



CLINICAL RESEARCH:

Changes in Buccolingual Inclination of the Posterior Maxillary Teeth with Forces Applied from the Mini-Implants in the Sagittal and Vertical Direction-A non-Randomized Clinical Study

Cambios en la inclinación bucolingual de los dientes maxilares posteriores con fuerzas aplicadas con mini-implantes en dirección sagital y vertical: un estudio clínico no aleatorizado

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ABSTRACT: To compare the changes in the buccolingual inclination of the posterior teeth when forces are applied from mini-implants placed on the buccal side of the maxillary posterior teeth in both sagittal and vertical directions. Sixteen young patients requiring distal movement of the maxillary teeth with mini-implants and ten patients requiring intrusion of the posterior teeth with mini-implants were included in group 1(G1) and group 2(G2), respectively. In G1,200 grams of sagittal forces were applied bilaterally using NiTi coil springs from mini-implants placed between the maxillary second premolar and first permanent molar to attachments on a 0.018"X0.025" stainless steel wire in the anterior region. In G2,200 grams of vertical forces were applied bilaterally through an elastic thread from the mini-implants onto a 0.019"X0.025" stainless steel archwire. CBCT scans were taken before and towards the end of distalisation/intrusion. Paired t-tests and Independent t-tests were performed. There was statistically significant buccal tipping of the maxillary second premolar in G2 (p-value of .008) accompanied by mild buccal tipping in G1. However, not statistically significant, mild buccal tipping of the maxillary second molar was observed in both groups. The maxillary first molar though not statistically significant demonstrated lingual tipping in G1 while no changes in buccolingual inclination were noted in G2. There was a clinically significant buccal tipping of maxillary second molar and second premolar in G1 and G2, lingual tipping of the maxillary first molar in G1. Significant changes were observed in the buccolingual inclination of the maxillary second premolars and second molars when forces were applied in the sagittal and vertical direction in the buccal direction. Lingual tipping of the maxillary first molar was noted in the sagittal direction.



KEYWORDS: Distal movement; Intrusion; Posterior teeth; Mini-implants; Buccolingual inclination; Forces.

RESUMEN: Comparar los cambios en la inclinación bucolingual de los dientes posteriores cuando se aplican fuerzas con mini-implantes colocados en la cara bucal de los dientes posteriores maxilares en dirección sagital y vertical. Se incluyeron dieciséis pacientes jóvenes que requerían el movimiento distal de los dientes maxilares mediante mini-implantes y diez pacientes que requerían intrusión de los dientes posteriores con mini-implantes, conformando el grupo 1 (G1) y el grupo 2 (G2), respectivamente. En G1, se aplicaron fuerzas sagitales de 200 gramos bilateralmente utilizando resortes de NiTi desde mini-implantes colocados entre el segundo premolar maxilar y el primer molar permanente hacia aditamentos en un arco de acero inoxidable de 0.018" x 0.025" en la región anterior. En G2, se aplicaron fuerzas verticales de 200 gramos bilateralmente mediante un hilo elástico desde los mini-implantes hacia un arco de acero inoxidable de 0.019" x 0.025". Se realizaron tomografías CBCT antes y al final del proceso de distalización/intrusión. Se aplicaron pruebas t pareadas y pruebas t independientes. Se observó una inclinación bucal estadísticamente significativa del segundo premolar maxilar en G2 (valor $p=0.008$), acompañada de una inclinación bucal leve en G1. Aunque no estadísticamente significativa, se evidenció una inclinación bucal leve del segundo molar maxilar en ambos grupos. El primer molar maxilar, aunque sin significancia estadística, mostró inclinación lingual en G1, mientras que no se observaron cambios en la inclinación bucolingual en G2. Se evidenció clínicamente una inclinación bucal significativa del segundo molar y del segundo premolar maxilar en G1 y G2, así como inclinación lingual del primer molar maxilar en G1. Se observaron cambios significativos en la inclinación bucolingual de los segundos premolares y segundos molares maxilares cuando las fuerzas fueron aplicadas en dirección sagital y vertical desde la cara bucal. Se registró inclinación lingual del primer molar maxilar en dirección sagital.

PALABRAS CLAVE: Movimiento distal; Intrusión; Dientes posteriores; Mini-implantes; Inclinación bucolingual; Fuerzas.

