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Occlusal Plane Changes after Maxillary Molar Distalization Using Temporary Skeletal Anchorages Devices: A Narrative Review and Preliminary Study

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Abstract: Background: We conducted a narrative review of studies analyzing the occlusal and mandibular plane angles after maxillary molar distalization using temporary skeletal anchorage devices (TADs). An original preliminary investigation was conducted on the occlusal and mandibular plane angle changes according to the design of TAD-supported distalization. Methods: We included 51 participants stratified into three groups (buccal TAD, lingual arch TAD, and pendulum TAD) who underwent lateral cephalography before and after treatment. The paired t-test and ANOVA were used to analyze the significant differences among the groups. Results: The pterygoid vertical to maxillary second molar ($p < 0.01$) significantly differed before and after treatment within each group (group 1, 1.29 $\pm$ 1.73 mm; group 2, 2.01 $\pm$ 1.46 mm; group 3, 1.12 $\pm$ 1.43 mm). The angle between the Frankfort horizontal and anatomical occlusal plane increased by 1.96 $\pm$ 2.88° ($p < 0.05$) and 2.51 $\pm$ 2.57° ($p < 0.01$) in groups 2 and 3, respectively. Conclusions: The measured variables did not significantly differ among the three groups. The Frankfort-mandibular plane angle and functional occlusal plane did not change after maxillary molar distalization. The anatomical occlusal plane is influenced by the anterior teeth and may be unrelated to maxillary molar distalization. Further studies are required to verify the exact relationship between maxillary molar distalization and occlusal plane angle.

Keywords: distalization; maxillary molars; temporary anchorage devices; occlusal plane

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1. Introduction

Maxillary molar distalization is a commonly employed effective treatment strategy, which is useful not only for patients with Class II malocclusion but also for resolving crowding caused by maxillary arch length discrepancy. In the early 2000s, before the advent of temporary anchorage devices (TADs), removable or dental anchorage devices were mainly used, whose inherent disadvantages included the need for patient cooperation and the possibility of undesired tooth movement [1–7]. Since the 2000s, many of the designs of various existing orthodontic treatment devices have been modified to incorporate the use of TADs, and new designs of maxillary molar distalization using TADs have also been posited by numerous clinicians [6,8–11].

In most of the reported maxillary molar distalization cases, the force vector is designed to pass in the molar occlusal direction of the center of resistance of the maxillary dentition because of anatomical limitations. Molar distalization with conventional appliances, or TADs-assisted appliances, results in a substantial amount of simultaneous undesirable distal tipping tooth movement [6,11–13].

Distal tipping movement of the maxillary molar can cause unplanned clockwise rotation of the entire maxillary dentition, resulting in a steepening of the maxillary occlusal plane. Numerous studies have reported an increase in the slope of the maxillary occlusal plane after maxillary molar distalization [12,14–19]. However, different results have been reported depending on the device design and location of the TADs; some studies have reported no change in the angle of the maxillary occlusal plane [20,21].

Although the importance of the occlusal plane is not yet fully understood, changes in this plane are known to affect the position of the mandible during oral functions such as mastication and pronunciation. Oral function and esthetics and maxillofacial growth have been reported to be influenced by the inclination of the occlusal plane [22–25]. In Class II malocclusion, an increase in the occlusal plane angle can be a useful treatment strategy for achieving a dental Class l relationship, but excessive steepening can have a detrimental effect on oral function and esthetics, necessitating a cautious approach [26]. Furthermore, several studies have reported an increase in the facial vertical dimension after maxillary molar distalization [15,16,19,27–29]. This change in the facial vertical dimension is due to maxillary molar extrusion, which results in clockwise rotation of the mandible, and can cause unfavorable facial changes in patients with Class II malocclusion.

Changes in the angle between the occlusal plane and mandibular plane that can be caused by maxillary molar distalization affects oral function and facial esthetics; however, the few studies that have been conducted on maxillary molar distalization have reported conflicting results. Since the introduction of orthodontic skeletal anchorage, maxillary molar distalization has been actively used as a clinical treatment method. More research is needed on the dental and skeletal changes resulting from maxillary molar distalization. Therefore, in this study, we aimed to conduct a narrative review of studies with a special focus on the occlusal plane angle. In addition, a preliminary study was performed using lateral cephalogram measurements to compare the alterations in the occlusal plane and mandibular plane angle based on the maxillary molar distalization appliance design.

2. Materials and Methods

This study was approved by the Institutional Review Board at the Kyung Hee University Hospital at Gangdong (IRB number: KHNMC 2022-06-014), which waived the requirement for written informed consent because of its retrospective nature. The study population included consecutive patients who visited the Department of Orthodontics at Kyung Hee University Hospital in Gangdong between March 2007 and April 2022 for orthodontic treatment.

