Original Article

Miniscrew anchorage versus Class II elastics for maxillary arch distalization using clear aligners

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ABSTRACT

Objectives: To identify whether intramaxillary miniscrew anchorage could achieve a better maxillary arch distalization effect in clear aligner treatment compared to Class II elastics.

Materials and Methods: Thirty adult patients with Class II dentition who were treated with whole maxillary arch distalization using clear aligners were collected. Either intramaxillary miniscrew anchorage (miniscrew group, $n = 17$) or intermaxillary Class II elastics (Class II elastic group, $n = 13$) were used to support maxillary arch distalization. Three-dimensional predicted and achieved displacements, and angular changes of maxillary posterior teeth and anterior teeth, were measured and compared.

Results: The achieved distalization efficiency was 36.2%–43.9% in the posterior teeth and the retraction efficiency was 36.9%–49.4% in the anterior teeth. No statistically significant differences were found in maxillary arch distalization efficiency between the groups. The miniscrew group achieved less incisor extrusion and posterior tooth distal tipping than the Class II elastic group. Both groups achieved comparable arch expansion, posterior tooth buccal inclination, and anterior tooth lingual inclination.

Conclusions: Intramaxillary miniscrew anchorage and intermaxillary Class II elastics achieved comparable efficiency in maxillary arch distalization. However, the miniscrew anchorage showed better vertical control in anterior teeth and mesiodistal tipping control in posterior teeth. (*Angle Orthod*. 2024;94:383–391.)

KEY WORDS: Maxillary arch; Distalization; Miniscrew; Class II elastics; Clear aligners

INTRODUCTION

Maxillary molar distalization is a common nonextraction treatment strategy used to correct Class II malocclusion. In fixed orthodontics, many auxiliary appliances, such as headgear, Herbst, distal jet, pendulum appliance, and miniscrews have been used effectively to achieve molar distalization. Recently, clear aligners have become a popular option for molar distalization.[1–6] Using clear aligners, the efficiency of

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molar distalization was reported to be as high as 87% and the amount of molar distalization achieved was reported to be 2–3 mm.[1–4]

The efficiency of molar distalization in a previous study was calculated on the assumption that the rest of the teeth were stable.[1] However, anchorage loss might happen in the premolars and incisors due to anterior reciprocal force. When using the palatal rugae for registration, the efficiency of molar distalization decreased to 74%.[5] In addition, the premolars and/or anterior teeth also need to be distalized in Class II cases to complete the whole treatment, and relapse of molar distalization might happen during premolar distalization and anterior tooth retraction.

To reinforce anchorage, a sequential distalization protocol, Class II elastics and miniscrews are often used clinically in clear aligner treatment.[6,7] However, Li et al. reported first-molar distalization of no more than 1 mm after whole maxillary arch distalization treatment, and the efficiency of first molar distalization was only 36.5% even with Class II elastics or miniscrews.[6] Other studies also reported that distalization of the posterior teeth did not occur as estimated in virtual planning, with or without elastics.[8,9]

Overall, recent clinical studies indicated that clear aligners were not highly efficient in whole maxillary arch distalization. However, a finite element study supported that anchorage loss during molar distalization could be alleviated by elastics from miniscrews to clear aligners.[10] Maxillary total arch distalization using temporary skeletal anchorage devices was also regarded as an effective and stable treatment procedure in fixed orthodontics.[11] Therefore, this retrospective study aimed to investigate whether intramaxillary miniscrews provided better anchorage control than traditional Class II elastics in whole maxillary arch distalization with clear aligner treatment.

MATERIALS AND METHODS

The sample comprised patients who started orthodontic treatment from July 2017 to March 2021 at two centers (Department of Orthodontics, the Affiliated Stomatological Hospital, Jiangxi Medical College, Nanchang University and Second Clinical Division, Peking University School and Hospital of Stomatology). The protocol for this retrospective study was approved by the institutional review boards of the two hospitals (No. 2022065). Inclusion criteria were (1) Angle Class II molar relationship, (2) a treatment plan of whole maxillary arch distalization via sequential distalization by which each tooth was distalized about one-half of its total amount before the next tooth to the mesial was retracted, until the retraction of the upper anterior segment was completed en masse using Invisalign with molar distalization > 2.0 mm and incisor retraction > 0 mm, (3) congenitally missing, or extraction of, maxillary third molars before treatment, (4) use of intermaxillary Class II elastics or intramaxillary miniscrews for anchorage control, (5) completion of the first series of aligners without midcourse correction, (6) no combined treatment with fixed or other auxiliary appliances, and (7) complete pretreatment and posttreatment cone-beam computed tomography (CBCT) images and digital dental models. Throughout this study, posttreatment refers to after treatment with the first aligner series.

