Original Article

Effects of transpalatal arch wire dimension and temporary skeletal anchorage device position on maxillary molar intrusion

Xiaoting Wang[a]; Yichen Zhao[b]; Mingyue Fan[c]; Ting Zhou[d]; Bing Fang[e]; Niansong Ye[f]

ABSTRACT

Objectives: To investigate the effects of transpalatal (TPA) wire dimension and temporary skeletal anchorage device (TSAD) position on maxillary molar intrusion.

Materials and Methods: The maxillary molar intrusion measurement system included a maxillary acrylic model, TPA, TSADs, and a three-dimensional Force/Moment (F/M) sensor. The intrusion patterns were categorized into six groups: buccal-mesial, buccal-distal, buccal-mesiodistal, palatal-mesial, palatal-distal, and palatal-mesiodistal. TPA wire dimensions were designed to be 0.7 mm, 0.9 mm, and 1.2 mm. The force and moment loads of the maxillary first molar were measured by the F/M sensor.

Results: Single buccal or palatal TSADs induced torquing movement, and single mesial or distal TSADs tended to promote tipping movement. Mesiodistal TSADs would have eliminated tipping, but accentuated torquing movement. The TPA significantly reduced the force and moment experienced by the maxillary first molar along three-dimensional axes. The thicker the TPA wire, the smaller the force and moment to which the maxillary first molar was subjected.

Conclusions: Precise placement of TSADs might have a substantial influence on tooth movement and should be determined in accordance with specific clinical requirements. Increasing the TPA wire dimension could diminish the tipping, torquing, and rotation during TSAD-assisted maxillary molar intrusion, but these tendencies could not be completely eliminated. (*Angle Orthod*. 2024;94:408–413.)

KEY WORDS: Transpalatal arch; Molar intrusion; TSADs; F/M sensor

INTRODUCTION

The transpalatal arch (TPA) is a palatal device commonly used in orthodontic treatment for anchorage control, maintenance of arch width, and control of molar movement in three dimensions.[1] Among them, the role of the TPA in vertical control has gained increasing attention. Vertical deformities of the dentition, such as anterior open bite, characterized by the absence of occlusal contact between maxillary and mandibular anterior teeth, can adversely impact occlusal function and smile esthetics.[2] With increased use of temporary skeletal anchorage devices (TSADs), posterior tooth intrusion using TSADs has emerged as a promising and effective method to correct anterior open bite. However, the tendency for tipping or torquing, particularly in the absence of auxiliary orthodontic appliances, is a challenge during TSAD-assisted molar intrusion. Currently, the combined application of a TPA and TSADs is a conventional approach employed to mitigate this challenge in the orthodontic treatment of anterior open bite.[3] TSADs provide absolute anchorage for posterior intrusion, reduce posterior occlusal distance, cause a counterclockwise mandibular rotation, and improve overbite.[4] Simultaneously, the TPA plays a crucial role in restricting intermolar width, diminishing the buccal or lingual torque of posterior teeth during intrusion, and promoting intrusion efficiency.

The stiffness of TPA wire directly influences its control over the posterior teeth; however, a consensus on the