The inclusion criteria for this retrospective study were as follows: (1) dental Class II relationship before treatment and dental Class l relationship after treatment, (2) lateral cephalography acquired before and after treatment, (3) use of a buccal or palatal TAD appliance for maxillary molar distalization, and (4) patients aged above 15 years and those with cessation of maxillofacial growth changes. The exclusion criteria were as follows: (1) missing congenital teeth, (2) use of Class II elastics or orthopedic appliances, (3) therapeutic intrusion or extrusion of posterior teeth that may have affected the occlusal plane angle, (4) distalization appliance designs other than the designated ones, and (4) patients aged under 15 years or those showing growth changes on the lateral cephalogram.

After screening using these eligibility criteria, 51 study participants (14 men and 37 women; mean age, 22.24 ± 6.66 years; range, 14–44 years at pre-treatment; Table 1) were enrolled. Patients were divided into three groups according to the location of the TADs and device design.

Table 1. Demographic features of the subjects.

Variables	Group 1	Group 2	Group 3	p-Value
Sex (male/female)	5/14	4/12	5/11	0.92 *
Mean age (year)	21.79 ± 6.91	25.19 ± 6.82	19.83 ± 5.57	0.07 †
Range of age (year)	15–44	16–42	14–35	

Values are presented as number only or mean ± standard deviation. * $\chi 2$ test was performed. † ANOVA was performed.

In group 1, the TADs were inserted into the posterior interradicular buccal area for maxillary molar distalization (Figures 1 and 2). The TADs, 7.0 mm in length and 1.6 mm in coronal diameter (Orlus; Ortholution, Seoul, Korea), were placed between the maxillary second premolars and first molars. Subsequently, a 0.019 × 0.025 inch stainless steel rectangular archwire using crimpable hooks located between the maxillary lateral incisor and canine was placed on the buccal fixed appliances. An elastomeric power chain (Ormco, Glendora, CA, USA) was used from each miniscrew to the hook for molar distalization with a distal driving force of 150 g and replaced at 4-week intervals.

