Case Report

Enhanced pendulum appliance utilizing temporary anchorage device-based Nance arch and modified springs for optimized molar distalization control: a case report

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ABSTRACT
A 20-year-old female patient with severe maxillary crowding and skeletal Class III malocclusion was successfully treated using an enhanced pendulum appliance. Camouflage treatment was chosen because the patient refused surgical intervention. Detailed examination and analysis revealed that labial inclination of the maxillary anterior teeth could provide the alignment space necessary after tooth extraction in the maxillary arch but it would not be beneficial esthetically and would increase the moment perpendicular to the tooth long axis as well as increase the risk of bone dehiscence. Therefore, lingual inclination of the mandibular anterior teeth was performed. To create space for aligning the maxillary arch, an enhanced pendulum appliance was utilized, in addition to premolar extraction. The enhanced pendulum appliance had one mesial and one distal helix on each spring, exerting opposing forces in the buccolingual direction and reducing the buccolingual inclination of the molars. In addition, miniscrews were integrated into the Nance arch of the enhanced pendulum appliance to provide skeletal anchorage, minimizing the reciprocal movement of anchorage teeth. This modification not only enhanced control over tooth movement but also improved treatment efficiency. During the entire treatment duration of 17 months, substantial improvement in facial and occlusal aspects were noted. Additionally, the patient retained these positive changes until the subsequent 2-year follow-up period. (*Angle Orthod*. 2025;95:126–136.)

KEY WORDS: Pendulum appliance; Molar distalization

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INTRODUCTION

In cases with severe crowding in which tooth extraction alone is inadequate for creating space for alignment, molar distalization can be used as an effective supplementary method. Various devices are used to achieve molar distalization and they can be categorized into extraoral[1] and intraoral appliances. Intraoral appliances include the pendulum appliance,[2–4] distal jet appliance,[5] magnetic appliances,[6–8] and the Herbst appliance.[9,10] The pendulum appliance, a commonly used intraoral device, uses the soft and hard tissues of the oral cavity for anchorage.[2] The pendulum appliance offers more esthetic benefits than extraoral appliances and does not rely on patient compliance. However, the pendulum appliance can lead to unwanted movements, such as the mesial movement of premolars and anterior teeth, distal tipping of molars, and transverse changes between molars.[3,11–13] To address these negative effects, various modified pendulum appliances incorporating uprighting bends,[14] distal screws,[15] and temporary anchorage devices (TADs)[16,17] have been developed. In this case report, an enhanced pendulum appliance is introduced, utilizing a TAD-based Nance arch and modified pendulum springs for optimized molar distalization control. This innovation integrated TADs with the pendulum appliance and included multiple activation helices on the spring to prevent unwanted tooth movements.

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Figure 1. Pretreatment facial and intraoral photographs.

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Diagnosis and Etiology

The patient was a 20-year-old Chinese female with the chief complaint of crooked teeth. The lateral view revealed a mild convex facial profile, whereas the frontal view showed a slight leftward shift of the chin and lip incompetence without excessive gingival display (Figure 1). No substantial temporomandibular joint (TMJ) symptoms were present.

Intraoral examination and dental casts indicated a Class I molar relationship and a Class III canine relationship on the left side, along with a Class II molar relationship and a Class III canine relationship on the right side. The patient exhibited an anterior crossbite (between U1 and L1) and an open bite (between U2, U3, and L2, L3, L4) on both sides. In addition, the maxillary dental midline was 1-mm left of the facial midline, and the mandibular dental midline coincided with the facial midline. Severe crowding was observed in the maxillary dental arch, with the second premolars completely displaced palatally. The maxillary right canine was displaced labially, and both second molars were inclined buccally. Additionally, moderate crowding was noted in the mandibular dental arch with mesial impaction of the second molars. There was a posterior crossbite between UR5 and LL4, indicating a slight maxillary transverse discrepancy (Figure 2). Mild gingivitis was observed due to poor oral hygiene; however, probing depths were within normal limits.

