Original Article

Clear aligners for Class II correction in growing patients: elastics vs mandibular advancement

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ABSTRACT

Objectives: To evaluate the skeletal and dental effects of Class II correction in growing patients using clear aligners, with either elastics or mandibular advancement (MA).

Materials and Methods: The study included 66 growing Class II patients: 45 patients treated with clear aligners (20 using Class II elastics and 25 with MA) and 21 untreated controls observed over a comparable time period. Nine cephalometric and three study cast measurements were evaluated initially (T1) and the end of treatment (T2) to assess skeletal and dental changes.

Results: The control group maintained a Class II molar relationship and overjet, whereas both treatment groups corrected to Class I. In the MA group, statistically significant skeletal changes from T1 to T2 were observed, including reduction in SNA (–1.09°) and ANB (–1.69°), in addition to dento-alveolar Class II correction. The elastic group showed no statistically significant changes in SNA and ANB compared to the control group. Linear regression revealed 5.28° of lower incisor proclination with Class II elastics, whereas lower incisor inclination was maintained with MA treatment.

Conclusions: Clear aligner treatment with Class II elastics and MA were effective for correcting Class II malocclusion in growing patients that would have otherwise been maintained without intervention. Although Class II correction was mainly due to dentoalveolar changes, a skeletal component was observed with MA treatment. (*Angle Orthod*. 2026;96:165–172.)

KEY WORDS: Clear aligner; Class II; Growing patients; Elastics; Mandibular advancement

INTRODUCTION

Class II malocclusion is prevalent in 13% of adults and 15%–23% of younger patients.[1] There are numerous benefits to the correction of Class II malocclusion, including improved esthetics, speech, and decreased risk of trauma.[2,3] Nonsurgical treatment options involve distalization of the maxillary dentition and mesialization of the mandibular dentition with or without extractions. Additionally, growing patients have the option of growth modification to promote differential growth between the maxilla and mandible. Skeletal correction, primarily from continued growth of the mandible, contributes to Class II correction in growing patients.[4,5] The correction of Class II malocclusion is particularly beneficial in these patients, as it stabilizes the bite and allows natural mandibular growth to progress without interference.[6]

For teenage patients with esthetic concerns, clear aligners provide an alternative treatment option.[7] The mandibular advancement (MA) feature in clear aligners is specifically designed for growth modification. The effectiveness of the MA in Class II correction varies across studies, particularly regarding its skeletal and dentoalveolar contributions. Studies comparing functional appliances, such as the Twin Block and Herbst appliance, with the MA have shown that the MA achieves similar overall Class II correction outcomes.[8,9] Another study reported minimal skeletal changes with the MA feature,[10,11] although the absence of a control group limited the strength of those findings. Class II elastics with clear

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Accepted: August 24, 2025. Submitted: March 28, 2025.
Published Online: September 25, 2025

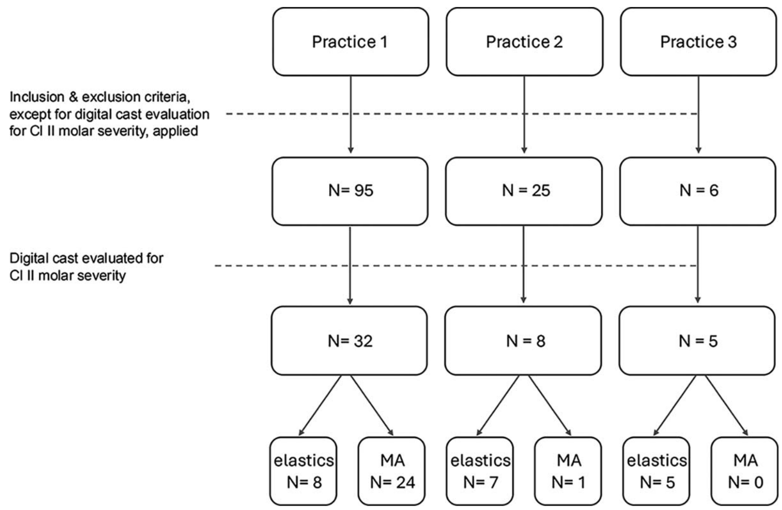

Figure 1. Sample collection flow chart for treatment groups.

aligners were shown to be effective in growing and nongrowing patients, with overbite and overjet correction comparable to full fixed appliances (FFA).[12,13] In growing patients, Class II elastics with clear aligners may achieve outcomes comparable to those of the MA. This raises the question: is the MA feature worth its complexity, or would Class II elastics provide a simpler alternative?

