TURKISH JOURNAL OF
ORTHODONTICS

DOI: 10.4274/TurkJOrthod.2025.2024.153

Original Article

Impact of Camouflage Treatment with Class III Elastics on Temporomandibular Joint and Dentoskeletal Relationships: A Pilot CBCT and MRI-Based Clinical Trial

Panjaree Panpitakkul[1], Teekayu Plangkoon Jorns[2], Warinthorn Phuttharak[3], Rajda Chaichit[4], Pipop Sutthiprapaporn[1]

[1]Khon Kaen University Faculty of Dentistry, Department of Preventive Dentistry, Division of Orthodontics, Khon Kaen, Thailand
[2]Khon Kaen University Faculty of Dentistry, Department of Oral Biomedical Science, Division of Oral Biology, Khon Kaen, Thailand
[3]Khon Kaen University Faculty of Medicine, Department of Radiology, Khon Kaen, Thailand
[4]Khon Kaen University Faculty of Dentistry, Department of Preventive Dentistry, Division of Dental Public Health, Khon Kaen, Thailand

Cite this article as: Panpitakkul P, Jorns TP, Phuttharak W, Chaichit R, Sutthiprapaporn P. Impact of camouflage treatment with Class III elastics on temporomandibular joint and dentoskeletal relationships: a pilot CBCT and MRI-based clinical trial. *Turk J Orthod.* 2025; 38(2): 116-127

Main Points

- Camouflage treatment with conventional Class III elastics significantly improves the dentoskeletal relationship and soft tissue profile.
- Camouflage treatment with conventional Class III elastics did not induce significant adverse changes in the condyles or articular discs, nor cause temporomandibular disorders.

ABSTRACT

Objective: Orthodontic camouflage effectively addresses mild to moderate skeletal Class III malocclusion by repositioning the mandible and anterior teeth. However, recent findings suggest potential temporomandibular joint (TMJ) impact of the intermaxillary elastics frequently used in this treatment. This study aims to comprehensively assess changes in the TMJ and dentoskeletal relationship following Class III camouflage treatment, using a combination of CBCT and MRI.

Methods: This clinical trial enrolled skeletal Class III malocclusion patients meeting eligibility criteria. Non-extraction camouflage treatment was administered, employing the straight wire technique with conventional Class III intermaxillary elastics. CBCT and MRI were conducted at baseline (T0) and after achieving normal occlusion (T1). Condylar position in three dimensions and dentoskeletal relationship were assessed from CBCT images using Dolphin® imaging software, while TMJ disc position and length were measured from MR images using MicroDicom software. Statistical analyses were performed with IBM® SPSS® software.

Results: The dataset comprised nine subjects, with a mean age of 24.3±7.0 years. CBCT analyses indicated significant changes in dentoskeletal relationship, especially those of the mandible (increased ANB 2.32±0.51°, increased SN-MP 2.61±1.05°, decreased profile angle 5.40±1.07°), but nonsignificant changes in condylar position post-treatment (0.11±0.15 mm). Similarly, MRI measurements demonstrated non-significant changes in both position (0.91±1.61°) and length (0.07±0.37 mm) of the articular disc post-treatment.

Conclusion: Class III camouflage treatment using conventional intermaxillary elastics significantly improves the dentoskeletal relationship without significant adverse effects on the condyle and articular disc of the TMJ.

Keywords: Class III malocclusion, camouflage treatment, intermaxillary elastics, condyle, articular disc

Corresponding author: Pipop Sutthiprapaporn, **e-mail:** spipop@kku.ac.th
Received: October 14, 2024 **Accepted:** May 28, 2025 **Publication Date:** July 02, 2025

INTRODUCTION

Skeletal Class III malocclusion is recognized as a prevalent concern prompting patients to seek orthodontic care, especially within Asian populations.[1] It is typically characterized by concave profile with anterior crossbite or minimal overjet, attributed to mandibular prognathism, maxillary deficiency, or a combination of both.[2] Addressing this type of malocclusion in adults is particularly challenging for orthodontists due to the limited treatment options.

Camouflage orthodontic treatment provides a viable alternative for addressing mild-to-moderate skeletal Class III malocclusion, aiming to enhance both function and facial aesthetics. This approach is especially beneficial for patients who want to avoid the risks of orthognathic surgery or have financial constraints. Various approaches can be implemented to correct anterior crossbite and obtain normal occlusion in Class III camouflage treatment, including extracting two lower premolars, extracting one lower incisor, extracting four premolars, distalizing whole lower teeth (with and without temporary anchorage devices, TADs), tipping lower teeth posteriorly by multiloop edgewise archwire (MEAW) technique, and utilizing Class III intermaxillary elastics.[3-8] Among numerous methods, the straight-wire technique combined with conventional Class III intermaxillary elastics stand out as one of the most widely adopted approaches for correcting Class III malocclusion owing to its effectiveness and ease of use. They compensate for skeletal Class III malocclusion mainly through proclination of the upper anterior teeth, retroclination of the lower anterior teeth, and extrusion of the upper molars, resulting in a favorable clockwise rotation of the mandible and reversion of the occlusal plane.[3]

Although the treatment alternative using intermaxillary elastics has long been described with the understanding that correction will be achieved solely at the dentoalveolar level without altering the underlying skeletal components,[9,10] recent studies employing finite element analysis (FEA) have reported the potential impact of intermaxillary elastics on the mandibular position and thus the temporomandibular joints (TMJs).[11-14] Those studies demonstrated that the mechanical stress generated by the Class III intermaxillary elastics could project toward the TMJs and likely initiate a posterior-superior displacement of the condyles. Furthermore, this excessive mechanical stress has been regarded as a crucial factor, given its potential to induce degenerative changes in the TMJs.[12,15]

However, the lack of clinical evidence leaves an important gap in understanding whether camouflage treatment with Class III intermaxillary elastics displaces the condyles and could cause degenerative changes in the TMJ disc-condyle complex. This study aimed to answer this important question in a clinical setting, highlighting the significant impact of elastics on real patients. Consequently, the purpose of this study was to assess changes in the condyles and TMJ articular discs following camouflage treatment with Class III intermaxillary elastics, using a combination of the cone-beam computed tomography (CBCT) and the magnetic resonance imaging (MRI) analyses.

The primary objective of this study was to compare the positions of the condyles and articular discs of the TMJs at baseline (T0) and after achieving normal occlusion (T1) through conventional Class III camouflage treatment. The null hypothesis for this objective postulated that there are no differences in the positions of the condyles and articular discs of the TMJs between baseline (T0) and after achieving normal occlusion (T1).

Whereas, the secondary objective was to investigate the dentoskeletal effects of conventional Class III camouflage treatment by comparing the lateral cephalometric measurements (skeletal, dental, and soft tissues components) at baseline (T0) and after achieving normal occlusion (T1). The null hypothesis for this objective was that there would be no significant difference in the lateral cephalometric measurements between baseline (T0) and after achieving normal occlusion (T1).

