

# Total arch distalisation using clear aligners and micro-implant anchorage for treating crowding and lip protrusion in an adult

U-Hyeong Cho\* and Hyo-Sang Park†

Postgraduate Student, Department of Orthodontics, School of Dentistry, Kyungpook National University, Daegu, Korea (Rep)\*

Professor and Chair, Department of Orthodontics, School of Dentistry, Kyungpook National University, Daegu, Korea (Rep)†

This case report presents a treatment approach which combines clear aligners and skeletal anchorage, mainly micro-implants, to address crowding and lip protrusion in a middle-aged adult who presented with multiple prosthetic restorations. Tooth movements were strategically staged in a virtual setup, beginning with canine retraction using micro-implants to resolve anterior crowding, followed by en-masse distalisation of the dentition. For refinement, additional in-house aligners were employed alongside fixed auxiliaries. The total treatment duration was 9 months, demonstrating high time efficiency. Cone beam computed tomography superimposition indicated posterior tooth distalisation, slight dental arch expansion, and predominantly tipping movements of the distalised teeth. This approach of total arch distalisation rather than conventional sequential distalisation, proved to be temporally efficient against equivalent treatment results. Further research is warranted to improve biomechanical predictability and develop standardised treatment protocols.

(Aust Orthod J 2026; 41: 418 - 433. DOI: 10.2478/aoj-2025-0030)

Received for publication: June, 2025

Accepted: August, 2025.

U-Hyeong Cho: fulook@knu.ac.kr; Hyo-Sang Park: parkhs@knu.ac.kr

## Introduction

Clear aligners are widely preferred over conventional fixed orthodontic appliances by adult patients due to their superior aesthetics, convenience, and patient ease of maintaining oral hygiene.<sup>1</sup> Additionally, aligners facilitate selective tooth movement and allow precise control over the direction and magnitude of movement which enables efficient correction of mild malocclusions.<sup>2</sup>

The treatment modality is particularly suitable for middle-aged adults who often prioritise aesthetics due to active social engagement and typically demonstrate high compliance with appliance wear.<sup>3</sup> However, clear aligners are generally less effective for complex tooth movements involving significant

root displacement or full arch movement.<sup>3-5</sup> Although recent attempts have integrated skeletal anchorage, such as micro-implants, to overcome the limitations, research evaluating treatment outcomes and underlying biomechanical mechanisms remains limited. In conventional clear aligner protocols for full-arch distalisation, the terminal molars are typically distalised first, followed by sequential distalisation of the proximal molars and premolars.<sup>6</sup> This stepwise approach might prolong treatment duration and reduce patient compliance. In contrast, en-masse distalisation, commonly employed in fixed appliance therapy, could enhance treatment efficacy, although no previous trials have evaluated its application using clear aligners.<sup>7</sup>



Figure 1. Pre-treatment photographic records. A. Intraoral views. B. Extraoral views.

The present case report describes the effective and efficient management of crowding and lip protrusion in a middle-aged female patient with previous implant restorations, and achieved through total arch distalisation using clear aligners and skeletal anchorage. Treatment outcomes were assessed via a voxel-based registration of cone beam computed tomography (CBCT) data.

### Diagnosis and aetiology

A 46-year-old female patient presented with chief complaints of incisal crowding and protrusion. An extraoral examination revealed a long facial type, a convex profile, lower lip protrusion, and lip incompetence accompanied by mentalis muscle strain (Figure 1). Written informed consent was

obtained from the patient for the use and publication of her records.

Intraorally, the maxillary left first and second molars were restored with splinted full-coverage crowns. The mandibular right first and second molars were replaced with implant-supported splinted crowns. A mild Class II canine relationship was noted on the right, while the left canines and molars exhibited a Class I relationship. The anterior overbite measured 1.5 mm, the overjet was 2 mm, and the curve of Spee was 1 mm which were all within normal limits. The maxillary arch had an ovoid form, whereas the mandibular arch appeared relatively square. Mild anterior crowding was noted and characterised by tooth rotations (maxilla: 2 mm, mandible: 3.5 mm). The anterior Bolton ratio was 81.9 percent, indicating a 2.2 mm excess in mandibular anterior tooth size.

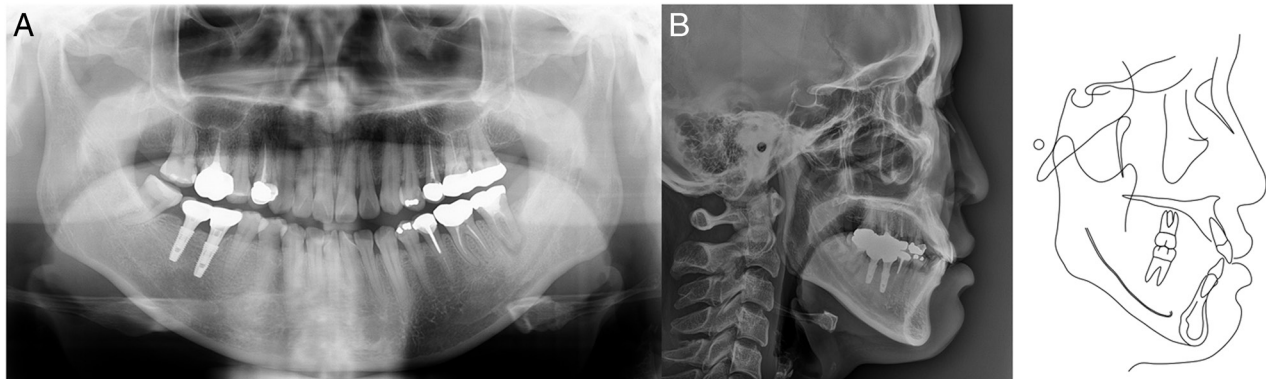


Figure 2. Pre-treatment radiographic records. A. Panoramic radiograph. B. Lateral cephalogram with corresponding tracing.

A panoramic radiograph revealed a root canal-treated mandibular left second molar but with a periapical radiolucency. Previous root canal treatment was also evident in several other posterior teeth. A fully-erupted third molar was present only in the mandibular right quadrant and which occluded with the maxillary right second molar. A lateral cephalometric analysis indicated a skeletal Class I pattern with a high mandibular plane angle and increased anterior facial height (Figure 2, Table I).

Based on the findings, a diagnosis was a skeletal Class I malocclusion with a hyperdivergent vertical facial pattern, characterised by a mild arch length discrepancy, lip protrusion, and lip incompetence.

### Treatment objectives

The treatment objectives were to resolve the crowding, establish a stable occlusal relationship, and enhance facial aesthetics by correcting the lip protrusion and incompetence.

