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# Displacement and stress distribution pattern during complete mandibular arch distalization using buccal shelf bone screws – A three-dimensional finite element study

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## Abstract

**BACKGROUND:** To evaluate and compare the distribution of stress and displacement of teeth during mandibular arch distalization using buccal shelf screws.

**MATERIALS AND METHODS:** Three three-dimensional finite element models of mandibular arch were constructed with third molars extracted. Models 1, 2, and 3 were constructed on the basis of the lever arm heights of 0 mm, 3 mm, and 6 mm, respectively, between the lateral incisor and canine. A buccal shelf screw was placed at the area in the second molar region with the initial point of insertion being inter-dental between the first and second molars and 2 mm below the mucogingival junction. MBT pre-adjusted brackets (slot size 0.022 × 0.028") were placed over the clinical crown's center with a 0.019 × 0.025" stainless-steel archwire on three models. A retraction force of 300 g was applied with buccal shelf screws and a lever arm bilaterally using nickel-titanium closed coil springs. The displacement of each tooth was calculated on X, Y, and Z axes, and the von Mises stress distribution was visualized using color-coded scales using ANSYS 12.1 software.

**RESULT:** The maximum von Mises stress in the cortical and cancellous bones was observed in model 1. The maximum von Mises stress in the buccal shelf screw and the cortical bone decreased as the height of the lever arm increased. Applying orthodontic forces at the level of 6 mm lever arm height resulted in greater biomechanical bodily movement in distalization of the mandibular molars compared to when the orthodontic forces were applied at the level of 0 mm lever arm height.

**CONCLUSION:** Displacement of the entire arch may be dictated by a direct relationship between the center of resistance of the whole arch and the line of action generated between the buccal shelf screw and force application points at the archwire, which makes the total arch movement highly predictable.

**Keywords:**

Buccal shelf screw (BSS), distalization, finite element method, von Mises stress

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## Introduction

Malocclusion occurs in three planes of space, that is, sagittal, vertical, and transverse. In the sagittal plane, malocclusion is classified as Angle's Class I, Class II, and Class III. Class III malocclusion is one of the most common skeletal malocclusions, and mandibular prognathism is one of the most prevalent complaints for Asian orthodontic patients.[1] Class III treatment is a considerable clinical challenge and commonly includes growth modification involving a chin cup to restrain mandibular growth, dentoalveolar compensation, or

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camouflage involving dental extractions or orthognathic surgery.[2]

In growing Class III patients, upward-and-forward rotation of the mandible in combination with forward growth is highly associated with unsatisfactory treatment outcomes after pubertal growth.[3] Surgical repositioning of the mandible is often required when treating severe Class III adult patients. Mild to moderate Class III patients can be treated non-surgically, but proper diagnosis and realistic treatment objectives are necessary to prevent undesirable sequelae. The choice between camouflage treatment and orthognathic surgery remains a challenge to clinicians.[4]

Class III patients who are not willing to undergo orthognathic surgery are treated with conventional fixed orthodontic appliances along with mandibular cervical headgear, mandibular high-pull J-hook headgear, Class III elastics, extractions, and multi-loop edgewise archwire therapy. Clinicians have attempted to treat Class III malocclusion by various methods of distalization of the mandibular dentition. Although distalization of the molars has been one of the most difficult biomechanical problems in traditional orthodontics, particularly in adults, it has now become possible to distalize mandibular molars with the use of various temporary skeletal anchorage devices (TSADs).[5,6]

Nowadays, the buccal shelf area is a common site for the insertion of temporary anchorage devices (TADs). This area is bound externally by the external oblique ridge and internally by the slope of the residual ridge. It lies lower and lateral to the second molar region. Buccal shelf bone screws can also be placed in the external oblique ridge of the mandible if the buccal shelf area is found to be thin or too deep.

Originally, the main purpose for TADs in the posterior mandibular arch was for maximal retraction of the anterior segment following extraction of premolars. The main advantage of buccal shelf screws is that it does not depend on patients' compliance and is easy to place. Various studies have been done in which the whole mandibular arch was retracted using inter-radicular mini screws. No study has been done yet in which a buccal shelf screw is used to distalize the whole mandibular arch.[7]

Finite element analysis (FEA) is a three-dimensional (3D) virtual model source for assessing force systems and their possible outcomes depending upon selected mechanical properties of appliance, tissue, and model design. However, these models cannot reproduce an exact biological phenomenon; they mimic it up to a certain level, resulting in substantial differences from reality. These models are capable of reflecting the clinical circumstances because they are fabricated after taking into consideration that the biological structures have homogeneous properties, whereas in humans, these structures are heterogeneous.[8] These models help create a virtual clinical scenario, which can be further applied in clinical practice to assess the reliability of a particular method.[9,10] Many studies have evaluated the stress distribution and the displacement of the anterior teeth using mini-screw-assisted retraction. However, a few studies evaluated the stresses in the alveolar bone and implant during en masse retraction of anteriors. The purpose of the present study is to evaluate and compare the displacement and the stress distribution pattern on the teeth during complete mandibular arch distalization with buccal shelf bone screws using the finite element method.