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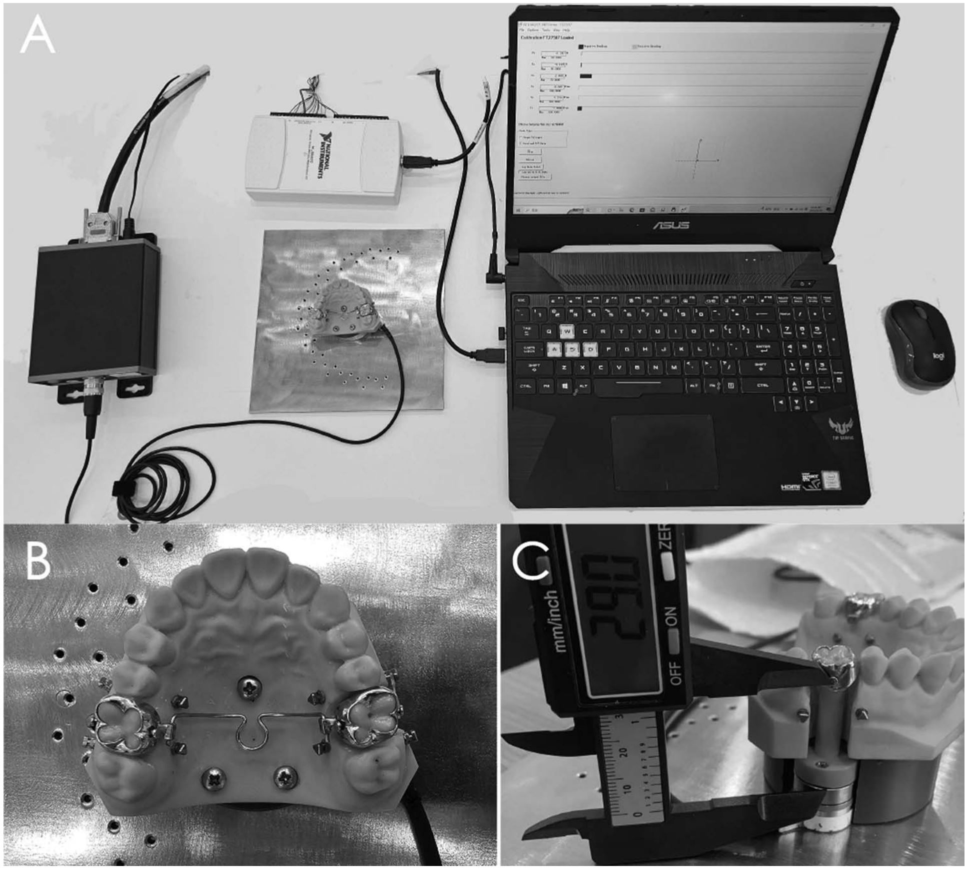

Figure 1. (A) Extra-oral measurement system for orthodontic force on the left maxillary first molar. (B) Maxillary acrylic model with TPA and TSADs. (C) Isolation from the model and connection of the left maxillary first molar to the F/M sensor; the sensor was located 29 mm in the negative direction of the z-axis to the center of the crown. TPA indicates transpalatal; TSAD, temporary skeletal anchorage device.

optimal TPA wire dimension remains elusive. Orthodontists and dental technicians often select the TPA wire dimension based on clinical preferences. Most clinical studies have used a TPA wire with a diameter of 1.2 mm for vertical control of the posterior teeth,[5,6] whereas other studies have preferred a TPA with 0.9 mm wire,[7–9] or other specific sizes.[10] Theoretically, a larger TPA wire should offer better rigidity for controlling the tipping or torquing of posterior teeth, but this assumption lacks substantiated research results.

The implant positions of TSADs vary based on the inter-root distance, maxillary sinus position, and orthodontic appliance type. Commonly used implant sites include the region between the maxillary second premolar and first molar, as well as between the maxillary first and second molars. For labial fixed appliances, TSADs are predominantly implanted buccally, whereas palatal implantation is more customary for lingual fixed appliances. The location of TSADs substantially influences the direction of the intrusive force and generates distinct tooth movement patterns. Consequently, the primary objective of this study was to investigate the influence of TPA wire dimension and TSAD position on maxillary molar intrusion.