INTRODUCTION

Evaluation of treatment outcome in orthodontics typically focuses on the sagittal and vertical dimensions. Evaluating treatment changes in the transverse dimension is often challenging due to the routine use of lateral cephalograms, which only provide a two-dimensional view of the craniofacial structures in the anteroposterior and vertical planes. Although transverse measurements can be obtained from study models, they only indicate variations in inter-molar or inter-premolar widths and fail to reflect the buccolingual inclination of the teeth, the spatial relationship of posterior teeth to the basal bone, or the position of the root within the alveolar bone. Posterior-anterior cephalograms can help determine the buccolingual inclination of posterior teeth, but the overlapping structures in

these images may complicate the identification of specific landmarks.

Recently, cone beam computed tomography (CBCT) has gained popularity in orthodontics for various purposes including diagnosis, treatment planning, and monitoring treatment progress (1,2). CBCT allows clinicians to view cranial structures in three dimensions, free from overlap or obstruction posed by adjacent structures (3-5). This capability makes CBCT a valuable tool for assessing the skeletal bases and dentition in the transverse dimension.

Measurements obtained through CBCT are reliable for evaluating the craniofacial complex (6). Moreover, radiation exposure from CBCT has significantly decreased in recent years (7,8), contributing to its safety as a diagnostic tool. Its accuracy

in measuring dental structures in the transverse plane makes CBCT a superior alternative to traditional two-dimensional imaging techniques like posterior-anterior cephalograms. However, careful consideration is necessary when adopting its routine use.

Mini-implants are widely used in orthodontics to facilitate various types of tooth movement. The most common placement site for mini-implants is in the buccal region, specifically in the inter-radicular space between the maxillary second premolar and maxillary first permanent molar (9-13). These mini-implants allow force application in both the sagittal and vertical directions to achieve different tooth movements. By applying appropriate biomechanical principles, mini-implants positioned in this area can help retract the maxillary anterior teeth in extraction cases (11,12), facilitate the distal movement of the maxillary dentition in non-extraction cases (13,14), intrude both anterior and posterior teeth (9,15,16) and enable individual tooth movements based on the type of malocclusion.

Sagittal forces from the mini-implant to the teeth primarily result in the retraction of anterior teeth and some degree of intrusion (11,13). Conversely, vertical forces mainly result in the intrusion of either the anterior or posterior teeth (9,15) depending on the placement site of the mini-implant and the direction of applied force. The transverse effects of these forces on the dentition, however, have not been well studied. It is theorized that these forces may lead to buccal or lingual tipping of the posterior teeth in the transverse plane. According to biomechanical principles, using forces from mini-implants situated on the buccal side of the maxillary posterior region may result in a buccal flaring of the posterior teeth due to the relative apical location of the mini-implant to the point of force application on the archwire. However, there is sufficient research data to confirm this theory or to clarify how poste-

rior teeth move in the transverse plane when mini-implants are used as anchorage.

To address this gap, the present study aims to evaluate changes in the buccolingual inclination of posterior teeth when forces are applied in either the sagittal or vertical direction. The study was designed such that the applied forces represented orthodontic techniques routinely performed in clinical practice.

The null hypothesis is that there is no significant difference in the change in buccolingual inclination of the posterior teeth when forces were applied in these two directions. The objective of the study is to compare the changes in buccolingual inclination of the posterior teeth resulting from sagittal forces applied from a mini-implant positioned between the maxillary second premolar and maxillary first permanent molar onto attachments on the anterior teeth, with changes arising from intrusive forces applied from the mini-implant onto the archwire in the posterior region.

MATERIALS AND METHODS

This study was conducted in the Department of Orthodontics of our institution. The study was approved by the scientific board of our university under reference number SRB/SDC/FACULTY/20/ORTHO/11. Ethical clearance was obtained for the study (IHEC/SDC/FACULTY/20/ORTHO/11). Patients seeking orthodontic treatment were screened, leading to the selection of sixty individuals undergoing treatment with mini-implants as anchorage.

