Controlled Molar Inclination during Maxillary Dental Expansion Using a Straight Rectangular Archwire

Chanchai Pattanaviriyapisan, Chairat Charoemratrote, Udom Thongudomporn

Department of Preventive Dentistry, Faculty of Dentistry, Orthodontic Section, Prince of Songkla University, Hat Yai, Songkhla, Thailand

Abstract

Purpose: The purpose of this study was to examine whether the amount of transversal dental expansion, controlled using a straight rectangular beta-titanium alloy (TMA®) wire, has an influence on changes in maxillary first molar inclination. **Materials and Methods:** Twenty patients requiring bilateral maxillary dental arch expansion were treated using a 0.018"-slot preadjusted edge-wise fixed appliance. Once leveled and aligned, the maxillary dental arches were expanded using a 0.016" × 0.022" straight TMA® wire. Changes in arch width and maxillary first molar inclination were assessed before (T0) and after (T1) expansion using three-dimensional scanned models. Mann–Whitney *U*-test, Wilcoxon signed-rank test, and Kruskal–Wallis test were used, where appropriate, to compare changes between and within groups. **Results:** Intermolar width expanded at a rate of 0.8 ± 0.3 mm/month, and first molar buccal crown tipping occurred at 2.1° ± 1.2° ($P < 0.05$). Changes in inclination between minor expansion (1.0–2.5 mm) and moderate expansion (2.6–4.0 mm) groups were not statistically significant (1.8 ± 0.5 vs. 2.2 ± 1.2; $P > 0.05$). **Conclusions:** Use of a straight rectangular TMA® wire in conjunction with a fixed orthodontic appliance successfully expanded the maxillary dental arch. The amount of expansion had no effect on molar inclination.

Keywords: *Molar inclination, slow maxillary expansion, straight rectangular archwire*

Introduction

In adult patients, in whom growth has ceased, maxillary dental expansion is commonly used to correct mild or moderate transverse maxillary deficiencies.[1,2] Appliances such as the quad helix, nickel-titanium (Ni-Ti) palatal expander, overexpanded archwire, and removable plates with expansion screws are typical treatment modalities.[3,4] However, a common side effect of dental expansion is uncontrolled buccal crown tipping, which generates high stress on the buccal alveolar bone crest and palatal root apex of the posterior maxillary teeth.[1] Periodontal problems, such as buccal dehiscence on the maxillary posterior teeth, have also been reported after expansion.[4,5] Moreover, palatal cusp extrusion may cause increased posterior vertical dimension of occlusion, bite opening in the anterior region, mandibular posterior rotation, and worsening of the facial profile.[4] According to a study that assessed the Ni-Ti palatal expander, approximately 8° of maxillary first molar tipping and 1.4° increase in SN-MP occurred in participants.[6]

The use of a rectangular overexpanded stainless steel archwire has been suggested as a way to prevent buccal crown tipping.[3] When inserted into the brackets, the rectangular shape of the wire produces a moment around the teeth. This counteracts the tipping effect induced by the expansion force, leading to reduced buccal tipping of the posterior teeth.[3] However, stainless steel wire is characterized by a high load deflection rate and stiffness, which may cause a large increase in force, even if a small amount of deactivation occurs.[7] Attempts to use a lighter magnitude of force have been made. A recent case report demonstrated the successful application of a straight 0.032" round beta-titanium alloy wire overlaid on a 0.016" × 0.022" Ni-Ti archwire to simultaneously align and expand the dental arch.[8] However, the magnitude of the expansion force was not quantified.

We chose to use rectangular beta-titanium alloy (TMA®) wire as an alternative to stainless steel wire, as TMA® wire has a lower load deflection rate and stiffness.[7] Based on pilot laboratory tests on ten pretreatment maxillary models

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Address for correspondence:
Assoc. Prof. Udom Thongudomporn, Department of Preventive Dentistry, Faculty of Dentistry, Orthodontic Section, Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand.
E-mail: udom2t@gmail.com

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requiring dental maxillary expansion (intermolar width of 43–47 mm), straight 0.016” × 0.022” TMA® wires were bent into an arch. These were found to produce 126 ± 27 cN of expansion force and successfully promoted dental expansion in our pilot clinical test. From these results, we postulated that, with the torque control effect of the rectangular wire, molar inclination should be controlled regardless of the amount of expansion.