MATERIALS AND METHODS

The principal components of the maxillary molar intrusion measurement system included a maxillary acrylic model, TPA, TSADs and a three-dimensional (3D) Force/Moment (F/M) sensor (Figure 1A). The simulated maxillary model was manufactured directly using 3D printing after the digital design. The TPA bands were made of 3D-printed stainless steel based on the tooth surface morphology of the maxillary first molars, featuring welded metal buttons on both the buccal and lingual surfaces. To simulate different TSAD positions encountered in clinical practice, TSADs (Ormco, VectorTAS, CA, USA, 8 $\times$ 1.4 mm) were securely screwed into the mesial and distal sites of the maxillary first molar on both the buccal and lingual sides (Figure 1B). An intrusion force was applied to the first molar by connecting the button of the TPA to the TSADs using elastic chain (3M Unitek, Monrovia, CA, C-1 Alastik, 406-612). Experimental measurements were conducted specifically on the left maxillary first molar. To avoid potential intertooth

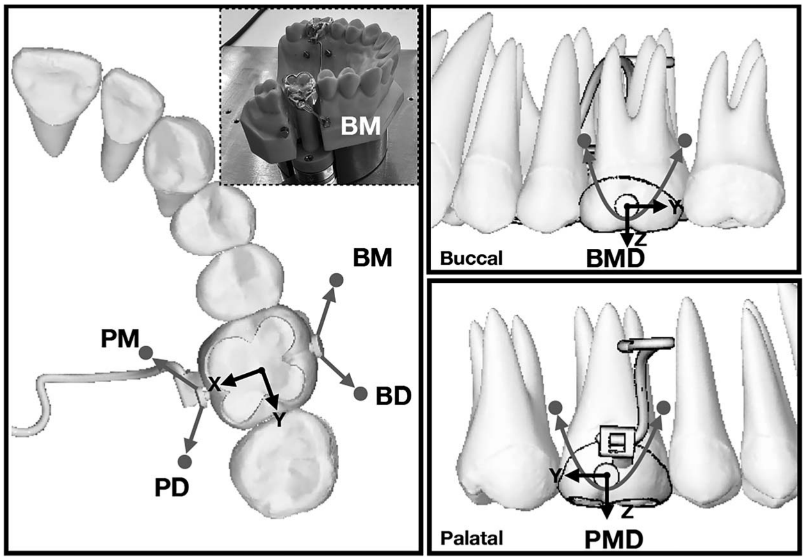

Figure 2. Schematic diagram of intrusion patterns: buccal-mesial (BM), buccal-distal (BD), palatal-mesial (PM), palatal-distal (PD), buccal-mesiodistal (BMD), and palatal-mesiodistal (PMD).

collisions during the experimental procedure, the left maxillary first molar was detached from the baseplate of the model and affixed to the 3D F/M sensor through a rigid fixation mechanism (Figure 1C). The mechanical sensor employed for measurements was the Nano17 F/T sensor (ATI Industrial Automation, NC, USA), designed to simultaneously measure force and moment in three directions with an accuracy of 1/160 N and 1/32 N·mm, respectively.

A spatial local coordinate system was established with the center of the crown of the left maxillary first molar as the origin. The x-axis corresponded to the buccolingual direction (+lingual, −buccal), the y-axis corresponded to the mesiodistal direction (+distal, −mesial) and the z-axis corresponded to the vertical direction (+occlusal, −apical). Mechanical data were collected over a 40-second interval at a frequency of 62.5 Hz from 10 s to 50 s, resulting in a total of 2,500 sample points. Given that the measurement center of the sensor was located 29 mm in the negative direction of the z-axis at the center of the crown (Figure 1C), the software coordinate system transform function was employed to reposition the center of the measurement to +29 mm along the z-axis. Consequently, the transformed data corresponded to the actual force and moment experienced at the center of the crown. To ensure accuracy and reliability of the experimental measurements, all clinical procedures, such as TPA assembly and elastic chain loading, were performed consistently by the same orthodontist. In each test, a fresh elastic chain was applied to the left maxillary first molar to prevent elastic attenuation. TPA wire dimensions were designed to be 0.7 mm, 0.9 mm, and 1.2 mm respectively (Dentaurum, Ispringen, Germany, stainless steel, 1400-1600N/mm^2). Intrusion patterns were categorized into six groups: buccal-mesial (BM), buccal-distal (BD), buccal-mesiodistal (BMD), palatal-mesial (PM), palatal-distal (PD), and palatal-mesiodistal (PMD) (Figure 2). In the BM, BD, PM, and PD, two modules of elastic chain were used. One was ligated to the TSADs and the other to the button. In the BMD and PMD, three modules were used: the first and last modules were ligated to the mesial and distal TSADs, respectively, and the middle module was ligated to the button. The force and moment in each group were measured three times, and the mean value was considered as the measurement result.