METHODS

Trial Design and Important Changes after Trial Commencement

This study is a single-arm clinical trial, specifically a pre-post intervention study. No changes in the method were made after the trial commencement. This clinical trial was registered under the number TCTR20220316003 at the Thai Clinical Trials Registry (www.thaiclinicaltrials.org).

Participants, Eligibility Criteria, and Settings

The study population consists of non-growing patients with mild to moderate skeletal Class III malocclusion who met the eligibility criteria. Subjects were recruited using the consecutive sampling method at the Orthodontic Clinic of the Dental Hospital, Faculty of Dentistry, Khon Kaen University, Thailand, from January to December 2022.

The inclusion criteria included: (1) complete mandibular growth (determined by cervical vertebral maturation stage 6);[16] (2) mild to moderate skeletal Class III malocclusion [skeletal Class III with ANB angle <0.5°, anterior crossbite or edge-to-edge bite, concave profile tendency with profile angle (G'-Sn-Pog') >171°];[17,18] (3) symmetric face (absence of significant chin deviation, ≥3 mm); (4) refusal of orthognathic surgery. Conversely, the exclusion criteria included: (1) pre-existing signs and symptoms of the temporomandibular disorders (TMDs); (2) pre-existing TMJ pathology and asymmetry; (3) presence of the malocclusion traits which indicate extraction (e.g., severe crowding); (4) history of craniofacial or TMJ trauma; (5) presence of contraindications for MRI (e.g., fixed/implanted non-precious metal prostheses, claustrophobia). Furthermore, a few withdrawal criteria were listed: (1) lack of compliance with elastic use and (2) patient request to withdraw.

This study obtained ethical approval from the Khon Kaen University Ethics Committee for Human Research, in accordance with the Declaration of Helsinki and the ICH Good Clinical Practice Guidelines (reference number HE641561). All subjects endorsed the written informed consent prior to participating in the study.

Interventions

All subjects underwent non-extraction camouflage treatment using the pre-adjusted edgewise fixed orthodontic appliances, by using straight-wire technique combined with conventional Class III intermaxillary elastics. Twin polycrystalline ceramic brackets with MBT prescription and 0.022 × 0.028-inch slot (3M™ Clarity™ Advanced Ceramic Brackets, 3M Unitek™, Monrovia, CA) were employed in this study, aiming to reduce metal artifacts and prevent any interaction between the non-precious metal brackets and the magnetic field of MRI system.

Sequence of round and rectangular nickel-titanium (NiTi) archwires (0.014, 0.016, 0.016 × 0.022, 0.017 × 0.025, 0.019 × 0.025-inch NiTi) were used for leveling and aligning. Posterior bite ramps (Ultra band-lok®, Reliance Orthodontic Products, Itasca, IL) were bonded on the occlusal surface of either maxillary or mandibular molars during the initial stage of leveling and aligning, to open the bite while correcting anterior crossbite, as shown in Figure 1. Moreover, archwire expansion, incisor protrusion, interproximal reduction (IPR), or a combination of these approaches were carried out to unravel crowding in cases with mild to moderate crowding.

After leveling and aligning, the sagittal relationship of molars and canines was corrected mainly by applying bilateral Class III intermaxillary elastics (Bear, 1/4", 4.5 oz., Ormco®, Ormco Corporation, Brea, CA) between the maxillary second molars and the mandibular canines, on rectangular stainless-steel archwires (0.017 × 0.025 or 0.019 × 0.025-inch SS), as shown in Figure 2. Subjects were instructed to wear the elastics full time and change them every morning and night. In late stage of Class III correction, unilateral application of these elastics was employed in a few cases due to varying severity of Class III relationship and uneven rate of tooth movement between the left and right sides.

Skull-CBCT and TMJ-MRI were performed to investigate the positions of the condyles and articular discs of the TMJs before treatment (T0) as a baseline and after achieving normal occlusion (T1)-defined as the point at which negative overjet was corrected and Class I molar and canine relationships were established through the use of Class III intermaxillary elastics, using the same machine and imaging settings for all subjects. CBCT images were acquired using the WhiteFox® 3D CBCT system (WhiteFox®, Acteon group, Merignac, France) with the imaging protocol set at 100 kVp, 8 mA, a 0.3 mm^3 isotropic voxel size, and a cylindrical-shaped field of view (FOV) measuring 20 cm in diameter × 17 cm in height. The scan time was 30 seconds, with an effective radiation dose of 30.45 μSv. Based on the manufacturer's specifications, this configuration provides a spatial resolution of approximately 0.3 mm, which corresponds to the selected voxel size and is consistent across the specified FOV. The chosen FOV allows for full coverage of the region of interest while maintaining adequate spatial resolution for diagnostic purposes. During imaging process, subjects were stabilized in the natural head position, with the mouth closed while biting in the maximum intercuspal position (MIP) and lips being relaxed. For MR images, the proton density (PD)-weighted images were obtained from Achieva dStream 3.0T MR Systems (Philips®, Koninklijke Philips N.V., Amsterdam,