The panoramic radiograph showed mesially impacted mandibular second molars and four impacted third molars (Figure 3B). Cone beam computed tomography (CBCT) images demonstrated buccally inclined maxillary second molars (Figure 3C). A screenshot of the TMJ from the CBCT image displayed a smooth and continuous condyle surface (Figure 3D). Cephalometric analysis (Table 1) revealed a mild skeletal Class III discrepancy with maxillary deficiency (SNA: 79.1°; SNB: 81.1°; ANB: −2.0°) and a hyperdivergent skeletal

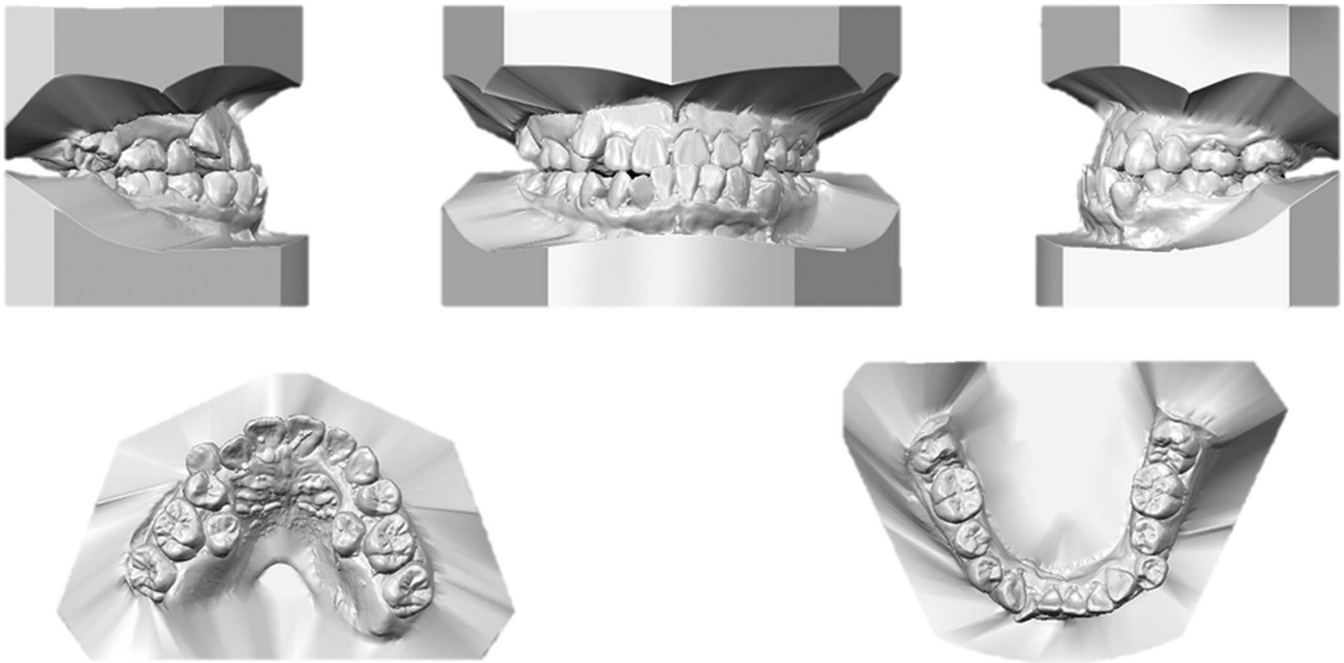

Figure 2. Pretreatment digital dental casts.

pattern (FMA: 32.7°). The maxillary incisors were proclined (U1-SN: 112.1°; Figure 3A). On the basis of these findings, a diagnosis of Class II malocclusion and a Class III skeletal pattern with an increased mandibular plane angle was established.

The patient's history of mouth breathing might have contributed to the skeletal problems.[18,19] The etiology of the crowding and displacement was unclear and could have been due to the development of tooth germ position or unnoticed premature loss of deciduous teeth during the mixed dentition period.

Treatment Objectives

The treatment goals were to align and level the maxillary and mandibular teeth, correct the reverse overjet and open bite, establish Class I canine and molar relationships, and enhance the facial profile.

Treatment Alternatives

Cephalometric analysis revealed a lack of sagittal coordination between the maxilla and mandible. Because the patient declined surgical intervention, camouflage orthodontic treatment was chosen. Two treatment strategies were presented:

1. The first strategy involved extracting the maxillary second premolars and second molars, along with distalizing the first maxillary molars, and removing the mandibular first premolars and third molars.
2. The second strategy involved extracting the maxillary second premolars and third molars, distalizing the maxillary molars, and removing the mandibular first premolars and third molars.