Statistical Analysis

All data are presented as mean ± standard deviation (SD). Statistical significance was set at $P < .05$ and two-tailed. Data analysis was performed using a one-way analysis of variance test and post-hoc Tukey correction. Statistical calculations were performed using SPSS software (v.24.0, USA).

RESULTS

In the case of a single buccal TSAD implantation, groups BM and BD exhibited negative values for Fx and My, suggesting a tendency for buccal torquing movement of the maxillary first molar. Conversely, Fx and My displayed positive values in groups PM and PD, indicating a palatal torquing movement. When TSADs were implanted on the mesial side, the maxillary first molar demonstrated a mesial tipping movement pattern, as evidenced by a negative Fy and positive Mx in the BM

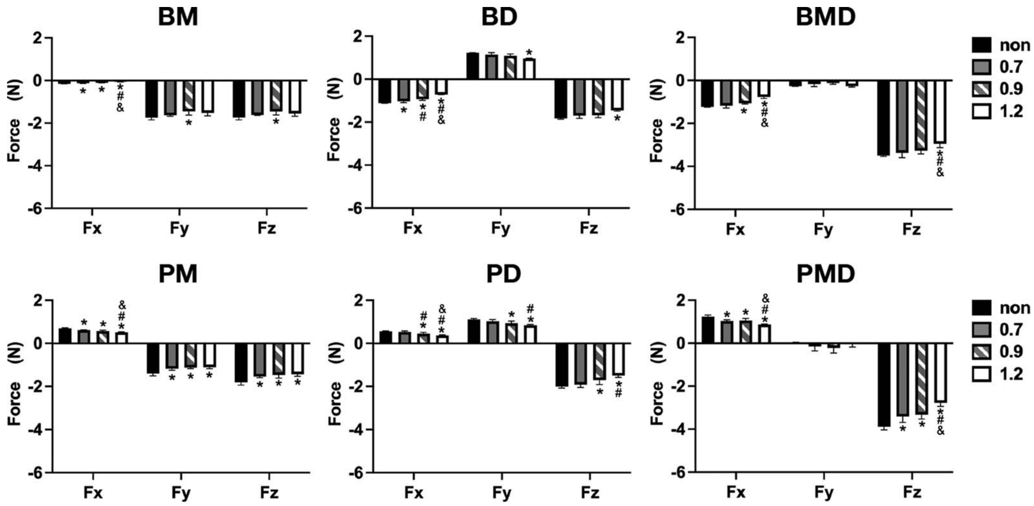

Figure 3. Bar charts illustrating the measured forces across different intrusion patterns.

and PM groups. In contrast, positive Fy and negative Mx values were observed in the BD and PD groups, indicating distal tipping movement. In addition, Mz was positive in the BM and PD groups, suggesting mesial rotation, whereas the opposite pattern was observed in the BD and PM groups with negative Mz.

In the case of both mesiodistal TSAD implantations, groups BMD and PMD, the force along the y-axis and moment at the z-axis were relatively small, and no significant differences in moment at the x-axis were detected among the TPA groups. This indicated that mesiodistal TSAD implantations effectively prevented mesiodistal tipping and rotation of the maxillary first molar. However, My was notably more prominent in both groups, indicating great torquing movement.