Thirty patients were finally included and divided into two groups: the miniscrew group and the Class II elastic group. The miniscrew group comprised 17 patients (two males, 15 females; age 26.7 ± 5.2 years) and the Class II elastic group comprised 13 patients (two males, 11 females; age 30.4 ± 9.3 years). All patients changed aligners every 1 to 2 weeks and were instructed to wear each aligner and elastics for 22 hour per day. In the Class II elastic group, the elastics were hooked from the mandibular first molar to the precision cut at the maxillary canine from step 1 onward (Figure 1A). In the miniscrew group, miniscrews were inserted buccally, mesial to the second molar when the first molar started distalization, and the miniscrews were used for anchorage in three patterns: fixed ligation pattern (fixed ligation to the canine during posterior tooth distalization and to the first molar during anterior tooth retraction), elastic pattern (elastics to the precision cut at the canine), or a mixed pattern (fixed ligation followed by elastics) (Figure 1B,C). The elastic force was100 to 170 g in both groups. The average treatment duration was 20.9 months in the miniscrew group and 22.2 months in the Class II elastic group.

To compare the effect of whole maxillary arch distalization between the groups, predicted and achieved tooth movements were measured in three steps.

Step 1: CBCT images were taken using a CBCT scanner (Kavo Dental GmbH, Biberach, Germany) with the following settings: 16×19 cm field of view, 120 kV tube voltage, 5 mA tube current, and 0.25 mm pixel size; or another scanner (DCT Pro; Vatech Co, Yongin-Si, South Korea) with the following settings: a 20×19 cm or 16×19 cm field of view, 90 kV tube voltage, 7 mA tube current, and 0.3 mm pixel size). The images were imported into Mimics software (version 10.01; Materialise, Leuven, Belgium) to generate the craniofacial models. Maxillary registrations of pretreatment and posttreatment craniofacial models were conducted using Rapidform 2006 (Inus Technology, Seoul, South Korea). The registration details have been described in a previous study.[12]

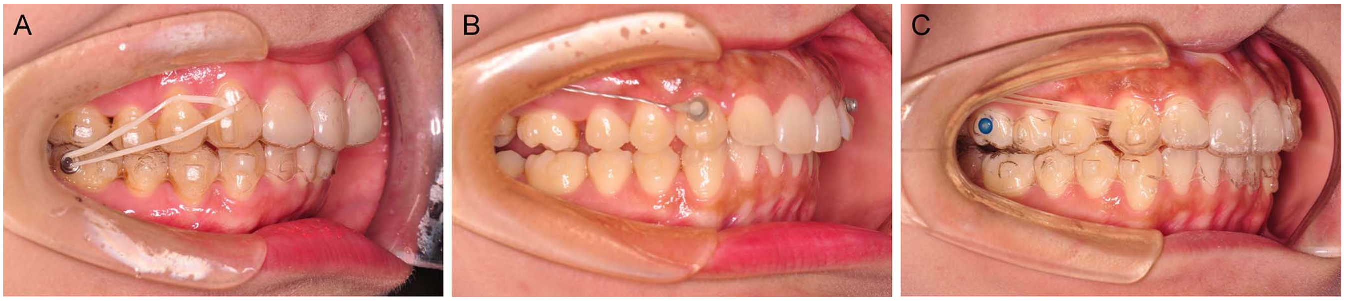

Figure 1. Anchorage control in maxillary arch distalization using Invisalign. (A) Intermaxillary elastics in the Class II elastic group. (B) Intramaxillary fixed ligation in the miniscrew group. (C) Intramaxillary elastics in the miniscrew group.

