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ORIGINAL RESEARCH

Comparative effects of clear aligner mandibular advancement and twin block appliances in Class II malocclusion

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Abstract

Background: This study compared the effects of clear aligner Mandibular Advancement (MA) and Twin Block (TB) appliances on Class II malocclusion in adolescents. **Methods**: A retrospective analysis was conducted on 47 patients divided into three groups: 19 (11 females, 8 males; 11.19 $\pm$ 1.31 years) underwent MA treatment, 15 (6 females, 9 males; 11.86 $\pm$ 1.92 years) received TB therapy and 13 (7 females, 6 males; 11.62 $\pm$ 1.85 years) served as controls. Cephalometric analyses assessed skeletal, dental and soft tissue changes before and after treatment. Statistical methods included normality tests, intra- and inter-group comparisons (*t*-tests, Wilcoxon signed-rank tests, Analysis of Variance (ANOVA), Kruskal-Wallis H tests), with significance set at $p < 0.05$. **Results**: Results revealed intra-group variations in mandibular and intermaxillary relationships across all groups. The Wits appraisal showed significant differences between the TB and control groups, while the TB group exhibited increased lower anterior facial height. Intra- and inter-group differences were observed in upper incisor inclination, lower incisor proclination, overjet, and overbite. Soft tissue changes included upper lip retraction in the TB group and forward pogonion shift in the MA group. **Conclusions**: MA improved soft tissue chin thickness and better controlled lower facial height, making it preferable for enhancing chin profiles. Conversely, TB enhanced upper lip position and facial convexity, making it more suitable for improving upper lip aesthetics. Clinicians should consider these distinct advantages when selecting an appliance for growing Class II malocclusion patients. **Clinical Trial Registration**: Registered at ClinicalTrials.gov: NCT06609733.

Keywords

Mandibular advancement; Clear aligner; Twin-block; Soft tissues; Class II malocclusion

1. Introduction

Class II malocclusion is commonly associated with mandibular retrusion, maxillary protrusion or both, affecting approximately 20–30% of children and adolescents globally [1–4]. Early intervention during the pubertal growth spurt is crucial for attaining the optimal treatment outcomes [5].

Functional appliances such as the Twin Block (TB) [6] are generally employed to correct the Class II malocclusion by advancing the mandible. TB possesses two separate acrylic plates (Fig. 1A) with angled surfaces to guide the mandible forward [7]. It can usually be removed and is fitted on maxilla and mandible [8]. However, it is criticized by the patients for being inconvenient, unattractive and uncomfortable [9, 10]. Clear aligners with mandibular advancement (MA) features have become important because of their aesthetic appeal and improved patient convenience [11]. These aligners (Align Technology Inc, San Jose, CA, USA) are a less visible alternative for correcting mandibular retrusion in adolescents through precision wings (Fig. 1B) [12].

Recent studies have shown that both MA and TB improve overjet and overbite [13, 14], achieving similar mandibular advancement and vertical facial height control, though TB yields greater chin advancement in soft tissues [15]. Most prior studies focused on dentoalveolar and skeletal effects, with limited attention to soft tissue changes and lacking untreated control groups [13, 15, 16].

This study was aimed to compare the maxillofacial morphological changes in hard and soft tissues resulting from MA and TB treatments. The outcomes were evaluated in relation to the growth-related changes in untreated control group with normal occlusion. The null hypothesis stated that MA would achieve comparable therapeutic effects to TB in treating Class II malocclusion.

2. Materials and methods

FIGURE 1. Intraoral views of twin-block (TB) appliance (A) and clear aligners with mandibular advancement (MA) (B) lateral and frontal perspectives.

2.1 Inclusion and exclusion criteria

Patients in the MA and TB groups had following inclusion criteria: cervical vertebral maturation stage (CS) between CS3 and CS4, bilateral Class II canine and molar relationship, and A point–nasion–B point (ANB) angle >4°. The control group was between CS3 and CS4 with ANB° of 2° to 4°. Exclusion criteria for all the groups were: prior orthodontic treatment, dental anomalies, poor oral hygiene, systemic diseases or congenital deformities, and trauma history.

2.2 Sample size calculation

Power analysis indicated 13 subjects per group for 0.90 power ($\alpha = 0.05$) [17]. The study thus included 19 MA (11 Females, 8 Males; 11.19 ± 1.31 years), 15 TB (6 Females, 9 Males; 11.86 ± 1.92 years) and 13 controls (7 Females, 6 Males; 11.62 ± 1.85 years). The chronological ages of participants had variations. Each sample group was matched for comparable growth phases by assessing the cervical vertebral maturation (CVM) stages.

2.3 Patient recruitment

Patients were recruited from the West China Hospital of Stomatology, Chengdu, China. The sample enrolment and the study duration were from January 2016 to December 2021. The treatment durations on average were 13 months for the MA group, and 10 months for TB group. The control group was observed for 12 months.