## Material and Methods

In this study, three 3D finite element models of the mandible, mandibular dentition with its periodontal structures, that is, periodontal ligament, alveolar bone, and cementum, were constructed after extraction of the third molar. The displacement and stress distribution pattern on the teeth were determined with 300 g force during mandibular arch distalization with NiTi closed coil springs and buccal shelf screws.

The following steps were included in the preparation of the finite element model:

1) The geometric model of the mandibular dentition with its periodontal structures (periodontal ligament, alveolar bone, and cementum) was constructed.
2) The geometric models were converted to a finite element model.
3) Material properties of the tooth structure and periodontium were incorporated.
4) Boundary conditions were defined.
5) Configuration was loaded.
6) Results and interpretation were translated.

A computed tomography (CT) scan image of a skull was taken, and the 3D geometrical construction of the finite element model of the mandibular dentition and their periodontal structures was done. This image was saved in DICOM format. According to a study, Coolidge's PDL was modeled of a thickness of 0.25 mm. The alveolar bone followed the CEJ gingivally and extended 1 mm beyond the apices. In the axial plane, the CT scan images of the mandible and mandibular dentition were taken. These data were exported to 3D image processing and editing software – MIMICS (version 8.11) (Materialise's Interactive Medical Image Control System). The geometric model was constructed consisting of only surface data with the help of Rapid Form 2004 software.

Geometric models were imported to HYPERMESH (version 11.0) software. In HYPERMESH software, all the individual parts, bone, teeth, periodontal ligament, MBT brackets 0.022 slots, wires, crimpable hooks, and buccal shelf screws (2 X 12), were assembled. With the help of HYPERMESH (version 11.0) software, the geometric models were converted into FEM. This process is called 'meshing'. The finite element model was the representative of geometry in terms of a finite number of elements and nodes. This process is called 'discretization'.

The total numbers of nodes (or total numbers of elements) comprising the model were 21,042 (93,958) for the teeth, 3960 (7574) for the PDL, 35,015 (135,463) for the cancellous bone, 29,551 (87,597) for the cortical bone, 17,688 (54,684) for the brackets, 3464 (11,840) for the buccal shelf screw, and 109 (108) for the archwire and lever arm.

In this study, the archwire and the brackets were assumed to be in a no-friction and no-play relationship. All materials employed for the finite element model study were considered to have homogeneous, isotropic, and linear elasticity. Material properties (Young's modulus and Poisson's ratio) were based on the results reported in the previous studies[10,11] [Table 1].

Three models of different lever arm heights (0, 3, and 6 mm) for distalization of the mandibular arch were installed on FEM:

Brackets were bonded on all teeth. A 0.019 × 0.025 inch SS arch wire was placed. A buccal shelf screw was placed at the area in the second molar region; the initial point of insertion is inter-dentally between the first and second molars and 2 mm below the mucogingival junction. Heights of 0 mm, 3 mm, and 6 mm lever arms were placed on the wire between the lateral and canine. 300 g of force was applied bilaterally with the help of a NiTi closed coil spring from the lever arm to the buccal shelf screw [Figure 1].

A finite element model consisting of nodes and elements of the teeth, periodontium, brackets, power arms, buccal shelf screws, and NiTi closed coil springs was then imported into ANSYS (12.1 version) software for analyzing the displacement and stress distribution.

A standard coordinate system was constructed with the x-axis corresponding to the buccolingual direction; the y-axis, the anteroposterior direction; and the z-axis, the superior-inferior direction. A +x value was defined as the medial direction, +y as the posterior direction, and +z as the occlusal direction. The displacements of the teeth were calculated by applying the x, y, and z coordinates at the midpoints of the incisal edges of the central and lateral incisors, the cusp tip of the canine, the buccal cusp tips of the premolars, the mesiobuccal cusp tip of the molars, and the root apices of each tooth. The changes in teeth axes were calculated in each plane of space. The von Mises stress distribution along the periodontal ligament was calculated and visualized in the contour plot.

The stress distribution and displacement corresponding to the application of force were analyzed in all the models. The results attained consisted of the maximum von Mises stress concentration, maximum displacement, and stress distribution in the alveolar bone and early displacement of each tooth in the Y- and Z-axes. For displacement and stress, color coding was used. Minimum displacement/stress is coded by blue and maximum coded by red, and the residual shades are the variations of stress from minimum to maximum.