The main objective of this study was to examine whether the amount of expansion has an effect on the change in molar inclination when a straight rectangular wire is used to expand the maxillary dental arch. Our null hypothesis was that the straight rectangular wire would have no effect on the ability to control molar inclination during maxillary dental expansion.

Materials and Methods

Subjects

This prospective clinical trial was approved by the Ethical Committee (approval no. EC 5803-13-P-HR) of the Faculty of Dentistry, Prince of Songkla University. The sample size was calculated using statistical software (PS-Power and Sample Size Calculation Properties program, PS, version 3.1.2, 2014, Vanderbilt University, Nashville, TN, USA)[9] based on a previous study (mean difference of 2.8 mm, difference in standard deviation (SD) of 4.2 mm, significance level of 0.05, and power of 0.80).[10] From these calculations, we determined that a sample size of twenty participants would be required for this study.

Twenty participants requiring bilateral maxillary dental expansion, who met the inclusion criteria of normal facial height, no posterior crossbite, no missing maxillary teeth, and healthy periodontal health, were recruited for this study. The exclusion criteria were the presence of progressive gingival recession, poor cooperation of the participants, and individuals who did not require expansion of the maxillary arch as the arch width had been corrected during the leveling stage. Participants were classified into two groups based on the amount of expansion as follows: minor expansion group (1.0–2.5 mm) and moderate expansion group (2.6–4.0 mm).

Study protocol

At the leveling and aligning stage, the maxillary teeth were bonded with 0.018” ×0.025” slot preadjusted edge-wise brackets from the left to right second premolars (Roth system, Master Series™, American Orthodontics®, Sheboygan, WI, USA), and molar buccal tubes (nonconvertible, LP™, American Orthodontics®, Sheboygan, WI, USA) were bonded to the left and right maxillary first molars. After bonding, series of 0.012” Ni-Ti, 0.014” Ni-Ti, and 0.016” × 0.016” Ni-Ti were delivered to align the maxillary teeth. When the maxillary teeth were leveled and aligned (T0), an alginate impression (Alginoplast®, Heraeus, Hanau, Germany) of the maxillary teeth was obtained following the manufacturer’s instructions, and then poured within 1 h with dental stone (Atlas®, ULTIMA, Seiches-sur-le-Loir, France) to make the maxillary models. The maxillary dental arch was expanded using a straight 0.016” × 0.022” beta-titanium alloy wire (TMA®, Ormco™, Orange, CA, USA) [Figure 1]. The TMA® wire was attached to all brackets using ligature wires. At subsequent visits, which were scheduled every 3–4 weeks, the wire was removed, straightened, re-engaged in the brackets, and ligature ties were replaced. At each visit, the periodontal health of all maxillary teeth was assessed.

When the predetermined maxillary posterior arch width had been achieved (T1), alginate impressions were made to fabricate the maxillary models.

Model analysis

All reference models were digitized using an orthodontic three-dimensional scanner (R700 model, 3Shape; Ivoclar Vivadent, Inc., Copenhagen, Denmark). The second maxillary molars were cut off with Ortho Analyzer software (3Shape, Ivoclar Vivadent, Inc., Copenhagen, Denmark) [Figure 2]. The prepared digital models were used to measure the amount of expansion and molar inclination.

The amount of expansion was measured directly on the digital maxillary models. The following distances were measured: intercanine width (U3–U3) between the cusp tips of the right and left maxillary canines; first and second interpremolar widths (U4–U4 and U5–U5) between the central grooves of the right and left first and second premolars, respectively; and intermolar width (U6–U6) between the central fossae of the right and left maxillary first molars [Figure 3a]. The expansion rate was calculated as the amount of expansion (T1 – T0) divided by the expansion time (months).