The selected patients were divided into two groups; Group 1 (G1) and Group 2 (G2). The treatment plan for G1 involved the distal movement of the maxillary teeth using mini-implants, while G2 focused on the intrusion of the posterior teeth with mini-implants. Patients in G1 had a full complement of teeth with mild to moderate

proclination of the maxillary anterior teeth in the initial leveling and aligning the phase of orthodontic treatment. These patients were scheduled for distal movement of the maxillary dentition without needing premolar extraction or interproximal reduction. G2 consisted of patients exhibiting a tendency towards vertical growth pattern and proclination of the upper anterior teeth requiring bilateral upper first premolar extraction. These patients needed posterior teeth intrusion to correct mild vertical discrepancies and to retract anterior teeth for axial inclination correction. Divergence was an inclusion criterion in G2 but not in G1. Both groups included young adults aged 15 to 25 years, with no history of orthodontic treatment, systemic diseases, or temporomandibular diseases.

The demographic data of the patients included in the study are presented in Table 1, showing a mean age of in G1 19.44 ± 4.07 years and 21.80 ± 3.05 years for G2.

Table 1. Baseline data showing the demographics of the patients included in the study.

	Number of patients	Gender		Age (years)	Duration (months)
		Male	Female	Mean(SD)	Mean(SD)
G1	16	7	9	19.44(4.07)	8.44(2.99)
G2	10	5	5	21.80(3.05)	7.70(1.62)

There was no available literature evaluating the change in buccolingual inclination of the posterior teeth with mini-implants. Based on earlier literature (16) that assessed the changes in buccolingual width of the maxillary first permanent molar, 10 samples with a power of 95 and an effect size of 1.333 were required to evaluate transverse changes. Accordingly, 16 participants in G1 and 10 participants in G2 were included. Written informed consent was obtained from all patients who agreed to participate in the study. A minimum change of 0.5° was considered clinically significant.

In G1, patients were treated with a non-extraction treatment protocol. Maxillary third molars if present, were removed. 0.022 MBT bracket prescription (3M Unitek) was bonded on all the teeth from the maxillary central incisor to the maxillary second molar on both sides for all patients. Leveling and aligning were carried out sequentially until a 0.018" X 0.025" stainless steel wire was passive in the slot. Stainless steel mini-implants (1.2mm X 8mm) were placed buccally at the mucogingival junction between the maxillary second premolar and maxillary first permanent molar on both sides under adequate local anaesthesia (17). A distalizing force of 200 grams was applied using pre-calibrated NiTi coil springs placed from the mini-implants to crimpable hooks positioned between the maxillary lateral incisor and maxillary canine on both sides. Patients were reviewed periodically every three weeks until distal movement of the maxillary teeth was completed. The entire treatment was performed by a single operator.

In G2, maxillary first premolars were extracted on both sides in all patients. Fixed orthodontic treatment commenced with 0.022 MBT bracket prescription (3M Unitek) bonded on all the teeth from the maxillary central incisor to the maxillary second molar on both sides in all patients. A transpalatal arch was placed between the maxillary first permanent molars, slightly away from the palate to avoid soft tissue impingement. Leveling and aligning were carried out sequentially until a 0.019" X 0.025" stainless steel wire was passive in the slot, and a mild reverse curve was incorporated in the archwire. Stainless steel mini implants (1.2mm X 8mm) were placed buccally at the mucogingival junction between the maxillary second premolar and maxillary first permanent molar on both sides under adequate anaesthesia (18). Intrusive forces were applied using elastic thread from the mini-implants to the archwire, delivering 200 grams of force per side. Only the intrusion of posterior teeth was performed and retraction of anterior teeth

was not initiated to prevent the effect of retractive forces on the posterior teeth. Patients were reviewed periodically every 3 weeks until intrusion was achieved. The entire treatment was performed by a single operator. CBCT scans were taken before the start (T1) and towards the end (T2) of intrusion and distalisation of the maxillary posterior teeth in groups G1 and G2, respectively.

The buccolingual inclination of the posterior teeth was measured with the Sidexis XG 2.63 machine (2016 Sirona Dental Systems, GmbH). The specifications of the CBCT machine were 90 kV, 9-12 mA, 8-14-second exposure time, 200 microns voxel resolution, and an 80 X 80 mm field of view. The image was viewed with a Galileos viewer 1.9 (2016 Sirona Dental Systems, GmbH).