Cephalometric analysis revealed a hyperdivergent skeletal pattern and upright positioning of the mandibular incisors within the alveolar bone (IMPA: 92.0°). Because of the patient's hyperdivergent skeletal pattern, appropriate lingual inclination of the mandibular incisors was deemed to be more beneficial for improving the lateral profile.[20] Concurrently, CBCT images indicated adequate lingual alveolar bone support for lingual movement of the mandibular incisors, confirming the feasibility of camouflage orthodontic treatment for this patient.

Given the buccal inclination of the maxillary second molars and the favorable position and morphology of the maxillary third molars, extraction of the maxillary second molars was proposed to prevent the need for correction of buccally inclined molars and to reduce the extent of molar distalization. This approach aimed to simplify clinical steps and shorten the treatment timeline. Ultimately, the patient opted for strategy 1.

Treatment Progress

Prior to orthodontic treatment, the patient underwent tooth extraction in accordance with strategy 1. Subsequently, 0.022 × 0.028-inch straight-wire preadjusted appliances (Shinya, Hangzhou, China) were installed on the maxillary and mandibular teeth. Additionally, two miniscrews (1.4 × 10 mm, Protect, Hu Zhou, China) were inserted laterally to the palatal suture. Alginate

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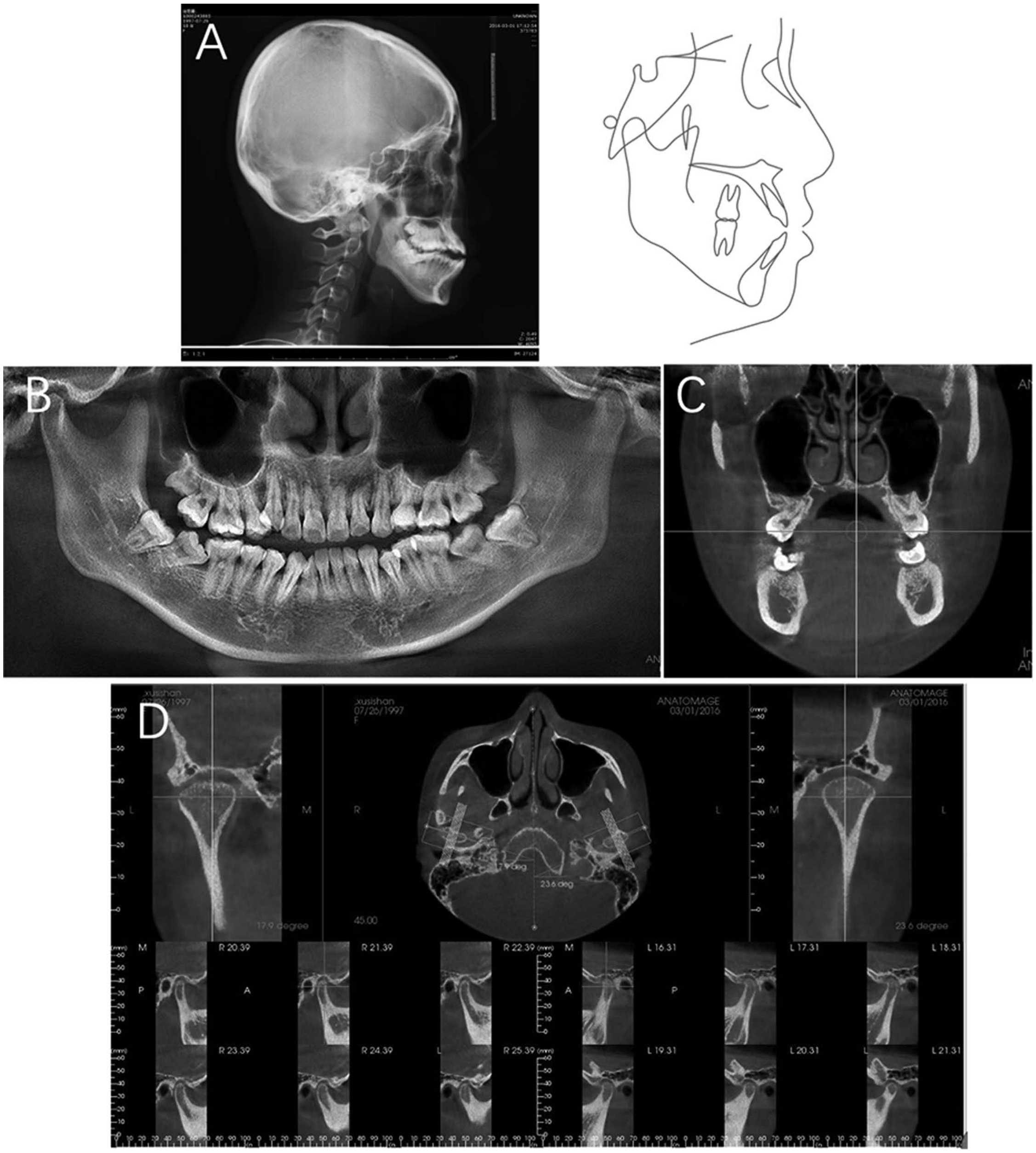