## Result

### von Mises stress

The maximum von Mises stress values induced in the buccal shelf screw, cortical bone, and cancellous bone at different lever arm heights in the mandible are shown in Table 2. The maximum von Mises stress in the buccal shelf screw was 146.690 Mpa when the lever arm height was 0 mm. The stress values gradually decreased to 135.570 and 114.840 Mpa as

**Table 1: Material properties used in the Finite Element Model**

| Materials | Young's modulus (MPA) | Poison's ratio |
|---|---|---|
| CorticalBone | 13700 | 0.3 |
| Cancellous Bone | 1370 | 0.3 |
| PDL | 0.667 | 0.49 |
| Teeth | 20000 | 0.3 |
| Brackets/Archwire and Buccal Shelf Screw | 200000 | 0.3 |

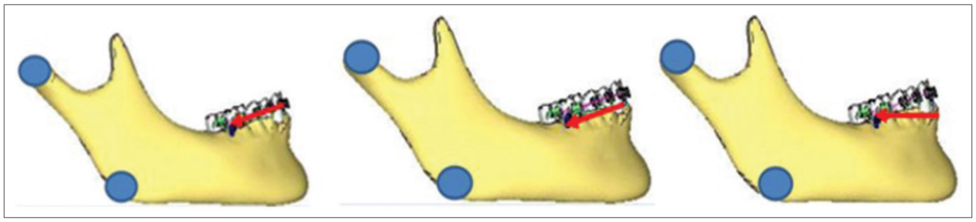


**Figure 1:** Finite element models of mandibular arch with brackets, archwire, NiTi closed coil spring, lever arm, and buccal shelf screw in models 1, 2, and 3

the lever arm height increased from 3 mm to 6 mm, respectively [Figure 2].

The von Mises stress in the cortical bone was 87.13 Mpa when the lever arm height was 0 mm. The stress values gradually decreased to 79.24 Mpa and 66.06 Mpa as the lever arm height increased from 3 mm to 6 mm, respectively. Thus, the von Mises stress was the highest when force was applied from a lever arm height of 0 mm and decreased with the increase in lever arm height. Minimal stress was transmitted to the cancellous bone. Stress was highly concentrated in the neck region of the buccal shelf screw, the contact point between the screw thread and cortical bone surrounding the screw. The cortical bone was subjected to higher stress levels than the cancellous bone. The cortical bones around the threads of the screw were the most stressed areas. Little stress was transmitted to the cancellous bone [Graphs 1-3].

### Displacement according to force application at the 0 mm lever arm height (model 1)

In the Y-axis, the displacement amount became greater at the coronal area of the teeth. The tipping movements