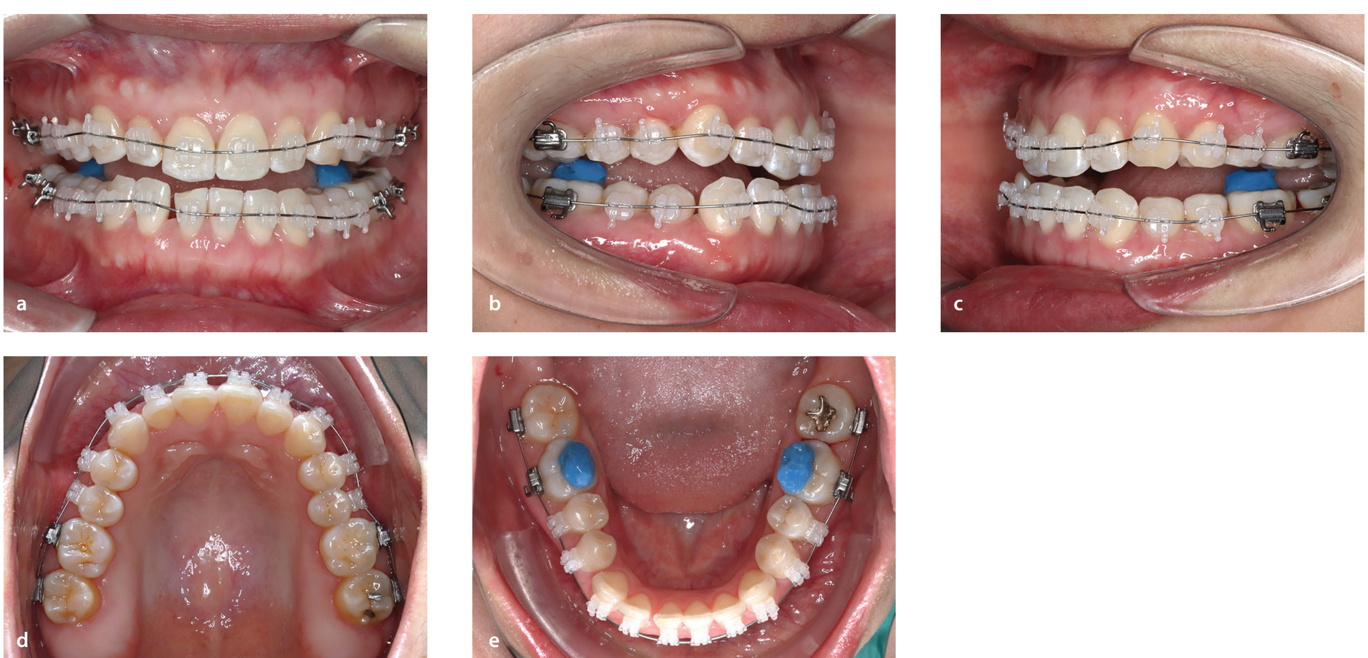

Figure 1. If possible, please explain the stages from a to e in the figures below the figures.

Netherlands) under the protocol of the PD-weighted spin-echo (SE) sequence, 2D acquisition (oblique-sagittal and coronal sections), TR 2200 ms, TE 30 ms, 2 excitations, 332 × 313 matrix size, 2.0 mm slice thickness with 0.2 mm inter-slice gap, 20 × 20 cm FOV, 90° flip angle, and 6 min. scan time. The MR images were taken in supine position while subjects biting in the maximum intercuspal position (MIP). All CBCT and MR images were exported and stored as Digital Imaging and Communications in Medicine format (DICOM) files.

Additionally, lateral cephalograms for each subject were generated from the CBCT volume using Dolphin® 3D imaging software (version 11; Dolphin Imaging and Management Solutions, Chatsworth, CA, USA), ensuring consistent resolution and image quality across all synthesized images. In addition to pre-treatment radiographic evaluation, overbite and overjet were measured intraorally using a calibrated periodontal probe with the patient in centric occlusion while centric occlusion–centric relation (CO-CR) discrepancy was assessed using the bimanual manipulation technique, followed by measurement of mandibular shift in the sagittal plane, to evaluate baseline characteristics of malocclusion.

Furthermore, history taking and clinical examination based on the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) examination form checklists were conducted every

Figure 2. Class III correction phase using class III intermaxillary elastics

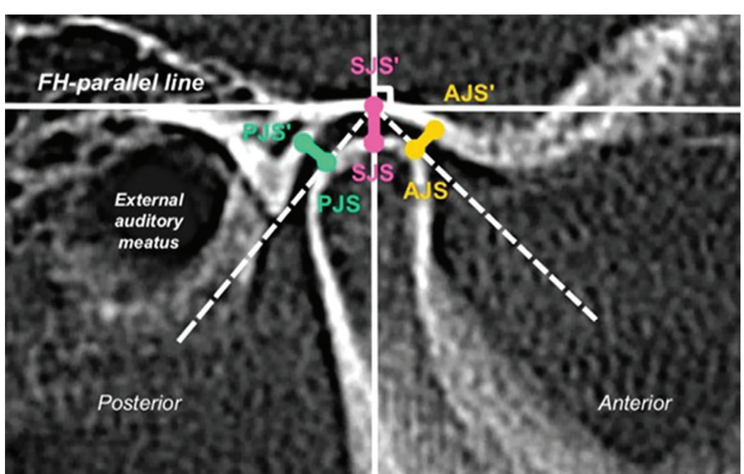

Figure 3. Joint space measurement on sagittal slices. Measurement method was as follows: 1) a vertical line perpendicular to the Frankfort horizontal (FH) plane was drawn through the most superior point of mandibular fossa, and the distance between the most superior point of mandibular fossa (SJS′) and condyle (SJS) was measured along this vertical line as superior joint space width (SJS-SJS′); 2) the anterior tangent line was drawn from the SJS′ point to the most anterior point (AJS) of condyle, and the distance between the most anterior point of mandibular fossa (AJS′) and condyle (AJS) was measured perpendicular to the anterior tangent line as anterior joint space width (AJS-AJS′); 3) the posterior tangent line was drawn from the SJS′ point to the most posterior point (PJS) of condyle, and the distance between the most posterior point of mandibular fossa (PJS′) and condyle (PJS) was measured perpendicular to the posterior tangent line as posterior joint space width (PJS-PJS′).

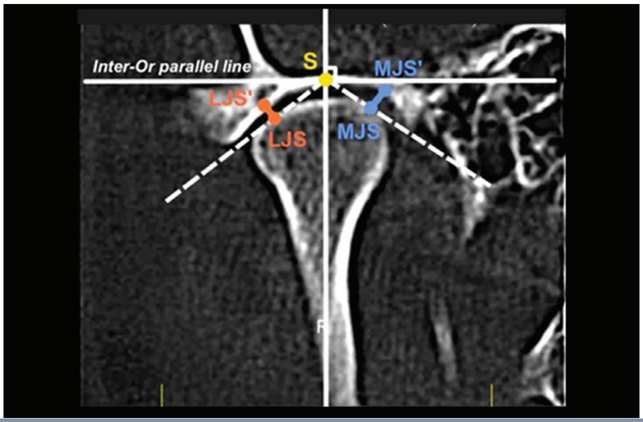

Figure 4. Joint space measurement on coronal slices. Measurement method was as follows: 1) a horizontal line parallel to the inter-orbitale (Or) line was drawn through the most superior point of mandibular fossa (S); 2) the medial tangent line was drawn from the S point to the most medial point (MJS) of condyle, and the distance between the most medial point of mandibular fossa (MJS') and condyle (MJS) was measured perpendicular to the medial tangent line as medial joint space width (MJS-MJS'); 3) the lateral tangent line was drawn from the S point to the most lateral point (LJS) of condyle, and the distance between the most lateral point of mandibular fossa (LJS') and condyle (LJS) was measured perpendicular to the lateral tangent line as lateral joint space width (LJS-LJS').

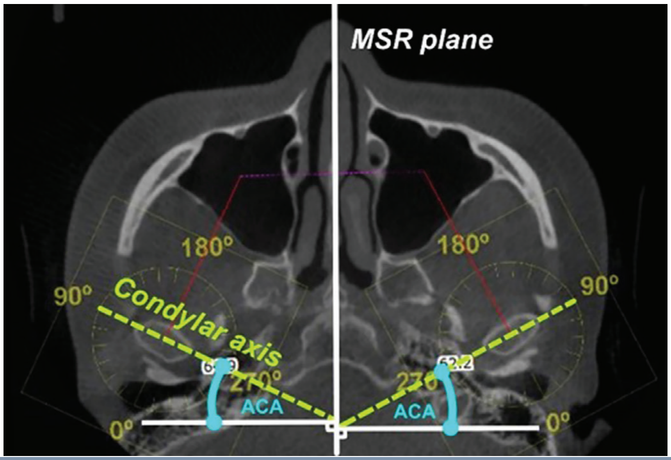

Figure 5. Axial condylar angle measurement on axial slices. Measurement method was as follows: 1) a horizontal line was drawn perpendicular to the mid-sagittal reference (MSR) plane, 2) the condylar axis line passing through lateral and medial poles of condyle was drawn, and 3) the angle formed between these two lines represents axial condylar angle (ACA).