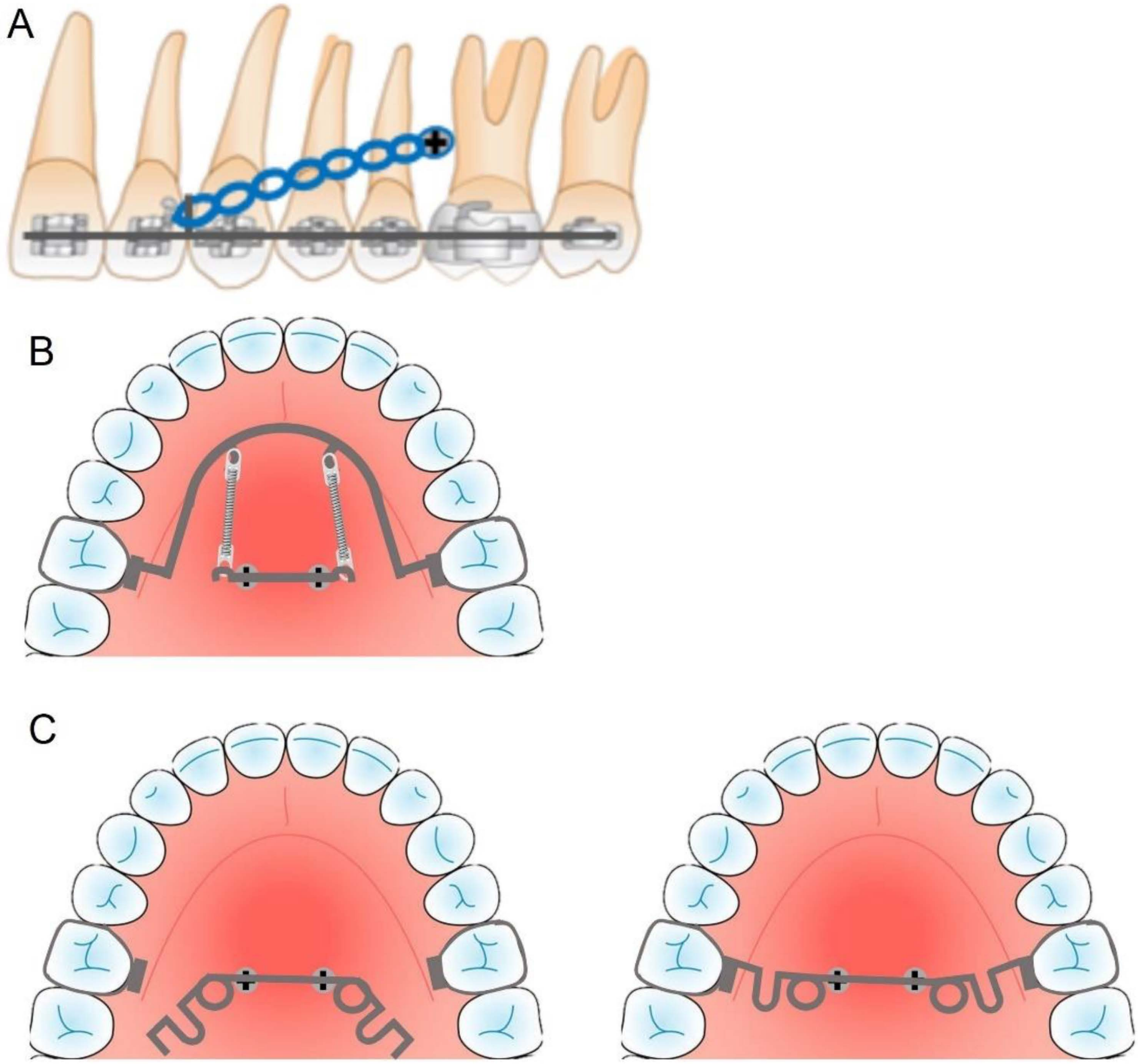

Figure 1. Schematic diagrams of maxillary molar distalization TAD appliances (**A**), group 1; (**B**) group 2; (**C**) group 3; From the left: before activation and after activation.

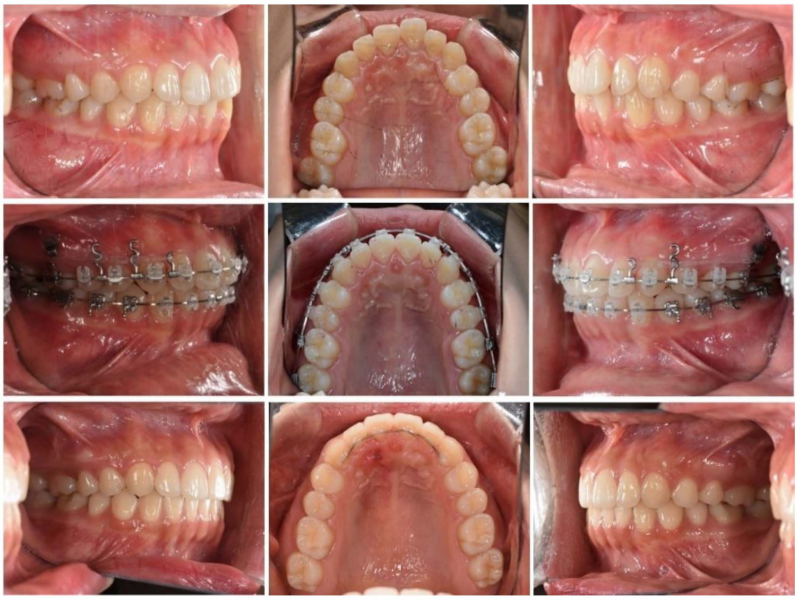

Figure 2. The TADs were placed in the posterior interradicular buccal area for maxillary molar distalization (group 1). From the upper: pretreatment, during treatment, and post-treatment.

In group 2, two miniscrew-type TADs (1.6 mm diameter × 6 mm length, 0.0215 × 0.025 inch slot size) (Machined-surface miniscrews, Jeil Medical, Seoul, Korea) were used as a rigid bone anchor. The screw was bilaterally inserted into the median palatal suture, and a lingual arch appliance (round 0.032 inch stainless steel wire) was placed on the palate, connecting the right and left first molars, and attached to a palatal bar (rectangular 0.021 × 0.025 inch stainless steel archwire) engaged through the head slot of the two palatal TADs (Figures 1 and 3). Closed-coil nickel–titanium springs were applied with a distal driving force of 150 g, and an elastomeric power chain (Ormco, Glendora, CA, USA) was replaced at 4-week intervals for molar distalization. Fixed buccal appliances with thicker than rectangular 0.016 × 0.022 inch stainless steel archwires were simultaneously used during molar distalization.