The purpose of this study was to evaluate skeletal and dental changes in growing patients treated with clear aligners using MA or Class II elastics. The findings were intended to help guide clinicians in selecting the most suitable treatment modality for individual patients.

MATERIALS AND METHODS

This retrospective study was approved by the Institutional Review Board of University of the Pacific (#2022-103). Sample size calculation indicated that 18 patients per group were needed to detect a 1° difference in ANB change and achieve a statistical power of 0.8 with α of 0.05. The effect size, using ANB as the primary outcome measurement, was determined based on a previous study.[8]

Class II treatment samples were collected from three private practices. Inclusion criteria were age $<$ 18 in the permanent dentition, treatment initiated after 2015 and completed with clear aligner therapy, and a molar relationship of at least bilateral half-cusp Class II or unilateral full-cusp Class II. Exclusion criteria included craniofacial conditions, use of the Carriere Motion Appliance or sequential distalization, extractions (except third molars), noncompliance with aligners, congenitally missing or impacted teeth (except third molars), prior orthodontic treatment, incomplete records, and use of adjunct appliances such as headgear or expanders. The final sample included 20 patients treated with elastics and 25 treated with MA (Figure 1).

For the untreated control group, records were obtained from the Michigan and Oregon growth collections of the American Association of Orthodontics Foundation (AAOF) Legacy Collection. Twenty-one subjects were selected based on initial molar relationship on study casts.

Patients in the Class II elastic group were instructed to wear each aligner for 20–22 hours per day and switch aligners every 1–2 weeks. Elastic use began at the first appointment and continued full time until the occlusion was corrected. Patients in the MA group underwent three phases: pre-MA, MA, and post-MA. The pre-MA phase involved initial clear aligner treatment to level the curve of Spee, procline the maxillary incisors, and correct maxillary molar rotations as needed. The mandibular advancement phase followed, with 2 mm mandibular advancements every 8 weeks until edge-to-edge incisor contact or Class I buccal occlusion on at least one side. For both groups, refinements were included in the overall treatment time, and final records were taken after completion.

Lateral cephalograms and digital models were taken for patients at treatment start (T1) and completion (T2), and the records were collected at corresponding timepoints for controls. Records were uploaded to Dolphin Imaging software (Dolphin 12, Chatsworth, Calif). Growth stages were evaluated using the cervical vertebral maturation method[14] by two raters, with differences resolved by consensus. Lateral cephalograms were traced by one rater (EP) and checked by a faculty member. Nine cephalometric values (SNA, SNB, ANB, Wits, Convexity angle (N-A-Pog), MP-SN, Occlusal plane-SN (OP-SN), U1-SN, and IMPA) were studied. These measurements were chosen for their relevance in evaluating skeletal and dental changes, ensuring comprehensive analysis while reducing redundancy and the risk of Type I error.

Digital models were analyzed for overjet (OJ), overbite (OB), and molar relationships using OrthoAnalyzer

Table 1. Sample Demographics

Group	Elastics (N = 20) Mean (SD)	MA (N = 25) Mean (SD)	Control (N = 21) Mean (SD)	*P* Value
Age at treatment start (y)	13.03 (1.20)	13.13 (1.47)	13.34 (1.88)	
CVM at treatment start	3.43 (0.79)	3.41 (0.73)	3.17 (0.97)	.3669
Treatment time (mo)*	24.0 (7.4)[a]	28.7 (21.8)[b]	24.6 (21.4)[a,b]	.0368

* Median and interquartile range (IQR) were reported for data not normally distributed. Different superscript letters indicate statistical significance from the post-hoc analysis. CVM indicates cervical vertebral maturation.

(3Shape, Copenhagen, Denmark) software. The distance between the mandibular first molar buccal groove and the maxillary first molar mesiobuccal cusp tip was measured bilaterally. A negative value indicated that the buccal groove was anterior to the maxillary cusp tip. Two raters measured each value, and discrepancies $>$ 0.5 mm were resolved by a third rater. Final values were determined by averaging the measurements.