2.4 Treatment protocols

MA Group:

It was treated with clear aligners having precision wings between the premolars and first molars to hold the mandible forward. Sagittal activation was carried out with 2 mm advancements every 8 weeks which depended on the patients' progress. Aligners were worn for 22 hours/day and replaced weekly.

TB Group:

Occlusion records were taken for the incisors in edge-to-edge position if the overjet was 7–8 mm. A two-step activation was used if the overjet exceeded 8 mm where the second activation was made after 3–4 months. The vertical activation was set for 5–7 mm of vertical opening in the posterior bite blocks. Adjustment was made by the selective acrylic removal to guide the posterior teeth eruption. Selective grinding began around third month to reduce 1 mm from the occlusal surfaces or as needed.

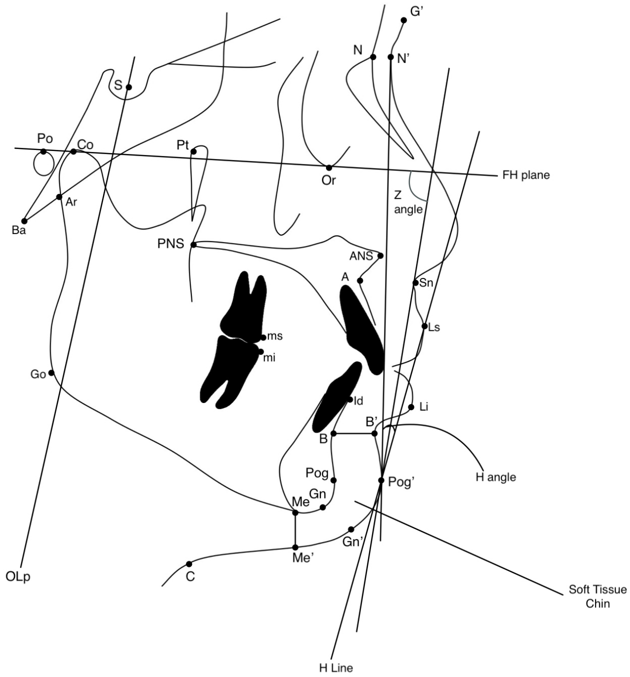
Both MA and TB patients wore respective appliances for 22 hours/day (except during meals/sports). The follow-up progress was monitored for 6 weeks.

Control Group:

It had Class I malocclusion patients to meet the ethical guidelines and serve as a baseline for assessing normal growth and development patterns.

2.5 Cephalometric analysis

The pre-treatment (T_0) and post-treatment (T_1) lateral cephalograms were obtained by the Veraviewepocs 2D system (X550, Morita, Kyoto, Japan). The images were traced and analyzed by Dolphin Imaging software version 11.90 (Dolphin Imaging and Management Solutions, Chatsworth, CA, USA) where 13 angular and 27 linear measurements (Fig. 2, Table 1) were analyzed. The soft tissue area was quantified by ImageJ 2.0.0.



F I G U R E 2. Landmarks, reference planes and cephalometric measurements applied in this study.

T A B L E 1. Landmarks, reference planes and cephalometric measurements applied in this study.

Measurement (s)	Definition
SNA (°)	The angle formed by the SN and NA lines
Maxillary Base Position (mm)	Distance between the landmarks of occlusal line perpendicular (OLp) and A point
SNB (°)	The angle formed by the SN and NB lines
Length of Mand Base (Go-Pog) (mm)	Distance between the landmarks of Go and Pog
Go-Gn (mm)	Distance between the landmarks of Go and Gn
Chin Angle (Id-Pog-MP) (°)	Angle formed by connecting infradentale, pogonion and mandibular plane
Condylar Head Position (mm) (OLp-Co)	Distance between the landmarks of OLp and Co
Ramus Height (Ar-Go) (mm)	Distance from the articulare and gonion
Y-Axis Length (mm)	Line joining the sella turcica centre (S) and gnathion which subtends measurable angle with FH
ANB (°)	The angle formed by the AN and NB lines
Wits Appraisal (mm)	Difference in the distance between vertical lines from A-point and B-point to the functional occlusal plane
Convexity (A-NPog) (mm)	Angle formed by nasion, A point and pogonion
Facial Plane to SN (SN-Npog) (°)	Angle between the anterior cranial base and the most anterior point of bony chin
MP-SN (°)	Angle between the anterior cranial base and mandibular plane
Lower Face Height (ANS-Gn) (mm)	Distance from ANS to Gn on lateral cephalogram
Anterior Face Height (NaMe) (mm)	Distance from anterior nasal spine to menton
Lower Anterior Facial Height ratio (ANS-Me/N-Me) (%)	Ratio of lower and total anterior face heights
Posterior Face Height (SGo) (mm)	Distance between the landmarks S and Go
P-A Face Height (S-Go/N-Me) (%)	Ratio of lower and total posterior face heights
U-Incisor Protrusion (U1-A-Pog) (mm)	Distance from the incisal edge of upper central incisor to A-Pog line
U-Incisor Inclination (U1-A-Pog) (°)	Angle formed between the long axis of upper central incisor and A-Pog line

TABLE 1. Continued.