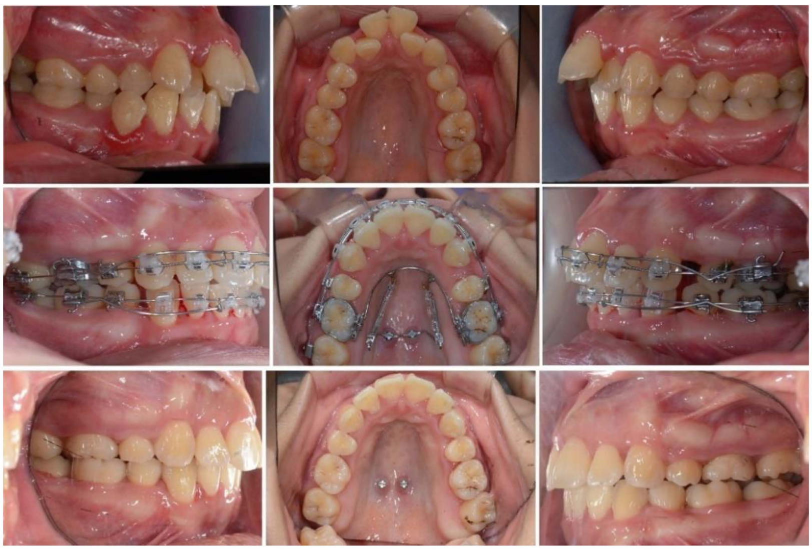

Figure 3. The TADs were inserted on the palatal side and lingual arch appliance was placed on the palate and connected to the palatal bar installed on the maxillary first molars for maxillary molar distalization (group 2) From the upper: pretreatment, during treatment, and post-treatment.

In group 3, two miniscrew-type TADs (1.6 mm diameter × 6 mm length, 0.0215 × 0.025 inch slot size) (Machined-surface miniscrews, Jeil Medical, Seoul, Korea) were bilaterally inserted into the median palatal suture, and a pendulum spring fabricated with a rectangular 0.021 × 0.025 inch stainless steel wire was engaged into the slots of the miniscrew heads (Figures 1 and 4). The pendulum springs were activated until the tip touched the palatal mucosa and engaged the lingual sheath of the maxillary molars, which was checked with a distal driving force of 150× g and re-activated every 4 weeks. Fixed buccal appliances with thicker than rectangular 0.016 × 0.022 inch stainless steel archwires were simultaneously used during molar distalization.

Figure 4. The TADs were inserted on the palatal side of the molars for maxillary molar distalization in combination with a pendulum spring (group 3) From the upper: pretreatment, during treatment, and post-treatment.

2.1. Reference Planes and Measurements

Lateral cephalograms were acquired using a DENTRI (HDXWILL., Seoul, Korea) with centric occlusion in the natural head position before and after treatment. Cephalometric tracing was digitized using V-ceph software (version. Osstem Inc., Seoul, Korea).

During image acquisition, the patients were in the standing position, with the Frankfort horizontal (FH) plane parallel to the floor, and the patient's head was stabilized by an ear rod. The line joining the center of the sella turcica to the nasion was designated as the horizontal reference plane (HRP). The plane that passed most posterior to the pterygomaxillary fissure (Pt) and was perpendicular to the HRP was designated as the vertical reference plane. The cephalometric landmarks, reference planes, and measurements used in this study are depicted in Table 2 and Figure 5.

Table 2. Definition of landmarks, reference planes, and measurements used in this study.

Reference Points	**Definitions**
Menton	The most inferior point on the symphysis.
Orbitale	The lowest point in the inferior margin of the orbit.
Porion	The point located at the most superior point of the external auditory meatus.
ANS	Anterior Nasal Spine, the tip of the body anterior nasal spine in the median plane.
PNS	Posterior Nasal Spine, the process formed by united projecting ends of the posterior borders of the palatal process of the palatal bone.
Gonion	The constructed point of the intersection of ramus plane and the mandibular plane.
Pt	The contour of the pterygomaxillary fissure projected onto the palatal plane.
Reference planes and measurements	
FH plane	Frankfort horizontal plane, a line from the center of sella turcica to nasion.
Palatal plane	A line drawn from ANS to PNS.
Functional occlusal plane	Defines a line drawn between the mid-point first permanent molars and the mid-point of the bicuspids.
Anatomic occlusal plane	Defines a line drawn between the mid-point first permanent molars and one half of the incisor overbite.
Mandibular plane	A line drawn from Menton to Gonion.
PtV plane	The PtV plane was set to the plane that passed the most posterior superior point of Pt (pterygomaxillary fissure) and was perpendicular to the HRP.
PtV to Mx 7	Perpendicular distance (mm) from the PtV plane and the most posterior part of maxillary second permanent molar.
Palatal plane to Mx 7	Perpendicular distance (mm) from the palatal plane and the most posterior part of maxillary second permanent molar.
FH to functional occlusal plane	Angle (°) between FH plane and functional occlusal plane.
FH to anatomical occlusal plane	Angle (°) between FH plane and functional occlusal plane.
FH to mandibular plane	Angle (°) between FH plane and mandibular plane.

