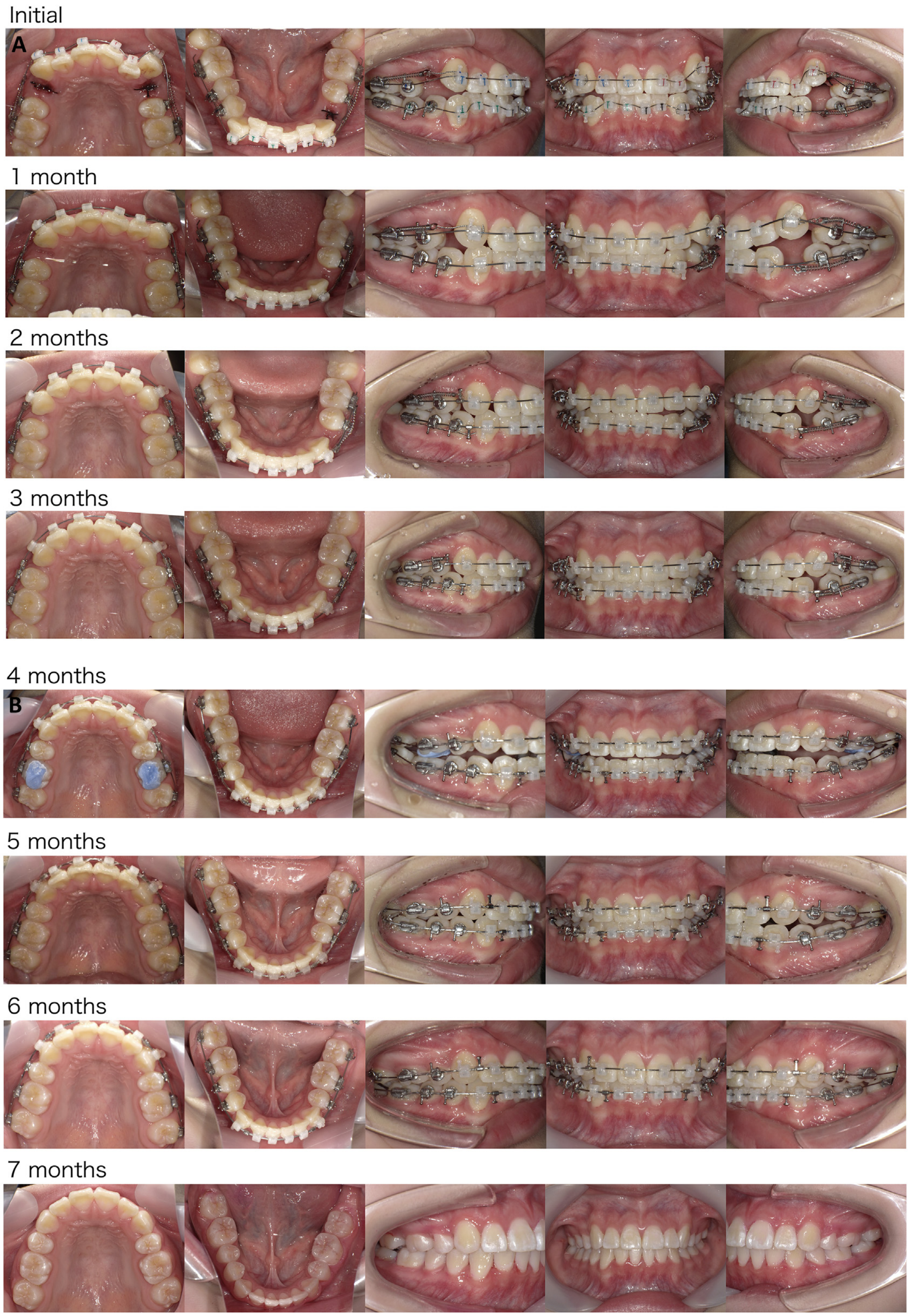

Fig 10. A, Initial, 1-, 2-, and 3-month treatment progress; **B,** The 4-, 5-, 6-, and 7-month treatment progress.

which the interaction of RANKL with OPG promotes alveolar bone remodeling. Further studies are warranted to investigate these signaling pathways and the RAP during accelerated OTM.