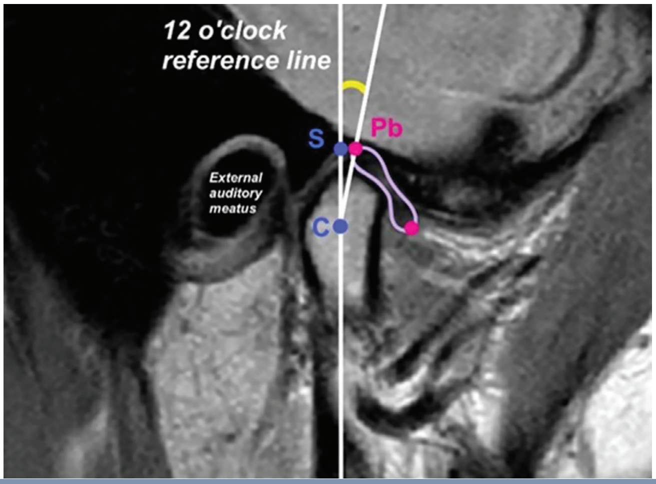

Figure 6. Measurement method for antero-posterior position of the articular disc was as follows: 1) a vertical line perpendicular to the Frankfort horizontal (FH) plane was drawn through center of the condylar head as the 12 o'clock reference line; 2) the tangent line was drawn from center of the condylar head, touching posterior border of the articular disc (Pb); 3) the angle formed between these two lines represents the antero-posterior position of the articular disc relative to the 12 o'clock reference line (SCPb).

three months throughout the period from T0 to T1, aiming to investigate signs and symptoms of TMDs during and after correcting Class III dental relationship with intermaxillary elastics.

Outcomes (Primary and Secondary Outcome Measures)

The primary outcomes were changes in the condyles and articular discs of the TMJs following camouflage treatment. These changes were comprehensively assessed from CBCT and MR images by using Dolphin® 3D imaging software (version 11; Dolphin Imaging and Management Solutions, Chatsworth, CA) and MicroDicom DICOM viewer software (version 2022.1; MicroDicom Ltd, Sofia, Bulgaria), respectively.

Position and rotation of the condyles were investigated from sagittal, coronal, and axial TMJ slices that were generated from CBCT images at T0 and T1. Measurements included anterior, posterior, superior, medial, and lateral joint space width (mm), as well as the axial condylar angle (deg), whose measuring methods were illustrated in Figures 3-5. Additionally, the joint space index (JSI) was calculated using anterior and posterior joint space width: JSI (%) = [(post - ant)/(post + ant)]*100. This calculation determined the condylar position relative to the mandibular fossa; positive JSI indicates an anterior-positioned condyle, while negative JSI indicates a posterior-positioned condyle.

For the articular discs, their position and length were measured from oblique-sagittal and coronal slices of the PD-weighted MR images at T0 and T1. The antero-posterior position of articular discs relative to the 12 o'clock reference line (deg) and their length (mm) were measured from oblique-sagittal slice, while their medio-lateral position was measured from coronal slices. The measuring methods for these measurements were illustrated in Figures 6-8. In addition, the presence or absence of signs and symptoms of TMDs throughout a period from T0 to T1 was reported as the descriptive data.

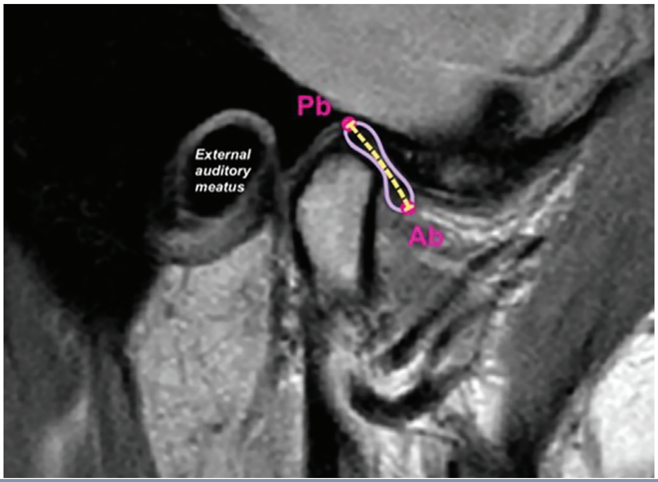

Figure 7. Measurement method for length of the articular disc. Articular disc length (Ab-Pb) was measured by a distance between anterior (Ab) and posterior (Pb) borders of the articular disc.

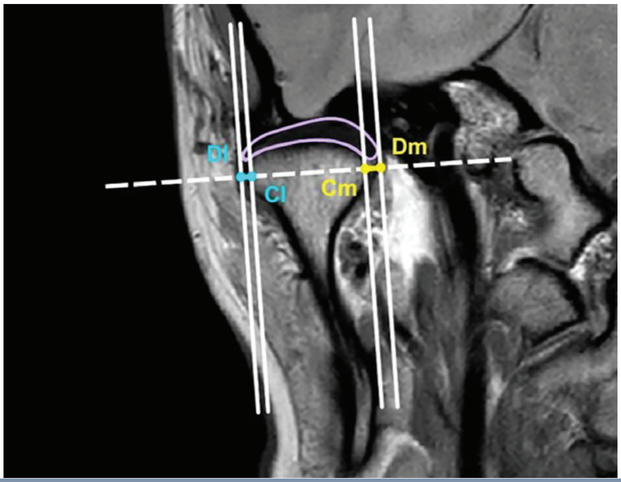

Figure 8. Measurement method for medio-lateral position of articular disc was as follows: 1) a horizontal line was drawn through medial (Cm) and lateral (Cl) poles of condyle; 2) four vertical lines perpendicular to this horizontal line were drawn through medial (Cm) and lateral (Cl) poles of condyle, as well as medial (Dm) and lateral (Dl) poles of the disc; 3) the distances between Dm-Cm and Dl-Cl were measured along this horizontal line, as medial (Dm-Cm) and lateral (Dl-Cl) extents of the articular disc.

The secondary outcomes encompassed dentoskeletal effects resulting from conventional Class III camouflage treatment, assessed from the lateral cephalogram which was generated from the skull-CBCT at T0 and T1. This aspect was measured as the lateral cephalometric measurements, including skeletal, dental, and soft tissue components. Skeletal measurements comprised SN-FH (deg), SNA (deg), CoA (mm), SNB (deg), CoGn (mm), SNPog (deg), ANB (deg), SN-MP (deg), and PP-MP (deg). Dental measurements contained U1-NA (deg), U1-NA (mm), L1-MP (deg), L1-NB (deg), L1-NB (mm), and SN-OP (deg). Soft tissue measurements included profile angle (G'-Sn-Pog') (deg), nasolabial angle (deg), upper lip to E-line (mm), and lower lip to E-line (mm).