The buccolingual inclination of the posterior teeth was assessed in the coronal view using a multi-planar window, with the nasal plane serving as a reference. This plane is drawn between the right and left sides of the nasal cavity, tangent to the nasal floor. For the maxillary permanent molars, a slice capturing the mid-section of the tooth in the transverse plane was identified. The long axis of the maxillary permanent molars was

drawn through the central fossa and the furcation of the roots (Figure 1). The buccolingual inclination of the maxillary permanent molars was measured at T1 and T2 as the inner angle formed between the long axis of the maxillary permanent molars and the nasal plane (Figure 1).

For the maxillary premolars, the long axis was drawn through the central fossa to the tip of the root in single-rooted teeth (Figure 2). In multi-rooted maxillary premolars, the long axis was drawn as the line connecting the central fossa and the furcation of the roots (Figure 3). The buccolingual inclination of the maxillary premolars was similarly measured at T1 and T2 as the inner angle formed between the long axis of the maxillary premolars and the nasal plane (Figure 2, Figure 3).

All measurements were conducted by a single investigator. The change in buccolingual inclination of the maxillary premolars and molars from T1 to T2 was determined in both groups, G1 and G2, and compared between them. Five samples from each group were randomly selected. To check, intra-operator and inter-operator error, all measurements were repeated in both groups.



Figure 1. Shows the buccolingual inclination of the permanent maxillary molars measured as the angle formed between the long axis of the permanent maxillary molar and the nasal plane. The long axis of the permanent maxillary molar was drawn through the central fossa and the furcation of the roots. The nasal plane was drawn between the right and left sides of the nasal cavity, tangent to the nasal floor.

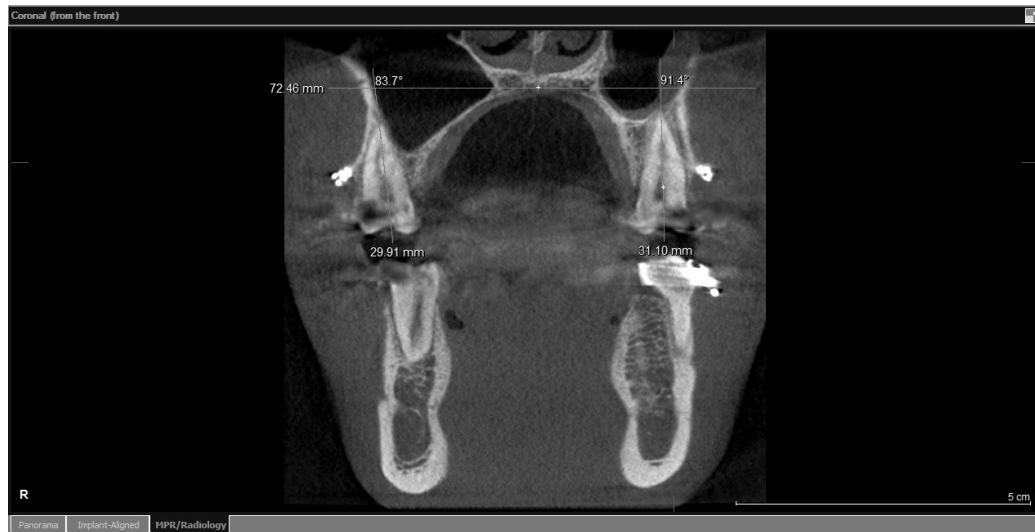


Figure 2. Shows the long axis of the premolars drawn through the central fossa to the tip of the root in single-rooted teeth. The buccolingual inclination of the maxillary premolar was measured as the angle formed between the long axis of the maxillary premolars and the nasal plane.