Statistical Analysis

Descriptive statistics, including mean and standard deviation, were calculated. Normality of the data was tested using the Shapiro-Wilk test and normal quantile-quantile (Q-Q) plot. Analysis of variance (ANOVA) with Tukey's Honest Significant Difference (HSD) test was used to compare the cervical vertebral maturation (CVM) stage, molar relationship, OJ, OB, and cephalometric measurements across the three groups at both T1 and T2. The Kruskal-Wallis test was performed to compare treatment times across the three groups. To account for the influence of confounding factors, multiple regression analysis, adjusted for variables such as treatment time, initial OB, initial Wits, and initial IMPA, was employed when comparing treatment changes across the three groups.[15] Treatment changes were the outcome variables, whereas treatment modality was a three-level categorical predictor (control, elastics, MA). *P* values $<$ 0.05 were considered statistically significant with Bonferroni correction to adjust for multiple comparisons. Linear regression coefficients with 95% confidence intervals are shown in the Forest plots. All statistical analyses were performed using the R language (version 3.6.1; Vienna, Austria).

RESULTS

The final sample included 20 patients in the elastic group (six male, 14 female), 25 in the MA group (11 male, 14 female), and 21 untreated Class II control subjects (10 male, 11 female). No significant differences were found in CVM stage ($P = .367$) and sex distribution ($P = .478$) among groups (Table 1). Inter-rater reliability was excellent for digital cast measurements (ICC = 0.99). Molar relationships were largely symmetric, with 55 of 66 cases showing $<$ 2 mm asymmetry; therefore, both sides were averaged for further analysis. The median treatment duration was 24.0 months for elastics and 28.7 months for MA, whereas the interval between records for the control group was 24.6 months (Table 1). The MA group had a longer treatment time than the elastic group, whereas the interval for the control group was not significantly different from either.

At T1, ANOVA revealed no significant differences in 12 skeletal and dental variables (Table 2). OB was less

Table 2. Cast and Cephalometric Measurements at T1

Group	Elastics (N = 20) Mean (SD)	MA (N = 25) Mean (SD)	Control (N = 21) Mean (SD)	*P* Value*
Cast measurements				
Severity of Class II molar relationship (mm)	2.82 (1.01)	3.63 (1.12)	3.48 (1.56)	1
OJ (mm)	5.32 (2.26)	6.04 (1.78)	5.26 (2.30)	1
OB (mm)	3.90 (1.26)	3.97 (1.18)	2.57 (2.22)	.0918
Cephalometric measurements				
SNA (°)	81.86 (4.02)	81.16 (3.50)	79.75 (3.21)	1
SNB (°)	77.47 (3.83)	75.17 (2.98)	74.86 (3.26)	.3507
ANB (°)	4.40 (2.03)	5.98 (1.69)	4.89 (1.80)	.1831
Wits Appraisal (mm)	1.99 (2.49)[a]	3.74 (1.94)[b]	4.19 (2.13)[b]	0.0556
Convexity (N-A-Pog) (°)	7.54 (5.24)	11.65 (4.96)	7.71 (5.55)	0.1649
OP-SN (°)	16.04 (4.22)	18.19 (3.19)	16.06 (4.10)	1
MP-SN (°)	30.53 (4.73)	33.43 (4.34)	33.11 (4.81)	1
U1-SN (°)	102.54 (9.00)	104.82 (8.48)	101.83 (7.50)	1
IMPA (L1-MP) (°)	95.41 (9.33)	101.18 (6.47)	97.11 (5.88)	0.3359

* Bonferroni correction was applied to analysis of variance *P* values to account for multiple testing; different superscript letters indicate statistical significance from the post-hoc analysis.

Table 3. Cast and Cephalometric Measurements at T2

Groups	Elastics (N = 20) Mean (SD)	MA (N = 25) Mean (SD)	Control (N = 21) Mean (SD)	*P* Value*
Cast measurements				
Severity of Class II molar relationship (mm)	-0.30 (0.75)[a]	-0.19 (0.70)[a]	3.18 (1.65)[b]	< .0001
OJ (mm)	2.85 (0.57)[a]	3.03 (0.72)[a]	5.26 (2.04)[b]	< .0001
OB (mm)	2.33 (0.65)	2.08 (0.85)	2.28 (2.28)	1
Cephalometric measurements				
SNA (°)	81.26 (4.13)	80.06 (3.71)	79.98 (2.82)	1
SNB (°)	77.69 (3.64)	75.76 (3.55)	75.65 (3.34)	1
ANB (°)	3.58 (1.87)	4.29 (2.07)	4.31 (1.88)	1
Wits Appraisal (mm)	-0.40 (2.02)[a]	-0.19 (2.22)[a]	4.36 (2.69)[b]	< .0001
Convexity (N-A-Pog) (°)	5.81 (5.00)	7.84 (5.63)	6.38 (5.23)	1
OP-SN (°)	18.49 (4.25)[a]	20.56 (4.38)[a]	14.46 (4.03)[b]	.0007
MP-SN (°)	30.18 (4.62)	33.56 (4.73)	31.98 (4.83)	.7864
U1-SN (°)	102.77 (5.47)	100.85 (6.34)	102.86 (8.73)	1
IMPA (L1-MP) (°)	101.20 (7.14)	102.10 (6.31)	96.22 (6.99)	.1412