All outcome variables in this study were assessed and analyzed by a single examiner. The examiner underwent training and standardization with both an oral and maxillofacial radiologist and a medical radiologist until achieving an intraclass correlation coefficient (ICC) greater than 0.8 for all variables, at which point the measurement process commenced.

Sample Size

The sample size was calculated based on joint space width changes, using data from a previous study by Guo (2020), which reported a mean difference of 0.67 mm and a pooled variance of 0.76 mm. To achieve 80% power at a 5% significance level, 7 patients (14 TMJs) were needed. Accounting for a 30% expected dropout rate, 10 patients were recruited.

Statistical Analysis

CBCT and MR images were anonymized before assessment, and the data analyst remained blinded during statistical analysis. The images of 30% of all subjects were randomly selected and measured repeatedly by the examiner three times with 14-day interval. The intra-examiner reliability was assessed using the ICC and the average values from the three measurements were used for statistical analysis.

Statistical analysis was conducted using IBM SPSS software (version 28.0; IBM Corp., Armonk, NY). Normal distribution was determined using the Shapiro-Wilk test. Comparisons between T0 and T1 data, regarding condylar position and rotation (i.e., joint space width, axial condylar angle), articular disc position and length, as well as lateral cephalometric measurements, were performed using either paired t-test or Wilcoxon signed-rank test, based on the normality. The significant level was set at p-value < 0.05.

RESULTS

Participant Flow (Including Exclusions after Randomization, and Recruitment and Follow-up Periods)

Subject recruitment took a full year in 2022 (January to December 2022). A total of 36 patients with skeletal Class III malocclusion were assessed for eligibility; 24 did not meet the inclusion criteria, and 2 declined to participate. Consequently, 10 patients (representing 20 TMJs) were successfully recruited at the beginning of the trial. Length of follow-up period varies for each subject, depending on the severity of the initial malocclusion and rate of tooth movement. However, one of the 10 subjects was excluded during treatment due to poor compliance with the use of Class III intermaxillary elastics, leaving a total of 9 patients (18 TMJs) for analysis.

Baseline Data

Demographic data for the entire subject group (n=9), including sex, age, elastics-application duration, and total treatment duration (T0 to T1), were presented in Table 1. An overview of the baseline characteristics of malocclusion was described in Table 2.

Numbers Analyzed (Including Number of Participants, Reliability, Each Primary and Secondary Outcome, and Power of Test)

One out of 10 patients (10%) was excluded during the treatment period because of poor compliance with Class III intermaxillary elastics use. The primary analyses were carried out on a per-protocol basis, involving all remaining subjects (n=9). Furthermore, excellent intra-examiner reliability was verified by ICC values ranging from 0.94 to 0.99. As primary outcomes, the differences of condylar position, condylar rotation, articular disc position, and articular disc length between T0 and T1 were individually analyzed.

Regarding condylar changes, displacement of the condyle was demonstrated by alterations in joint space width on both sagittal and coronal planes, while outward rotation of condyle was indicated by decreased axial condylar angle (Δ T0-T1 = R 0.32 ± 1.73°, L 0.32 ± 1.73°) on the axial planes. Condylar displacement occurred in posterior, superior, and lateral

Table 1. Demographic data

Variables	Mean	SD	Range
Sex, n=9			
Male, 1	11.11%		
Female, 8	88.89%		
Age (year)	24	6.59	18-36
Elastics application duration (month)	4.57	1.64	2-7
Total treatment duration, T0 to T1 (month)	12.44	1.74	10-15

SD: Standard deviation

Table 2. Baseline characteristics of malocclusion

Variables	Mean	SD	Range
Overjet (mm)	(-) 2.28	0.57	(-) 1.5 - (-) 3
Overbite (mm)	3.5	1.87	1 - 5.5
CO-CR discrepancy (mm)	1.72	0.78	0 - 2.5
ANB (°)	(-) 2.96	1.55	(-) 1.5 - (-) 6.6
Profile angle (°)	180.08	2.48	176.8 - 183.2

SD: Standard deviation

directions, as evidenced by decreased posterior joint space width (Δ T0-T1 = R 0.08 ± 0.31 mm, L 0.10 ± 0.24 mm), increased anterior joint space width (Δ T0-T1 = R (-) 0.06 ± 0.16 mm, L (-) 0.02 ± 0.24 mm), decreased superior joint space width (Δ T0-T1 = R 0.03 ± 0.20 mm, L 0.04 ± 0.27 mm), decreased lateral joint space width (Δ T0-T1 = R 0.08 ± 0.21 mm, L 0.11 ± 0.15 mm), and increased medial joint space width (Δ T0-T1 = R (-) 0.06 ± 0.45 mm, L (-) 0.03 ± 0.24 mm). Moreover, the decrease in JSI reinforces the posterior displacement of the condyle. This JSI value was also observed to decrease towards zero, reflecting that the condyle moved towards the center of the mandibular fossa. The same direction of displacement and rotation of the condyle was noted in both left and right condyles, with similar magnitude. Nonetheless, the amount of condylar displacement in all three planes was considered statistically insignificant, as shown in Table 3.

In addition to the condylar changes, there were also minor alterations in both position and length of the TMJ articular disc. On the oblique-sagittal plane, anterior displacement of the articular disc was indicated by an increase of S-Pb (Δ T0-T1 = R (-) 0.91 ± 1.61°, L (-) 0.81 ± 1.78°), while a slight decrease of the articular disc length was also observed (Δ T0-T1 = R 0.07 ± 0.37 mm, L 0.06 ± 0.16 mm). On the coronal plane, minimal medial displacement of the articular disc was demonstrated through increased Dm-Cm (Δ T0-T1 = R 0.15 ± 0.39 mm, L 0.04 ± 0.52 mm) and decreased Dl-Cl (Δ T0-T1 = R 0.11 ± 0.34 mm, L 0.05 ± 0.19 mm). Similarly to the condylar changes, none of the articular disc changes were statistically significant, as shown in Table 4.

Since the main results (condylar and articular disc changes) did not show significant findings in our group of subjects, a post-hoc power analysis was conducted to evaluate the adequacy of the sample size and statistical power for the measurements. The analysis revealed acceptable power levels for condylar measurements (ranging from 0.84 to 0.98) and articular disc measurements (ranging from 0.78 to 0.93).

For secondary outcomes, the dentoskeletal changes resulting from this camouflage treatment were individually analyzed as three main parts: skeletal, dental, and soft tissue. The significant changes were indicated in all three parts, as described by the lateral cephalometric measurements at T0 and T1 in Table 5.