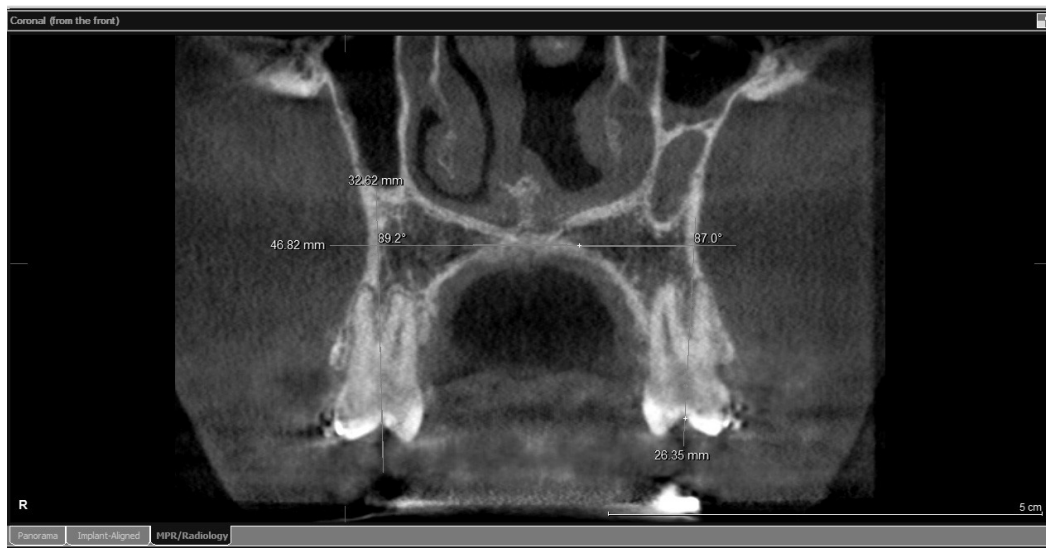


Figure 3. Shows the buccolingual inclination of the maxillary premolars measured as the angle between the long axis of the maxillary premolars and the nasal plane. The long axis of the premolar was drawn through the central fossa and the furcation of the root in multi-rooted premolars.

STATISTICAL ANALYSIS

Descriptive statistics was conducted to ascertain the mean age of the patients, the mean duration of treatment, and the gender distribution across both groups. The Shapiro-Wilk test indicated a normal distribution. A paired t-test was performed to evaluate the changes in the buccolingual inclination of the maxillary molars and premolars within each group. Additionally, an Independent t-test was performed to compare the changes in the buccolingual inclination of the posterior teeth between the two groups, G1 and G2. The intra-operator and inter-operator reliability was assessed using the intraclass correlation coefficient ensuring consistent measurements across tests.

RESULTS

Of the 60 patients undergoing orthodontic treatment with mini-implants, 26 participants were identified. Of these, 10 participants required intrusion of the posterior teeth as part of their treatment plan, while 16 required distal movement of the entire dentition as part of the treatment protocol.

The mean age of the patient in G1 was 19.44 ± 4.07 years, and in G2 was 21.80 ± 3.05 years. The mean duration of treatment was 8.44 ± 2.99 months for G1 and 7.70 ± 1.62 months for G2, respectively (Table 1). The intraclass correlation coefficient was approximately 0.8 and 0.78 for most variables, indicating good intra-operator and inter-operator reliability.

Thirty-two maxillary first premolars, fifty-two teeth each from the maxillary second premolars, maxillary first permanent molars, and maxillary second permanent molars were assessed for changes in buccolingual inclination (Table 2). Due to the extraction of the maxillary first premolar in G2, fewer maxillary first premolars were included in the evaluation (Table 2).

Before the application of force, the mean buccolingual inclinations of the maxillary second molar, maxillary first molar, maxillary second premolar, and maxillary first premolar were recorded as follows; $98.79 \pm 6.38^\circ$, $92.27 \pm 6.58^\circ$, $93.56 \pm 7.43^\circ$ and $93.22 \pm 9.80^\circ$, respectively (Table 2).

Table 2. Showing the mean and standard deviation of the buccolingual inclination of the posterior teeth in both G1 and G2 measured prior to the application of orthodontic force.