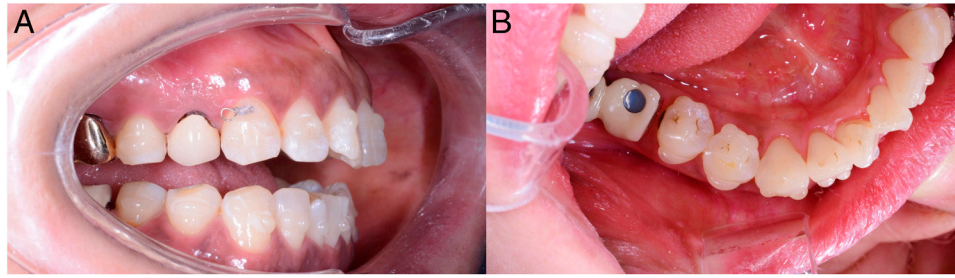
### Treatment alternatives

The first option was non-extraction treatment using conventional edgewise appliances. Although this approach could effectively address the patient's chief complaints, it was anticipated to be unaesthetic due to appliance visibility and was therefore declined. The second option involved non-extraction treatment

Table I. Cephalometric measurements

	Measurements	Norm	Pre-treatment	Post-treatment
Anterior Posterior	SNA (°)	81.7	81.8	81.9
	SNB (°)	79.0	79.6	79.4
	ANB (°)	2.8	2.3	2.6
Vertical	FMA (°)	25.4	32.3	33.2
	Gonial Angle (°)	124.2	126.8	126.8
	FH-Occ (°)	5.9	12.1	12.9
	ANS to Me (mm)	69.1	78.0	79.1
Dental	U1 to FH (°)	116.6	113.0	106.7
	IMPA (°)	87.3	86.4	79.6
	U1 to Sn-TVL (mm)	-9.3	-4.1	-6.3
	L1 to Sn-TVL (mm)	-12.4	-7.8	-9.2
Soft tissue	Upper lip to E-line (mm)	-2.1	-1.1	-1.6
	Lower lip to E-line (mm)	0	2.6	0.2

Note. TVL refers to a true vertical line that passes through the subnasale.



**Figure 3.** Preparatory procedures for the virtual setup. A. Intraoral attachments directly bonded to the teeth, including elliptical attachments and cervical eyelets on the canines. B. Mesial interproximal reduction of the mandibular right posterior implant restoration.

using lingual appliances, which could improve the aesthetic appearance during treatment; however, it was also rejected due to concerns about tongue discomfort and potential speech impairment. The third option was clear aligner therapy, which requires high patient compliance. This option was selected, as the patient committed to consistent aligner wear.

### Treatment progress

Due to a poor prognosis determined by the Department of Conservative Dentistry, the mandibular left second molar was indicated for extraction. The patient was informed that an implant-supported prosthetic restoration would be required following orthodontic treatment, both to increase masticatory efficiency and to prevent super-eruption of the opposing tooth. The existing splinted crowns on the maxillary left first and second molars were also separated to facilitate individual tooth movement. Subsequently, the maxillary left second premolar, first molar, and second molar underwent endodontic treatment and were restored with single-unit aesthetic full-coverage crowns.

Clear aligners were fabricated in-house. Initially, elliptical attachments were directly bonded to the facial and lingual surfaces of the teeth using flowable composite resin. Attachments were not applied to teeth with full-coverage crowns and implant restorations. Using 0.010-inch diameter dead-soft stainless steel ligature wire and flowable resin, eyelets for elastic thread application were bonded to the cervical areas of both maxillary canines and the mandibular left canine. Additionally, the mesial surface of the crown of the mandibular right first molar implant restoration was reduced to create approximately 2 mm of space (Figure 3).

Full-arch digital scans were obtained using an intraoral scanner (Trios, 3Shape, Copenhagen, Denmark) and a virtual setup for aligner fabrication was performed using orthodontic computer-aided designing software (CS Ortho 2.0, CareDent Korea, Seoul, Korea). In the setup, tooth movement per aligner stage was limited to a maximum of 0.25 mm for mesiodistal or buccolingual translation, 0.1 mm for extrusion or intrusion, 3° for rotation, and 2.5° for mesiodistal or buccolingual angulation (Figure 4). These parameters were based on the established protocol provided by Align Technology. A total of 17 and 19 stages were designed for the maxillary and mandibular arches, respectively. Working models were fabricated by printing liquid resin (S-100M, Graphy, Seoul, Korea) using a liquid crystal display-based Stereolithography three-dimensional (3D) printer (NBEE, UNIZ, San Diego, CA, US) with a Z-axis resolution of 100 µm. Each aligner was thermoformed from 0.75 mm thick transparent sheets (CA Pro+, Scheu Dental, Iserlohn, Germany) using a pressure moulding device (Biostar 2006-2009, Scheu Dental, Iserlohn, Germany).

As a general protocol, the patient was instructed to wear the aligners full-time, except during meals. With one to three aligners per arch dispensed at each visit, the aligner change interval ranged from 7 to 10 days and adjusted at the clinician's discretion. If the patient was unable to proceed to the next aligner within the designated period, she was advised to continue wearing the current aligner until the next appointment.

To address the crowding and correct the Bolton ratio, interproximal reduction (IPR) was progressively performed particularly in the mandibular anterior region (Figure 4). The planned IPR was limited to a maximum of 0.2 mm per interproximal surface,