Skeletal measurements demonstrated no significant changes in the anterior cranial base and maxilla (as indicated by stable SN-FH and SNA). However, significant changes in mandibular position resulting from clockwise rotation were observed (as indicated by decreased SNB and SNPog, as well as increased

Table 3. Changes in condylar position and rotation (Mean ± SD)

Variables	Pre-treatment (T0)		Post-treatment (T1)		Differences (ΔT0-T1)[b]		p-value	
	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.
Sagittal dimension								
AJS-AJS' (mm)	1.54±0.45	1.40±0.41	1.61±0.48	1.42±0.47	(-) 0.06±0.16	(-) 0.02±0.24	0.282	0.820
SJS-SJS' (mm)	2.29±0.79	2.35±0.59	2.25±0.79	2.31±0.76	0.03±0.20	0.04±0.27	0.637	0.691
PJS-PJS' (mm)	1.67±0.27	1.70±0.30	1.59±0.25	1.61±0.37	0.08±0.31	0.10±0.24	0.467	0.255
JSI[a]	4.97%	10.60%	0.61%	7.11%	4.37%	3.49%	-	-
Coronal dimension								
MJS-MJS' (mm)	2.46±1.01	2.49±0.74	2.52±0.81	2.52±0.79	(-) 0.06±0.45	(-) 0.03±0.24	0.684	0.996
LJS-LJS' (mm)	1.76±0.33	1.80±0.38	1.67±0.35	1.68±0.46	0.08±0.21	0.11±0.15	0.287	0.275
Axial dimension								
ACA (°)	17.17±7.78	17.01±6.65	16.86±7.19	15.70±6.04	0.32±1.73	1.31±2.61	0.600	0.172

[a]JSI percentage was reported as the average values (mean)
[b]Value indicating increase, + value indicating decrease
SD: Standard deviation

Table 4. Changes in articular disc position and length (Mean ± SD)

Variables	Pre-treatment (T0)		Post-treatment (T1)		Differences (ΔT0-T1)[b]		p-value	
	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.
Sagittal dimension								
SCPb (°)	11.09±4.17	11.82±8.19	12.01±4.33	12.63±8.37	(-) 0.91±1.61	(-) 0.81±1.77	0.128	0.210
Ab-Pb (mm)	10.78±1.37	10.27±1.37	10.71±1.41	10.21±1.45	0.07±0.37	0.06±0.16	0.579	0.281
Coronal dimension								
Dm-Cm (mm)	3.26±1.15	2.86±0.78	3.40±1.34	2.91±0.82	(-) 0.15±0.38	(-) 0.04±0.52	0.288	0.804
Dl-Cl (mm)	2.13±0.59	1.93±0.44	2.02±0.40	1.88±0.43	0.11±0.34	0.05±0.18	0.352	0.428

[b]Value indicating increase, + value indicating decrease
SD: Standard deviation

Table 5. Comparison of lateral cephalometric measurements between T0 and T1 (Mean ± SD)

Variables	Pre-treatment (T0)	Post-treatment (T1)	Differences (ΔT0-T1)	p-value
Skeletal measurements				
SN-FH (°)	6.80±1.62	6.80±1.62	0.00	N/A[a]
SNA (°)	83.38±2.69	83.42±2.65	(-) 0.04±0.15	0.403
SNB (°)	86.33±2.79	84.06±2.69	2.28±0.53	<0.001*
SNPog (mm)	86.13±2.21	83.82±2.09	2.31±0.55	<0.001*
ANB (°)	(-) 2.96±1.55	(-) 0.63±1.41	(-) 2.32±0.51	<0.001*
SN-PP (°)	6.39±3.33	6.42±3.25	(-) 0.03±0.13	0.471
SN-MP (°)	26.20±4.95	28.81±5.24	(-) 2.61±1.05	<0.001*
PP-MP (°)	20.20±4.88	22.74±4.89	(-) 2.54±1.24	<0.001*
Dental measurements				
U1-NA (°)	25.74±5.42	29.42±2.63	(-) 3.68±4.96	0.057
U1-NA (mm)	6.46±1.94	7.29±1.44	(-) 0.83±0.87	0.021*
L1-MP (°)	84.90±5.67	82.01±5.32	2.89±1.88	0.002*
L1-NB (°)	21.50±4.38	19.14±4.70	2.36±2.88	0.04*
L1-NB (mm)	5.47±1.26	4.29±1.64	1.18±0.92	0.005*
SN-OP (°)	11.61±4.95	13.19±5.71	(-) 1.58±1.83	0.033*
Soft tissue measurements				
Profile angle (°)	180.08±2.48	174.68±2.87	5.40±1.07	<0.001*
Nasolabial angle (°)	91.84±11.19	95.86±9.96	(-) 4.02±2.44	0.001*
U lip to E-line (mm)	(-) 2.73±2.09	(-) 2.13±1.68	(-) 0.60±0.73	0.039*
L lip to E-line (mm)	2.53±2.06	1.80±1.63	0.73±0.58	0.005*

[a]The correlation and T cannot be computed because the standard error of the difference is 0.
*Statistically significant (p-value <0.05)
SD: Standard deviation

SN-MP), leading to significant alterations in the maxillo-mandibular relationship in both antero-posterior and vertical dimensions (as indicated by increased ANB and PP-MP).

Dental measurements demonstrated significant forward movement of the upper incisor (as indicated by increased U1-NA) along with significant backward movement of the lower incisor as indicated by decreased L1-MP and L1-NB), leading to the attainment of a normal overjet (OJ) following treatment. Also, significant clockwise rotation of the occlusal plane was noticed.

In the soft tissue aspect, the measurements demonstrated significantly enhanced facial profile concavity (as indicated by decreased profile angle), improved upper lip retrusion (as indicated by increased upper lip to E-line distance), and reduced lower lip protrusion (as indicated by decreased lower lip to E-line distance).

The follow-up period for the nine patients ranged from 10 to 15 months, corresponding to the duration of treatment needed to achieve normal occlusion using Class III intermaxillary elastics. The results from the DC/TMD examination, conducted at 3-month intervals during and after correcting Class III with intermaxillary elastics (from T0 to T1), revealed that no signs or symptoms of TMDs were reported by any subjects, except for one individual (a 20-year-old female) reported painless unilateral TMJ clicking that began approximately two months after discontinuing elastic use and resolved spontaneously within about 14 days. This presentation was consistent with asymptomatic TMJ clicking commonly observed in the general population. Therefore, no active intervention or modifications to her treatment protocol were made.

No significant adverse events were observed apart from the general adverse effects commonly associated with full-fixed orthodontic appliances. These include pain, difficulty in eating, mucosal irritation from the appliances, and gingivitis associated with plaque accumulation.