Measurement (s)	Definition
L1 Protrusion (L1-A-Pog) (mm)	Distance from the incisal edge of lower central incisor to A-Pog line
L1 to A-Pog (°)	Angle formed between the long axis of lower central incisor and A-Pog line
Interincisal Angle (U1-L1) (°)	Angle formed by the upper and lower incisors
Overjet (mm)	The horizontal distance between incisal edges of maxillary and mandibular central incisor
Overbite (mm)	The vertical distance between incisal edges of maxillary and mandibular central incisors
Maxillary Molar Position (mm)	Distance between the landmarks of OLp and ms
Mandibular Molar Position (mm)	Distance between the landmarks of OLp and mi
Molar Relation: ms/OLp–mi/OLp (mm)	Difference between the distance from point ms to OLp and point mi to OLp
Lower Lip to E-Plane (mm)	Distance from the lower lip to esthetic line
Upper Lip to E-Plane (mm)	Distance from the upper lip to esthetic line
B-B' (mm)	Distance between the landmarks of B and B'
Pog-Pog' (mm)	Distance between the landmarks of Pog and Pog'
Gn-Gn' (mm)	Distance between the landmarks of Gn and Gn'
Me-Me' (mm)	Distance between the landmarks of Me and Me'
Soft Tissue Chin (mm^2)	Total area of the soft tissue chin
Facial Convexity (G'-Sn-Pog') (°)	Angle formed by connecting the soft tissue glabella, subnasale and soft tissue pogonion
G'-Pog' Perpendicular (mm)	The distance from the Pog' to the G' line, representing the degree of mandibular prominence or retrusion
Lower Face-Throat Ang (Sn-Gn'-C) (°)	Angle formed by connecting the soft tissue subnasale, soft tissue gnathion, and cervical point
H Angle (°)	Angle between the Pog' and lip superioris with NPog
Z Angle	Angle formed by the intersection of Frankfort horizontal (FH) plane and a line connecting the soft-tissue chin (Pog') and the most protrusive lip point

Abbreviations: SNA, Sella-Nasion-A point angle; SNB, Sella-Nasion-B point angle; OLp, Occlusal Line Perpendicular; Go-Pog, Gonion-Pogonion Distance; MP, Mandibular Plane; Id, Infradentale; Pog, Pogonion; Co, Condylion; Ar, Articulare; Go, Gonion; Gn, Gnathion; FH, Frankfort Horizontal Plane; Wits, Wits Appraisal; A, A point; B, B point; NPog, Line from nasion to pogonion for measure of facial height and other measure (facial plane); ms, maxillary molar position; mi, mandibular molar podition; G', soft tissue glabella; Pog', Soft Tissue Pogonion; Me, Menton; Me', Soft Tissue Menton; B', Soft Tissue B Point; ms, Maxillary First Molar; mi, Mandibular First Molar; ANS, Anterior Nasal Spine; Na, Nasion; Me, Menton; SGo, Sella-Gonion Distance; L1, Lower Central Incisor; U1, Upper Central Incisor; SN, Sella-Nasion Plane; A-Pog, A point to pogonion plane; E-Plane, Esthetic Plane; C, cervical point.

2.6 Intra- and inter-rater reliability

Ten T_0 cephalograms were traced and measured on two occasions by the same examiner following a sufficient period to prevent the recall bias. The intraclass correlation coefficient (ICC) ascertained the reliability of repeated measurements. The ICC values from 0.93 to 0.99 for linear and angular metrics indicated high to excellent reliability for the examiner's sequential measurements.

2.7 Statistical analysis

Analyses were made by SPSS 20.0 (IBM, Armonk, NY, USA). Means and standard deviations (SDs) were calculated. Shapiro-Wilk tests assessed the normality at T_0 and T_0–T_1. The *t*-tests or Wilcoxon signed-rank tests based on the normality were used for intra-group comparisons. Inter-group comparisons were made by using ANOVA, Kruskal-Wallis H or Mann-Whitney U depending on the normality and sample number. The significance level was considered as $p < 0.05$.

3. Results

3.1 Baseline

The baseline examination showed no significant difference in Sella-Nasion-A point angle (SNA°) and Sella-Nasion-B point angle (SNB°) among the MA, TB and control groups ($p > 0.05$) (Table 2). There were differences between the experimental (MA and TB) and control groups regarding ANB°, lower anterior facial height ratio (anterior nasal spine (ANS)-Me/N-Me, %), overjet (mm) and overbite (mm) ($p < 0.05$).

The skeletal, dental and soft tissues were affected in all three groups as shown in **Supplementary Table 1**. The inter-group comparison of changes in the skeletal, dental and soft tissues are shown in Table 3.

3.2 Skeletal effects

Maxilla: no significant sagittal change was there in the maxilla measurements of three groups (Table 3).