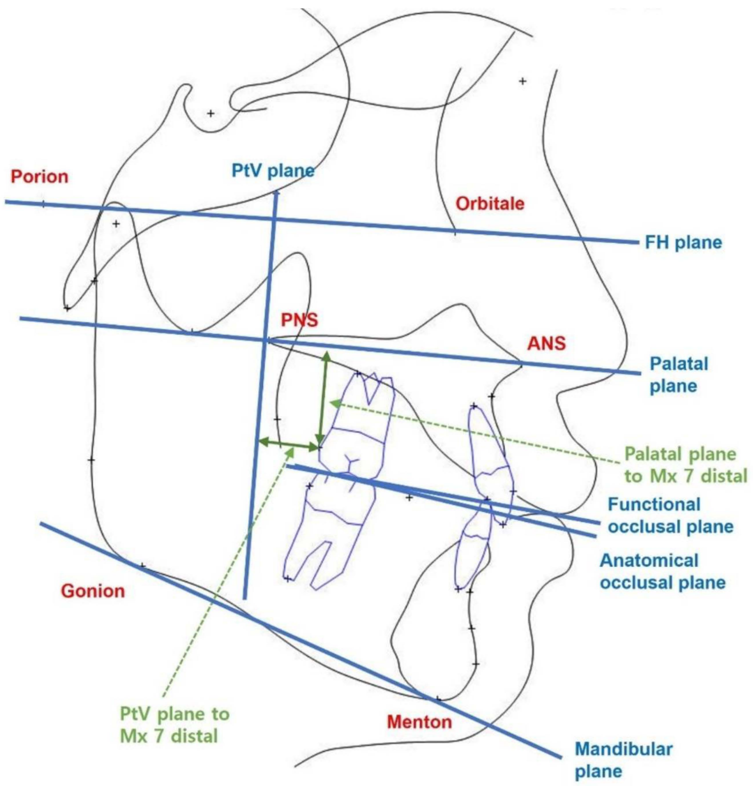

Figure 5. Definitions of cephalometric reference planes and measurements.

2.2. Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics software for Windows (version 15.0; IBM Corp., Armonk, NY, USA). The Shapiro–Wilk test was used to confirm the normality of data distribution. The differences in demographic features, such as sex, among the groups were analyzed using the $\chi 2$ test. Paired *t*-tests were used to compare the differences before and after treatment within each group. Analysis of variance (ANOVA) with Bonferroni correction was used to evaluate the differences between the three groups. Differences with a probability of less than 5% ($p < 0.05$) were considered statistically significant.

Orientation and measurements were performed by a single examiner (H.J.P.). The same examiner remeasured 20 randomly selected cephalograms after a 2-week interval to determine the intraexaminer reliability. The resultant intraclass correlation coefficient (ICC) indicated high reliability (ICC > 0.9).

3. Results

The demographic features of the participants, including sex and age, did not significantly differ among the three groups (Table 1). There were no differences in the pretreatment maxillary second molar measurements among the three groups (Table 3). However, there were significant differences in some pretreatment dental variables, such as the FH plane to functional occlusal plane ($p < 0.05$) and FH plane to anatomical occlusal plane ($p < 0.01$).

Table 3. Comparison of pre-treatment cephalometric variables between groups.

Variables	Group 1 (n = 19)	Group 2 (n = 16)	Group 3 (n = 16)	p-Value
PtV to Mx 7 (mm)	8.26 ± 3.34	10.56 ± 5.53	9.02 ± 2.59	0.238
Palatal plane to Mx 7 (mm)	14.76 ± 3.22	16.33 ± 3.45	14.99 ± 1.90	0.265
FH to functional occlusal plane (°)	11.76 ± 4.29	8.99 ± 4.28	7.75 ± 4.56	0.027 *
FH to anatomical occlusal plane (°)	11.26 ± 4.07	6.71 ± 4.12	6.56 ± 3.55	0.001 **
FH to mandibular plane (°)	28.49 ± 5.84	24.14 ± 24.19	26.31 ± 4.95	0.132

Values are presented as mean ± standard deviation. ANOVA were performed to compare the three groups. * $p < 0.05$, ** $p < 0.01$. See Figure 4 and Table 2 for definitions of each landmark.