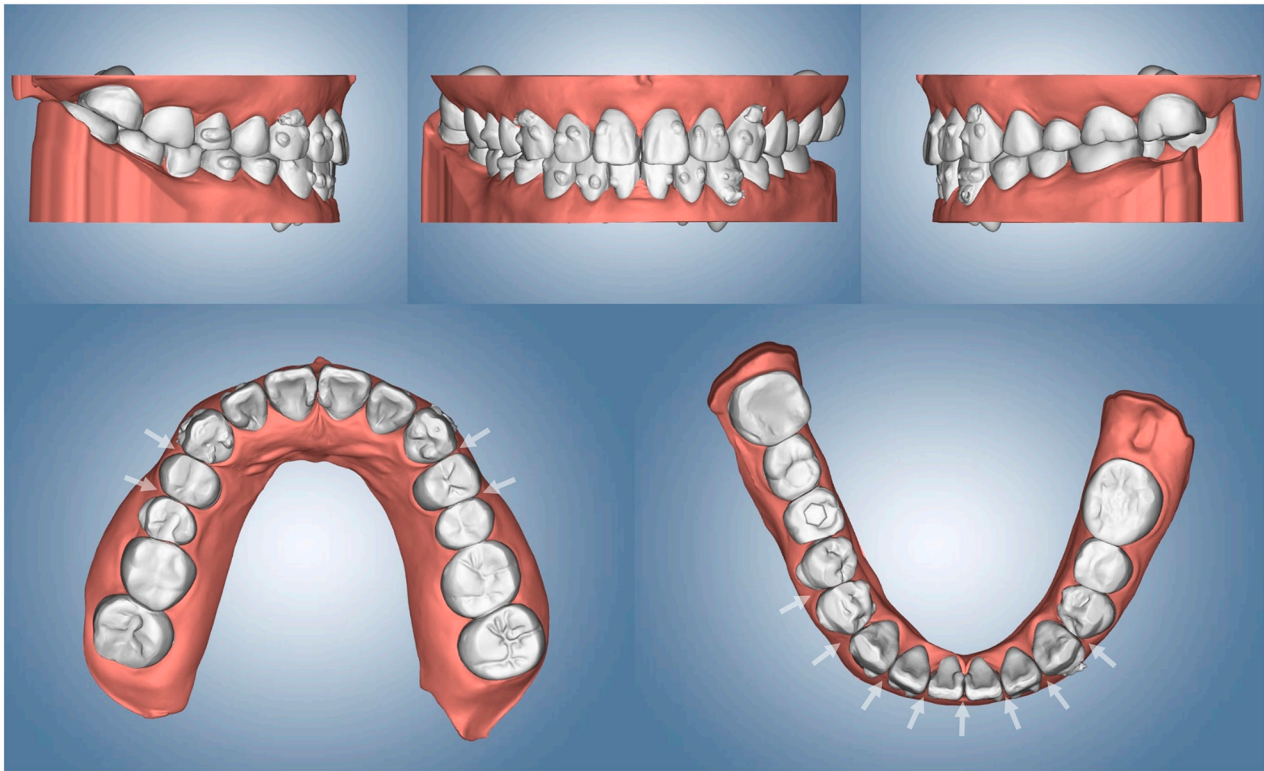


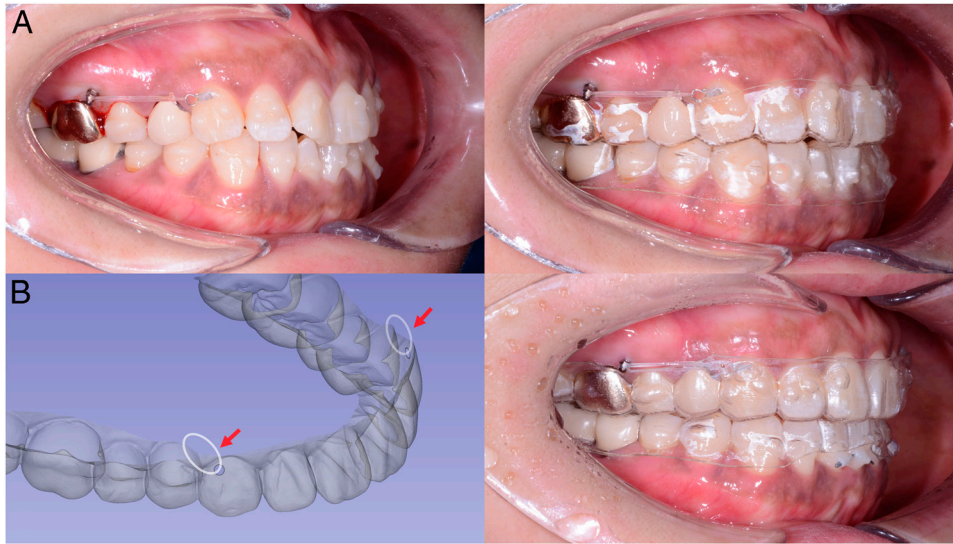
Figure 4. The initial virtual setup created using orthodontic computer-aided designing software, highlighting the planned interproximal reduction site (white arrow), with a maximum reduction of approximately 0.2 mm.

with a total maximum of 0.8 mm for the maxillary arch and 1.6 mm for the mandibular incisors. For distalisation anchorage, micro-implants (8 mm length; 1.4 mm cervical diameter and 1.2 mm apical diameter; Absoanchor, SH1413-08, Dentos, Daegu, Korea) were bilaterally placed in the alveolar bone between the second premolar and first molar in the maxilla. An additional, larger-diameter micro-implant (8 mm length; 1.5 mm cervical diameter and 1.4 mm apical diameter; Absoanchor, SH1514-08, Dentos, Daegu, Korea) was placed disto-buccal to the mandibular left first molar. A distalising force was applied by connecting each micro-implant to the eyelet on the ipsilateral canine using elastic thread (Super Thread, RMO, IN, USA) after aligner delivery (Figure 5). The mandibular right canine was distalised via aligner-driven mechanics, using the posterior dental implant as anchorage.

After confirmation of anterior crowding improvement, the distalising force was maintained to achieve further distalisation of the entire dentition. After 3 months of treatment and beginning with the 11th maxillary aligner stage, the elastic threads were

attached to the cervical areas of the maxillary aligners corresponding to the right and left canines. After aligner insertion, the patient was instructed to hook the integrated elastic threads to the ipsilateral micro-implants. Each elastic thread was pre-calibrated using a force gauge to deliver approximately 200 g of force to the aligners (Figure 5). After 5 months of treatment, following aligner stage 14 in both arches, substantial alignment of the dentition was achieved and accompanied by a noticeable improvement in facial aesthetics (Figure 6). As the patient expressed a desire to further enhance her facial profile, total arch distalisation was continued.

At the 5.3-month evaluation, following the 17th and final planned maxillary aligner, the patient complained of minor residual rotation and misalignment of the maxillary central incisors. Consequently, three additional aligners were prescribed for refinement. Concurrently, the mandibular central incisors were also found to require further rotational adjustment and to enhance treatment efficiency in angulation control, a fixed auxiliary approach was employed. Aesthetic mini-tube appliances were bonded to the



**Figure 5.** The application of the distalising force using micro-implant anchorage. A. Distalising forces applied to bonded eyelets for initial canine retraction (left: pre-wear; right: post-wear). B. The integrated aligner elastic technique. An elastic is threaded through holes in the aligner, forming a single, integrated unit delivering approximately 200 g of force upon engagement (left: three-dimensional illustration showing the elastic anchored at the aligner [red arrows]; right: clinical application).



**Figure 6.** Mid-treatment photographic records at 5 months. A. Intraoral views. B. Extraoral views.



Figure 7. Micro-implant uprighting cantilever used for root control of the mandibular right central incisor.

labial cervical areas, and a sectional super-elastic nickel-titanium wire was inserted. These auxiliaries were used together with the aligners for 20 days. Since the aligner was designed to counteract any undesirable reactive forces from the mini-tube appliance, strict patient compliance with aligner wear was emphasised. At 6.6 months into the treatment, the patient was satisfied with the improvement in her facial profile, and the application of the distalising force was discontinued. However, as an additional refinement of the anterior teeth was still indicated, two additional aligner stages were prescribed.

After 8 months of treatment, three additional aligner stages were also prescribed for the mandibular arch to allow further detailing of the mandibular central incisors. To enhance control of the mandibular right central incisor, a micro-implant uprighting cantilever was employed.<sup>8</sup> A micro-implant (6 mm length; 1.3 mm cervical diameter and 1.2 mm apical diameter; Absoanchor, SH1312-06, Dentos, Daegu, Korea) was placed between the mandibular right central and lateral incisors. A 0.016-inch super-elastic NiTi sectional wire was bonded to the labial cervical area of the mandibular right central incisor, forming a cantilever. The free end of the cantilever was engaged onto the head of the micro-implant for activation (Figure 7). This configuration was designed to generate a root-uprighting moment on the central incisor via the elastic recovery force of the NiTi wire, with the resulting reactive forces counteracted by both the micro-implant and the aligner. The cantilever was maintained for 16 days and then removed. Subsequently, following the patient's request for minor refinement of the maxillary right central incisor, one final additional aligner was fabricated for the maxillary arch. To improve control, IPR was performed on the distal surface of the maxillary right central incisor, and the aligner was