Step 2: Pretreatment and predicted posttreatment digital dental models, corresponding to the initial and last step models of the first ClinCheck plan, respectively, were exported from ClinCheck Pro software (Align Technology Inc., Tempe, AZ, USA). The actual posttreatment digital dental model was derived from the initial step model of the second ClinCheck plan (the next refinement strategy). Using Rapidform software, pretreatment and actual posttreatment dental models were superimposed with the corresponding pretreatment and posttreatment craniofacial models, respectively. Ultimately, the three dental models were superimposed in the same coordinate system (Figure 2A).

Step 3: The coordinate system was generated based on the pretreatment craniofacial and dental models. Cusps of bilateral maxillary first molars, second premolars, and first premolars were used to fit the mutual transverse plane. The points of nasion, anterior nasal spine, and pogonion were used to fit the initial sagittal plane. The intersection line of the two planes was set as the *X* axis, indicating the anteroposterior direction. The normal plane of the *X* axis intersected with the transverse plane, which generated the *Y* axis, indicating the medial-lateral direction. Accordingly, the *Z* axis indicated the occlusal-gingival direction (Figure 2B). Thereafter, the maxillary second molar, first molar, second premolar, canine, and central incisor were selected for evaluation (Figure 2C). Tooth crown movements were measured as three-dimensional displacements and angular (angulation, inclination, and rotation) changes after treatment, according to the method described previously.[12]

Statistical Analysis

Data were analyzed using SPSS Statistics for Windows (version 21.0; IBM Corp., Armonk, NY, USA). Bilateral measurements were pooled together to obtain a doubled sample. The predicted and achieved crown movements were compared within each group. If the data presented a normal distribution, a paired *t*-test was used; if the data were not normally distributed, a Wilcoxon signed-rank test was used. The predicted crown movement, the difference between predicted and achieved crown movement, and the efficiency of distalization were compared between the groups using an independent *t*-test or Mann–Whitney *U*-test. A P value $< .05$ was considered statistically significant.

RESULTS

The predicted tooth crown movements are shown in Table 1. Before treatment, both groups had similar predicted posterior tooth distalization, anterior tooth retraction, and buccal expansion; however, the miniscrew group showed slightly more intrusion in the central incisor and more extrusion in the premolar and

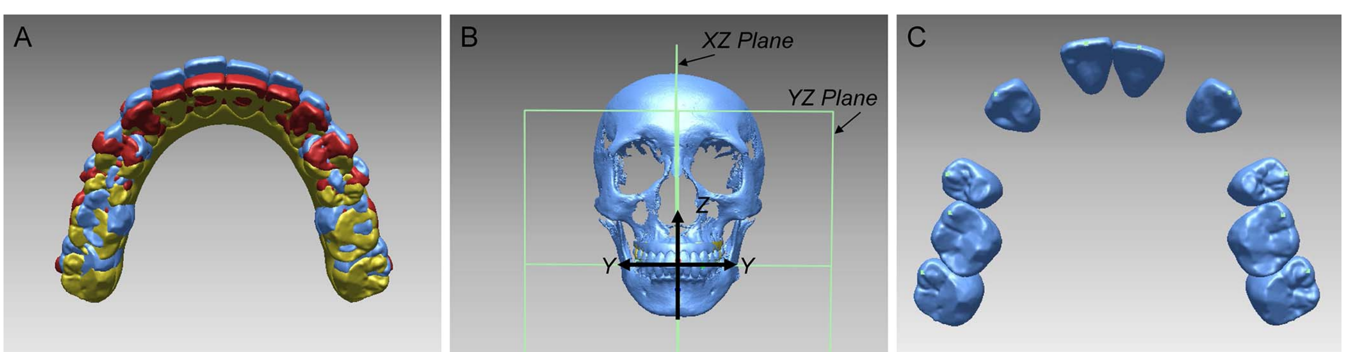

Figure 2. Tooth movement measurements. (A) Registration of pre- (blue), predicted post-treatment (yellow), and actual post-treatment (red) models. (B) The coordinate system. (C) The teeth and landmarks for displacement measurements.