Comparison within each group during the treatment period revealed significant differences before and after treatment in the pterygoid vertical (PtV) to maxillary second molar (Mx 7) (1.29 ± 1.73 mm, $p < 0.01$; Table 4) in group 1. Groups 2 and 3 also showed significant differences in the PtV to Mx 7 (group 2, $p < 0.001$; group 3, $p < 0.01$; Table 4) and the angles between the FH and anatomical occlusal planes (group 2, $p < 0.05$; group 3, $p < 0.01$; Table 4). The distance between the PtV and Mx 7 increased by 2.01 ± 1.46 mm and 1.12 ± 1.43 mm in groups 2 and 3, respectively. The angle between the FH and anatomical occlusal planes increased by 1.96 ± 2.88° ($p < 0.05$) in group 2 and by 2.51 ± 2.57° ($p < 0.01$) in group 3 (Table 4). There were no other significant differences in the measured variables. Skeletal and dental measurements did not significantly differ among the three groups.

Table 4. Comparison of the skeletal and dental changes during the treatment period.

Variables	T2	ΔT1–T2	p-Value
	Group 1 (n = 19)		
PtV to Mx 7 (mm)	6.97 ± 3.91	1.29 ± 1.73	0.004 **
Palatal plane to Mx 7(mm)	15.33 ± 2.87	−0.56 ± 1.29	0.074
FH to functional occlusal plane (°)	12.07 ± 4.10	−0.32 ± 3.24	0.676
FH to anatomical occlusal plane (°)	11.82 ± 3.83	−0.56 ± 2.77	0.392
FH to mandibular plane (°)	28.37 ± 5.94	0.13 ± 0.82	0.51

Table 4. *Cont.*

Variables	T2	ΔT1–T2	*p*-Value
	Group 1 (n = 19)		
	Group 2 (n = 16)		
PtV to Mx 7 (mm)	8.55 ± 5.45	2.01 ± 1.46	0.001 **
Palatal plane to Mx 7 (mm)	16.12 ± 2.91	0.21 ± 1.02	0.426
FH to functional occlusal plane (°)	9.61 ± 5.03	−0.62 ± 3.01	0.424
FH to anatomical occlusal plane (°)	8.66 ± 4.91	−1.96 ± 2.88	0.016 *
FH to mandibular plane (°)	7.73 ± 8.45	−0.06 ± 1.20	0.854
	Group 3 (n = 16)		
PtV to Mx 7 (mm)	7.92 ± 2.61	1.12 ± 1.43	0.007 **
Palatal plane to Mx 7(mm)	14.88 ± 2.22	0.11 ± 1.75	0.808
FH to functional occlusal plane (°)	9.20 ± 4.77	−1.46 ± 3.89	0.155
FH to anatomical occlusal plane (°)	9.08 ± 3.79	−2.51 ± 2.57	0.001 **
FH to mandibular plane (°)	26.16 ± 4.79	0.15 ± 1.01	0.561

Values are presented as mean ± standard deviation. Paired *t*-tests were performed to compare before and after treatment. T1, pre-treatment; T2, post-treatment. * $p < 0.05$, ** $p < 0.01$. See Figure 4 and Table 2 for definitions of each landmark.

4. Discussion

TADs have transformed several aspects of n orthodontic practice. Maxillary molar distalization is not an exception, and we think that TADs can provide more predictable and reliable maxillary molar distalization compared with traditional non-TAD devices. TADs do not require patient compliance, and their use also minimizes the adverse effects of maxillary molar distalization. Studies were conducted to validate the effectiveness of TAD-assisted maxillary molar distalizers, all of which demonstrated their efficacy not only in maxillary molar distalization, but also in effecting pure molar distalization without significant anchorage loss (mainly mesial tipping of the maxillary premolars and proclination of the incisors). Numerous maxillary molar distalization appliance designs utilizing TADs (mainly the miniscrew type) have been introduced, which either include TADs as adjunctive measures in combination with conventional appliances or TADs as the principal distalization tool. The two most reported types in the literature that are used in conjunction with fully fixed buccal appliances entail placement of the TAD in the palate and connected to a lingual arch appliance, or inserting the TAD on the buccal side of the maxillary dentition and directly connecting the TAD with the maxillary dentition using coil springs or elastomeric materials [10,14,16,17]. En masse, one-step total distalization of the maxillary dentition is usually performed with buccally placed TADs [16].