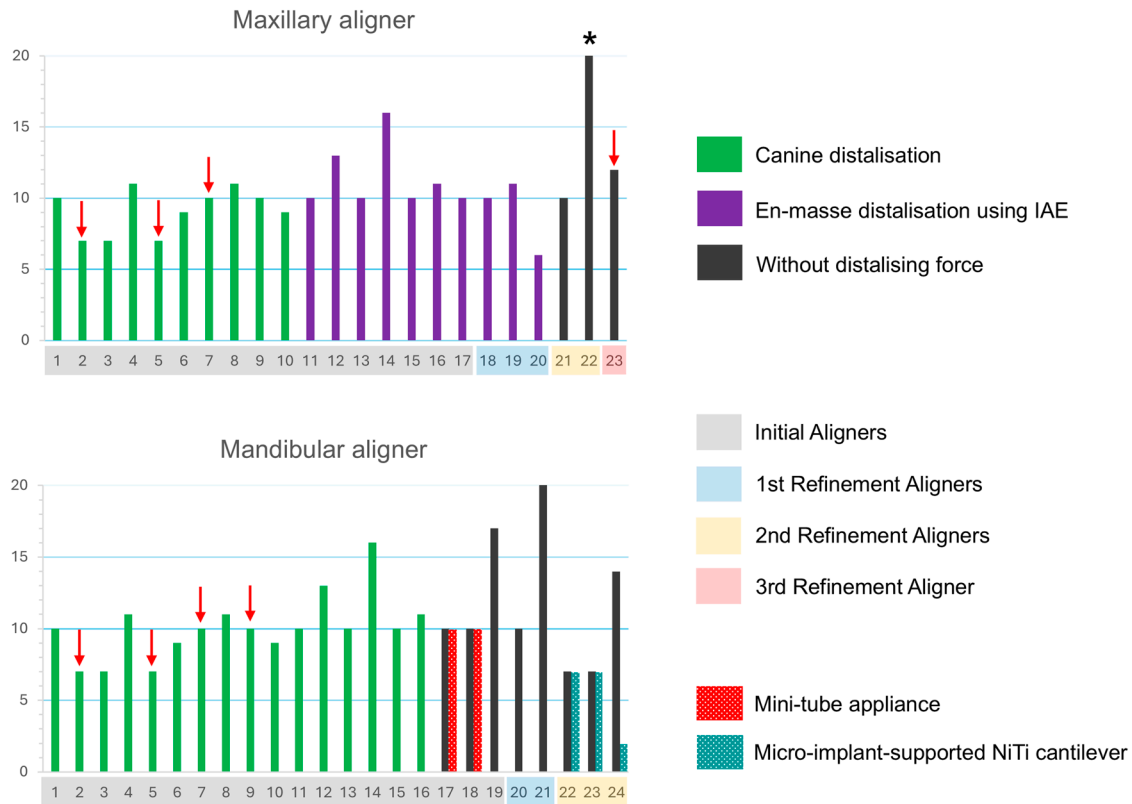
worn for 12 days. A summary of the entire treatment sequence is provided in Figure 8.

At 9 months, active treatment was completed. For retention, a mandibular canine-to-canine fixed lingual retainer was bonded, and clear retainers and circumferential retainers were provided for daytime and night-time wear, respectively. In addition, full-time wear of removable retainers for the first 6 months, followed thereafter by night-time wear, was prescribed.

### Treatment results

The anterior crowding was resolved in both arches, resulting in well-aligned dentitions. Stable posterior occlusal contacts and intercuspation were achieved, and the arch forms were improved with appropriate transverse co-ordination. Anterior tooth retraction contributed to a reduction in lower lip protrusion and a resolution of mentalis muscle hyperactivity during lip closure, thereby enhancing the facial profile which appeared straighter and more natural (Figure 9). Post-treatment panoramic radiography demonstrated favourable root parallelism (Figure 10). Cephalometric superimposition revealed that the anterior teeth were retracted primarily through tipping, accompanied by mild distal movement of the posterior teeth. Additionally, extrusion of the mandibular teeth and a slight increase in the mandibular plane angle ( $0.9^\circ$ ) were confirmed (Figure 11, Table I).

To comprehensively evaluate the treatment outcomes, a voxel-based superimposition technique was applied to the CBCT volume data.<sup>9</sup> All procedures were performed using 3D Slicer (version 5.8.0, open-source software; <https://www.slicer.org>). After re-orienting the pre-treatment volume data, the post-treatment volume was superimposed onto the



**Figure 8.** Timeline of treatment progress. The horizontal axis represents the aligner stages; the vertical axis indicates the wear duration (in days). The asterisk (\*) indicates an aligner worn as a provisional retainer (48 days); the red arrow indicates the timing of interproximal reduction; the green bar represents canine distalisation; the purple bar represents en-masse distalisation using the integrated aligner elastic technique; the black bar indicates phases without a distalising force.

pre-treatment dataset by using stable anatomical structures in the cranial base and mandibular symphyseal region as reference areas for registration.<sup>10</sup> After segmentation of the maxillofacial structures and dentition, 3D mesh models were generated. The 3D dental mesh data obtained from pre- and post-treatment intra-oral scans were then registered to their corresponding CBCT volumes (Figure 12). The resulting digital dental models, integrating voxel-based superimposition results with intraoral scan data for crowns and CBCT data for roots, were used to assess 3D tooth positions and analyse tooth movement patterns.

In the sagittal view, all maxillary tooth crowns exhibited posterior movement, with notable distalisation of the terminal molars (Figure 12, Table II). The maxillary central incisors and canines demonstrated posterior crown movement with lingual tipping, leading to a reduced axial inclination (Figure 13). Vertically, the incisal edges and canine cusp tips remained relatively stable, while the root

apices of both central incisors showed signs of intrusion. Transversely, the maxillary intercanine and intermolar widths increased by 0.8 mm and 0.6 mm, respectively (Figure 14).

All tooth crowns in the mandibular arch exhibited posterior movement in the sagittal plane (Figure 12, Table II), with crown tipping most prominent in the left central incisor (Figure 13). Vertical changes included extrusion on the left side, while the right implant restoration remained vertically stable. In the horizontal plane, the central incisors and canines primarily shifted distally, but an additional lingual movement of both canines resulted in a reduction of the intercanine width by approximately 0.9 mm. Conversely, both second premolars showed buccal expansion. The left first molar underwent distalisation accompanied by slight buccal movement by 0.2 mm (Figure 14).

At the 6-month post-treatment follow-up, intraoral photographs confirmed stable maintenance of the treatment outcomes (Figure 15).