Figure 3. Pretreatment radiographs: (A) Lateral cephalogram and tracing. (B) Panoramic radiograph. (C) Coronal sections of CBCT images. (D) Screenshot of TMJ from CBCT images. CBCT indicates cone beam computed tomography; TMJ, temporomandibular joint.

impressions were obtained, and gypsum was used to create dental casts. The shape and position of the miniscrew heads were transferred to the cast, which was then used to fabricate the pendulum appliance.

The bracket for the maxillary right canine was not initially bonded due to its labial malposition to prevent labial movement of the adjacent incisors.

The enhanced pendulum appliance consisted of one Nance arch and two springs. The Nance arch had two holes positioned for miniscrew heads on the cast. Springs were prepared using 0.9-inch stainless steel wire. During installation, it was ensured that the two holes in the Nance arch aligned with the miniscrew heads, and the miniscrews were bonded to the Nance arch using light-curing resin. After installation, two helices on each spring were activated to facilitate molar distalization.

Two months later, the molars reached their correct distal positions, and the right maxillary canine was incorporated into the orthodontic treatment for alignment. At this stage, two miniscrews (1.2 × 8 mm, Protect, Hu Zhou, China) were implanted for anchorage between the mandibular second premolars and first molars. Glass ionomer was used to construct bite raisers to prevent occlusal interference during retraction. The anterior teeth

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Table 1. Cephalometric measurements

Measurement	Chinese Norms	Pretreatment	Posttreatment
SNA (°)	82.8 ± 4.0	79.1	79.9
SNB (°)	80.1 ± 3.5	81.1	80.2
ANB (°)	2.7 ± 2.0	−2.0	−0.3
FMA (°)	28.0 ± 3.0	32.7	32.6
FMIA (°)	63.9 ± 6.1	55.3	67.5
IMPA (°)	90.8 ± 5.2	92.0	79.9
U1-SN (°)	104.6 ± 6.0	112.1	110.9
Z-angle (°)	71.2 ± 4.7	65.1	77.1

were retracted to ensure appropriate inclination of the mandibular incisors lingually.

After 17 months of treatment, the reverse overjet and open bite in the anterior arch were successfully corrected, establishing a Class I relationship in anterior and posterior regions (Figure 4). Immediately after the brackets were debonded, a vacuum-formed retainer was inserted.

Treatment Results

The posttreatment photographs (Figure 5) and dental casts (Figure 6) revealed excellent alignment, with Class I canine and molar relationships. The arch forms were well-coordinated in the sagittal, vertical, and transverse dimensions. The patient's smile exhibited improved esthetics, and the facial profile benefited from the retraction of the mandibular incisors.

The panoramic radiograph confirmed good root alignment without substantial root or alveolar bone resorption (Figure 7). Cephalometric tracing superimposition indicated significant distalization of the maxillary molars and retraction of the mandibular incisors (Figure 8).

Cephalometric analysis revealed a decrease of 12.1° in the IMPA value from pretreatment, indicating compensatory lingual inclination of the mandibular incisors to achieve normal anterior overjet. The FMA and U1-SN angles remained stable (Table 1).

The occlusal relationship and facial lateral profile were maintained satisfactorily at the 24-month follow-up (Figure 9).

DISCUSSION

Orthodontic extractions in adult patients pose a substantial clinical challenge, warranting the consideration of various factors, including crowding, soft tissues,

Figure 4. Treatment progress. (A) Bonding of maxillary and mandibular arches. (B) Springs of the modified pendulum appliance were activated for molar distalization. (C) 2-month follow-up result. (D) 17-month treatment result.

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Figure 5. Posttreatment facial and intraoral photographs.