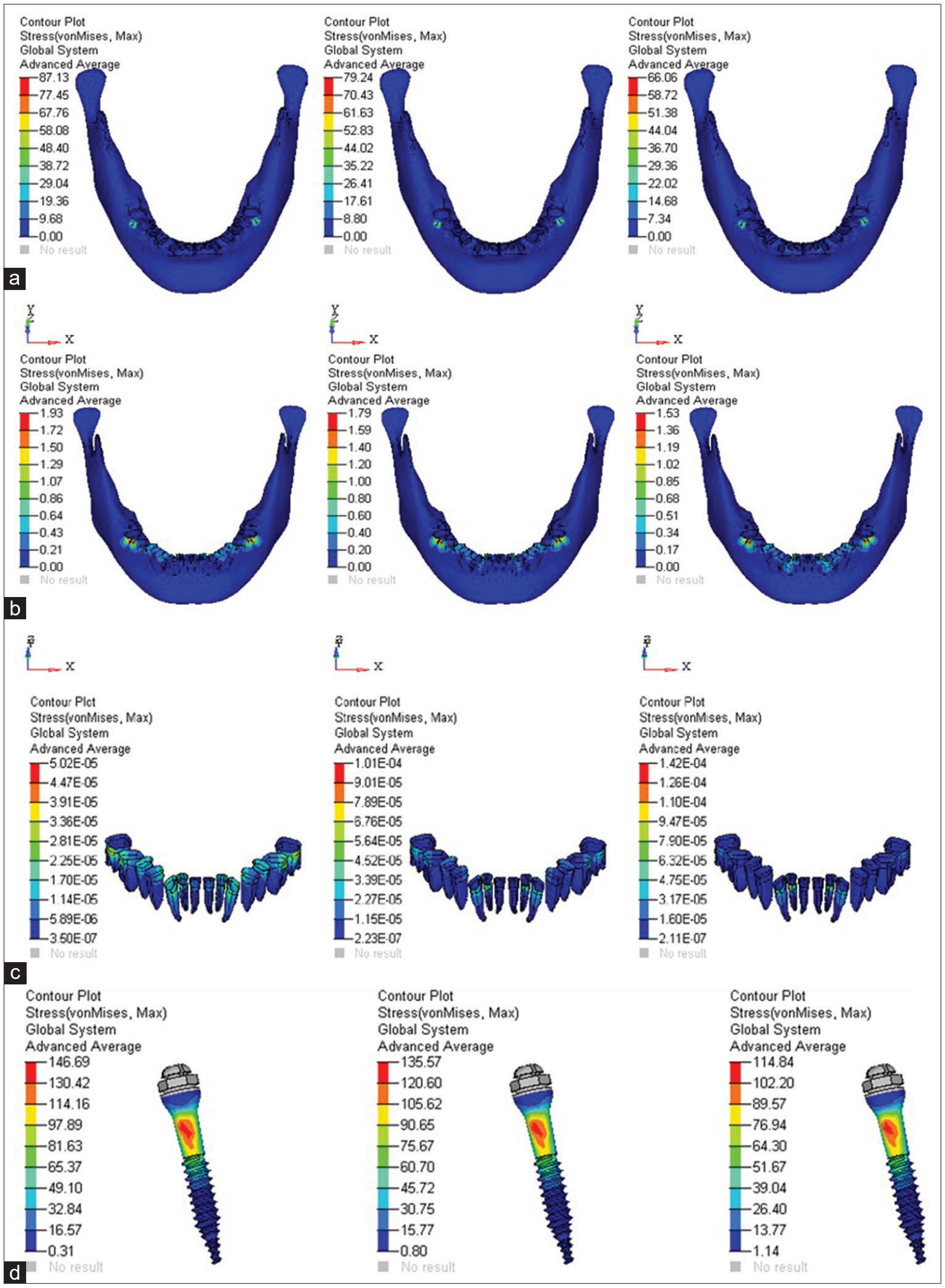


**Figure 2:** von Mises stress in (a) cortical bone, (b) cancellous bone, (c) periodontal ligament with BSS, and (d) buccal shelf screw in models 1, 2, and 3

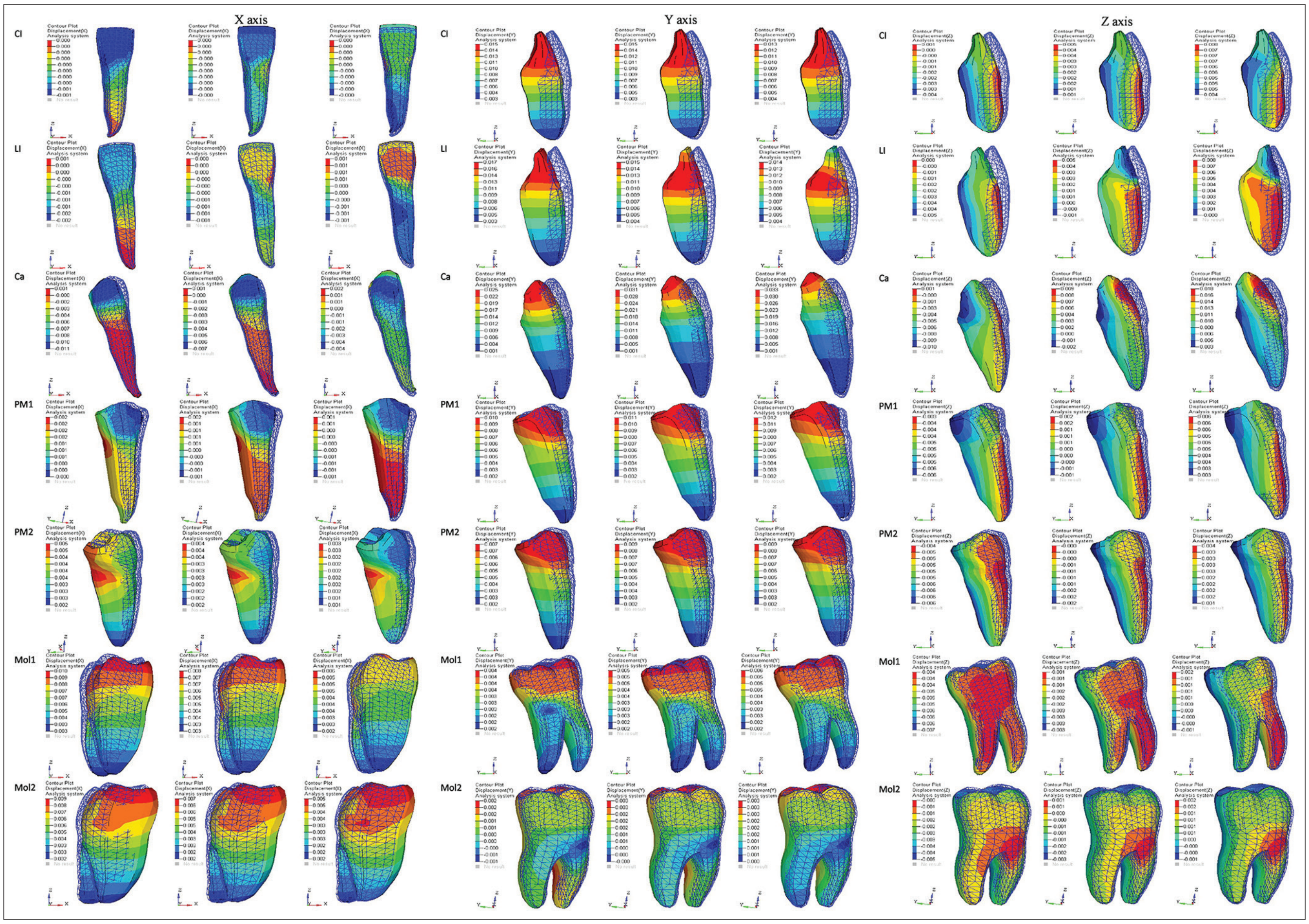


**Figure 3:** Displacement of mandibular arch with BSS in models 1, 2, and 3 (CI: central incisor; LI: lateral incisor; Ca: canine; first premolar: PM 1; second premolar: PM 2; first molar: Mol 1; second molar: Mol 2) in X-, Y-, and Z-axes