Yee et al[19] reported that light forces (50 g of force) provide a greater percentage of canine distalization than heavy forces (300 g of force) in humans. Superelastic NiTi wires[20] and NiTi closed coils[21] have been used to generate

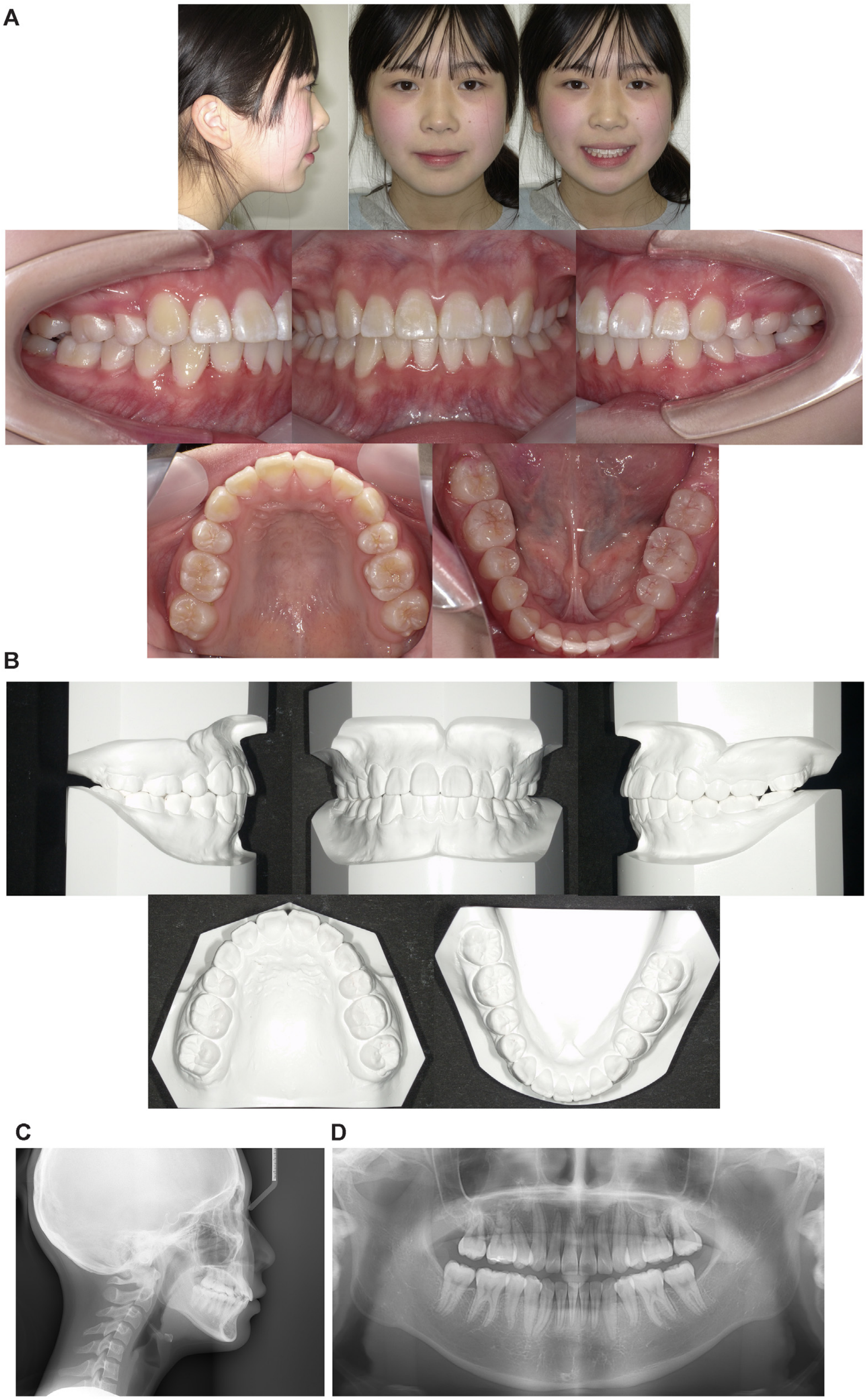

Fig 11. A, Postreatment facial and intraoral photographs; **B,** Study models; **C,** Lateral cephalogram; **D,** Panoramic radiograph (patient aged 14 years 4 months).