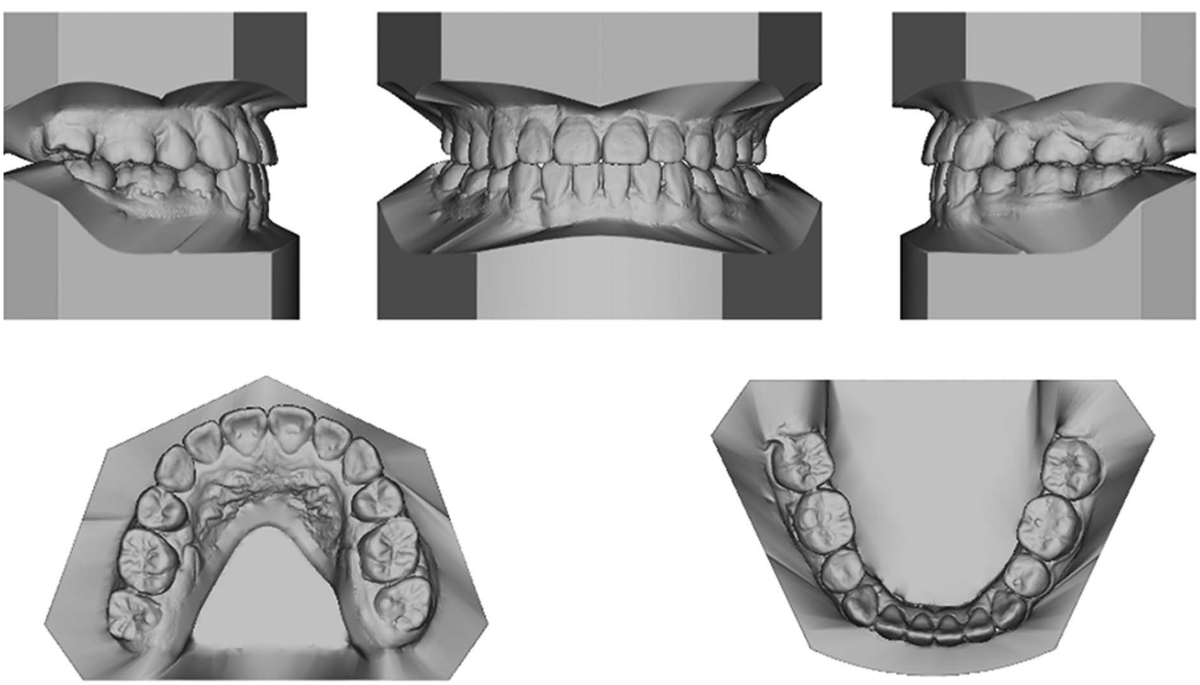

Figure 6. Posttreatment digital dental casts.

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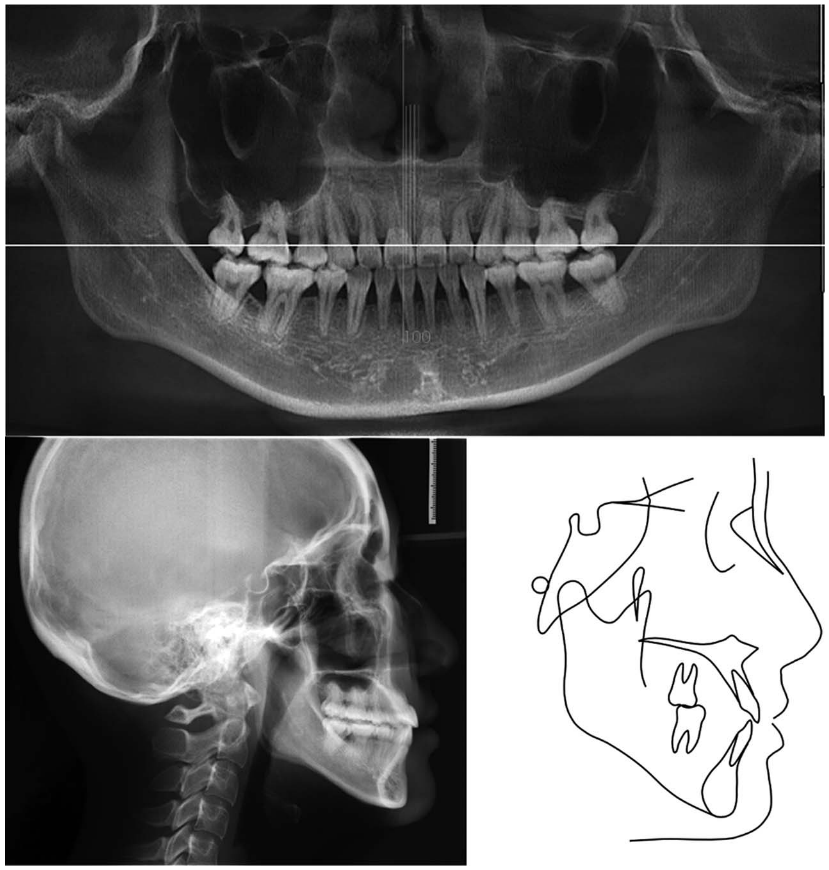