**Table 2: Stress in different regions**

| Region | Stress | | |
|---|---|---|---|
| | 0 mm | 3 mm | 6 mm |
| Cortical bone | 87.13 | 79.24 | 66.06 |
| Cancellous bone | 1.93 | 1.79 | 1.53 |
| PDL | 5.02E-05 | 1.01E-04 | 1.42E-04 |
| Buccal Shelf Screw | 146.690 | 135.570 | 114.840 |

were more prominent in the mandibular dentition. In the X-axis, the crown parts of teeth showed buccal movement in the anterior region. However, the movement pattern of the root areas showed lingual movement in the anterior teeth. In the posterior teeth, the crown parts of the teeth showed lingual movement. In the Z-axis, the intrusive movement was found in both anterior and posterior teeth [Figure 3, Table 3, Graph 4].

## Displacement according to force application at the 3 mm lever arm height (model 2)

The Y-axis shows almost controlled tipping in all teeth except the mandibular canine. In the X-axis, the crown parts of teeth showed buccal movement in the anterior region. In the posterior teeth, the crown parts of the teeth showed lingual movement. In the Z-axis, intrusive movement was seen in the posterior teeth and extrusive movement was seen in the anterior teeth [Figure 3, Table 3, Graph 5].

## Displacement according to force application at the 6 mm lever arm height (model 3)

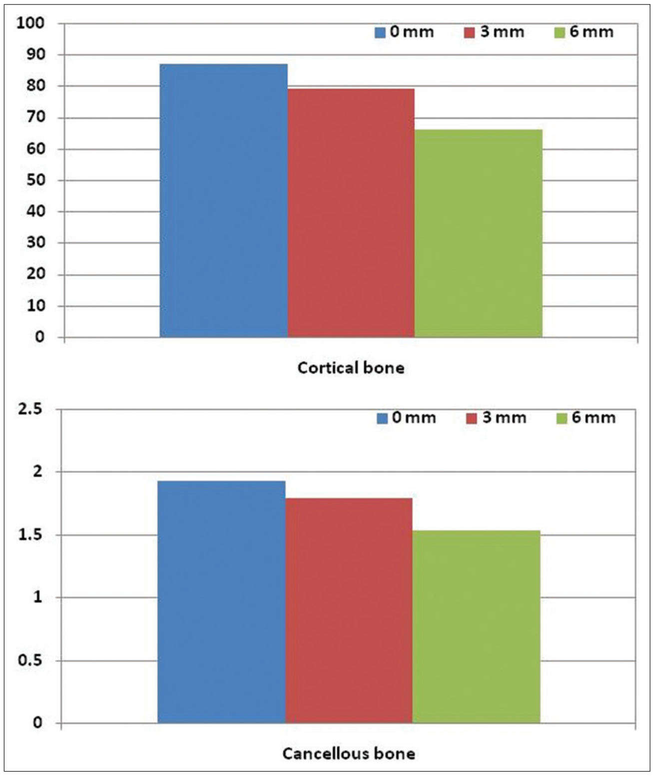
In the Y-axis, maximum distal movement is seen in anterior teeth, with the maximum in canine. In the X-axis, the crown parts of teeth showed buccal movement in the anterior. However, the movement pattern of the root areas showed lingual movement in the anterior teeth. In the posterior teeth, the crown parts of the teeth showed lingual movement. In the Z-axis, the extrusive movement tendency became prominent toward the posterior teeth, except for the mandibular canine [Figure 3, Table 3, Graph 6].

## Comparison of the mode of tooth movement according to vertical force application (0, 3, and 6 mm)

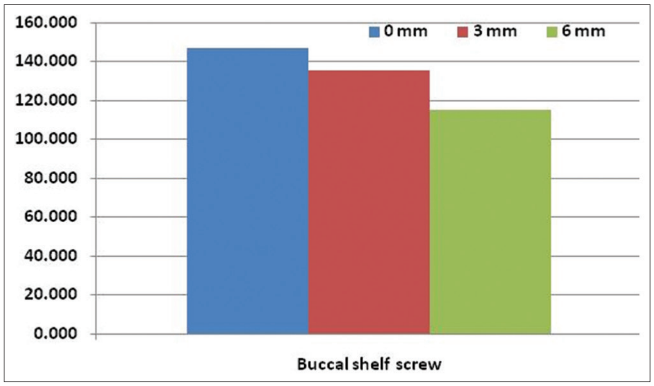
In the Y-axis, the resultant displacement was larger in