* Bonferroni correction was applied to ANOVA p-values to account for multiple testing; different superscript letters indicate statistical significance from the post-hoc analysis.

in the control group compared to the treatment groups ($P = .092$), whereas Wits was less in the elastic group compared to the other groups ($P = .056$), but neither was statistically significant. Although IMPA was not significantly different, the MA group had a higher IMPA angle. Linear regression accounted for treatment time and these initial differences. All patients had mild or no crowding.

At T2, all MA patients, and all but one patient treated with Class II elastics, achieved a Class I molar relationship. All control subjects remained Class II except one, who developed to Class I. Significant differences were found in molar relationship, OJ, OP-SN, and Wits (Table 3). The control group retained a Class II molar relationship (3.18 mm), while both treatment groups achieved Class I (elastics: –0.30 mm, MA: –0.19 mm). OJ remained at 5.26 mm for controls but reduced to 2.85 mm (elastics) and 3.03 mm (MA). OP-SN was 4°–6° lower in controls than in the treatment groups. Wits remained Class II in controls but shifted to Class I in the treatment groups.

Table 4 presents T2–T1 changes. MP-SN changes were minimal in both treatment groups (<0.4°) but there was more reduction in the control group (1.13°), with no significant difference between groups. SNB changes also did not differ significantly. In contrast, SNA and ANB significantly decreased in the MA group compared to the elastic and control groups. Linear regression, adjusted for treatment duration and initial differences, confirmed that these group differences were not solely due to treatment time (Table 5). Skeletally, ANB, SNA, convexity angle, and Wits decreased significantly in MA compared to controls, as indicated by negative regression coefficients (Figure 2A). With Class II elastics, only the Wits value showed reduction compared to controls ($P < .0001$). MA resulted in a 2.25° decrease in convexity angle, whereas elastics showed a non-significant 0.66° decrease compared to

Table 4. Changes in Cast and Cephalometric Measurements (T2-T1)

Groups	Elastics (N = 20) Mean (SD)	MA (N = 25) Mean (SD)	Control (N = 21) Mean (SD)	*P* Value*
Cast Measurements				
Severity of Class II molar relationship (mm)	−3.12 (1.34)[a]	−3.81 (0.95)[a]	−0.30 (0.97)[b]	< .0001
OJ (mm)	−2.47 (2.07)[a]	−3.01 (1.74)[a]	+0.01 (1.15)[b]	< .0001
OB (mm)	−1.58 (1.22)[a]	−1.89 (1.18)[a]	−0.28 (1.18)[b]	.0008
Cephalometric measurements				
SNA (°)	−0.59 (1.03)[a]	−1.09 (1.06)[b]	+0.23 (1.29)[a]	.0105
SNB (°)	+0.22 (0.93)	+0.59 (1.07)	+0.79 (1.13)	1
ANB (°)	−0.82 (0.83)[a]	−1.69 (1.02)[b]	−0.58 (1.06)[a]	.0074
Wits appraisal (mm)	−2.39 (2.20)[a]	−3.93 (1.70)[b]	+0.17 (1.55)[c]	< .0001
Convexity (N-A-Pog) (°)	−1.73 (1.70)[a]	−3.81 (2.15)[b]	−1.33 (2.19)[a]	.0022
OP-SN (°)	+2.45 (2.41)[a]	+2.38 (3.37)[a]	−1.60 (1.44)[b]	< .0001
MP-SN (°)	−0.35 (1.71)	+0.13 (1.42)	−1.13 (1.63)	.3732
U1-SN (°)	+0.23 (7.07)	−3.97 (8.04)	+1.02 (3.16)	.2977
IMPA (L1-MP) (°)	+5.79 (4.70)[a]	+0.92 (4.38)[b]	−0.89 (3.14)[b]	< .0001

* Bonferroni correction was applied to analysis of variance *P* values to account for multiple testing; different superscript letters indicate statistical significance from the post-hoc analysis.