Figure 7. Posttreatment panoramic radiograph, lateral cephalogram, and tracing.

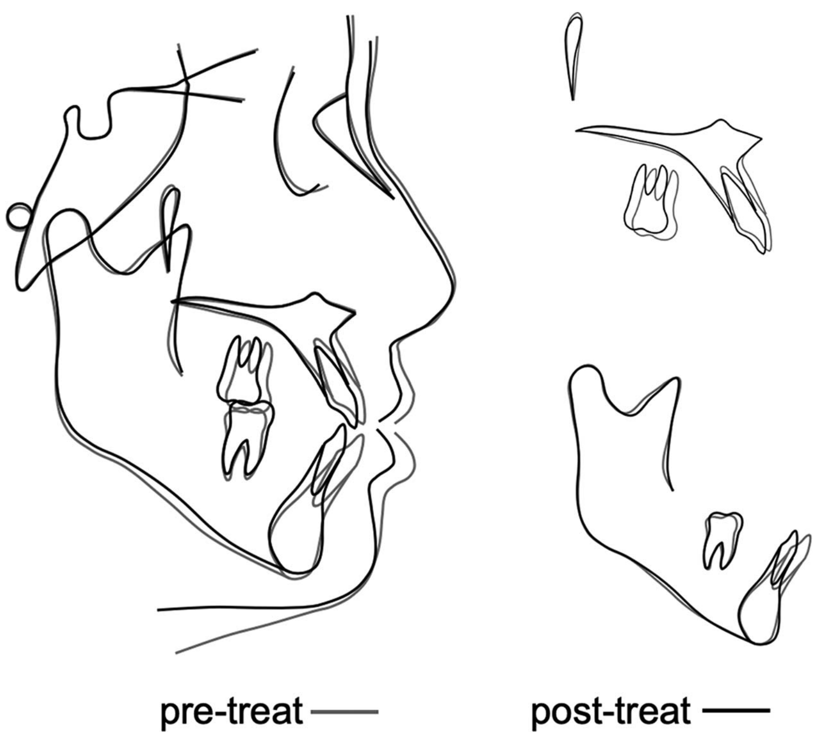

Figure 8. Cephalometric superimpositions between pretreatment and posttreatment images.

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Figure 9. Facial and intraoral photographs after 2 years of retention.

periodontal status, facial morphology, skeletal pattern, TMJ disorders, and the patient's perspective. In the present case of severe crowding, an additional 6 mm of space was required in the maxillary arch even after extracting two palatally displaced premolars, which necessitated molar distalization. However, third molars could impede the movement of the first and second molars during distalization. Given the buccal displacement of the maxillary second molars and the favorable anatomic shape and position of the maxillary third molars, opting to extract the maxillary second molars appeared viable. This strategy not only simplified treatment by reducing the number of molars requiring distalization, but also increased the possibility of the third molars erupting in a favorable position.[21] Notably, the degree of treatment difficulty and duration of treatment vary depending on the teeth being extracted.

For patients with severe skeletal malocclusions, orthognathic surgery is often recommended to enhance occlusal function and correct a substantial jaw discrepancy. However, this patient exhibited a minor anteroposterior jaw discrepancy and was reluctant to undergo surgery. Thus, camouflage treatment was preferred, which is considered a viable alternative to surgical treatment in such patients.