**Table 3: Displacement of teeth with buccal shelf screw**

| | x-axis | | | y-axis | | | z-axis | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 mm | 3 mm | 6 mm | 0 mm | 3 mm | 6 mm | 0 mm | 3 mm | 6 mm |
| Teeth | | | | | | | | | |
| CI | -0.001 | 0.00 | 0.00 | 0.015 | 0.015 | 0.013 | -0.004 | 0.005 | 0.008 |
| LI | -0.002 | -0.001 | 0.001 | 0.017 | 0.015 | 0.014 | -0.005 | 0.005 | 0.008 |
| Ca | -0.011 | -0.007 | -0.004 | 0.025 | 0.031 | 0.033 | -0.01 | 0.009 | 0.018 |
| PM 1 | 0.002 | -0.002 | 0.001 | 0.010 | 0.011 | 0.012 | -0.006 | 0.002 | 0.006 |
| PM 2 | 0.005 | 0.004 | 0.003 | 0.007 | 0.009 | 0.009 | -0.006 | -0.002 | 0.004 |
| Mol 1 | 0.010 | 0.008 | 0.006 | 0.004 | 0.005 | 0.006 | -0.007 | -0.003 | 0.002 |
| Mol 2 | 0.009 | 0.007 | 0.005 | 0.002 | 0.003 | 0.003 | -0.005 | 0.001 | 0.002 |

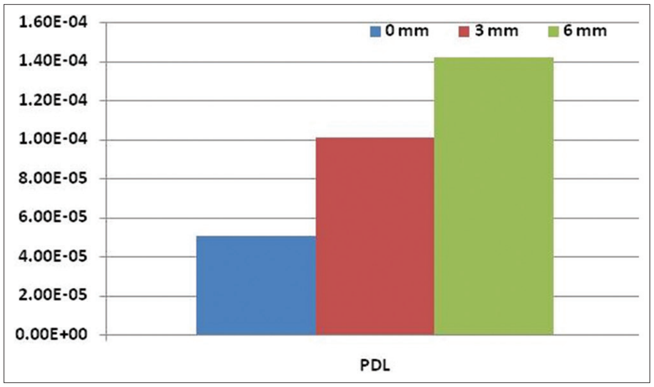


**Graph 1:** Stress on cortical and cancellous bones with different lever arm heights

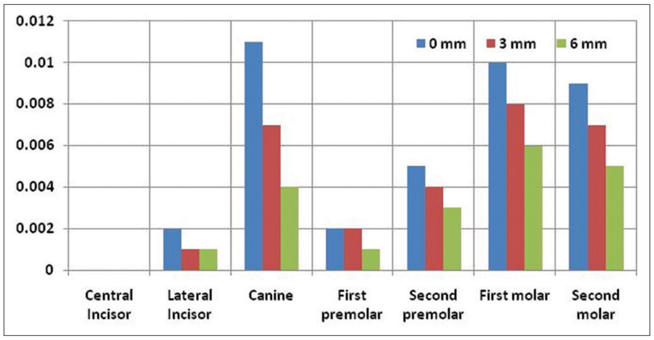


**Graph 3:** Stress on buccal shelf screws with different lever arm heights

the root area when orthodontic force was applied with increased hook height.



**Graph 2:** Stress on PDL with different lever arm heights



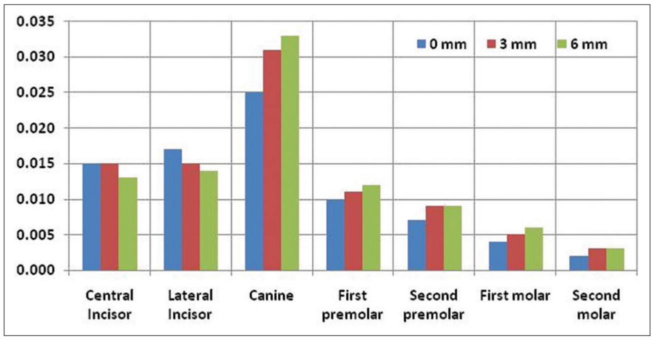
**Graph 4:** Displacement of teeth with different retraction lever arm heights in X-direction

Tipping movement (0 mm) changes to more bodily displacement (6 mm) with the change in vertical force application.

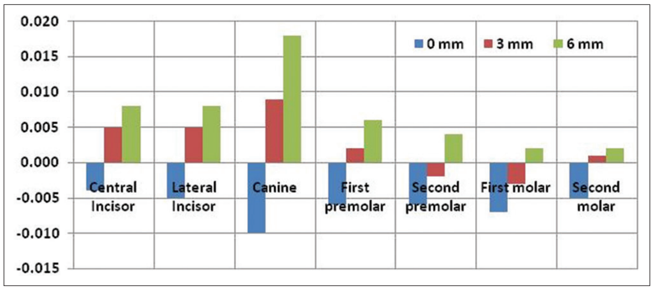
In the X-axis, the crown area of the anterior teeth showed outward movement and the posterior teeth showed lingual crown movement.

In the Z-axis, unwanted extrusive movement was produced when applying force at 6 mm of lever arm height as compared to the 0 mm lever arm height.

The displacement magnitude is the sum of all axis displacements and expresses the total displacement of the movement in the 3D space.



**Graph 5:** Displacement of teeth with different retraction lever arm heights in Y-direction



**Graph 6:** Displacement of teeth with different retraction lever arm heights in Z-direction

The rotation of the teeth was less when force was applied at 6 mm hook height compared to the force application at 0 mm lever arm height.