Table 5. Linear Regression Coefficients of Skeletal Variables

Outcome	Treatment	Coefficients	*P* Value*
ANB	Elastics vs Control	−0.28	1
	MA vs Control	−1.08	.0176
SNA	Elastics vs Control	−0.91	.3442
	MA vs Control	−1.53	.0016
SNB	Elastics vs Control	−0.53	1
	MA vs Control	−0.47	1
MP-SN	Elastics vs Control	0.62	1
	MA vs Control	1.37	.1368
Convexity (N-A-Pog)	Elastics vs Control	−0.66	1
	MA vs Control	−2.25	.0124
Wits	Elastics vs Control	−3.32	<.0001
	MA vs Control	−4.44	<.0001

* Multiple linear regression with Bonferroni correction.

controls. For MA vs controls, all dental variables except IMPA and OB were significant different (Table 6, Figure 2B). For elastics vs controls, molar relationship, OJ, IMPA, and OP-SN were significantly different. All regression coefficients for the dental variables, except OP-SN and IMPA, were negative, indicating a decrease in these variables with treatment compared to no treatment.

DISCUSSION

Both treatment modalities (MA and Class II elastics) achieved a Class I molar relationship and similar OJ reduction compared to controls. The MA group molar change (3.81 mm) and OJ reduction (3.01 mm) were in agreement with previous studies.[8,16] The elastic group demonstrated greater OJ correction (2.47 mm) compared to previous studies (1.40–1.70 mm).[12,13] However, comparison was limited since previous studies did not include molar relationship change in their analyses. Based on regional superimposition, the upper and lower incisors in the MA group moved 0.6 mm distally and 0.4 mm forward, respectively; in the elastic group, only the lower incisors advanced 1.6 mm (Figure 3).

There was a change of –1.09° in SNA and –1.69° in ANB with MA treatment in the current study (Figure 3), consistent with previous research (–0.84° SNA and –1.50° ANB).[8] Previous studies reported smaller SNA changes of –0.55° and –0.40°, but similar ANB changes of –1.67° and –1.50°.[9,16] Glaser et al. also reported a 3.62° improvement in convexity angle, close to the 3.81° improvement in this study.[16] These results were supportive of the growth modification effect of MA through decreased SNA and ANB, and improved convexity angle. However, since only one study included a control group,[9] the present study provided further insight by comparing MA to the elastic and control groups.

Class II skeletal correction with functional appliances has been shown to restrict maxillary forward growth while allowing normal mandibular growth, also known as the 'headgear effect'.[17] Both treatment groups showed a decrease in SNA from T1 to T2, though the change was only significant in the MA group (Table 4). Regression analysis, accounting for differences in treatment time and initial conditions (OB, Wits, and IMPA), revealed a significant improvement in ANB for the MA group, mainly attributed to a 1.53° decrease in SNA compared to controls, while SNB showed no significant changes