All patients included in this study were treated with en masse retraction with TADs as part of the treatment protocol. Maxillary molar distalization was indirectly achieved in group 1 by en masse maxillary dentition distalization, whereas the maxillary first molars were subjected to direct distalization forces in groups 2 and 3. Group 1 underwent one-stage maxillary dentition distalization, while groups 2 and 3 underwent two-stage distalization (the molars were distalized first, followed by the premolars and mesial teeth). All treatment groups showed effective maxillary molar distalization, as revealed by statistical analysis (PtV to Mx, 7 mm). None of the three groups showed changes in the Frankfort-mandibular plane angle (FMA); therefore, there were no vertical skeletal changes in nongrowing patients with maxillary molar distalization. Studies analyzing the effects of conventional maxillary molar distalizers, such as pendulum and distal jets, have reported an increase in the FMA due to the extrusion of the maxillary molars after treatment and a decrease during follow-up [12,19,29,30]. The reason for the lack of changes in the FMA in this study may be attributed to all participants being in the nongrowth stage, and fixed buccal appliances were simultaneously used during molar distalization. Similarly, several studies have found no vertical changes even though intrusion of the maxillary molars occurred after distalization with TADs [10,31–34].

The results of this study indicate that the cant of the anatomical occlusal plane can be increased according to the position of the TAD. Although the changes in the anatomical occlusal plane did not significantly differ among the three groups, the intragroup comparison revealed that the palatally positioned (groups 2 and 3) TADs groups showed an increase (steepening) in the anatomic occlusal plane angle after treatment, while buccally positioned TADs (group 1) produced no changes in the anatomical occlusal plane after treatment. This finding should be interpreted with caution. Despite the increase in the anatomical occlusal plane in groups 2 and 3, the other occlusal plane, i.e., the functional occlusal plane, did not show statistically significant changes.

In this study, both the anatomical and functional occlusal planes were measured. Previous studies involving maxillary molar distalization measured the anatomic occlusal plane, and not many of them, if any, measured the functional occlusal plane. Class II malocclusions are often accompanied by a deep anterior overbite, and resolving the deep overbite can affect the anterior occlusal plane, which in turn affects the anatomical occlusal plane. This change is unrelated to maxillary molar distalization but can be misinterpreted as a result of maxillary molar distalization. During anterior bite opening, the intrusion of maxillary incisors may result in the flattening of the anatomical occlusal plane because the anterior overbite midpoint moves upward, whereas intrusion of the mandibular incisors may result in steepening of the anatomical occlusal plane. To avoid misinterpretation, a lateral cephalogram taken after leveling stage and just before distalization should be served as T1, as indicated by Chou et al. and Kook et al. [14,17]. Another way might be measuring the functional occlusal plane, as performed in this study. None of the three groups showed changes in the functional occlusal plane, whereas groups 2 and 3 showed significant increases in the anatomical occlusal plane. This inconsistency between the changes in the functional and anatomical occlusal planes leaves considerable room for thought.

From the biomechanical perspective, no changes were expected in the occlusal plane in group 2 because the distalizing force passes near the center of resistance of the maxillary molars, which may not cause distal tipping of molars. A clinical study using the same maxillary molar distalizer as that was used in group 2 showed no distal tipping of the maxillary molars after distalization [10]. Similarly, changes in the occlusal plane were expected in groups 1 and 3. For group 1, the distalization force vector passes occlusal to the center of resistance of the maxillary dentition, thereby causing a clockwise rotation of the maxillary dentition that results in a steepening of the occlusal plane. For group 3, it is well-known that pendulum arms significantly tip the maxillary molars distally, and this tipping moment might also tip the maxillary occlusal plane to a steeper cant [10,19]. The results of the current study showed an unexpected increase in the anatomical occlusal plane in group 2 and no changes in group 1. As expected, group 3 showed steepening of the anatomical occlusal plane.

A finite element method (FEM) study investigated the changes in the maxillary dentition in response to whole arch distalizing forces according to various force directions measured from the maxillary occlusal plane [35]. The authors found that all angulated distalization forces from -30° to $+30^\circ$ caused lingual and distal tipping of the incisors and molars. This movement pattern created a clockwise rotation of the occlusal plane, which included extrusion of the incisors and intrusion of the second molars. This FEM study design was very similar to that of group 1. Another clinical study investigating dental and skeletal changes after maxillary molar distalization and long-term follow-up using the same set-up as group 1 reported an increase in the anatomical occlusal plane after treatment, which was stable after two years of follow-up [16]. Unlike the previous FEM and clinical studies, in the current study, we found no significant changes in either the anatomical or functional occlusal plane.