Mandible: an increase in SNB° ($p > 0.05$) was recorded without any significant inter-group difference (Table 3). The mandibular body (Go-Pog) was increased from 58.54 ± 0.87 mm to 61.45 ± 0.8 mm in MA group.

Maxillomandibular Relationship: ANB° and Wits appraisal were decreased in MA and TB groups ($p < 0.05$) (**Supplementary Table 1**).

Condyle: sagittal and vertical growths were detected in the MA group, while TB group had the vertical growth only (**Supplementary Table 1**). The control group's condylar dimension had change in the normal growth from 6.4 ± 0.84 mm to 6.92 ± 0.92 mm to demonstrate the absence of orthodontic intervention in natural growth tendencies.

3.3 Dental effects

Anterior Teeth: lingual maxillary incisor tipping (Upper incisor to A-Pogonion angle, U1-A-Pog° from 37.32° ± 1.18 to 32.73° ± 0.85 in MA, from 41.45° ± 2.4 to 31.28° ± 1.98 in TB, $p < 0.05$) and labial mandibular incisor tipping (Lower incisor to A-Pogonion angle, L1-A-Pog° increased to 26.10° ± 0.66 in MA, $p < 0.05$, and to 22.72° ± 1.15, $p < 0.01$, in TB) reduced the overbite and overjet in TB and MA groups (**Supplementary Table 1**). Overjet was decreased from 6.18 ± 0.21 mm to 3.92 ± 0.18 mm ($p < 0.01$) in MA, and from 10.05 ± 1.06 mm to 4.28 ± 0.44 mm in TB group ($p < 0.01$). The overbite reduction was detected from 2.83 ± 0.25 mm to 1.64 ± 0.24 mm ($p < 0.01$) in MA, and from 4.17 ± 0.43 mm to 2.23 ± 0.42 mm ($p < 0.01$) in TB group. The control group had normal increase in the overbite and overjet growth.

Molar Relation: Mandibular molar was anteriorly migrated in TB (mandibular molar position, mi-OLp from 49.36 ± 4.01 mm to 50.96 ± 1.39 mm, $p < 0.05$) and MA (mi-OLp from 50.76 ± 0.77 mm to 53.16 ± 0.73 mm, $p < 0.05$) groups, and the molar relationship was improved (**Supplementary Table 1**). The improvement in molar relationship was more effective in TB group ($p < 0.01$) (Table 3).

TABLE 2. Pre-treatment baseline skeletal and soft tissue measurements (mean ± standard deviation).

Measurement(s)	MA group n = 19	TB group n = 15	Control group n = 13	*p*-value
SNA	81.06 ± 0.54	80.59 ± 1.11	79.45 ± 1.06	0.372
SNB	75.28 ± 0.51	74.74 ± 0.91	75.86 ± 1.18	0.696
ANB	5.79 ± 0.35	5.83 ± 0.55	3.62 ± 0.86	0.015*
MP-SN	37.89 ± 0.87	34.67 ± 2.00	37.11 ± 2.21	0.367
NaMe (mm)	108.14 ± 0.92	114.82 ± 9.76	107.02 ± 1.43	0.360
S-Go (mm)	68.72 ± 0.75	75.91 ± 5.46	67.93 ± 1.90	0.278
S-Go/N-Me (%)	63.59 ± 0.60	66.82 ± 1.60	63.53 ± 1.64	0.115
Ar-Go (mm)	39.13 ± 0.65	42.54 ± 2.61	38.27 ± 1.40	0.335
Go-Gn (mm)	70.13 ± 0.97	73.41 ± 5.37	71.48 ± 1.33	0.685
N-ANS (mm)	49.83 ± 0.57	63.95 ± 5.86	48.45 ± 0.78	0.467
ANS-Me (mm)	60.74 ± 0.71	52.82 ± 0.62	60.12 ± 1.24	0.493
ANS-Me/N-Me (%)	56.15 ± 2.13	72.78 ± 0.99	56.15 ± 2.45	0.005**
Overjet (mm)	6.10 ± 0.21	10.05 ± 1.06	5.30 ± 0.72	<0.001***
Overbite (mm)	2.81 ± 0.25	4.17 ± 0.43	1.87 ± 0.58	<0.001***
U1-L1 (°)	118.33 ± 1.57	120.15 ± 3.31	119.54 ± 2.93	0.891
Wits Appraisal (mm)	2.00 ± 0.45	4.10 ± 0.72	0.18 ± 0.59	<0.001***

Abbreviations: MA, Mandibular advancement group; TB, Twin Block group; SNA, Sella-Nasion-A point angle; SNB, Sella-Nasion-B point angle; ANB, A point-Nasion-B point angle; MP-SN, Mandibular Plane to Sella-Nasion Angle; NaMe, Nasion-Menton Distance (Anterior Facial Height); S-Go, Sella-Gonion Distance (Posterior Facial Height); S-Go/N-Me, Ratio of Posterior to Anterior Facial Height; Ar-Go, Articulare-Gonion Distance; Go-Gn, Gonion-Gnathion Distance (Mandibular Length); N-ANS, Nasion to Anterior Nasal Spine Distance; ANS-Me, Anterior Nasal Spine to Menton Distance (Lower Anterior Facial Height); ANS-Me/N-Me, Ratio of Lower to Total Anterior Facial Height; U1-L1, Interincisal Angle (Angle between Upper and Lower Incisors).