Table 1. Comparison of Predicted Tooth Displacements and Angular Changes Between the Miniscrew Group and the Class II Elastic Group[a–g]

	Miniscrew Group					
	X	*Y*	*Z*	In	An	Ro
U1	3.12 ± 2.16	0.04 ± 0.98	0.61 ± 1.35	3.18 ± 7.35	2.22 ± 4.43	−5.44 ± 8.28
U3	3.40 ± 1.54	1.20 ± 1.15	0.00 ± 1.53	3.22 ± 7.45	−4.92 ± 7.35	4.81 ± 13.85
U5	3.35 ± 0.92	1.23 ± 1.01	−0.49 ± 0.70	−1.21 ± 6.77	−4.08 ± 5.09	−2.04 ± 5.86
U6	3.34 ± 0.91	1.25 ± 0.82	−0.30 ± 0.49	−1.42 ± 7.41	−3.00 ± 3.93	−2.41 ± 4.25
U7	3.66 ± 0.88	0.13 ± 0.89	−0.22 ± 0.69	−3.44 ± 5.90	−0.39 ± 7.06	−0.64 ± 6.68

[a] U1∼U7 indicates maxillary central incisor to second molar.

[b] X indicates anteroposterior direction; +, distalization of posterior teeth or retraction of anterior teeth; −, mesialization of posterior teeth or protrusion of anterior teeth.

[c] Y indicates medial-lateral direction; +, buccal movement of posterior teeth and canines or distal movement of incisors; −, lingual movement of posterior teeth and canines or mesial movement of incisors.

[d] Z indicates occlusal-gingival direction; +, intrusion of teeth; −, extrusion of teeth.

[e] In indicates inclination; +, buccal inclination; −, lingual inclination.

[f] An indicates angulation; +, mesial tipping; −, distal tipping.

[g] Ro indicates rotation; +, mesial-lingual rotation; −, mesial-buccal rotation.

*Independent *t*-test or Mann–Whitney *U*-test, significant at $P < .05$.

first molar compared to the Class II elastic group. In addition, predicted inclination, angulation, and rotation changes were also not statistically different between the groups, except for the angulation changes of the canines.

Table 2 shows the difference between predicted and achieved crown movement of the miniscrew group. Table 3 shows the difference between predicted and achieved crown movement of the Class II elastic group. In both groups, the achieved distalization of posterior teeth and retraction of anterior teeth were significantly smaller than the predicted amount. The central incisors were predicted to intrude but, actually extruded, while the molars were predicted to extrude but, actually intruded. The anterior teeth were predicted to incline buccally but, actually inclined lingually, while the posterior teeth were predicted to incline lingually but, actually inclined buccally. The posterior teeth tipped distally, as predicted, in the miniscrew group, while they tipped more distally than predicted in the Class II elastic group. Both groups showed a statistically significant difference between predicted and achieved crown movement in rotation of the central incisor and second premolar.

Table 4 shows comparison of differences between predicted and achieved crown movement between the miniscrew group and the Class II elastic group. The miniscrew group showed less extrusion of the anterior teeth, less intrusion of the second molar, but slightly more intrusion of the second premolar and first molar, compared with those in the Class II elastic group. No differences were found between the groups for difference between predicted and achieved crown movement in the anterior-posterior and medio-lateral displacements. The canines and posterior teeth showed more distal tipping in the Class II elastic group than in the miniscrew group. No

Table 2. Comparison of Predicted and Achieved Tooth Displacements and Angular Changes in the Miniscrew Group[a–g]

	Predicted Movement					
	X	*Y*	*Z*	In	An	Ro
U1	3.12 ± 2.16	0.04 ± 0.98	0.61 ± 1.35	3.18 ± 7.35	2.22 ± 4.42	−5.44 ± 8.28
U3	3.40 ± 1.54	1.20 ± 1.15	0.00 ± 1.53	3.22 ± 7.45	−4.92 ± 7.35	4.81 ± 13.8
U5	3.35 ± 0.92	1.23 ± 1.01	−0.49 ± 0.70	−1.21 ± 6.77	−4.08 ± 5.09	−2.04 ± 5.86
U6	3.34 ± 0.91	1.25 ± 0.82	−0.30 ± 0.49	−1.42 ± 7.41	−3.00 ± 3.93	−2.41 ± 4.25
U7	3.66 ± 0.88	0.13 ± 0.89	−0.22 ± 0.69	−3.44 ± 5.90	−0.39 ± 7.06	−0.64 ± 6.68

[a] U1∼U7 indicates maxillary central incisor to second molar.