All of the results illustrated consistent effects of the TPA with the same intrusion methods, The TPA effectively reduced the force and moment experienced by the maxillary first molar in three dimensions. Additionally, the thicker the TPA wire, the smaller the force and moment to which the first molar was subjected (Figure 3 and 4).

DISCUSSION

In clinical orthodontic practice, inevitable buccal-palatal torquing movements occur when TSADs are implanted on the buccal or palatal sides to be used for maxillary molar intrusion. This can lead to the development of palatal cusp interference or a reduction in posterior overjet, potentially compromising the correction of open bite.[11] The TPA is formed by bending or casting a stainless steel wire across the palate, connecting bilateral maxillary first molars to create a single anchorage unit. Consequently, the intercuspal width of the first molars is restricted by the TPA.[12] When buccal or palatal TSADs are implanted and intrusion force is applied, the bilateral

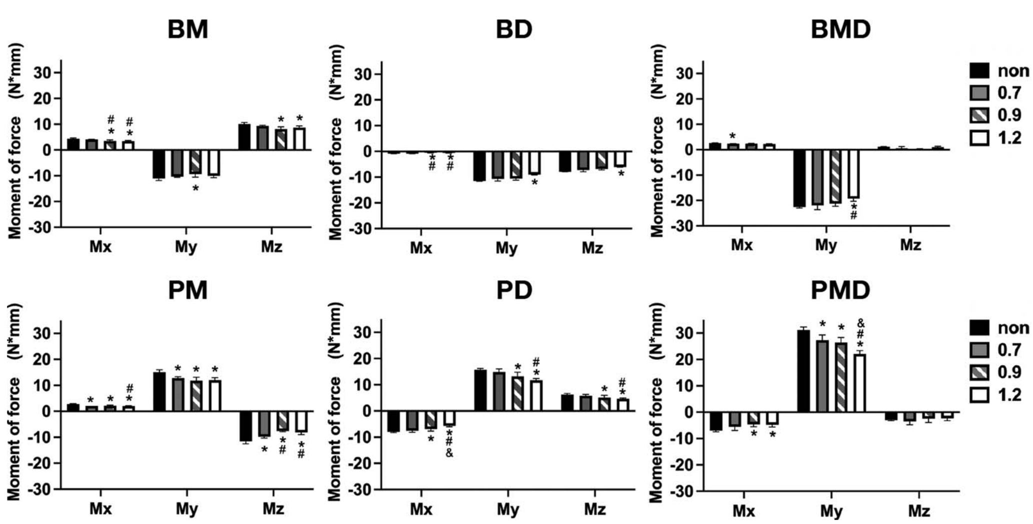

Figure 4. Bar charts illustrating the measured moments across different intrusion patterns.

first molars support each other, thereby reducing buccal-palatal torquing movement.

The TPA has been widely used as an auxiliary device for fixed orthodontics, and its effects on maintaining arch width, and providing support during arch alignment and sagittal control have been clinically recognized.[13] Numerous clinical and laboratory investigations have confirmed that a TPA combined with TSADs can effectively facilitate posterior tooth intrusion and prevent buccal-palatal torquing effects.[14] However, the current study suggests that, although the TPA could reduce such movements, it did not entirely eliminate them. Additionally, single mesial or distal TSAD would produce tipping movement during intrusion; therefore, in cases for which maximum anterior retraction is desired, TSADs are recommended to be implanted in sites distal to the maxillary first molar.