DISCUSSION

As mentioned in the introduction, recent FEA studies have revealed potential stress transmission from the intermaxillary elastics to the condyle and articular disc of TMJs, challenging the long-held understanding that these elastics only induce changes at the dentoalveolar level in non-growing patients.[11–13] Nonetheless, studies investigating TMJ changes following these elastics use in clinical settings remain limited. To the best of our knowledge, only one study by Guo Y et al.[19] (2020) has previously evaluated the condylar changes after Class III camouflage treatment, using the multiloop edgewise archwire

(MEAW) technique with short Class III intermaxillary elastics. However, this technique has not been generally adopted due to its time-consuming nature for the operator and higher discomfort for the patient.[20] This clinical trial is the first study to comprehensively investigate TMJ changes in non-growing patients undergoing conventional Class III camouflage treatment using the widely-used straight-wire technique with Class III intermaxillary elastics. A combination of CBCT and MRI were utilized to evaluate changes in both the condyle and articular disc. Regarding the MRI sequence used in this study, proton density-weighted imaging (PDWI) was selected due to its superior signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), and signal intensity ratio (SIR), all of which are critical for the clear visualization of the temporomandibular joint (TMJ) disc. These image quality parameters are especially important when assessing subtle changes in disc morphology and position.[21]

According to the results of this study, condylar displacement occurred in the posterior, superior, and lateral directions following treatment, as evidenced by changes in joint spaces. These findings coincide with those of Guo et al.[19] regarding the direction of condylar displacement after treatment, although our study observed a smaller magnitude of displacement. Furthermore, a recent FEA study by Gurbanov et al.[11] also demonstrated greater tensile stress on the anterior and anterosuperior regions, with greater compressive stress on the posterosuperior and posterior regions of the condyle due to the application of Class III intermaxillary elastics. This corresponds with the posterior and superior displacement observed in our study. Another FEA study by Zhang et al.[12] also indicated greater compressive stress on the posterosuperior surface of the condyle produced by both Class III and short Class III intermaxillary elastics. As demonstrated by our findings and those of previous studies, the direction of condylar displacement and the stress distribution pattern on the condyle clearly correlate with the force vectors of Class III intermaxillary elastics. These elastics, drawn from the mandibular canines to the maxillary second molars, generate both upward and backward traction forces at the mandibular canines, thus affecting the mandible and condyle. This posterior displacement of the condyle is advantageous in skeletal Class III patients since their condyles are likely to be positioned anteriorly in the glenoid fossa.[22] Consistent with the change of the JSI noticed in this study, which decreased towards zero after treatment, it re-emphasizes both posterior displacement and concentric movement of the condyle.

Several studies regarding the orthopedic treatment in growing patients and animal studies conducted in growing samples have indicated that changes in mandibular position following the application of external force are primarily associated with the remodeling of the condyle and mandible.[23-26] Despite the cessation of skeletal growth in non-growing patients, the remodeling of the condyle should not be overlooked as the forces transmitted to the TMJs could affect their inner structures, potentially leading to adaptive remodeling that may accrue in the condylar position.

With respect to the articular disc, only the negligible changes were observed regardless of FEA studies of Gurbanov et al.[11] and Zhang et al.[12] indicating the potentially transmitted compressive stress from Class III intermaxillary elastics toward the articular disc. Moreover, findings from Zhang's study which demonstrated greater compressive stress on the intermediate zone during elastics application are seemingly consistent with the superior displacement of the condyle shown in our study. However, a small anterior displacement of the articular disc may be related to the posterior displacement of the condyle, which could either induce actual anterior displacement of the disc or alter the position of the reference point for measurement located on the condyle. Likewise, medial displacement of the articular disc is possibly associated with lateral displacement of the condyle. Despite the small sample size, the post-hoc power analysis demonstrated acceptable power levels for the measurements, suggesting that the study's methodology was sufficient to evaluate the measurements.

Regarding the effects of intermaxillary elastics treatment on TMDs, the stress transmitted to the TMJs in this study does not appear to have any effect that predispose to any TMD sign or symptom, in spite of the presence of small changes in the TMJ disc-condyle complex and a recent three-dimensional finite element study observed that the elastic forces increase the stress on the TMJ, especially for Class III patients.[11] A potential rationale for this observation may be that these changes have not yet exceeded the individual adaptability and physiological tolerance threshold, as described by Michelotte et al.[27]

In terms of dentoskeletal changes, clockwise rotation of the mandible and dental compensation, specifically upper incisor proclination accompanied by lower incisor retroclination, play a crucial role in enhancing skeletal and soft tissue relationships as well as achieving normal occlusion following camouflage treatment. Additionally, clockwise rotation of the mandible is influenced by the extrusive force by intermaxillary elastics applied to the upper molars, as described in a study by Tseng, Chang, and Roberts[28] (2016). This study detailed the side effects of Class III intermaxillary elastics, including labial tipping of the upper incisors, distal tipping of the lower teeth, and extrusion of the upper molars, all of which are advantageous for patients with Class III malocclusion and deep overbite, as they could correct sagittal relationship and deep overbite simultaneously. Consequently, Class III intermaxillary elastics are particularly suitable for our samples. These data indicate that both skeletal and dental changes primarily stem from the dentoalveolar effect of Class III intermaxillary elastics. As a result of these changes, the soft tissue profile improvement was achieved as anticipated.

Study Limitations

A significant limitation of this study was the lack of an untreated sample of non-growing individuals with mild-to-moderate Class III malocclusion to serve as a control group. However, exposing an untreated group to unnecessary CBCT radiation and withholding needed treatment for a year would have raised ethical concerns. Additionally, since the intervention required patient compliance with elastics, unpredictable compliance may have introduced bias.

The generalizability of this study is supported by using specific inclusion criteria for young adults with skeletal Class III malocclusion, ensuring that the findings are applicable to non-growing patients within this group.

CONCLUSION

Conventional Class III camouflage treatment with intermaxillary elastics significantly improves the dentoskeletal relationship and shows no significant adverse effects on the condyles and articular discs of the TMJs.

Ethics

Ethics Committee Approval: This study obtained ethical approval from the Khon Kaen University Ethics Committee for Human Research, in accordance with the Declaration of Helsinki and the ICH Good Clinical Practice Guidelines (reference number: HE641561, date: 23.01.2022).

Informed Consent: All subjects endorsed the written informed consent prior to participating in the study.

Footnotes

Author Contributions: Surgical and Medical Practices - P.P., T.P.J., W.P., R.C., P.S.; Concept - P.P., T.P.J., P.S.; Design - P.P., T.P.J., W.P., R.C., P.S.; Data Collection and/or Processing - P.P., P.S.; Analysis and/or Interpretation - P.P., W.P., R.C., P.S.; Literature Search - P.P., P.S.; Writing - P.P., T.P.J., W.P., R.C., P.S.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: This study was funded by Khon Kaen University, Thailand, through internal research grants. There are no financial conflicts of interest to declare, and no commercial entities were involved in the funding or conduct of this research.