[b] X indicates anteroposterior direction; +, distalization of posterior teeth or retraction of anterior teeth; −, mesialization of posterior teeth or protrusion of anterior teeth.

[c] Y indicates medial-lateral direction; +, buccal movement of posterior teeth and canines or distal movement of incisors; −, lingual movement of posterior teeth and canines or mesial movement of incisors.

[d] Z indicates occlusal-gingival direction; +, intrusion of teeth; −, extrusion of teeth.

[e] In indicates inclination; +, buccal inclination; −, lingual inclination.

[f] An indicates angulation; +, mesial tipping; −, distal tipping.

[g] Ro indicates rotation; +, mesial-lingual rotation; −, mesial-buccal rotation.

* Paired *t*-test or Wilcoxon signed-rank test, significant at $P < .05$.

Table 1. Extended

Class II Elastic Group						P Value*					
X	*Y*	*Z*	In	An	Ro	*X*	*Y*	*Z*	In	An	Ro
4.03 ± 1.40	0.14 ± 1.07	0.42 ± 1.44	1.26 ± 7.63	1.93 ± 6.79	−6.01 ± 10.69	0.052	0.730	0.007	0.330	0.521	0.821
2.79 ± 1.14	1.10 ± 1.25	0.12 ± 0.93	2.27 ± 6.49	1.75 ± 5.30	−2.51 ± 12.28	0.170	0.698	0.263	0.438	<0.001	0.124
3.13 ± 0.77	1.06 ± 2.24	−0.32 ± 0.71	−1.64 ± 6.41	−4.06 ± 4.81	−0.74 ± 8.71	0.307	0.602	<0.001	0.395	0.987	1.000
3.36 ± 0.79	1.36 ± 0.76	−0.16 ± 0.47	−0.28 ± 5.11	−2.68 ± 3.92	−3.83 ± 5.70	0.924	0.582	<0.001	0.964	0.835	0.347
3.53 ± 0.74	0.41 ± 0.81	−0.05 ± 0.63	−2.91 ± 4.85	−1.56 ± 4.11	−1.98 ± 4.33	0.553	0.318	0.120	0.303	0.263	0.353

differences were found between the groups for difference between predicted and achieved crown movement in the inclination and rotation changes.

The efficiency of maxillary arch distalization is calculated as the ratio of achieved/predicted amount of posterior tooth distalization or anterior tooth retraction. The ratio for posterior tooth distalization was 36.2%–43.9%. The ratio for anterior tooth retraction was 36.9%–49.4%. No statistically significant differences were found between the groups.

DISSCUSSION

Anchorage control is important in total arch distalization. The differential force concept has been used to preserve anchorage during the sequential distalization strategy in clear aligner treatment but, even so, the anchorage teeth were not absolutely stable. After molar distalization, the incisors showed flaring.[5] The later stage of anterior tooth retraction after posterior tooth distalization is similar to that in premolar extraction treatment, in which posterior anchorage loss commonly occurs.[12,13]

Class II elastics and miniscrews are commonly used to reinforce maxillary anchorage.[6,7] In the current study, the net efficiency of molar distalization after total maxillary arch distalization was only 36.2% at the first molar and 42.6% at the second molar in the miniscrew group, and 41.7% at the first molar and 43.9% at the second molar in the Class II elastic group. The results were comparable to those reported by Li et al. with the Class II elastic cases and miniscrew cases pooled together.[6] This indicated that it was hard to achieve the predicted distalization with high efficiency, even with the aid of auxiliary anchorage devices.