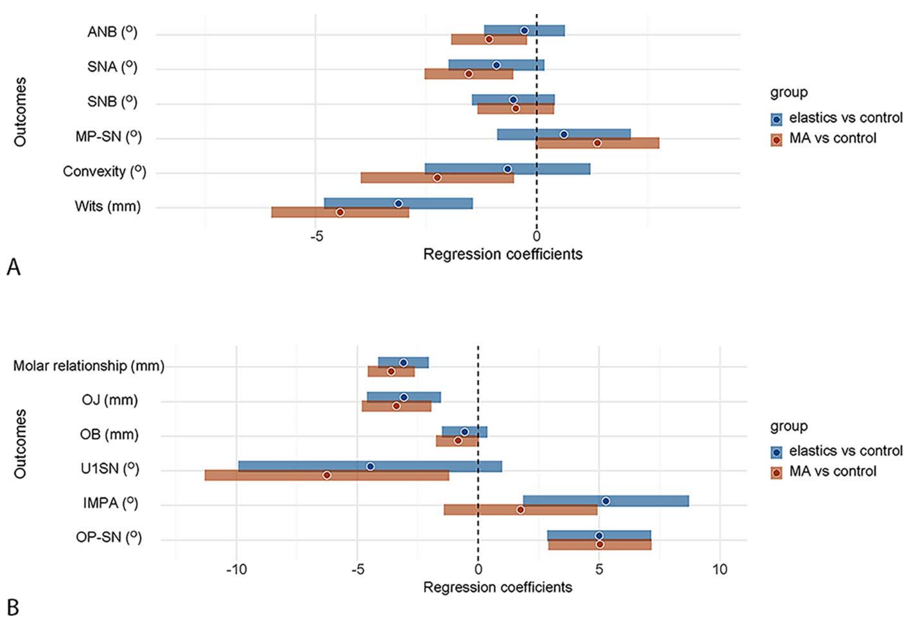

Figure 2. (A) Forest plot of linear regression coefficients with 95% confidence interval for skeletal variables, adjusted for multiple comparison using Bonferroni correction. (B) Forest plot of linear regression coefficients with 95% confidence interval for dental variables, adjusted for multiple comparison using Bonferroni correction.

Table 6. Linear Regression Analysis of Dental Variables

Outcome	Treatment	Coefficients	*P* Value*
Severity of Class II Molar Relationship	Elastics vs Control	−3.09	<.0001
	MA vs Control	−3.60	<.0001
OJ	Elastics vs Control	−3.06	<.0001
	MA vs Control	−3.42	<.0001
OB	Elastics vs Control	−0.56	1
	MA vs Control	−0.94	.0661
U1-SN	Elastics vs Control	−4.45	.4031
	MA vs Control	−6.25	.0200
IMPA	Elastics vs Control	5.28	.0015
	MA vs Control	1.75	1
OP-SN	Elastics vs Control	5.01	<.0001
	MA vs Control	5.03	<.0001

* Multiple linear regression with Bonferroni correction.

across groups. Improvement in convexity angle (N-A-Pog) was also greater in the MA group (–3.81°) than in the elastic and control groups (–1.73°, –1.33°), further supporting skeletal change with MA treatment compared to elastics.

Common side effects of Class II treatment include lower incisor proclination and poor vertical control. In this study, both treatment groups maintained vertical dimension, with no significant change in MP-SN, in agreement with previous findings.[8,9,12,13,16] Clear aligners have been reported to offer superior lower incisor torque control compared to conventional functional appliances and FFA.[4,8,12,13,17] However, the elastic group showed greater lower incisor proclination, with the regression coefficient indicating 5.28° more proclination compared to controls. This was in contrast to prior studies reporting 0.5° to 0.12° decreases in lower incisor inclination when Class II elastics with clear aligners were used.[12,13] The molar relationship correction reported in these studies was < 1 mm and OJ correction was < 2 mm,[12,13] whereas the present study achieved molar correction > 3 mm, and about 2.5 mm OJ correction for both treatment groups. The degree of proclination was similar to, or less than, findings from FFA treatment with Class II elastics. For instance, a meta-analysis[5] reported proclination ranging from 3.1° to 4.3°, whereas other studies found greater proclination, between 3.5° and 13.7°.[4,13,18] The elastic group in the current study had less proclined lower incisors before treatment compared to previous clear aligner studies,[12,13] which might explain the accepted increase in proclination when correcting OJ and molar relationships. However, neither of the previous studies included a control group, making direct comparison challenging.

In contrast, MA treatment did not significantly increase lower incisor proclination, consistent with prior findings.[8,9,16] The MA group began with more proclined lower incisors in this study, and the treatment plan likely aimed to avoid further proclination. Despite this, the MA group achieved similar molar relationship and OJ corrections as the elastic group. Class II correction in the MA group was achieved