According to a systematic review of miniscrew-supported maxillary molar distalization, maxillary molars distally tipped when distalized, and this distal tipping was less when force was applied from the palatal side [13]. This systematic review also stated that the reason for a lesser degree of distal tipping with palatal distalizing forces is that the force can be located close to the center of resistance of the molar. This situation is very similar to that of group 2 in this study, where it was expected that the occlusal plane changes would not occur due to less distal tipping. Two clinical studies conducted by the same research groups utilized a palatal plate as an anchor for maxillary molar distalization, a design similar to that of group 2 in this study. They found an increase in the occlusal plane (mean 2.81° and 3.77°) after molar distalization [14,17] and stated that the reason for this occlusal plane change was the extrusion of the maxillary incisors and intrusion of the maxillary molars [17]. These study results are consistent with the current result: the anatomical occlusal plane increased after maxillary molar distalization.

After reviewing the studies published on maxillary molar distalization with TADs, it seems logical to expect that the anatomical occlusal plane would become steeper after maxillary molar distalization, irrespective of the location of the TADs and the appliance design. There are some discrepancies among the studies, but a majority of them have reported the intrusion of the maxillary molars and extrusion of the maxillary incisors. The intrusion of the maxillary molars and resultant occlusal plane change should be considered with functional problems. Several studies found a possible correlation between occlusal plane cant and jaw growth direction; therefore, this should be considered when treating growing individuals with maxillary molar distalization [25,36]. However, if growth is not excessive, it is not expected to cause problems, and the results of this study showed no functional occlusal plane (i.e., posterior occlusal plane) changes after molar distalization with TADs. Extrusion of the maxillary incisors can be problematic. A deep anterior overbite and excessive incisor display are functional and esthetic issues. Harmony between condylar guidance and incisal guidance during functional movement of the mandible may be jeopardized with steeper incisal guidance caused by extrusion and upright maxillary incisors. Therefore, clinicians should be aware of maxillary incisor extrusion in patients scheduled to undergo maxillary molar distalization. Compensatory maxillary incisor intrusion combined with careful considerations of the dento-skeletal frame should be considered when formulating the treatment plan.

In our preliminary study, group 1 showed no anatomical occlusal plane changes, whereas the other two groups showed an increase in anatomical occlusal plane inclination. This may have occurred because not all features of the patients included in this study were controlled. Both extraction and nonextraction cases were included, the initial anterior overbite was not compared, skeletal vertical patterns were not controlled, and the mechanism of change in the anterior overbite was not calibrated among the groups. This heterogeneity in the sample characteristics may have resulted in different anatomical occlusal plane changes. As there were no functional occlusal plane changes before and after treatment in all three groups, these characteristics may be the reason underlying the anatomical occlusal plane change and not maxillary molar distalization. Furthermore, we found that some of these features were not controlled in previous studies that measured the occlusal plane (the anatomical occlusal plane, to be precise) after maxillary molar distalization. This could be the reason why most studies reported occlusal plane changes after maxillary molar distalization, whereas some of the others did not.

The exact reason for the lack of change in the functional occlusal plane is unclear within the scope of limitations of this study; they were biomechanically expected to increase in groups 1 and 3. We postulate four possible mechanisms for this finding. First, we simultaneously used a fixed buccal appliance with a molar distalizer. This could have minimized the distal tipping tendency of molars during distalization. Second, the unchanged mandibular occlusal plane stabilized with a fixed buccal appliance may have played a role in functional homeostasis. Oral function, especially mastication and biting, may have helped maintain the pretreatment value of the maxillary occlusal plane. Third, molar distalization was not as fast as the conventional maxillary molar distalizer (i.e., the pendulum appliance), which provided time for the molars to adapt to a new position (distal to their original position) and maintain their original occlusal plane. Fourth, the amount of distalization in this study may have been too small to trigger significant functional occlusal plane changes. Even though measuring sagittal movements in the second molar using two-dimensional lateral cephalography underestimates the real amount of movement, our study sample showed slightly less molar distalization than other maxillary molar distalization studies.

The aim of this study was to review previous studies that evaluated occlusal plane changes after maxillary molar distalization with TADs and evaluate and compare occlusal plane changes according to various molar distalization methods. Some critical variables were not appropriately controlled because this was a type of preliminary study. Further clinical studies with properly controlled variables are required. In addition, discriminating between the functional occlusal plane and the anatomical occlusal plane is strongly recommended in future studies.

5. Conclusions

In this study, we analyzed and compared maxillary molar distalization using a buccal miniscrew and two different palatal miniscrew designs. The functional occlusal plane did not change regardless of the design of the maxillary molar distalizer. In addition, the FMA did not change after maxillary molar distalization in any of the three groups. The anatomical occlusal plane increased after maxillary molar distalization in the two groups that used palatal miniscrews as TADs. Further studies are required to clarify the effect of maxillary molar distalization on the occlusal plane, to discriminate between the anatomic occlusal plane and functional occlusal plane, and to analyze them separately.

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