The molar inclination was the angle between two lines drawn from the mesiobuccal cusp through the mesiopalatal cusp of the right and left maxillary first molars [Figure 3b].

All data were measured by the same investigator who was blinded to the participants’ identity and the sequence of materials being measured. All data for ten randomly selected participants were measured at two time points (4 weeks apart) to assess accuracy and reliability.

Statistical analysis

Measurement error was <0.5 and 0.5 mm for linear and angular variables, assessed using Dahlberg’s formula.[11] Reliability was evaluated using paired *t*-tests. No significant differences between the two sets of measurements were observed ($P > 0.05$), confirming that the measurements were reliable.

Shapiro–Wilk tests showed that all parameters were nonnormally distributed. Consequently, the Mann–

Whitney *U*-test, Wilcoxon matched-pairs signed-rank test, and Kruskal–Wallis one-way analysis of variance with a Dunn–Bonferroni *post hoc* test were used to compare changes between two groups, within groups, and between three groups, respectively. All calculations were performed using statistical software (SPSS, version 23; IBM, NY, USA) with a significance level of 0.05.

Results

Nine males and 11 females with a mean age ± SD of 19.5 ± 2.1 years were recruited into the study. There was no significant difference in arch width between males and females [Table 1]; therefore, the data for male and female participants were pooled.

All arch width parameters significantly increased between T0 and T1 ($P < 0.05$). In descending order, the amount of expansion and the rate of expansion were highest at U6–U6 (2.4 ± 0.8 mm and 0.8 ± 0.3 mm/month, respectively), U5–U5 (2.3 ± 1.0 mm and 0.7 ± 0.3 mm/month, respectively), U4–U4 (1.7 ± 0.8 mm and 0.5 ± 0.3 mm/month, respectively), followed by U3–U3 (0.8 ± 0.5 mm and 0.2 ± 0.1 mm/month, respectively) [Table 2].

There were no significant differences in age or initial molar inclination between participants in the minor and moderate expansion groups [$P > 0.05$; Table 3], although there was a statistical difference between groups for initial arch width ($P < 0.05$). For the change in molar inclination, there was no significant difference between groups ($P > 0.05$). The molar inclination change of all participants was 2.1° ± 1.2°.

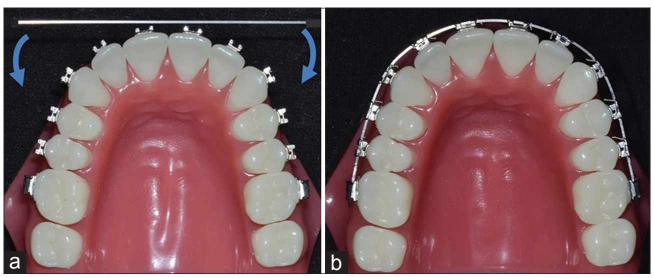

Figure 1: Dentoalveolar maxillary expansion with a straight rectangular TMA® wire. (a) The straight TMA® wire is inserted into brackets and buccal tubes on the right to left maxillary first molar. (b) Wire ligatures are used for attachment to all brackets

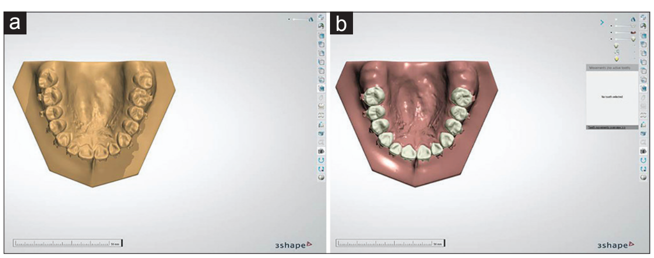

Figure 2: Three-dimensional digital maxillary model preparation using Ortho Analyzer software. (a) The original scanned model. (b) The digitized model with the second maxillary molars cut off

Discussion

This study showed that the use of a straight rectangular beta-titanium alloy wire, producing an estimated applied force of 126 ± 27 cN, can induce transverse expansion of the posterior teeth in adult patients while controlling molar inclination.