A compensatory approach for camouflaging a Class III skeletal malocclusion is to adjust the inclination of the anterior teeth, which can be performed in two ways. The first involves labial inclination of the maxillary anterior teeth, and the second involves lingual inclination of the mandibular anterior teeth. In this case, labial inclination of the maxillary anterior teeth could help achieve a normal overjet and provide space for aligning the maxillary dentition, thereby eliminating the need for maxillary molar distalization. This mode simplifies clinical procedures and reduces treatment time. However, in the present case, lingual inclination of the mandibular anterior

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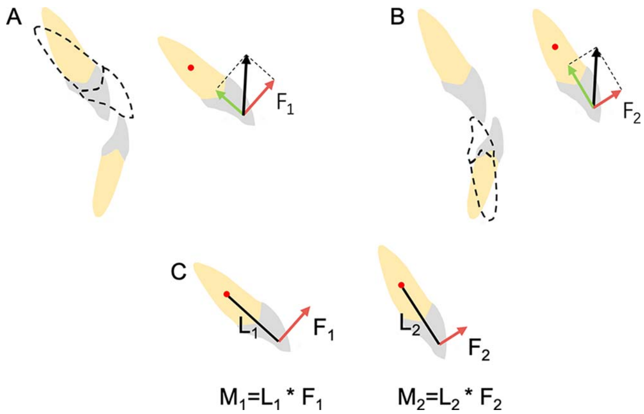

Figure 10. (A) Maxillary incisor labial inclination compensation and force analysis for maxillary incisor. (B) Mandibular incisor lingual inclination compensation and force analysis for maxillary incisor. (C) Moment analysis for two modes of compensation.

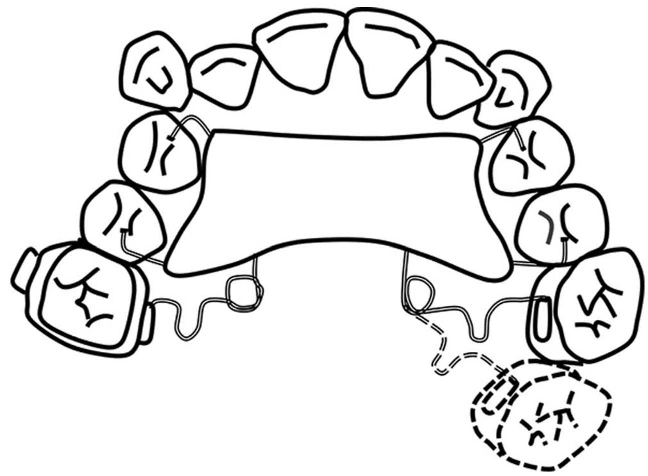

Figure 12. Molar movement path of the conventional pendulum appliance.

teeth was chosen as the compensatory mode for three reasons. First, from an esthetic viewpoint, labial inclination of the maxillary incisors might create the appearance of shorter anterior maxillary teeth when smiling. In contrast, the mandibular incisors are less visible because they are covered by the lower lip; thus, their impact on esthetics is minimal. Additionally, given the patient's convex facial profile, lingual inclination of the mandibular incisors is more effective in enhancing the overall appearance. Second, from a biomechanical perspective, the force applied to a tooth segregates into components perpendicular and parallel to the tooth's long axis. As depicted in Figure 10A, B, labial inclination of the maxillary incisor increases the force perpendicular to the tooth's long axis (F1 $>$ F2). Because the distance between the contact points of the maxillary and mandibular anterior teeth and the center of resistance remains almost unchanged (L1 $\approx$ L2), the moment perpendicular to the tooth's long axis increases greatly (M1 $>$ M2; Figure 11C), which, in turn, increases the risk of periodontal damage and is detrimental to retention. Third, in terms of alveolar bone considerations, CBCT images revealed that the lingual alveolar bone of the mandibular incisors was sufficient to accommodate movement lingually. In contrast, the labial alveolar bone of the maxillary incisors was deemed inadequate, and further labial inclination of the maxillary anterior teeth was considered to increase the risk for bone dehiscence and fenestration (Figure 11).

Conventional pendulum appliances have two main limitations. First, although the Nance arch and the premolars on both sides of a conventional appliance provide anchorage for molar distalization, they do not offer absolute anchorage, leading to the anterior inclination of the premolars and reduction of the efficiency of molar distalization.[11] Also, subsequent treatment would be necessary to correct the tipped premolars, thereby extending overall treatment time. Second, pendulum appliances operate along an arc with a trajectory centered on the helical spring (Figure 12). This movement pattern can result in lingual displacement of the molars during distalization.[3] Although incorporating a "U" curve into the spring arm can modify its position, this procedure is complex and cannot completely eliminate lingual misalignment.