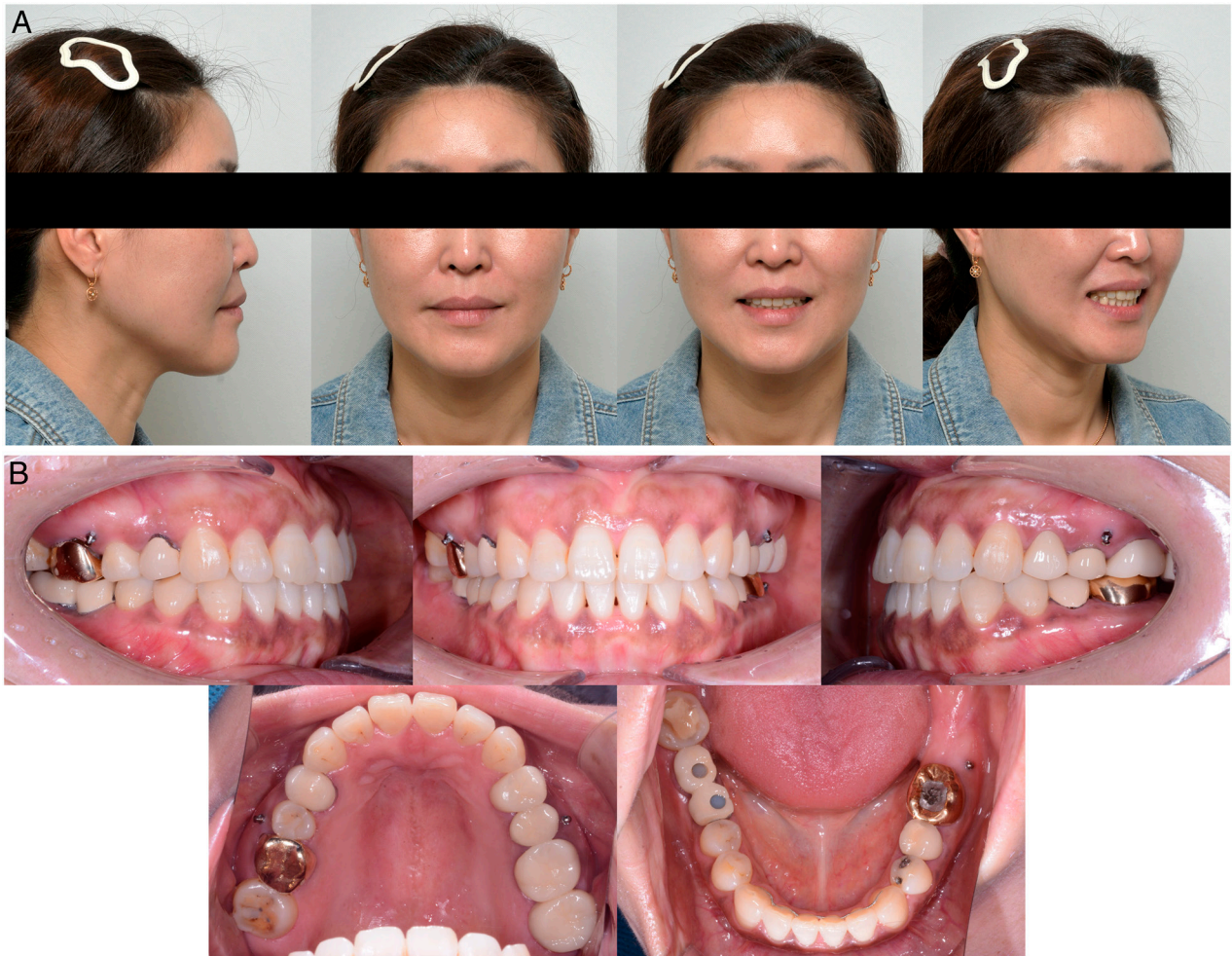


Figure 9. Post-treatment photographic records. A. Intraoral views. B. Extraoral views.

**Discussion**

The treatment demonstrated high temporal efficiency achieved within approximately 5 months and achieved significant improvements in facial profile and overall alignment. This efficiency can be

largely attributed to the en-masse arch distalisation combined with simultaneous tooth alignment. In contrast, conventional sequential distalisation typically involves initial movement of the terminal molars, followed by progressive movement of the

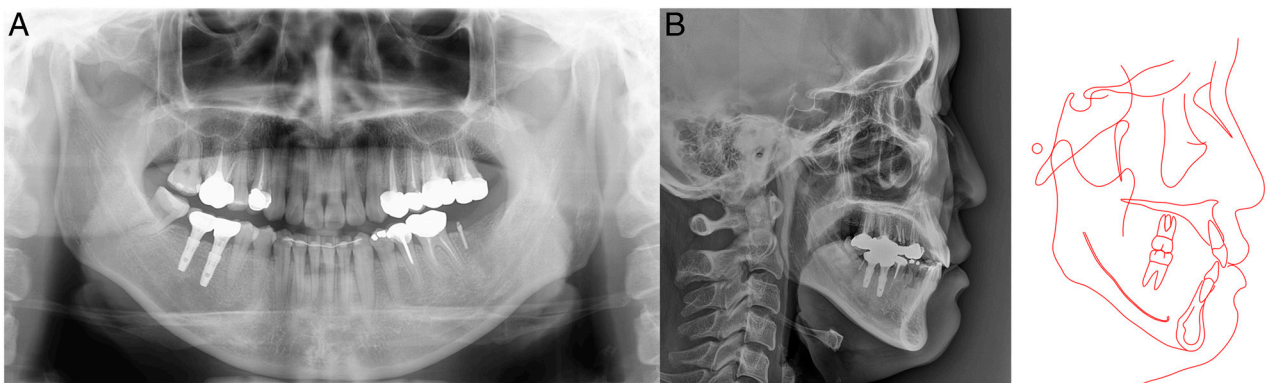


Figure 10. Post-treatment radiographic records. A. Panoramic radiograph. B. Lateral cephalogram with corresponding tracing.

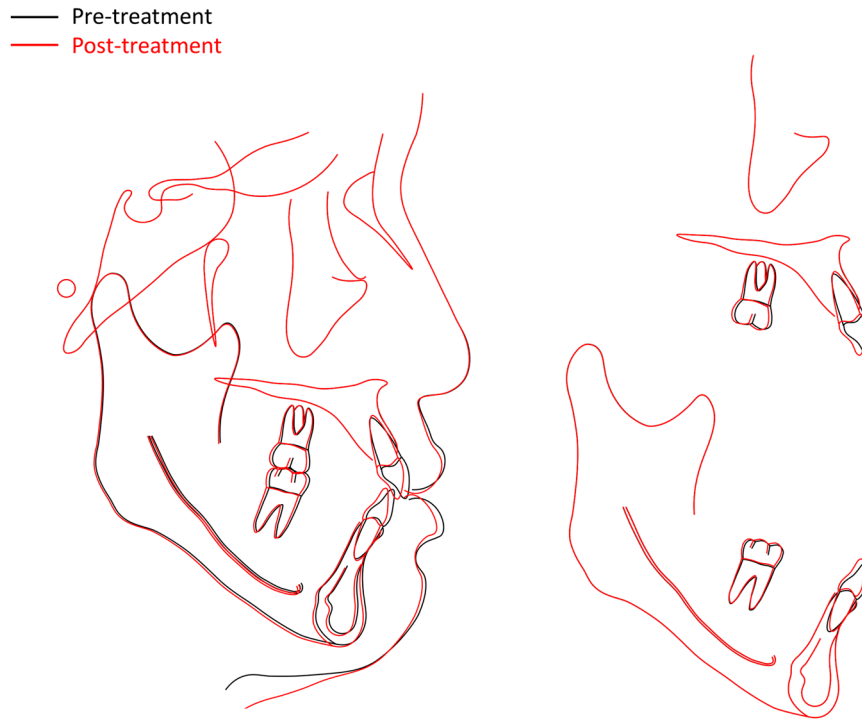


Figure 11. Superimposition of pre- and post-treatment lateral cephalograms.

remaining posterior and anterior teeth,<sup>6,11</sup> which extends treatment duration and complicates patient compliance.<sup>12</sup> In the present case, distalisation began with the canines and was subsequently extended to the entire dentition (Figure 8). This staged approach allowed continued distalisation after initial alignment to further enhance the facial profile and provided flexibility in determining the

treatment endpoint based on patient satisfaction.<sup>7</sup> By employing distinct phases of tooth movement, the protocol minimised unnecessary movements and prevented round-tripping, thereby improving overall temporal efficiency.<sup>13</sup> Absolute anchorage was critical for distalising the entire dentition, particularly the posterior segment, and in this context, micro-implants served as a pivotal anchorage system.<sup>11,14</sup>