The use of a straight rectangular beta-titanium alloy wire in this study resulted in decreased buccal tipping of the first molars (overall change of 2.1° ± 1.2°) in comparison with other studies that employed Ni-Ti palatal expanders (3°–5°)[6] or quad helix appliances (6.1° ± 4.7°).[10] These differences may be due to the greater expansion required in other studies, variation in measurement methods, or the improved ability of our system to control molar inclination during expansion. We used a 0.016” × 0.022” wire in 0.018” slot brackets which allowed only 0.002” of play between the wire and bracket slot, thereby limiting the amount of buccal crown tipping of the first molars. Another possible reason for the reduced first molar buccal crown tipping observed in our study is that the moment of the expansion force from the straight rectangular wire may have been greater than the moment of the couple producing the palatal crown torque moment.

Table 1: Comparison of pretreatment arch width in male and female patients

Arch width (mm)	Males (*n*=9)	Females (*n*=11)	*P*†
U3-U3	35.2±1.6	35.1±2.3	0.85
U4-U4	35.9±2.2	36.3±2.4	0.32
U5-U5	40.8±2.6	40.7±3.3	0.68
U6-U6	45.6±3.1	45.0±4.2	0.76

†Mann-Whitney *U*-test

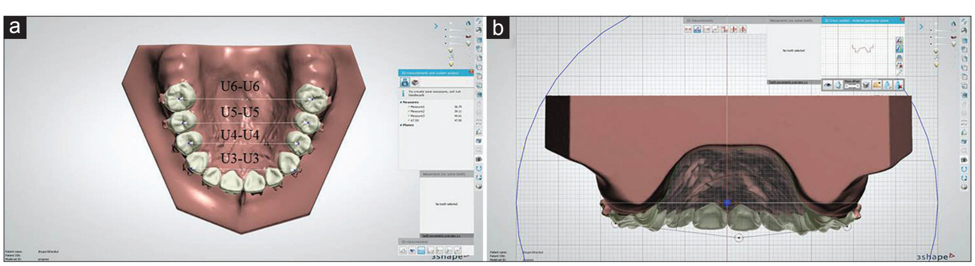

Figure 3: (a) Reference points used to determine the amount of expansion, intercanine width (U3–U3), first and second interpremolar widths (U4–U4 and U5–U5), and intermolar width (U6–U6). (b) Maxillary first molar inclination measurement

Table 2: Comparison of arch width expansion at each time point and rate of expansion

Variables	Arch width			Expansion (T1-T0) (mm)		Expansion rate (T1-T0/month) (mm/month)	
	Before expansion (T0) (mm), mean±SD	After expansion (T1) (mm), mean±SD	$P^{\dagger}$	Mean±SD	$P^{ǂ}$	Mean±SD	$P^{¥}$
U3-U3	35.2±1.8	36.1±1.7	0.03*	0.8±0.5[a]	0.00**	0.2±0.1[a]	0.00**
U4-U4	36.6±2.3	38.3±2.1	0.02*	1.7±0.8[b]		0.5±0.3[b]	
U5-U5	41.2±3.0	43.5±2.6	0.02*	2.3±1.0[c]		0.7±0.3[c]	
U6-U6	45.5±3.9	47.9±3.3	0.03*	2.4±0.8[c]		0.8±0.3[c]	

Different letters represent statistically significant differences (Kruskal-Wallis one-way ANOVA followed by Dunn-Bonferroni test). †Wilcoxon signed-rank test, ǂ,¥Kruskal-Wallis test, *P<0.05, **P<0.01. SD - Standard deviation

Table 3: Comparison of age, initial arch width, initial molar inclination, and molar inclination change among groups stratified with the amount of expansion