$*p < 0.05$: $**p < 0.01$: $***p < 0.0001$.

TABLE 3. Mean of the changes in skeletal and soft tissues measurements of TB, MA and control groups^{abc}.

Measurement(s)	Groups			*p*-value	Intergroup comparison		
	MA	TB	Control		MA-C *p*-value	TB-C *p*-value	MA-TB *p*-value
Skeletal							
SNA (°)	0.31 ± 0.30	−0.21 ± 0.34	0.63 ± 0.62	0.1340	/	/	/
OLp-A (mm)	1.42 ± 0.54	−2.39 ± 4.68	−0.04 ± 1.52	0.2990	/	/	/
SNB (°)	1.14 ± 0.32	0.97 ± 0.35	0.88 ± 0.36	0.8810	/	/	/
Go-Pog (mm)	2.91 ± 0.74	−1.51 ± 4.05	0.78 ± 1.13	0.5640	/	/	/
Go-Gn (mm)	3.71 ± 0.75	−1.93 ±4.88	0.97 ± 1.11	0.1260	/	/	/
Id-Pog-MP (°)	1.34 ± 0.55	0.51 ± 0.75	−1.78 ± 0.86	0.0170*	0.0160*	0.1350	0.65
OLp-Co (mm)	1.36 ± 0.59	−0.21 ± 1.04	0.52 ± 0.82	0.3400	/	/	/
Ar-Go (mm)	2.92 ± 0.56	0.57 ± 2.75	0.89 ± 0.96	0.3470	/	/	/
Y-Axis Length (mm)	6.74 ± 1.01	−2.43 ± 8.72	1.27 ± 1.83	0.0670	/	/	/
ANB (°)	−0.83 ± 0.24	−1.20 ± 0.38	−0.28 ± 0.49	0.2890	/	/	/
Wits Appraisal (mm)	−1.21 ± 0.53	−2.85 ± 0.62	0.51 ± 0.75	0.0150*	0.1670	0.0060**	0.12
A-Npog (mm)	−0.63 ± 0.26	−1.25 ± 0.49	−0.38 ± 0.46	0.3420	/	/	/
SN-Npog (°)	1.12 ± 0.32	0.96 ± 0.36	1.03 ± 0.38	0.9550	/	/	/
MP-SN (°)	−0.48 ± 0.47	0.43 ± 0.67	−1.73 ± 0.52	0.1130	/	/	/
N-ANS (mm)	3.92 ± 0.62	−1.71 ± 5.24	−0.52 ± 1.05	0.0070**	0.0200*	0.9150	0.56
ANS-Me (mm)	5.77 ± 0.87	−3.25 ± 8.47	0.23 ± 1.61	0.0350*	0.0070**	0.9600	0.53
ANS-Me/N-Me (%)	0.41 ± 1.34	0.71 ± 0.26	−0.45 ± 1.04	<0.0001****	<0.0001****	0.0200*	0.81
N-Me (mm)	5.77 ± 0.87	−3.25 ± 8.47	0.23 ± 1.61	0.0350*	0.0200*	0.9150	0.56
S-Go (mm)	4.32 ± 0.52	−1.67 ± 5.16	0.99 ± 0.64	0.0950	/	/	/
S-Go/N-Me (%)	0.65 ± 0.35	−0.11 ± 0.63	1.35 ± 0.40	0.2690	/	/	/
Dental							
U1-A-Pog (mm)	−1.11 ± 0.25	−4.09 ± 1.20	0.35 ± 0.37	<0.0001****	0.0100**	0.0070**	0.07
U1-A-Pog (°)	−4.6 ± 1.01	−10.17 ± 2.57	0.38 ± 1.11	<0.0001****	0.0100**	<0.0001****	0.14
L1-A-Pog (mm)	1.19 ± 0.22	1.93 ± 0.53	−0.86 ± 0.29	<0.0001****	<0.0001****	<0.0001****	0.41
L1 to A-Pog (°)	1.81 ± 0.77	−10.17 ± 2.57	−1.55 ± 0.71	0.0060**	0.0080**	<0.0001***	0.29
U1-L1 (°)	2.78 ± 1.30	5.83 ± 2.70	1.17 ± 1.50	0.3420	/	/	/

TABLE 3. Continued.