Table 2. Extended

Achieved Movement						P Value*					
X	*Y*	*Z*	In	An	Ro	*X*	*Y*	*Z*	In	An	Ro
1.20 ± 2.21	−0.01 ± 0.92	−0.52 ± 1.12	−4.52 ± 8.01	0.76 ± 4.50	−3.02 ± 6.00	<0.001	0.616	<0.001	<0.001	0.003	0.005
1.37 ± 1.77	0.90 ± 1.23	0.02 ± 1.39	1.57 ± 7.36	−6.21 ± 6.21	4.92 ± 11.12	<0.001	0.006	0.893	0.038	0.069	0.222
1.24 ± 1.11	1.10 ± 1.03	0.23 ± 0.58	0.70 ± 4.22	−3.91 ± 4.19	−0.08 ± 6.14	<0.001	0.232	<0.001	0.007	0.725	<0.001
1.21 ± 1.15	1.23 ± 1.04	0.51 ± 0.71	2.00 ± 7.38	−1.85 ± 5.12	−1.92 ± 3.74	<0.001	0.626	< .001	<0.001	0.007	0.130
1.56 ± 1.21	0.25 ± 1.03	0.26 ± 0.67	−0.31 ± 5.43	−0.26 ± 6.30	−0.35 ± 5.56	<0.001	0.164	<0.001	<0.001	0.799	0.407

Table 3. Comparison of Predicted and Achieved Tooth Displacements and Angular Changes in the Class II Elastic Group[a–g]

	Predicted Movement					
	X	*Y*	*Z*	In	An	Ro
U1	4.03 ± 1.40	0.14 ± 1.07	0.42 ± 1.44	1.26 ± 7.63	1.93 ± 6.79	−6.01 ± 10.69
U3	2.79 ± 1.14	1.10 ± 1.25	0.12 ± 0.93	2.27 ± 6.49	1.75 ± 5.30	−2.51 ± 12.28
U5	3.13 ± 0.77	1.06 ± 2.24	−0.32 ± 0.71	−1.64 ± 6.41	−4.06 ± 4.81	−0.74 ± 8.71
U6	3.36 ± 0.79	1.36 ± 0.76	−0.16 ± 0.47	−0.28 ± 5.11	−2.68 ± 3.92	−3.83 ± 5.70
U7	3.53 ± 0.74	0.41 ± 0.81	−0.05 ± 0.63	−2.91 ± 4.85	−1.56 ± 4.11	−1.98 ± 4.33

[a] U1∼U7 indicates maxillary central incisor to second molar.
[b] X indicates anteroposterior direction; +, distalization of posterior teeth or retraction of anterior teeth; −, mesialization of posterior teeth or protrusion of anterior teeth.
[c] Y indicates medial-lateral direction; +, buccal movement of posterior teeth and canines or distal movement of incisors; −, lingual movement of posterior teeth and canines or mesial movement of incisors.
[d] Z indicates occlusal-gingival direction; +, intrusion of teeth; −, extrusion of teeth.
[e] In indicates inclination; +, buccal inclination; −, lingual inclination.
[f] An indicates angulation; +, mesial tipping; −, distal tipping.
[g] Ro indicates rotation; +, mesial-lingual rotation; −, mesial-buccal rotation.
*Paired *t* test or Wilcoxon signed-rank test, significant at $P < .05$.

Interestingly, miniscrews provided better maxillary distalization than Class II elastics in fixed bracket treatment,[11,14] but not in clear aligner treatment according to the current results. This finding could be explained by the fact that, in clear aligner treatment, miniscrews reinforce anchorage in different patterns from those in fixed treatment. In this study, elastics were hooked from the miniscrews to the aligners, which provided force relying on patient compliance, similar to Class II elastics; and, in the fixed ligation pattern, the point-to-point ligation can hardly fix the anchorage tooth completely. However, power-chain or nickel-titanium springs were used from miniscrews to the arch wire for 24 hours in fixed treatment, which provided more constant and persistent force. Additionally, the teeth only experienced distal force from miniscrew traction in fixed treatment, while they experienced both distal force from miniscrew anchorage and mesial force from the aligners at the anchorage teeth stage in clear aligner treatment.[15] Hence, miniscrew-aided maxillary arch distalization did not perform as well in clear aligner treatment as in fixed treatment. Though not statistically significant, distalization efficiency at the first molar in the miniscrew group was slightly lower than that in the Class II elastic group, which might be explained by the fact that the inter-radicular miniscrew had a risk of blocking root movement during distalization because of the limited space available and this was not discovered in time.[11] In addition, the fixed ligation pattern might generate different efficiency in arch distalization than the elastic pattern in the miniscrew group.