Variables	Amount of expansion group		$P^{\dagger}$
	Minor expansion (1.0-2.5 mm) (n=10)	Moderate expansion (2.6-4.0 mm) (n=10)	
Age (year)	18.9±2.7	19.2±3.1	0.85
Initial arch width (mm)	47.5±2.9	43.4±3.8	0.04*
Initial molar inclination (°)	165.9±2.8	167.5±2.7	0.54
Molar inclination change (°)	1.8±0.5	2.2±1.2	0.25

†Mann-Whitney U-test, *P<0.05

A previous study showed that molar tipping increases with the extent of molar expansion,[6,10] which suggests that the counter moment provided by other expanders is not sufficient to prevent tipping of the molars. The expansion method used in the current study appears to have created an adequate counter moment to limit molar tipping, so it did not exceed the clinically important range of intermolar width expansion of up to 4 mm.

This study used cusp tips as the reference points for measuring changes in molar inclination. Measurements performed using these landmarks can be affected by occlusal attrition. A prospective comparative study with other types of expanders and a larger sample size is required to confirm the efficacy, benefit, and cost-effectiveness of the straight wire technique employed in this study. In this study, the maxillary expansion technique using a straight 0.016” × 0.022” beta-titanium alloy wire successfully increased the maxillary arch width. As this technique increased the intermolar and intersecond premolar widths to a greater extent than the intercanine width, this method may be appropriate for the treatment of individuals with constriction of the maxilla in the intermolar area.

A limitation of this technique is that it may not be appropriate for patients with severe crowding, a posterior crossbite, or a tendency toward an anterior open bite. Another clinically important factor is that, although this technique appears to be effective, the appliance must be frequently monitored and not be left engaged for too long as there are no self-limiting or other safety features to prevent continued active forces and potential iatrogenic amounts of expansion if, for example, the patient misses appointments or withdraws.

Conclusions

The use of a 0.016” × 0.022” straight beta-titanium alloy wire engaged in a fixed orthodontic appliance was able to effectively expand the maxillary dental arch in this group of patients. The straight rectangular wire controlled molar inclination within the range of 1.0–4.0 mm.

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Conflicts of interest

There are no conflicts of interest.

References

1. Bishara SE, Staley RN. Maxillary expansion: Clinical implications. Am J Orthod Dentofacial Orthop 1987;91:3-14.
2. Proffit W. Contemporary Orthodontics. 5th ed. Mosby, St. Louis: Elsevier; 2013.
3. Gill D, Naini F, McNally M, Jones A. The management of transverse maxillary deficiency. Dent Update 2004;31:516-8, 521-3.
4. Agarwal A, Mathur R. Maxillary expansion. Int J Clin Pediatr Dent 2010;3:139-46.
5. Garib DG, Henriques JF, Janson G, de Freitas MR, Fernandes AY. Periodontal effects of rapid maxillary expansion with tooth-tissue-borne and tooth-borne expanders: A computed tomography evaluation. Am J Orthod Dentofacial Orthop 2006;129:749-58.
6. Karaman AI. The effects of nitanium maxillary expander appliances on dentofacial structures. Angle Orthod 2002;72:344-54.
7. Kusy RP, Whitley JQ. Thermal and mechanical characteristics of stainless steel, titanium-molybdenum, and nickel-titanium

archwires. Am J Orthod Dentofacial Orthop 2007;131:229-37.
8. Gurgel JA, Pinzan-Vercelino CR, Leon-Salazar V. Maxillary and mandibular dentoalveolar expansion with an auxiliary beta-titanium arch. Am J Orthod Dentofacial Orthop 2017;152:543-52.
9. Dupont WD, Plummer WD Jr. Power and sample size calculations. A review and computer program. Control Clin Trials 1990;11:116-28.
10. Huynh T, Kennedy DB, Joondeph DR, Bollen AM. Treatment response and stability of slow maxillary expansion using haas, hyrax, and quad-helix appliances: A retrospective study. Am J Orthod Dentofacial Orthop 2009;136:331-9.
11. Dahlberg G. Statistical methods for medical and biological students. Br Med J 1940;2:358-9.