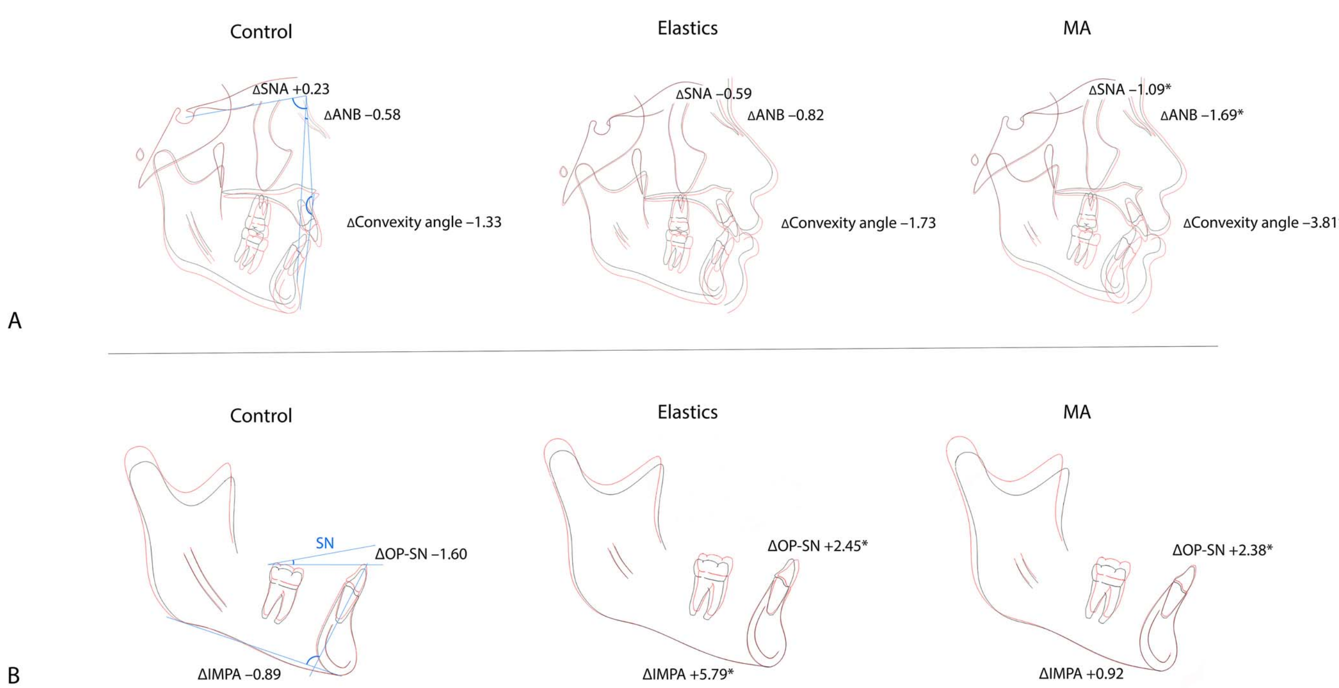

Figure 3. Superimpositions of averaged tracings for each group, illustrating skeletal and dental changes. Black: before treatment; Red: after treatment. (A) Cranial base superimposition; (B) Mandibular superimposition. *Indicates a statistically significant difference in treatment changes compared to the control group.

through a combination of skeletal correction and dentoalveolar compensation via upper incisor retroclination, while no further proclination of the lower incisors was planned.

Although both approaches effectively corrected Class II malocclusions, treatment choice should be guided by diagnosis and objectives. Patients with initially proclined lower incisors, particularly those with a thin gingival phenotype, may benefit from MA to avoid further proclination. Patients with a convex profile and more severe Class II malocclusions may benefit from growth modification, making MA the preferable option with clear aligners. Compared to conventional functional appliances like the Twin Block and Herbst, MA achieved similar Class II correction but with comparable or less skeletal change.[8,9,19] The Twin Block showed a greater reduction in convexity angle,[9] while MA provided better control over mandibular incisor inclination and superior vertical control.[8] Lastly, MA required a slightly longer treatment time (29 vs 24 months), likely due to staged tooth movements. Its success depends on patient education to posture the mandible forward, whereas issues such as poor fit or crushed wings can delay progress. Unlike fixed appliances, MA relies heavily on patient compliance, which may limit its effects.

Limitations of the current study included a small sample size, retrospective design, and lack of soft tissue analysis. Soft tissue analysis wasn't possible due to lateral cephalogram quality in the control group. Although sagittal skeletal changes were observed with MA treatment, the long-term skeletal effects need further investigation, as previous studies suggested that skeletal improvements may be transient.[17,20–22] Future research should explore long-term skeletal effects, evaluate soft tissue changes in growing patients, and compare alternative Class II correction strategies (eg, sequential distalization, Carriere Motion Appliance).[23,24]

CONCLUSIONS

- Clear aligner treatment using elastics and MA effectively corrected Class II malocclusions in growing patients through dentoalveolar changes, with MA demonstrating a combination of skeletal and dental changes.
- Mandibular plane angle remained stable in both treatment groups.
- MA achieved Class II correction with minimal lower incisor proclination.

ACKNOWLEDGMENTS

The authors thank John Mayberry for his insightful feedback and guidance on the statistical aspects of this work.

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