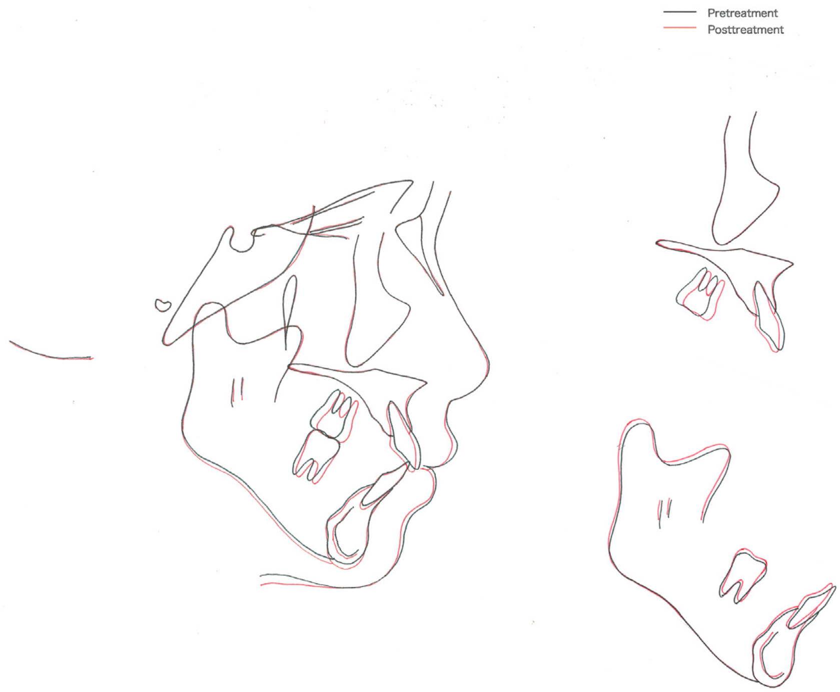

Fig 12. Superimpositions of pretreatment (black) and posttreatment (red) cephalometric tracings.

LCFs. Tomizuka et al[22] demonstrated that LCF initially induced better tooth movement in an experimental rat model. Therefore, LCF in the JET system may influence the duration of treatment. More force is required for anterior retraction than for canine distalization; therefore, this system uses 100 g of force.

Accurate positioning of brackets is essential for shortening the duration of conventional treatment's final phase (detailing or finishing). Watanabe and Koga[14] examined the morphology of bracket positions using the straight-wire method. Shirasuka et al[15] improved the accuracy of bracket positioning by temporarily attaching the brackets to a working model and then fabricating an indirect core in the dentition. Kalange[16] aligned the marginal ridges of the first molar and premolar by considering the differences between them and the slot lines. Koga[23] proposed an easy and quick method for fabricating transfer trays using indirect methods. Jackers et al[24] found that the indirect bonding SLB system exhibits the same treatment quality as the computer-aided design and manufacturing customized bracket system, despite its 26% longer operating time. The novel JET system used in this study uses PSLBs for orthodontic treatment and has significant advantages, including minimal pain associated with orthodontic force.[12,13,25,26]

Greco and Giancotti[27] reported treating maxillary and mandibular prognathism using an extraction-based approach with a bidimensional technique and 2 vertically slotted brackets of varying sizes (ie, central and lateral incisors: 0.018 × 0.025-in brackets; canines; molars; and premolars: 0.022 × 0.028-in). In contrast, the JET system involves the placement of 0.018 × 0.025-in brackets on the central and lateral incisors and canines, 0.021 × 0.026-in brackets on the premolars, and 0.022 × 0.028-in brackets on the molars, to enable smoother tooth movement with lower sliding forces.

Li et al[28] found that the bidimensional approach allowed stronger torque control for anterior teeth compared with conventional methods in patients who had undergone extractions and were treated with preadjusted appliances. This system applies 9.4° of torque to the maxillary anterior brackets. In contrast, the JET system applied a strong torque of 22° to the maxillary central incisor bracket using 0.016 × 0.022-in NiTi wires, resulting in approximately 10° of play, finalizing at 12°. It allows simultaneous distal movement of the canines and lingual movement of the anterior teeth, thus preventing excessive lingual displacement and decreasing the treatment duration.

These findings suggest that the JET system stimulates bone synthesis, activates bone remodeling, and accelerates tooth movement. Therefore, applying a combination of LCFs and low friction during the RAP stage can accelerate OTM, modulate bone metabolism, and activate osteogenesis and osteoclasts, thereby shortening the overall treatment duration to 7 months.

SUMMARY AND CONCLUSIONS

The JET system applies a combination of LCFs and low friction during the RAP stage to shorten the orthodontic treatment period during adolescence.

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AUTHOR CREDIT STATEMENT

Shinichi Narita contributed to formal analysis, investigation, and manuscript review and editing; Masaru Yamaguchi contributed to original draft preparation; and Kiyoko Narita contributed to formal analysis and investigation.

CONFLICTS OF INTEREST

All the authors have completed and submitted the ICMJE form of disclosure of potential conflicts of interest, and none were reported.

STATEMENT OF INFORMED CONSENT

Written informed consent has been obtained from the patient to publish this paper.

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