## Discussion

Although treatment of severe Class III skeletal relationships usually requires treatment and orthognathic surgery to achieve desirable results in adults, depending on the severity of malocclusion, treatment of Class III dental malocclusions with mild Class III or Class I skeletal relationships can be accomplished by camouflage treatment with various extraction/non-extraction modalities.[12] According to a patient's skeletal pattern and dental alignment, the non-extraction approach should be considered in orthodontics. Mandibular molar distalization and uprighting although complicated can be applied clinically to correct slight crowding or to facilitate prosthodontic treatment. Conventional orthodontic appliances have been known to elicit tipping rather than bodily movement.[13,14] The advent of skeletally derived anchorage systems, such as TSADs, gives us desired results with minimum undesirable side effects. Also, it allows practitioners to push the limits of mandibular arch distalization while treating Class III malocclusions without the need to extract teeth. For distalization in the mandibular arch, almost invariably third molar extraction is mandatory.[15] Studies have shown that the location of use of the skeletal anchorage system is important.[16-19] The site must have the proper bone quality to achieve primary stability, avoid certain anatomic structures, and be comfortable for the patient, and it must facilitate desired mechanics.[12] Distalization of the mandibular arch dentition can be achieved by using various biomechanical strategies according to force angulations to the occlusal plane.[20]

The finite element method has been used to analyze the displacement and stress distribution of the teeth and surrounding structures due to the different distalization modalities. The finite element method was chosen because it allows the construction of a model similar to an actual object allowing 3D visualization for the analysis and is capable of linear, non-linear, and solid and fluid structural interaction.

Displacement of the lower posterior teeth within the computed FE model was measured at the coronal, middle, and apical thirds for each tooth. The amounts of movement in the Y-axis were assigned specific colors to improve visual interpretation. Therefore, if a tooth was assigned more than one color, the results implied a possible combination of resultant movement types (e.g., tipping, bodily movement, and varying magnitudes of movement). In this study, when the proportion of uniform color along a tooth axis is higher, it is more likely that the tooth would undergo bodily movement as opposed to tipping. If each part of a given tooth (coronal, middle, and apical thirds) had been assigned the same color, the degree of displacement would tend to be consistent. However, if each tooth section had been assigned a different color, it indicated that when measured at various points along the tooth's axis, the tooth would tend to manifest different degrees of displacement.[10]

The 3D control of the molar during distalization using TADs for anchorage is important.[21-23] Since the distalizing force is applied buccal to the center of resistance of the posterior teeth, some consequences like distal tipping, mesial out rotation, and inadequate torque of the posterior teeth can occur. To prevent the first- and second-order side effects, the use of wires of adequate stiffness is imperative. Hence, 0.019 X 0.025 SS wire is used for mandibular arch distalization, and the wire is expanded for correction of lingual tipping of molars.

The treatment outcome may vary from the presence or absence of molar rotation, inclination, and other factors. For example, treatment of distal tipping can be effectively done by distal movement of the crown portion only. But in our study, models were assumed to have normal alignment; our primary concern was the evaluation of bodily movement during molar distalization.[24] Occlusal relations can worsen if molars extrude during treatment, causing clockwise mandibular rotation or open bite. Distal tipping of the first molar may cause premature contact, which might lead to relapse. Therefore, the clinician should ensure intrusion or maintenance of the pre-treatment molar position during distalization.

The force magnitude used in extra-alveolar mini-implant mechanics is an important factor for the therapy's success due to its influence on anchorage stability.[6] The recommended magnitude varies from 220 to 340 g (8 to 12 oz) for mechanics with mini-implants in the IZC site and from 340 to 450 g for the ones with mini-implants in the BS site.

### Determination of von Mises stress in all the hook height models

Stress is an essential factor in buccal shelf screw stability as increased stress might draw more cytokines, macrophages, and inflammatory mediators to the implant site, possibly resulting in a higher risk of mini-implant failure through loss of primary stability.[25] Biomechanical stresses and strains at the bone–implant interface have been attributed to implant failure in most instances, resulting in peri-implant inflammation leading to bone loss.[26]

The patterns of stress distribution of the mini-implant under loading of 300 g of force showed that the area of stress distribution was around the head and neck of the buccal shelf screw, the cortical bone. The site of maximum stress was concentrated around the point of force application, that is, the neck region of the buccal shelf screw. The stress concentration gradually decreased from the neck toward the apex. This was probably because maximum resistance is exerted at the buccal shelf screw entrance into the cortical and cancellous bones. This result correlates well with other similar studies.[27]

### Determination of displacement of mandibular dentition

In the Y-axis, the similarity of the indexing color of target teeth was higher when the force was applied at 6 mm hook height as compared with 0 mm hook height. Results showed that as the hook height increased, displacement within the mandibular molar region was likely to be bodily movement. Therefore, if the point of force application is moved vertically, from the bracket level to the cementoenamel junction level, then the application of orthodontic force can engender more bodily movement. The vertical position of force application is, therefore, an important consideration since more efficient translatory movement was achieved by changing the vertical force position. It is thought that as the cementoenamel junction level of the mandibular canine was below that of posterior teeth, it would be in the vicinity of the center of resistance vertically in all posterior teeth of this study, even though we cannot digitize the exact position of the center of resistance in them. The same result was reported by Tai *et al*.[12] Sung *et al*.[11] reported that displacement of the entire maxillary arch may be dictated by a direct relationship between the line of action generated between the mini-screws and force application points at the archwire and the center of resistance of the whole arch. In addition, Sohn[28] also proved that lower second molars were tipped distally in the experimental group according to changing hook length while retracting maxillary and mandibular dentition using a mini-screw. Their results were not consistent with our study of the pattern of root movements. We think that the pattern of displacement may change according to the anterior-posterior and vertical position of the skeletal anchorage as well as force application points.