Measurement(s)	Groups			*p*-value	Intergroup comparison		
	MA	TB	Control		MA-C *p*-value	TB-C *p*-value	MA-TB *p*-value
Overjet (mm)	−2.26 ± 0.24	−5.77 ± 1.13	1.19 ± 0.41	<0.0001****	<0.0001****	<0.0001****	0.02*
Overbite (mm)	−1.19 ± 0.31	−1.94 ± 0.46	0.81 ± 0.71	<0.0001****	0.0380*	0.0090**	0.44
ms-OLp (mm)	1.22 ± 0.75	−0.73 ± 3.27	−0.13 ± 1.15	0.5330	/	/	/
mi-OLp (mm)	2.39 ± 0.90	1.60 ± 3.31	−0.10 ± 1.13	0.0750	/	/	/
Molar Relation (mm)	−1.17 ± 0.34	−2.29 ± 0.51	−0.05 ± 0.31	0.0120**	0.0520	<0.0001****	0.18
Soft tissue							
Lower Lip to E-Plane (mm)	−0.33 ± 1.51	−0.64 ± 0.52	0.19 ± 1.68	0.4620	/	/	/
Upper Lip to E-Plane (mm)	−1.40 ± 1.17	−2.41 ± 0.39	−0.59 ± 1.14	<0.0001****	0.1100	<0.0001****	0.08
B-B’ (mm)	1.81 ± 2.98	0.25 ± 0.54	0.21 ± 3.08	0.1590	/	/	/
Pog-Pog’ (mm)	1.22 ± 1.44	0.21 ± 0.51	−0.38 ± 1.85	0.0100**	0.0370*	0.7030	0.20
Gn-Gn’ (mm)	0.50 ± 1.63	−0.32 ± 0.44	−0.01 ± 1.23	0.2170	/	/	/
Me-Me’ (mm)	0.61 ± 1.84	−0.08 ± 0.39	0.35 ± 1.28	0.4160	/	/	/
Soft Tissue Chin (mm^2)	46.12 ± 39.92	12.57 ± 9.75	2.37 ± 41.34	<0.0001****	0.0130**	0.7870	0.02*
G’-Sn-Pog’ (°)	−1.40 ± 2.95	−2.92 ± 0.95	0.66 ± 2.78	0.0160*	0.0980	0.0220*	0.35
G’-Pog’ Perpendicular (mm)	2.48 ± 4.46	1.35 ± 1.04	−0.53 ± 2.00	0.6830	/	/	/
Sn-Gn’-C (°)	0.76 ± 9.20	−8.37 ± 3.85	−0.07 ± 0.17	0.0170*	0.9970	0.1040	0.10
H-Angle (°)	−1.56 ± 1.87	−4.67 ± 0.98	0.02 ± 0.07	<0.0001****	0.2810	<0.0001****	0.02*
Z Angle (°)	3.45 ± 4.12	6.43 ± 1.44	0.33 ± 2.86	<0.0001****	0.0190*	<0.0001****	0.18

Abbreviations: OLp-A (mm), Occlusal Line Perpendicular to A Point; Id-Pog-MP (°), Infradentale-Pogonion-Mandibular Plane Angle; OLp-Co (mm), Occlusal Line Perpendicular to Condylion; ms-OLp (mm), Maxillary Molar Position to Occlusal Line Perpendicular; mi-OLp (mm), Mandibular Molar Position to Occlusal Line Perpendicular; Molar Relation (mm), Difference between the Mesial Contact Points of Maxillary and Mandibular First Molars to the Occlusal Line Perpendicular; Lower Lip to E-Plane (mm), Distance from Lower Lip to Esthetic Plane; Upper Lip to E-Plane (mm), Distance from Upper Lip to Esthetic Plane; B-B’ (mm), Distance between B Point and Soft Tissue B Point; Pog-Pog’ (mm), Distance between Pogonion and Soft Tissue Pogonion; Gn-Gn’ (mm), Distance between Gnathion and Soft Tissue Gnathion; Me-Me’ (mm), Distance between Menton and Soft Tissue Menton; Soft Tissue Chin (mm^2), Area of Soft Tissue Chin; Nasolabial Angle (°), Angle between Columella, Subnasale and Upper Lip; G’-Sn-Pog’ (°), Glabella-Subnasale-Soft tissue Pogonion Angle; G’-Pog’ Perpendicular (mm), Perpendicular Distance from Soft Tissue Pogonion to Vertical Line through Soft Tissue Glabella; Sn-Gn’-C (°), Subnasale-Soft tissue Gnathion-Cervical Point Angle; H-Angle (°), Angle between Soft Tissue Pogonion and lip superioris with NPog; Z Angle (°), Angle formed by the intersection of Frankfort horizontal (FH) plane and a line connecting the soft-tissue chin (Pog’) and the most protrusive lip point.

[a]: **p < 0.05; **p < 0.01; ***p < 0.001; ****p < 0.0001.*

[b]: *C, Control group; TB, Twin Block group; MA, Mandibular advancement group.*

[c]: *No statistically significant differences among the groups. Post hoc pairwise comparisons not made because of no overall significance.*

3.4 Soft tissue effects

Lips: Both TB and MA groups led to the retraction of upper lip ($p < 0.05$) to improve the facial convexity and reduce H angle ($p < 0.05$) (**Supplementary Table 1**). These changes were more significant in the TB group (Table 3). There was no significant change in lower lip of all the groups (**Supplementary Table 1**).