To address the problems anticipated, an enhanced pendulum appliance was developed. First, TADs, such

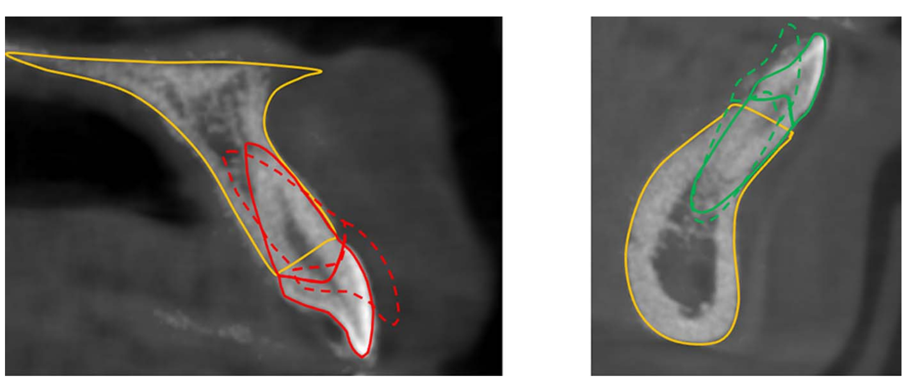

Figure 11. Schematic illustration of the risk of bone dehiscence with different compensation modes.

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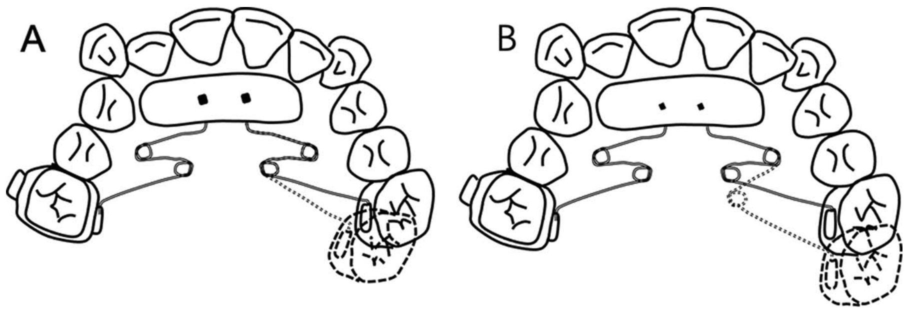

Figure 13. Molar movement path of the enhanced pendulum appliance: (A) Distal and lingual movements with distal helix activation. (B) Distal and buccal movements with mesial helix activation.

as miniscrews, are widely used in orthodontic practice due to their convenience and effective anchorage. Many studies have reported successful outcomes obtained using miniscrews as anchorage for molar distalization.[12,17] In this case, a TAD-based Nance arch was employed, with a miniscrew inserted on each side of the palatal suture. These miniscrews were bonded to the Nance arch by using light-cured resin to establish absolute anchorage. This approach prevented reciprocal movement of the premolars. Second, traditional pendulum appliances produce an arc of movement due to the presence of a single activation helix on the spring, resulting in the generation of transverse forces. Kinzinger et al. suggested that placing the spring as posteriorly as possible could reduce transverse forces.[15] In the present case, two helices were incorporated on each spring. Activation of the distal helix induced an arc movement of the molars in the distal and lingual directions (Figure 13A). In contrast, activation of the mesial helix caused molar movement in the distal and buccal directions (Figure 13B). The mesial and distal helices exerted opposing forces in the buccolingual direction, enabling better control of molar movement. In addition, the use of longer wires improved elasticity. The incorporation of two activation helices led to an increase in the length of the distalization spring, thereby enhancing its elasticity and enabling the application of light and continuous orthodontic forces.

At 2-year follow-up, the treatment outcome remained stable. The posttreatment panoramic radiograph demonstrated satisfactory root parallelism, and the anterior and posterior teeth maintained a stable Class I relationship, which is beneficial for postoperative maintenance. These results indicated that the use of an enhanced pendulum appliance, which utilized a TAD-based Nance arch and modified pendulum springs, resulted in the achievement of effective molar distalization.

CONCLUSIONS

- A patient with a skeletal Class III malocclusion, characterized by severe crowding, open bite, crossbite, and a high mandibular plane angle, underwent successful orthodontic treatment attributed to careful planning, attention to detail, and the use of skeletal anchorage.
- The treatment outcomes remained stable, as evidenced by 2-year posttreatment records.

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