Previous studies have discussed the adjunctive role of a TPA during posterior intrusion; however, variations in TPA design have not been fully investigated. The material, stiffness, and thickness of the TPA wire are important factors affecting orthodontic force delivery. Hoederath et al. found that TPA wire made of stainless steel delivered greater moments than TMA for first order activation.[15] Crismani et al. compared the deformation of stainless steel TPA wires sized 0.8 to 1.2 mm and found that TPA wire exceeding a 1.2 × 1.2 mm dimension was essential to avert significant anchorage loss.[16] Therefore, the thinner the TPA wire, the lower its stiffness and the greater its elasticity, so it would provide lesser control of the abutment teeth. Results from this study supported those findings. When the TPA was combined with TSADs for posterior tooth intrusion, the thicker the TPA wire, the smaller the buccal-palatal torquing and mesial-distal tipping effects on the posterior teeth. In addition, Li et al. demonstrated that a fully cast TPA exhibited superior control in the transverse and vertical dimensions compared to traditionally-formed stainless steel TPA wire, consistent with the results of this study.[17] In the current study, 3D-printed bands were used to ensure a better fit to the crown. A 3D-printed or fully cast TPA is also recommended to increase molar control. If preformed bands and a formed TPA wire were used clinically, it is important that bands are well fitted and accurately placed. Selecting the thickest possible TPA wire and using flowable resin to cement bands and heavy ligature wire to tie the TPA in place tightly would help to reduce unwanted side effects.[18]

Achieving pure molar intrusion is considered to be a formidable challenge because the intrusion force line must pass through the center of resistance (CR) of the molar. According to Gandhi et al., the CR of the maxillary first molar is located nearly midway within the buccolingual crown width,[19] indicating that single buccal or palatal intrusion will inherently generate torquing movement. However, according to the current study, a TPA

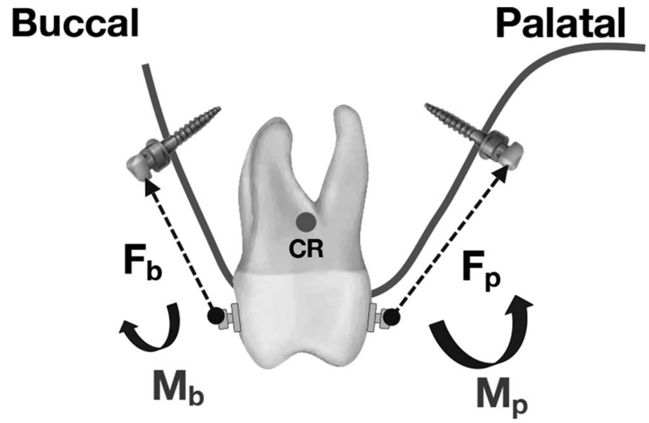

Figure 5. Influence of alveolar bone morphology on TSAD-assisted maxillary molar intrusion. Palatal TSADs are positioned at a greater horizontal distance from CR in the horizontal direction, resulting in an increased horizontal force component and palatal torque moment applied to the maxillary first molar. CR indicates center of resistance; TSAD, temporary skeletal anchorage device.

cannot completely eliminate this tendency. Therefore, the use of both buccal and palatal TSADs is highly recommended.[20] Additionally, the effects of buccal and palatal TSADs could not be directly compared because the magnitude and direction of the force components are not the same, nor completely opposite. Therefore, the forces and moments of different intrusion patterns were not compared in this study. Although the same intrusion force was applied on both the buccal and palatal sides, individual factors that may influence the actual intrusive outcomes can exist, such as morphological variations in CR and alveolar bone. Owing to the anatomical features of maxillary alveolar bone, palatal TSADs are located at a greater horizontal distance from the CR than buccal TSADs, which might produce a greater horizontal force component and lead to palatal torquing (Figure 5). However, the palatal region remains the preferred choice among clinicians because of its advantages over the buccal side, such as the presence of keratinized gingiva, greater inter-radicular space, lower risk of dental root perforation, and appropriate bone thickness in the palatal region.[21–23]

CONCLUSIONS

- The precise placement of TSADs was found to exert a substantial influence on tooth movement and should be determined according to specific clinical requirements.
- Increasing the TPA wire dimensions could reduce unwanted torquing, tipping, and rotation during TSAD-assisted maxillary molar intrusion. However, these tendencies could not be completely eliminated.

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