Posterior teeth	N	Buccolingual inclination ($^\circ$) Mean (SD)
Maxillary second permanent molar	52	98.79(6.38)
Maxillary first permanent molar	52	92.27(6.58)
Maxillary second premolar	52	93.56(7.43)
Maxillary first premolar	32*	93.22(9.80)

*Maxillary first premolar was extracted in G2

In G1, the evaluation of buccolingual inclination revealed a buccal tipping of the maxillary second permanent molar measuring $1 \pm 4.89^\circ$, with a 95% confidence interval of $-2.76 - .76$. However, this change was not statistically significant (p-value of .256) (Table 3). Additionally, mild lingual tipping of the maxillary first permanent molars was observed at $1.05 \pm 5.16^\circ$, with a 95% confidence interval of $-.81 - 2.91$, but this change was also not statistically significant (p-value of .260) (Table 3). For the maxillary second premolar, there was a mild buccal tipping of $1.21 \pm 5.84^\circ$, with a 95% confidence interval ranging from $-3.32 - .89$ and this result was similarly not statistically significant (p-value of .249) (Table 3). Lastly, the maxillary first premolar exhibited a minimal change in the buccolingual inclination, recorded as $0.32 \pm 4.59^\circ$, with a 95% confidence interval of $-1.34 - 1.98$ (p-value of .698) (Table 3).

In G2, there was mild buccal tipping of the maxillary second permanent molar by $.89 \pm 2.62^\circ$

with a 95% confidence interval of -2.12 - $-.34$ and the change was not statistically significant, showing a p-value of $.145$ (Table 3). The buccolingual inclination of the maxillary first permanent molar showed no change, with a difference of $0.13 \pm 2.37^\circ$ between T1 and T2, a 95% confidence interval of -1.24 - $-.98$, and a p-value of $.808$ (Table 3). In contrast, there was significant buccal tipping of the maxillary second premolar by $3.01 \pm 4.52^\circ$, with a 95% confidence interval of -5.12 - $-.89$, and this change was statistically significant with a p-value of $.008$ (Table 3). The maxillary first premolar was extracted in G2, so the buccolingual inclination of the maxillary first premolar could not be determined. Comparison of treatment change between T1 and T2, showed a clinically significant buccal tipping of maxillary second molar and second premolar in G1 and G2 and a clinically significant lingual tipping of the maxillary first molar in G1 but not in G2. There lingual tipping of the maxillary first premolar in G1 but this was not clinically significant.

When comparing the changes in buccolingual inclination between the groups, G1 and G2, the findings for the maxillary second permanent molar revealed similar changes in both groups,

characterized by mild buccal tipping. The mean difference in inclination between G1 and G2 was $0.11 \pm 1.04^\circ$, with a 95% confidence interval of -2.21 - 1.99 . This result was not statistically significant with a p-value of $.916$ (Table 4).

For the maxillary first permanent molar, the mean difference in buccolingual inclination was $1.18 \pm 1.05^\circ$ in G1, which exhibited lingual tipping, while G2 showed no tipping. The 95% confidence interval for this measurement was $-.94$ - 3.29 and again, this result was not statistically significant, with a p-value of $.270$ (Table 4).

Both groups demonstrated buccal tipping of the maxillary second premolar, but the tipping was more pronounced in G2 than in G1 (Table 4). The mean difference in the change in buccolingual inclination of the maxillary second premolar between G1 and G2 was $1.79 \pm 1.53^\circ$ with a confidence interval of -1.29 - -4.87 . This result was also not statistically significant with a p-value of $.248$ (Table 4).

Throughout the treatment, no evident harm was encountered, and the radiation exposure was within permissible limits.

Table 3. Changes in buccolingual inclination of the posterior teeth in G1 and G2.

Posterior teeth	N	buccolingual inclination (°)		buccolingual inclination (°)		
		Pre Mean(SD)	Post Mean(SD)	Change Mean(SD)	95% CI	Sig. (2-tailed)
G1						
Maxillary second permanent molar	32	98.82(7.19)	99.82(5.22)	-1.00(4.89)	-2.76 - .76	.256
Maxillary first permanent molar	32	92.07(7.24)	91.03(4.63)	1.05(5.16)	-.81 - 2.91	.260
Maxillary second premolar	32	92.38(6.65)	93.59(6.14)	-1.21(5.84)	-3.32 - .89	.249
Maxillary first premolar	32	91.63(6.35)	91.31(5.17)	.32(4.59)	-1.34 - 1.98	.698
G2						
Maxillary second permanent molar	20	98.76(4.99)	99.65(5.16)	-.89(2.62)	-2.12 - .34	.145
Maxillary first permanent molar	20	92.01(4.48)	92.14(4.29)	-.13(2.37)	-1.24 - .98	.808
Maxillary second premolar	20	95.26(6.98)	98.26(5.93)	-3.01(4.52)	-5.12 - -.89	.008*

First premolar was extracted in G2. Therefore bucco-lingual inclination was not determined for first premolar in G2.