Soft Tissue Chin: an anterior shift of the Pog along with increase in the thickness of soft tissues were detected in the MA group ($p < 0.05$) (**Supplementary Table 1** and Table 3).

4. Discussion

Most patients of skeletal Class II malocclusion experienced mandibular anteroposterior deficiency [18, 19]. Functional appliances like the Twin Block (TB) had been generally employed to treat Class II growing patients [4, 5]. The study herein compared effects of TB and clear aligner mandibular advancement (MA) appliances on the skeletal, dental, and soft tissues. The findings suggested that MA and TB improved incisor positions and soft tissue profile. MA had an increase in the soft tissue chin thickness and advancement of pogonion. TB improved upper lip position and facial convexity. MA had better control on the lower facial height due to specific pre-MA characteristics.

The increase in SNB angle across all groups suggests forward mandibular movement, critical for addressing skeletal Class II malocclusion where the mandible is initially retruded. This forward shift, seen in both treatment groups, underscores the potential of TB and MA to improve the maxillomandibular relationship, an essential clinical outcome in Class II correction. The retrospective study by Sun *et al*. [20] highlights the importance of timing and appliance type, with TB and MA demonstrating improvements in skeletal, dental and soft tissue profiles, particularly facial aesthetics. The reduction in ANB angle observed in both TB and MA groups, but not in the control, highlights their effectiveness in decreasing the Class II discrepancy, reflecting an improvement in skeletal alignment between maxilla and mandible. While the Wits appraisal was reduced in both groups, only the TB group showed a statistically significant difference compared to the control. However, neither MA nor TB demonstrated significant mandibular growth beyond natural development, as reflected in the control group. TB induced some mandibular growth (1.9 mm), however this change was small and might not be clinically significant [21]. Regression analysis showed that treatment effects accounted for 54% of the final ANB angle, indicating that dentoalveolar adjustments, rather than skeletal growth, are the primary contributors to changes observed with these appliances. Clinically, this finding is vital as it emphasizes the importance of managing expectations regarding skeletal outcomes and recognizing the primary dentoalveolar effects of these appliances [21, 22]. This aligns with systematic reviews reporting limited mandibular length enhancement with functional appliances, where variability in outcomes is often linked to selection bias and secular growth trends [23].

The retraction of upper incisors, proclination of lower incisors, and reduction of overjet and overbite were observed after the TB and MA treatments as compared to the control. These findings being consistent with the literature [11, 13] demonstrated that both MA and TB could retract the upper incisors. This outcome was expected because of the Class II "traction effect" [24] of functional appliances and the pressure exerted by upper lip musculature during treatments [25]. Both upper and lower incisors served as the key anchorage points in MA and TB treatments. The orthopaedic force transmitted by appliances led to the upper incisor retraction and lower incisor proclination. The control group exhibited stable overbite and increased overjet as compared to the decrease in overbite and overjet among TB and MA groups. Overjet was corrected by improving the bimaxillary relationship; overbite by the lower incisor protrusion and increase in the lower anterior facial height (ANS-Me/N-Me*%) of both treatment groups. In addition to improving incisor positioning and overjet, early intervention in Class II correction has secondary benefits, including enhanced facial aesthetics and increased social acceptance. Research indicates that children with Class II malocclusion are at higher risk for bullying, low self-esteem and poor social perception [26]. Effective reduction of overjet not only contributes to functional improvement but also addresses these important psychosocial aspects, underlining the broader clinical relevance of early intervention.

Lower anterior facial height ratio (LAFR) was increased after the TB and MA treatments as compared to the control, however to a lesser extent after MA than TB. MA had better control to lower the face height than TB [13]. The increase in LAFR with TB and MA treatments might be attributed to the factors such as anterior tooth early contact and mandibular clockwise rotation during occlusion reconstruction [27]. The bite opening effect of TB appliances could lead to guided extrusion of upper molars which further contributed to the increase in lower facial height [28]. Contrarily, MA with clear aligners (CA) might have better control over the lower facial height compared to TB [13], as the MA could intrude anterior teeth via programmed tooth movements (Pre-MA and MA stages) and reduce the early contacts [11, 12]. The use of MA such as Precision Wings incorporated in CA had better efficacy in correcting Class II malocclusion. The present study depicted notable improvements by the clear aligners (CAs) combined with mandibular advancement regarding the overjet reduction, molar relationships, and mandibular positioning. Hosseini *et al*. [29] found that the CAs with mandibular advancement achieved comparable results through fixed functional appliances like the Herbst appliance which corroborated the positive effects of CAs in Class II correction, particularly in controlling vertical dimension and improving skeletal relationships. Although Lo Giudice *et al*. [30] evaluated condylar cortical bone thickness differences among patients with various vertical facial dimensions, it did not specifically examine Class II malocclusion. However, the findings suggest that hyperdivergent patients generally have thicker condylar cortical bone than hypodivergent patients. Extrapolating this to Class II malocclusion, it could be hypothesized that hyperdivergent and hypodivergent Class II patients may have distinct condylar characteristics, potentially impacting their response to functional appliances. Future research could explore these anatomical variations within Class II populations to refine and personalize treatment protocols further.