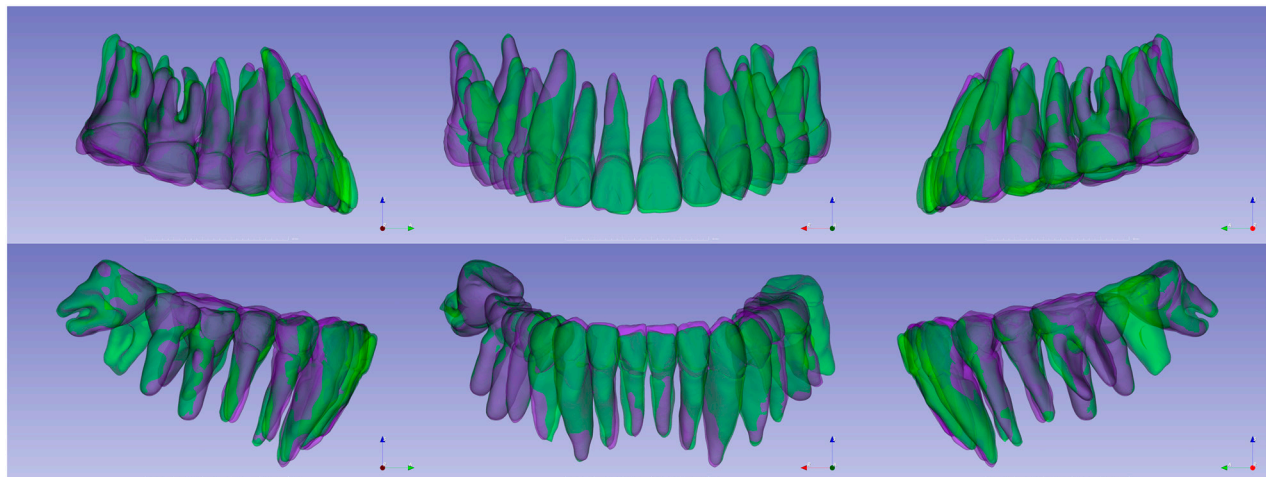


Figure 12. Voxel-based superimposition of three-dimensional dental models before and after treatment. The maxillary dentition was superimposed on the cranial base; the mandibular dentition was superimposed on the mandibular symphysis. Green: pre-treatment; purple: post-treatment.

Table II. Evaluation of tooth movements

	#17	#15	#13	#11	#21	#23	#25	#27	#45	#43	#41	#31	#33	#35	#36
On Sagittal Reference Plane															
Z-axis Root															
Direction of Movement	E	E	R	I	I	E	R	E	I	E	R	E	I	E	E
Z-axis Crown															
Direction of Movement	E	E	R	R	I	I	I	E	E	E	E	E	E	E	E
Y-axis Crown															
Type of Movement	T	N	T	T	T	T	T	N	T	T	T	T	T	T	T
Axial Change	-1.6	0.9	6	6.9	6.3	5.6	-2.3	0.9	4.2	5.9	6.6	7.6	5.4	0.8	2.4
Direction of Movement	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Amount of Movement	0.4	0.3	2.1	2.5	2.1	1.9	0.5	1.0	0.9	1.8	1.3	1.3	2.2	0.2	0.6
On Horizontal Reference Plane															
X-Y axis Crown															
Amount of Movement	0.9	0.9	2.2	2.5	2.1	1.9	0.6	1.0	1.4	1.9	1.3	1.3	2.3	1.1	0.4
Lateral Deviation	57	68.6	15.1	5.3	11.4	5.4	24.8	11.4	51.3	14.6	16.3	7.5	10.4	77.1	24.6
Angle															

Note. E, extrusion; I, intrusion; N, no tipping; P, posterior; R, retained; T, tipping; Axial Change (°); Amount of Movement (mm); Lateral Deviation Angle, the angle between the crown movement vector and the sagittal reference plane on horizontal reference plane (°).

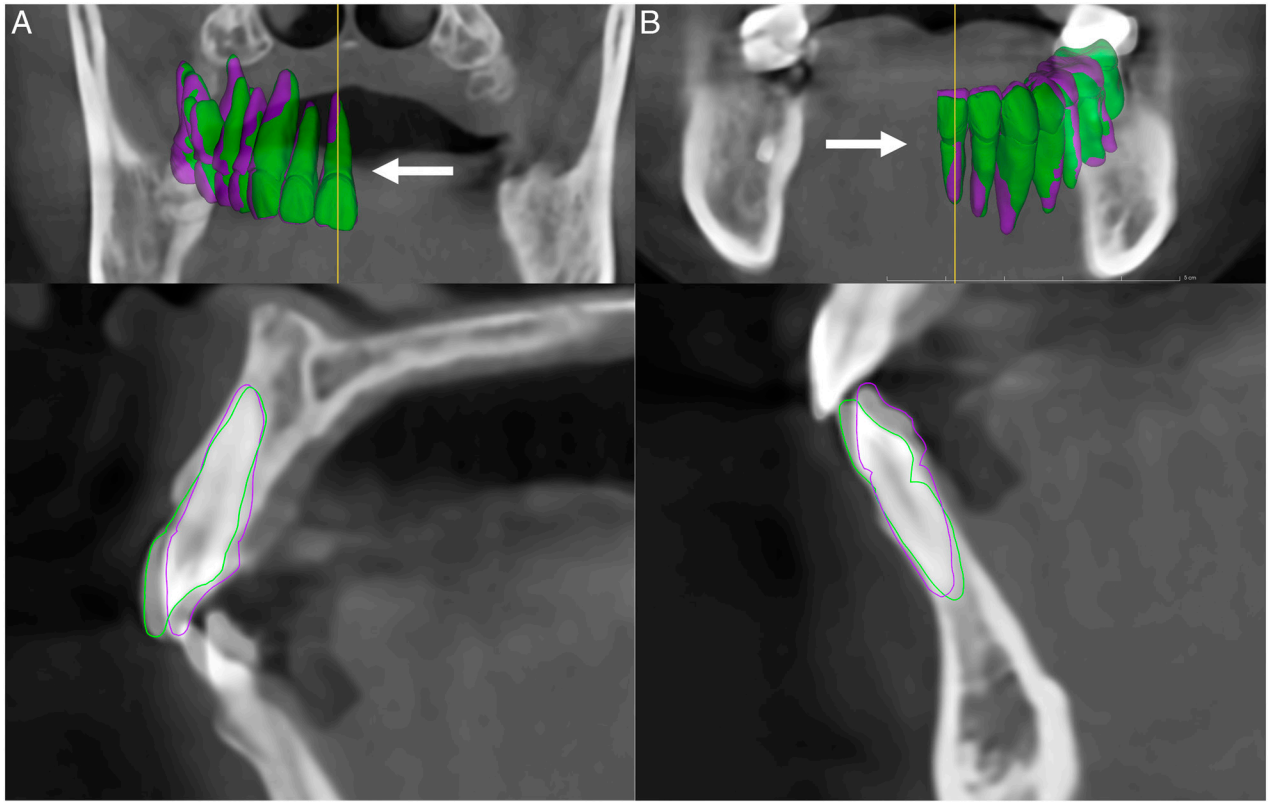


Figure 13. Sagittal evaluation of the maxillary and mandibular central incisors. Green: pre-treatment; purple: post-treatment. The sagittal slicing plane (yellow line) and viewing direction (white arrow) are shown. A. Maxillary right central incisor. B. Mandibular left central incisor.