*p<0.05 is statistically significant, negative sign indicates buccal movement and positive sign indicates lingual movement.

Table 4. Comparison of changes in buccolingual inclination of the posterior teeth between G1 and G2.

Posterior teeth	N		Changes in buccolingual inclination (°) Mean(SD)		Mean Difference (SE)	95% CI	Sig. (2-tailed)
	G1	G2	G1	G2			
Maxillary second permanent molar	32	20	-1.00(4.89)	-.89(2.62)	-.11(1.04)	-2.21 - 1.99	.916
Maxillary first permanent molar	32	20	1.05(5.16)	-.13(2.37)	1.18(1.05)	-.94 - 3.29	.270
Maxillary second premolar	32	20	-1.2(5.84)	-3.01(4.52)	1.79(1.53)	-1.29 - 4.87	.248

*p<0.05 is statistically significant. negative sign indicates buccal movement and positive sign indicates lingual movement.

DISCUSSION

When a distalising force is applied in the anteroposterior direction on the maxillary dentition to attachments placed on the archwire in the anterior region, the primary effect is a retractive force, accompanied by a minor intrusive component that depends on the relative height of the attachment and the mini-implant (19). This force is likely to cause a buccal movement of the posterior teeth as the point of force application is buccal and apical to the center of resistance of the maxillary dentition. Similarly, when an intrusive

force is applied from the mini-implant to the base archwire to intrude the maxillary posterior teeth, a buccal flaring of the molars may occur, as the point of force application is again buccal and apical to the center of resistance of the posterior teeth. This study evaluates the changes in the buccolingual inclination of the posterior teeth under sagittal and vertical forces.

The results of the present study demonstrate several key findings regarding dental movements under applied forces in G1. There was observed buccal tipping of the maxillary second permanent

molar, mild lingual tipping of the maxillary first permanent molar, and also buccal tipping of the maxillary second premolar. However, the buccolingual inclination of the maxillary first premolar showed minimal change when subjected to sagittal forces. An explanation for the lingual tipping of the maxillary first permanent molar during these forces remains elusive.

In contrast, when considering vertical forces in G2, significant buccal tipping of the maxillary second premolar was noted alongside mild buccal tipping of the maxillary second permanent molar due to point of force application being apical and buccal to the centre of resistance of the dentition. The inclination of the maxillary first permanent molar remained stable, likely due to the support provided by the transpalatal arch soldered onto the palatal side of its molar band. Clinically, instances of buccal tipping of the maxillary second premolars accompanied by an overhanging palatal cusp were observed in a few cases within G2. Moreover, an increased buccolingual inclination of the tooth (20) may lead to balancing interferences, particularly in the second molar region, potentially affecting the normal function of the stomatognathic system.

Buccolingual inclination is important in assessing transverse discrepancy in Class II division 1 malocclusion (19). The transverse discrepancy in Class II division 1 malocclusion may be due to nasal obstruction, thumb-sucking or finger-sucking habits, or a low tongue position (20) resulting in a compensatory lingual inclination of the maxillary molar (21,22). Mini-implants placed in the posterior region for correction of class II molar relation by distalisation may improve buccolingual position of the molars without additional mechanics.

In the present study, CBCT was used to visualize the teeth and determine buccolingual inclination as these cannot be determined on study

casts. There are several methods to draw the long axis of the multi-rooted teeth on a DICOM image such as a line drawn through the buccal roots (23), a line connecting the central groove to the furcation (24), line from the central groove to the middle of the apices (25) or a line drawn to pass through the midpoint at one-half the crown width and the midpoint at one-third the distance from the apex (26). In the current study, the long axis of the posterior teeth was drawn through the central fossa and the furcation of the multi-rooted teeth. The long axis of the teeth may be drawn digitally using custom root vector-analysis software (27).