Vertically, both groups showed actual intrusion of posterior teeth, despite predicted extrusion, and actual extrusion of incisors, despite predicted intrusion. Maxillary molar intrusion after total arch distalization was also found in

Table 4. Comparison of DPACMs for Displacement and Angular Changes Between the Miniscrew Group and the Class II Elastic Group

	Miniscrew Group					
	X	*Y*	*Z*	In	An	Ro
U1	−1.92 ± 0.88	−0.06 ± 0.64	−1.13 ± 1.61	−7.70 ± 6.81	−1.46 ± 2.65	2.42 ± 7.44
U3	−2.02 ± 0.99	−0.30 ± 0.60	0.02 ± 0.90	−1.65 ± 4.44	−1.29 ± 4.01	0.11 ± 5.35
U5	−2.12 ± 0.97	−0.14 ± 0.66	0.72 ± 0.63	1.91 ± 5.19	0.17 ± 2.79	1.96 ± 2.41
U6	−2.13 ± 1.03	−0.01 ± 0.72	0.80 ± 0.59	3.42 ± 3.69	1.15 ± 3.92	0.50 ± 1.86
U7	−2.10 ± 1.05	0.12 ± 0.82	0.48 ± 0.65	3.13 ± 4.63	0.14 ± 3.08	0.13 ± 2.01

[a] DPACMs indicates differences between predicted and achieved crown movements (achieved − predicted).
[b] U1∼U7 indicates maxillary central incisor to second molar.
[c] X indicates anteroposterior direction; +, distalization of posterior teeth or retraction of anterior teeth; −, mesialization of posterior teeth or protrusion of anterior teeth.
[d] Y indicates medial-lateral direction; +, buccal movement of posterior teeth and canines or distal movement of incisors; −, lingual movement of posterior teeth and canines or mesial movement of incisors.
[e] Z indicates occlusal-gingival direction; +, intrusion of teeth; −, extrusion of teeth.
[f] In indicates inclination; +, buccal inclination; −, lingual inclination.
[g] An indicates angulation; +, mesial tipping; −, distal tipping.
[h] Ro indicates rotation; +, mesial-lingual rotation; −, mesial-buccal rotation.
*Independent *t*-test or Mann–Whitney *U*-test, significant at $P < .05$.

Table 3. Extended

Achieved Movement						*P* Value*					
X	*Y*	*Z*	In	An	Ro	*X*	*Y*	*Z*	In	An	Ro
1.99 ± 1.59	0.05 ± 0.91	−1.63 ± 1.04	−7.44 ± 6.91	1.13 ± 7.11	−4.73 ± 8.53	<0.001	0.405	<0.001	<0.001	0.059	0.036
1.03 ± 1.09	0.90 ± 0.94	−0.72 ± 0.72	−1.12 ± 6.11	−3.06 ± 4.07	−1.66 ± 9.04	<0.001	0.064	<0.001	<0.001	<0.001	0.732
1.23 ± 0.88	1.02 ± 1.99	−0.01 ± 0.99	0.45 ± 7.79	−5.98 ± 4.46	0.52 ± 8.46	<0.001	0.702	0.015	<0.001	0.015	0.002
1.40 ± 0.86	1.40 ± 0.85	0.48 ± 0.59	2.19 ± 3.23	−4.10 ± 2.53	−3.36 ± 5.11	<0.001	0.726	<0.001	0.003	0.046	0.238
1.55 ± 0.83	0.53 ± 0.86	0.85 ± 0.74	0.32 ± 4.00	−2.87 ± 3.20	−1.99 ± 4.00	<0.001	0.437	<0.001	<0.001	0.091	0.962

other studies,[6,16] which was explained by the thickness of the aligner and the resulting "bite block" effect. The extrusion of incisors that accompanied retraction was similar to that during premolar extraction treatment, which could be explained by the loss of incisor torque control and a bowing effect.[11,12]