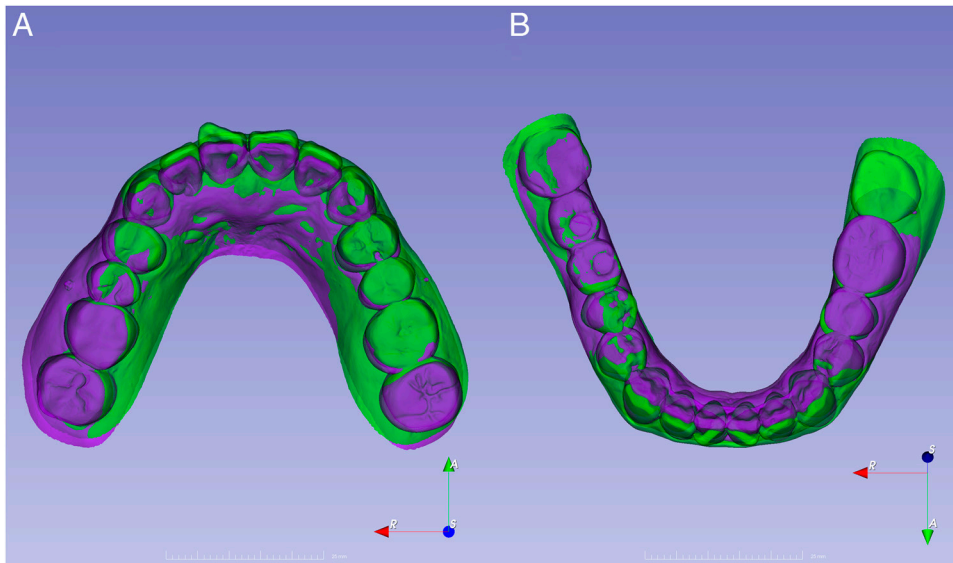


Figure 14. Horizontal plane evaluation of the maxillary and mandibular arches using voxel-based superimposition. Green: pre-treatment; purple: post-treatment.



Figure 15. Intraoral photographic records taken 6 months after the completion of active treatment during the retention phase.

Additionally, the integrated aligner elastic (IAE), a novel approach for delivering an en-masse distalising force, was employed, wherein elastics were threaded through designated holes in the aligners to form a unified system (Figure 5). The IAE technique simplifies the process for patients by eliminating the need for manual elastic attachment and reducing the burden of carrying elastics. The thin, smooth elastics minimise discomfort from foreign body sensations and are compatible with small-headed micro-implants which facilitate easy engagement. Moreover, their favourable mechanical properties enable sustained force delivery over time.<sup>15</sup> Importantly, this technique allows the clinician to exert more precise control over the magnitude and direction of the elastic force.

Aligners were delivered at 2–3-week intervals, with tooth movement closely monitored at each visit. When refinement was necessary, additional aligners were pro-actively fabricated based on minimal, precisely planned adjustments to the existing digital setup model, without requiring new intraoral scans (Figure 8). This strategy ensured an optimal fit, minimised complications, and reduced the number of aligners. Notably, all aligners were fabricated in-house, thereby eliminating reliance on external laboratories. The in-house production enabled immediate setup modifications based on real-time feedback and removed delays associated with third-party processing and delivery. Consequently, resource consumption and turnaround time were significantly reduced, ensuring an uninterrupted

aligner supply commensurate with treatment progress and contributing to an overall reduction in treatment duration.

When more precise control of tooth movement was required, a hybrid approach combining aligners with fixed auxiliary appliances was implemented. To refine mandibular incisor position, a mini-tube appliance was used for 4 weeks, followed by a micro-implant uprighting cantilever that was applied for 2 weeks (Figure 8). The bonded cantilever appliance, in particular, proved highly effective for controlling root position (Figure 7).<sup>8</sup> A three-dimensional CBCT evaluation confirmed excellent root alignment of the mandibular anterior teeth, with rapid improvement and no evidence of significant root resorption.

Previous studies have largely relied on digital dental models, and a limited assessment of tooth movement in relation to craniofacial structures.<sup>14,16</sup> Although previous research has used cephalometric analysis, quantitative evaluations using CBCT remain scarce, particularly regarding en-masse distalisation using aligners.<sup>17</sup> This limitation hinders direct comparisons between the present case and the existing literature.

Despite the limitations, a few key studies provide relevant benchmarks. According to Li et al., who evaluated sequential maxillary arch distalisation using dental model superimposition with anchorage reinforcement from Class II elastics and miniscrews, the mean posterior movement of the maxillary first and second molars was 0.783 mm and 0.994

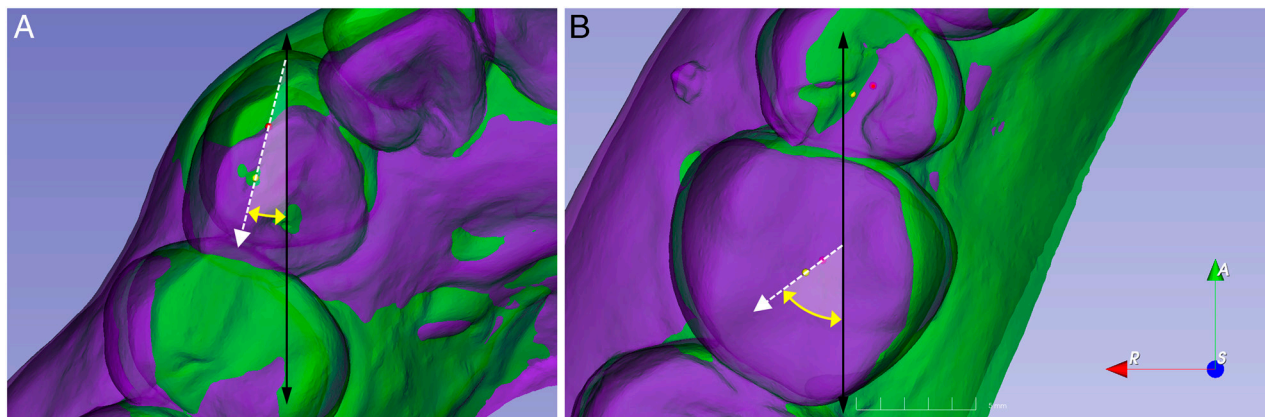
mm, respectively.<sup>11</sup> The study by Qiang et al. used CBCT scans, which provided an excellent point of reference.<sup>17</sup> The study, which also involved sequential distalisation, found the mean crown distalisation of the first and second molars to be 0.44 mm and 0.73 mm, respectively. This finding is also comparable to the present results. Furthermore, the Li et al. study observed non-statistically significant lingual tipping of the central incisors following TAD use, whereas the use of Class II elastics resulted in statistically significant labial tipping of the central incisor crowns and greater mesial movement of the first molar roots. These results underscore the importance of skeletal anchorage, such as micro-implants, when considering total arch distalisation.

Moreover, a direct comparison of temporal efficiency is challenging, as neither study specified the total treatment duration. However, in the study by Qiang et al., the aligners were changed every 1 to 2 weeks, and an average of 2.2 refinements were performed.<sup>17</sup> Given that the present case achieved comparable therapeutic efficacy within a total treatment time of only 9 months, it may be concluded that the present approach demonstrates high efficiency and acceptable treatment duration.