REFERENCES

1. Hardy DK, Cubas YP, Orellana MF. Prevalence of angle class III malocclusion: a systematic review and meta-analysis. *Open J Epidemiol*. 2012;2(4):75-82. [CrossRef]
2. Kolokitha O-E, Georgiadis T. Differential diagnosis of skeletal Class III. *Balk J Dent Med*. 2019;23(3):55-62. [CrossRef]
3. Sakoda KL, Pinzan A, Cury SEN, Bellini-Pereira S, Castillo AA-D, Janson G. Class III malocclusion camouflage treatment in adults: a systematic review. *J Dent Open Access*. 2019;1(1):1-12. [CrossRef]
4. He S, Gao J, Wamalwa P, Wang Y, Zou S, Chen S. Camouflage treatment of skeletal Class III malocclusion with multiloop edgewise arch wire and modified Class III elastics by maxillary mini-implant anchorage. *Angle Orthod*. 2013;83(4):630-640. [CrossRef]
5. Færøvig E, Zachrisson BU. Effects of mandibular incisor extraction on anterior occlusion in adults with Class III malocclusion and reduced overbite. *Am J Orthod Dentofac Orthop*. 1999;115(2):113-124. [CrossRef]
6. Ning F, Duan Y. Camouflage treatment in adult skeletal Class III cases by extraction of two lower premolars. *Korean J Orthod*. 2010;40(5):349-357. [CrossRef]
7. Nakamura M, Kawanabe N, Kataoka T, Murakami T, Yamashiro T, Kamioka H. Comparative evaluation of treatment outcomes between temporary anchorage devices and Class III elastics in Class III malocclusions. *Am J Orthod Dentofac Orthop*. 2017;151(6):1116-1124. [CrossRef]
8. Yu J, Park JH, Bayome M, et al. Treatment effects of mandibular total arch distalization using a ramal plate. *Korean J Orthod*. 2016;46(4):212. [CrossRef]
9. Jayachandran S, Wiltshire WA, Hayasaki SM, Pinheiro FHSL. Comparison of AdvanSync and intermaxillary elastics in the correction of Class II malocclusions: A retrospective clinical study. *Am J Orthod Dentofac Orthop*. 2016;150(6):979-988. [CrossRef]
10. Mazzini WU, Torres FM. Orthodontic camouflage: a treatment option - a clinical case report. *Contemp Clin Dent*. 2017;8(4):658-661. [CrossRef]
11. Gurbanov V, Bas B, Öz AA. Evaluation of stresses on temporomandibular joint in the use of Class II and III orthodontic elastics: a three-dimensional finite element study. *J Oral Maxillofac Surg*. 2020;78(5):705-716. [CrossRef]
12. Zhang Y, Keilig L, Dörsam I, Bourauel C. Numerical investigation of the biomechanical effects of orthodontic intermaxillary elastics on the temporomandibular joint. *J Mech Behav Biomed Mater*. 2023;141(December 2022). [CrossRef]
13. Uzunçıbuk H, Marrapodi MM, Meto A, Ronsivalle V, Cicciù M, Minervini G. Prevalence of temporomandibular disorders in clear aligner patients using orthodontic intermaxillary elastics assessed with diagnostic criteria for temporomandibular disorders (DC/TMD) axis II evaluation: A cross-sectional study. *J Oral Rehabil*. 2024;51(3):500-509. [CrossRef]
14. Sambataro S, Bocchieri S, Bafumi L, Fiorillo L, Cervino G, Cicciù M. Elastics selector gauge as orthodontics device applied to inter-maxillary traction during malocclusion correction. *J Funct Morphol Kinesiol*. 2019;4(3). [CrossRef]
15. Tanaka E, Detamore MS, Mercuri LG. Degenerative disorders of the temporomandibular joint: etiology, diagnosis, and treatment. *J Dent Res*. 2008;87(4):296-307. [CrossRef]
16. Baccetti T, Franchi L, McNamara Jr JA. The cervical vertebral maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. In: *Seminars in Orthodontics*. Vol 11. Elsevier; 2005:119-129. [CrossRef]
17. Suchato W CJ. Cephalometric evaluation of the dentofacial complex of Thai adults. *J Dent Assoc Thai*. 1984;34(5):233-243. [CrossRef]
18. Sutthiprapaporn P Manosudprasit A, Manosudprasit M, Pisek P, Phaoseree N, Manosudprasit A. Establishing esthetic lateral cephalometric values for Thai adults after orthodontic treatment. *Khon Kaen Dent J*. 2020;23(2):31-41. [CrossRef]
19. Guo Y, Qiao X, Yao S, Li T, Jiang N, Peng C. CBCT analysis of changes in dental occlusion and temporomandibular joints before and after MEAW orthotherapy in patients with nonlow angle of skeletal Class III. *Biomed Res Int*. 2020;2020. [CrossRef]
20. Hisano M, Chung C ryung J, Soma K. Nonsurgical correction of skeletal Class III malocclusion with lateral shift in an adult. *Am J Orthod Dentofac Orthop*. 2007;131(6):797-804. [CrossRef]
21. Dong M, Sun Q, Yu Q, Tao X, Yang C, Qiu W. Determining the optimal magnetic resonance imaging sequences for the efficient diagnosis of temporomandibular joint disorders. *Quant Imaging Med Surg*. 2021;11(4):1343. [CrossRef]

22. Seren E, Akan H, Toller MO, Akyar S. An evaluation of the condylar position of the temporomandibular joint by computerized tomography in Class III malocclusions: A preliminary study. *Am J Orthod Dentofac Orthop*. 1994;105(5):483-488. [CrossRef]
23. De Clerck H, Nguyen T, De Paula LK, Cevidanes L. Three-dimensional assessment of mandibular and glenoid fossa changes after bone-anchored Class III intermaxillary traction. *Am J Orthod Dentofac Orthop*. 2012;142(1):25-31. [CrossRef]
24. Gökalp H, Kurt G. Magnetic resonance imaging of the condylar growth pattern and disk position after chin cup therapy: A preliminary study. *Angle Orthod*. 2005;75(4):568-575. [CrossRef]
25. Kurt H, Alioğlu C, Karayazgan B, Tuncer N, Kılıçoğlu H. The effects of two methods of Class III malocclusion treatment on temporomandibular disorders. *Eur J Orthod*. 2011;33(6):636-641. [CrossRef]
26. Xu Y, Wu T, Chen Y, Zhang Z. Regulation of the response of the adult rat condyle to intermaxillary asymmetric force by the rankl-opg system. *Angle Orthod*. 2009;79(4):646-651. [CrossRef]
27. Michelotti A, Rongo R, D'Antò V, Bucci R. Occlusion, orthodontics, and temporomandibular disorders: Cutting edge of the current evidence. *J World Fed Orthod*. 2020;9(3):S15-S18. [CrossRef]
28. Tseng LLY, Chang CH, Roberts WE. Diagnosis and conservative treatment of skeletal Class III malocclusion with anterior crossbite and asymmetric maxillary crowding. *Am J Orthod Dentofac Orthop*. 2016;149(4):555-566. [CrossRef]