However, vertical differences were observed between the groups. The miniscrew generated distal and intrusive forces which were close to the center of resistance of the maxillary arch, whereas the Class II elastics generated distal and extrusive forces, which were away from the center of resistance. Therefore, the elastics resulted in more clockwise moment[14] and, thus, more extrusion and lingual inclination of anterior teeth. These results were not in agreement with the study of Rongo and colleagues, which showed adequate control of upper incisor inclination.[17] The difference might have been due to the different samples in each study. Tooth movements were evaluated at the end of the first set of aligners in the present study, whereas they were assessed at the end of whole treatment in the previous study. This may indicate that inadequate control of the upper incisors during the first series of aligners could be corrected in the following refinements. The miniscrew group had a slightly greater difference between predicted and achieved crown movement for first molar intrusion because the miniscrew itself had a molar intrusive effect in arch distalization.[11] In addition, greater difference between predicted and achieved crown movement in the distal tipping of the posterior teeth and canine were observed in the Class II elastic group, which could also be explained by the greater clockwise moment.[14]

In the transverse dimension, both groups showed expected arch width increases but unexpected buccal

Table 4. Extended

Class II Elastic Group						*P* Value*					
X	*Y*	*Z*	In	An	Ro	*X*	*Y*	*Z*	In	An	Ro
−2.05 ± 0.92	−0.09 ± 0.51	−2.05 ± 1.03	−8.69 ± 4.02	−0.80 ± 2.07	1.28 ± 2.95	0.588	0.788	<0.001	0.484	0.282	0.676
−1.76 ± 0.83	−0.20 ± 0.53	−0.84 ± 0.92	−3.38 ± 3.48	−4.80 ± 3.78	0.85 ± 3.98	0.267	0.506	0.001	0.095	<0.001	0.654
−1.89 ± 0.91	−0.04 ± 0.50	0.31 ± 0.59	2.09 ± 3.34	−1.92 ± 3.75	1.26 ± 1.82	0.368	0.524	<0.001	0.754	0.022	0.205
−1.96 ± 0.92	0.04 ± 0.57	0.64 ± 0.58	2.47 ± 3.85	−1.43 ± 3.93	0.47 ± 1.75	0.507	0.964	<0.001	0.165	0.001	0.623
−1.98 ± 0.91	0.12 ± 0.79	0.91 ± 0.77	3.23 ± 3.12	−1.31 ± 3.70	−0.02 ± 1.92	0.634	0.581	<0.001	0.551	0.156	0.548

inclination of the posterior teeth. This indicated a certain difficulty in arch expansion in terms of bodily buccal tooth movement. Generally, molar crown buccal inclination is a common phenomenon, not only accompanied by arch expansion in total arch distalization cases,[6] but also by arch constriction in premolar extraction cases.[12] The factors causing unintended buccal crown inclination has been previously discussed in detail.[18]

Besides the type of auxiliary anchorage (intramaxillary miniscrews or intermaxillary elastics), many other factors, such as the type of elastic auxiliary,[9] the elastic traction force,[19] the need for anterior tooth retraction,[6] and the posterior alveolar bone space available,[20] also influence the effect of arch distalization. In the present study, consistent inclusion of anterior tooth retraction cases and examination of posterior available space were performed in both groups; however, three different miniscrew patterns were used in the miniscrew group and the elastic forces were 100 to 170 g in both groups.

This study focused on the efficiency of maxillary tooth movement after maxillary arch distalization. The mandibular tooth movement and potential mandibular repositioning were not explored. As well as distalization of the maxillary arch, Class II elastics could result in mesial movement of mandibular molars,[19] which would further improve the Class II molar relationship. However, no significant changes were found in the mandibular molar position and condylar position.[4] Therefore, whether there are differences in the improvement of molar relationship between the groups requires further investigation.

CONCLUSIONS

- The efficiency of posterior tooth distalization is approximately 36.2%–43.9% after completion of whole arch maxillary distalization with clear aligners.
- Intramaxillary miniscrews and intermaxillary Class II elastics achieved comparable effects in terms of maxillary arch distalization efficiency.
- However, the miniscrews showed better vertical control of anterior teeth and tipping control of posterior teeth.

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