In untreated patients, a buccal inclination of maxillary first permanent molars has been observed in 90.7% of the teeth (26), which was similar to the findings in the current study. The mean buccal inclination of the maxillary first permanent molar in untreated cases ranged from 4.05° per side to 8.0° (25,26) with no significant difference in the buccolingual inclination of the maxillary molar between the right and left mean values (28). In these studies, the buccal inclination of the posterior teeth was measured on the buccal side of the alveolar bone, contrary to the present study where the nasal plane was used. Under normal conditions, the maxillary molars have a slight buccal inclination and the mandibular molars have a slight lingual inclination (26,28,29). A significant difference in the inclination of the maxillary second molar between genders has been observed (29). However, sexual dimorphism with regard to bucco-lingual inclination was not evaluated in the present study.

There is some ambiguity regarding the effect of buccal tooth movement on the alveolar bone. One study found bone apposition on the buccal surface of the cortical bone over the roots (9) during buccal translation of the maxillary first premolar, with forces through the center of resistance. Conver-

sely, another study reported a loss of vertical bone height and a decrease in buccal bone thickness apical to the cemento-enamel junction (30).

Maintaining proper articulation of the maxillary and mandibular second permanent molars is essential for preserving the normal buccolingual inclination of molars, optimizing masticatory function, and preventing dehiscence and fenestration. The present study included patients between fifteen years and twenty-five years, as those younger than fifteen years were found to have poor bone quality and would affect the stability of the mini-implant. The stability of the mini-implant can also be increased with the use of motor-driven placement of mini-implants as these were found to be superior to hand-driven placement, resulting in better contact surface area with bone and fewer microcracks (31).

Care must be taken to reduce radiation exposure when using CBCT. Radiation exposure can be minimized by decreasing the field of view, employing proper scanning protocols, and utilizing shielding methods. The current study used a CBCT scan with a small field of view, recording only the maxilla. This effectively reduces the patient's exposure to ionizing radiation (4), decreases scatter, improves image resolution, and performs comparably to a scan with a larger field of view (4). Thyroid collar and eyeglasses were also given to protect the thyroid gland and the eyes.

Shielding devices such as thyroid collars and eyeglasses, along with optimal placement of the field of view, have been shown to result in the lowest locally absorbed doses and most effective dose (32). Thyroid gland shielding has been found to significantly lower the equivalent dose in various tissues under all radiation protocols and is recommended for all CBCT examinations (33).

Randomisation was not possible in the current study because the patients in G1 had a dental discrepancy in the sagittal direction requiring distal movement of the teeth whereas patients in G2 patients had a dental discrepancy in the vertical direction and required intrusion of the posterior teeth. Patients in both the group had mini-implants placed between the maxillary second premolar and first permanent molar bilaterally and the effect of orthodontic forces applied in different directions from mini-implants on the posterior teeth was evaluated.

Blinding of the treatment procedure was not possible as the operator has to be aware of the treatment mechanics required to bring about a particular type of tooth movement in each group. Long term follow up was not possible due to difficulty in recalling patients once treatment was completed.

In this study, observations indicated that the right and left maxillary premolars and molars might not appear on the same DICOM image and may need to be measured in separate slices. Additionally, locating the central fossa can be challenging if the molars are banded; thus, it might be more effective to make measurements before banding when feasible. Convergent roots, particularly in premolars, may present as single roots, necessitating careful identification before measurements. Furthermore, navigating through several slices of the CBCT to find a suitable image for measuring buccolingual inclination can be time-consuming and represents a limitation of this study. Expertise is essential for relocating the same DICOM image for evaluation and exporting images for future reference could be beneficial. A computational tool is currently in development aimed at automatically identifying cephalometric landmarks on computed tomography images (34). 3D superimposition of CBCT scans taken at different times was not

performed due to the high cost associated with the necessary software (35).

This study was conducted in a single centre. The results of the present study may be performed in other centres with similar settings.

CONCLUSION

Comparison of the buccolingual inclination of the posterior teeth between groups did not show a statistically significant change in the buccolingual inclination of the maxillary posterior teeth under sagittal and vertical forces except for a statistically significant buccal tipping of the maxillary second premolars due to the intrusive forces. There was a clinically significant buccal tipping of maxillary second molar and second premolar in both the sagittal and vertical direction and a clinically significant lingual tipping of the maxillary first molar in the sagittal direction but not in the vertical direction.

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