In present study, MA showed greater increment around soft tissue chin compared to that of TB. The Pog-Pog' was increased after the MA treatment compared to control. Soft tissue chin area was increased compared to both the control and TB groups. This enhancement in chin thickness and prominence may have important clinical implications for facial aesthetics in Class II correction. The retraction of upper incisors by MA, and reduction of overbite and overjet by TB could result in lower lip retraction and decrease the lower lip and chin tension. Facial profile is shaped by three main factors: soft tissue thickness, dental characteristics and skeletal features. Soft tissue, in particular, can vary independently of underlying bone and is key to defining the final profile [31, 32]. MA might thus result in better relaxation of chin soft tissue for leading to a more prominent chin. Contrarily, the greater clockwise mandibular rotation by TB stretched the chin's soft tissue. This was different from a previous study [15] where TB resulted in greater soft tissue chin advancement compared to MA. The discrepancy likely arose from the difference in measurement methods, *i.e.*, this study assessed the soft tissue chin thickness by Pog-Pog' while that study measured the position of soft tissue pogonion relative to the true vertical line (TVL).

Retraction of the upper lip was observed in TB and MA groups with significant reduction in the Upper Lip to E-Plane after the treatment. A significant difference was observed in TB group compared to that of control to indicate the higher efficiency of TB in upper lip retraction. The retraction of upper incisors contributed to the observed upper lip retraction. The lack of differences between MA and control groups remained unclear. There was no significant change in the lower lip among all groups of the present study. This was contrary to a previous study [24] which showed stable upper lip compared to a more protrusive lower lip after the treatment. Two explanations for this discrepancy might include: (1) retraction of the upper incisors and reduction of overjet and overbite in TB and MA could lead to lower lip retraction, and the mandibular advancement could result in lower lip protrusion, and (2) Class II patients might have insufficient lip muscle tension and thus requiring more time to recover normal tension, and could offset the lower lip protrusion due to mandibular forward movement.

An increase in the Z angle and soft tissue facial convexity (G'-Sn-Pog') was observed in both MA and TB groups. The improvement in Z angle was significant for both treatment groups compared to the control, however the increase in soft tissue facial convexity was observed only in TB group. The changes in these parameters were positively correlated to the changes in ANB angle and Wit appraisal. The Z angle could thus be employed as characteristic index to assess the lateral profile of soft tissue [33]. The Z angle increase was related to the upper lip retraction and/or forward movement of soft tissue pogonion. This finding was supported by the increase in soft tissue pogonion thickness and decrease in H angle. The reduction in convexity angle contributed to the Z angle increase and build-up of soft tissue pogonion [34]. This study focused on the short-term outcomes, however the potential long-term effects of MA and TB appliances should also be considered. Previous study by Schneider-Moser *et al.* [35] highlighted how early orthodontic intervention influenced the soft tissue stability and facial aesthetics. The long-term data on MA had been limited, however it could be expected that both appliances induced sustained changes in skeletal and soft tissue profiles when treatment was initiated in the growth period. Future studies should further explore the reliability of these effects as the early intervention in pubertal growth spurt might result in more stable long-term outcomes. These variations would need further investigations to confirm the findings beyond immediate post-treatment periods.

The promising outcomes needed careful interpretation of the data, particularly because of the limitation of control group composition. Ethical considerations prevented the inclusion of Class II malocclusion subjects in control group, which necessitated the use of Class I subjects for establishing a reference for normative growth trajectories. The study outcomes herein were aligned with the previous studies to suggest that Class II patients had smaller mandibles by age 15 compared to Class I subjects. The overall mandibular growth rate between 10 and 15 years was similar in both groups. This reinforced the validity of using Class I subjects as reference group for evaluating the mandibular advancement appliances [36].

5. Conclusions

- Clear aligner mandibular advancement (MA) increased the soft tissue chin thickness and advanced pogonion.
- TB improved the upper lip position and facial convexity.
- Evidence did not support that the MA or TB appliances enhanced the sagittal mandibular growth.

MA had better control over the lower facial height due to its pre-MA characteristics.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

LJT and PKW—designed the research study; PKW—performed the research; LJT and LM—provided help and advice on treatment design; PKW—analyzed the data; PKW, LJT and LM—wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The patients' parents or guardians have signed a written informed consent to use their data, including photos and images. This retrospective clinical study was approved by the Ethics Committee of the West China Hospital of Stomatology, Sichuan University after due examination and authorization (Approval No. WCHSIRB-D-2023-195) and is registered at ClinicalTrials.gov (NCT06609733).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/1963128678303842304/attachment/Supplementary%20material.docx.

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