As a result of en-masse distalisation, most tooth movements, aside from a few specific teeth, were primarily characterised by tipping. Although the labiolingual inclination of the maxillary central incisors was intended to remain stable, a 6° reduction was observed. Similar tipping patterns occurred in

the distalisation of the canines and several posterior teeth. It is well-recognised that clear aligners often struggle to produce sufficient moments for complex tooth movements.<sup>13,18</sup> This limitation was evident in the present case, in which achieving root movement was particularly challenging given the short treatment duration.<sup>19</sup> To overcome the limitations, the design of an effective force system based on sound biomechanical principles is critical. Recommended strategies include the customisation of attachments, careful optimisation of staging and movement magnitude, the incorporation of overcorrection in the treatment plan, the use of intermaxillary elastics, and the application of skeletal anchorage to enhance force vector control.<sup>5,13,14</sup>

In the sagittal view, a bilateral discrepancy was initially noted in the movement of the maxillary right and left terminal molars. However, when assessed by the horizontal reference plane (Frankfort horizontal plane), the overall displacement of both molars was approximately 1.0 mm, indicating no clinically significant difference between the sides. To understand this discrepancy, the direction of tooth movement was analysed in relation to the X-Y coordinate system by calculating the angle between the movement vector and the sagittal reference plane. To quantify the three-dimensional nature of molar distalisation along the dental arch and encompassing both posterior and transverse vectors, a novel metric termed the Lateral Deviation Angle (LDA) was introduced (Figure 16). The LDA was 11.4° for the



**Figure 16.** Measurement of the lateral deviation angle (LDA) in the maxillary right canine (A) and first molar (B). LDA is defined as the angle between the tooth movement vector (dotted white arrow) and a reference line parallel to the midsagittal plane (double-headed vertical arrow). The measured angle is represented by the yellow arrow and white arc.

maxillary left second molar and 57° for the right second molar (Table II), indicating a substantial buccal component of movement on the right side and manifest as buccal segment expansion. In contrast, the movement on the maxillary left side occurred predominantly in the anteroposterior direction. The quantitative assessment of the transverse changes, based on the distance from the median palatal raphe to each maxillary first molar, showed a reduction in the initial bilateral asymmetry. The pre-treatment difference of 2.2 mm (right: 22.7 mm; left: 24.9 mm) decreased to 1.4 mm post-treatment (right: 23.4 mm; left: 24.8 mm) and indicated improved arch symmetry (Figure 14). This combination of LDA analysis and quantitative transverse measurements suggests that the transverse movements planned within the digital setup were effectively expressed during the en-masse distalisation.<sup>17</sup>

The combined use of aligners and micro-implants in the present case, successfully addressed the patient's chief complaint and produced favourable treatment outcomes with high temporal efficiency. However, the long-term stability of the results requires further evaluation, as post-treatment retention has only been observed for nine months. Furthermore, since limitations inherent to aligner therapy were also identified, further studies with larger sample sizes are needed to improve the predictability of tooth movement and establish standardised treatment protocols.

## Conclusion

Crowding and lip protrusion in an adult patient presenting with multiple prosthetic restorations were well managed using a combined approach of clear aligners and micro-implant anchorage with high temporal efficiency. The chief complaint was promptly addressed through en-masse distalisation. Treatment efficiency was further optimised by continuous monitoring and the timely application of in-house fabricated aligners and fixed auxiliary appliances. A CBCT-based superimposition analysis demonstrated posterior tooth distalisation and mild arch expansion, with tipping identified as the primary mode of orthodontic tooth movement.

## Conflicts of interest

No conflicts of interest

## Corresponding author

Hyo-Sang Park, DDS, PhD, Professor and Chair, Department of Orthodontics, School of Dentistry, Kyungpook National University, Daegu, Korea. Tel: (82-53)-600-7373. Fax: (82-53)-421-4925. Email: parkhs@knu.ac.kr.

## References

1. Miller KB, McGorray SP, Womack R, Quintero JC, Perelmuter M, Gibson J, et al. A comparison of treatment impacts between Invisalign aligner and fixed appliance therapy during the first week of treatment. *Am J Orthod Dentofacial Orthop.* 2007;131:302.e1–302.e9.
2. Hou D, Capote R, Bayirli B, Chan DCN, Huang G. The effect of digital diagnostic setups on orthodontic treatment planning. *Am J Orthod Dentofacial Orthop.* 2020;157:542–9.
3. Gu J, Tang JS, Skulski B, Fields HW, Beck FM, Firestone AR, et al. Evaluation of Invisalign treatment effectiveness and efficiency compared with conventional fixed appliances using the Peer Assessment Rating index. *Am J Orthod Dentofacial Orthop.* 2017;151:259–66.
4. Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Forces and moments generated by removable thermoplastic aligners: Incisor torque, premolar derotation, and molar distalization. *Am J Orthod Dentofacial Orthop.* 2014;145:728–36.
5. Rossini G, Parrini S, Castorflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: A systematic review. *Angle Orthod.* 2015;85:881–9.
6. Schupp W, Haubrich J, Neumann I. Class II Correction with the Invisalign System. *J Clin Orthod.* 2010;44:28–35.
7. Oh YH, Park HS, Kwon TG. Treatment effects of microimplant-aided sliding mechanics on distal retraction of posterior teeth. *Am J Orthod Dentofacial Orthop.* 2011;139:470–81.
8. Noh HK, Kim HJ, Park HS. Micro-implant Uprighting cantilever for the correction of a severely rotated and angulated mandibular canine during clear aligner treatment. *Australas Orthod J.* 2025;41:18–31.
9. Cevidanes LHC, Motta A, Proffit WR, Ackerman JL, Styner M. Cranial base superimposition for 3-dimensional evaluation of soft-tissue changes. *Am J Orthod Dentofacial Orthop.* 2010;137:S120–9.
10. Ruellas AC de O, Yatabe MS, Souki BQ, Benavides E, Nguyen T, Luiz RR, et al. 3D Mandibular Superimposition: Comparison of Regions of Reference for Voxel-Based Registration. *PLoS One.* 2016;11:e0157625.
11. Li L, Guo R, Zhang L, Huang Y, Jia Y, Li W. Maxillary molar distalization with a 2-week clear aligner protocol in patients with Class II malocclusion: A retrospective study. *Am J Orthod Dentofacial Orthop.* 2023;164:123–30.
12. Patterson BD, Foley PF, Ueno H, Mason SA, Schneider PP, Kim KB. Class II malocclusion correction with Invisalign: Is it possible? *Am J Orthod Dentofacial Orthop.* 2021;159:e41–8.
13. Upadhyay M, Arqub SA. Biomechanics of clear aligners: hidden truths & first principles. *J World Fed Orthod.* 2022;11:12–21.
14. Saif BS, Pan F, Mou Q, Han M, Bu W, Zhao J, et al. Efficiency evaluation of maxillary molar distalization using Invisalign based on palatal rugae registration. *Am J Orthod Dentofacial Orthop.* 2022;161:e372–9.
15. Persson M, Kiliaridis S, Lennartsson B. Comparative studies on orthodontic elastic threads. *Eur J Orthod.* 1983;5:157–66.

16. Taffarel IA, Gasparello GG, Mota-Júnior SL, Pithon MM, Taffarel IP, Meira TM, et al. Distalization of maxillary molars with Invisalign aligners in nonextraction patients with Class II malocclusion. *Am J Orthod Dentofacial Orthop.* 2022;162:e176–82.
17. Qiang R, Zhang H, Xu Y, Zhang X, Jin F, Jin Z, et al. Accuracy of maxillary molar distalization with clear aligners in three-dimension: a retrospective study based on CBCT superimposition. *Clin Oral Investig.* 2025;29:138.
18. Grünheid T, Loh C, Larson BE. How accurate is Invisalign in nonextraction cases? Are predicted tooth positions achieved? *Angle Orthod.* 2017;87:809–15.
19. Haouili N, Kravitz ND, Vaid NR, Ferguson DJ, Makki L. Has Invisalign improved? A prospective follow-up study on the efficacy of tooth movement with Invisalign. *Am J Orthod Dentofacial Orthop.* 2020;158:420–5.