In the X-axis, the unwanted lingual movement was produced in force application. However, because our FE model was constructed as the mandibular hemisphere, the lingual movement would be less in the real patient's treatment in which the full archwire would be inserted. On the occlusal view of the displacement magnitude which is related to the X-axis movement of teeth, the rotation was less when applying the force on the cemento-enamel junction level. Thus, for the efficient movement of the mandibular arch, the vertical force position should be considered like the X-axis movement.

The vertical movement should be considered because the extrusive movement can affect the treatment efficiency and results while distalizing mandibular molars. The extrusive movement was mostly produced when applying the force at the cementoenamel junction level, unlike the force at the bracket level which produced the intrusive movement of teeth. This result should be considered because the force application of the cementoenamel junction level always would not cause favorable orthodontic movement. Considering the alignment of posterior teeth and the mode of orthodontic movement, the vertical level of force should be planned for the appropriate teeth movement. For example, extrusion of mandibular posterior teeth should be avoided in the treatment of severe dolicho-facial patients.[29] Meanwhile, the vertical movement of the mandibular canine itself showed intrusive movement when applying orthodontic force on the bracket level and extrusive movement of the mandibular canine when applying the force at the cementoenamel junction level. The vertical movement patterns of the mandibular canine could differ from that of mandibular premolars and molars at both force application systems because the mandibular canine was the direct force application point for mandibular teeth distalization.

It is impossible to make the absolute bodily movement of the mandibular posterior dentition with a mini-screw or a mini-plate. However, several studies show that the tipping movement became less with these skeletal anchorages similar to the results of this study, and the force direction also should be considered to make the extrusive or intrusive movement.[29-31] In this study, the extrusive movements occurred at 3 mm and 6 mm hook height, and slight intrusive movements occurred at bracket level (0 mm). Tai *et al*.[12] had the same results. Nakamura *et al*.[22] proved that if more intrusive movement is needed, the downward force vector relative to the occlusal plane could be considered in photo-elastic stress analysis. Hence, we think that it is necessary to elucidate more clearly the vertical movements of mandibular posterior teeth during their distalization in several situations through an FE analysis in future studies.

Anchorage stability also needs to be considered when providing orthodontic treatment. In studies comparing skeletal Class II correction with headgears, mini-screws, and mini-plates, the application of skeletal anchorage elicits greater changes within the anterior skeletal regions with less anchorage loss, and the application of mini-plates can be used to implement absolute intrusion of maxillary molars.[32] Because the mandible has an unfavorable anatomical structure compared to that of the maxilla for teeth movement, more stable skeletal anchorage such as a mini-plate should be considered preferentially for orthodontic treatment cases in which lower molar distalization and/or intrusion is being considered.[33] With these possibilities, appropriate force application and positioning combined with effective anchorage can favor teeth movement in the mandible.

### Limitation

The study intended to theoretically visualize the initial displacement and stress distribution of forces during full arch distalization using an FEM, so the results may not reflect the exact clinical outcomes, which were influenced by the cumulative effects of continuous bone reactions and rebounding of archwire related to the secondary displacement of the teeth. The thickness of the periodontal ligament was assumed to be uniform (0.25 mm), whereas in reality, it has an hourglass shape with the narrowest zone at the mid-root level. The mandible was constructed without the maxilla to simulate the distalization of mandibular dentition. Thus, the amount of extrusion displayed by the mandibular anterior teeth was increased. This may be because the occlusal force was not included in this study design; thus, it might be worthwhile to validate our results in clinical situations.

## Conclusion

The conclusions drawn from the present study are as follows:

1. The maximum von Mises stress to alveolar bone was the highest at the screw fixation region on the medial aspect of the buccal cortical plate in the 0 mm hook height model, and stress decreases with the increase in retraction hook height.
2. The maximum von Mises stress of the alveolar bone and the PDL in all the models were below their respective ultimate tensile strengths. Hence, the alveolar bone and PDL in all the models were safe with 300 g of distalization force using a buccal shelf screw.
3. The greater biomechanical bodily movement was seen with the increase in vertical hook height in mandibular arch distilization compared to the orthodontic forces when applied at the level of the bracket. The amount of lingual movement decreases with the increase in the vertical hook height.
4. The extrusive movement was mostly observed at 6 mm vertical hook height, unlike the force at the bracket level (0 mm), which produces the intrusive movement of the teeth.

Thus, this study shows that with the appropriate application of orthodontic force using buccal shelf screws at different vertical hook heights with a biomechanical understanding can result in proper distalization of the whole mandibular dentition.

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### Conflicts of interest

There are no conflicts of interest.

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