“COMPARISON OF STRESS DISTRIBUTION IN ALVEOLAR BONE DURING ANTERIOR EN-MASSE RETRACTION USING MINISCREWS – A FEM STUDY”

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ORTHODONTICS AND DENTOFACIAL ORTHOPAEDICS

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-Dr. Haobam Minerva

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S.NO	ABBREVIATED FORM	FULL FORM
1.	MSL	Miniscrew length
2.	PA	Powerarm
3.	FEM	Finite Element Analysis
4.	MPa	MegaPascal

Aim –To assess stress distribution on alveolar bone of maxilla at TAD bone interface, anterior teeth root and PDL during anterior en-masse retraction using different length of miniscrew when placed at different angulations in combination with different height of powerarm.

Material and method – A FEM model of maxillary arch with extracted first premolars was prepared on the basis of CBCT images with MIMICS software. A MBT bracket prescription 0.022’’slot ,rectangular SS wire with powerarm of 4mm and 8mm , titanium miniscrew of 8mm and 10mm length were scanned using laser scanner to make CAD model. A total of 8 FEM models using ALTAIRHYPERMESH were made with the different combination of miniscrew length, insertion angles and powerarm height .Von Mises Stress (MPa) generated on both the anterior segment (in the roots and PDL of anterior teeth) as well as the TAD bone interface at posterior segment were measured on simulating 150g of retraction force with software.

Result – Von Mises stress generated for both the anterior segment was lesser at 60^{o} than 90^{o}angulation of miniscrew. At 60^{o}, it was least with combinations of 10mm MSL irrespective of PA height (0.087MPa at root and 0.008MPa for PDL in anterior segment) ; and for 10mm MSL, stress at TAD bone interface was less for 8mm PA (0.876 MPa for Cortical bone and 0.161 MPa for Cancellous bone) than 4mm PA (0.994 MPa at Cortical bone and 0.183 MPa at Cancellous bone) . At 90^{o} it was least with combinations of 10mm MSL irrespective of powerarm (0.135 MPa at root and 0.130MPa at PDL); and at TAD bone interface it was least 8mm powerarm (1.339 MPa for Cortical bone and 0. 246 MPa for Cancellous bone) than 4mm PA (1.535 MPa at Cortical bone and 0.282 MPa at Cancellous bone) . Considering PA height stress for 8mm PA was lesser than 4mm PA and for MSL, 10mm MSL showed less stress than 8mm for all combinations.

Conclusion – Magnitude of stress as well as pattern of stress distribution varied with different miniscrew length, insertion angulation and powerarm length and was lesser than the respective material properties as incorporated in FEM model for present study. Hence it can be suggested that all combinations are clinically acceptable for en-masse retraction of anterior teeth.

Keywords- FEM, En-masse retraction, Miniscrew length, Miniscrew angulation, Power arm height ,CBCT.

The aim of the Orthodontic treatment is to move teeth to their desired position while maintaining sufficient anchorage control. This is done by creating appropriate force systems that provide the desired treatment effects. Dental protrusion is common in many ethnic groups around the world. It is characterized by dentoalveolar flaring of maxillary or both the maxillary and mandibular anterior front teeth, with resultant protrusion of the lips and convexity of the face[1]. This protrusion is treated by extracting all the first premolars, followed by anterior tooth retraction to obtain the desired dental and soft-tissue profile changes[2]. Controlled orthodontic movements such as retraction or protraction of teeth and intrusion of over erupted teeth are very difficult to achieve without patient cooperation and without causing undesirable reciprocal movement in the anchorage unit.

Conventionally, appliances such as headgears, TPA, Lingual arches, intraoral elastics etc are used to reinforce anchorage , but it is difficult to obtain stationary anchorage even when the patient shows excellent cooperation. In such cases, miniscrew implants provide an excellent alternative to conventional methods for anchorage control. Recently, miniscrews were introduced as absolute anchorage devices in Orthodontic treatment with the advantage of not requiring patient compliance. Excellent treatment results have been reported by using miniscrews for orthodontic anchorage in various malocclusions. Miniscrews have the ability to provide the same rigid anchorage against orthodontic loads as dental implants or miniplates[3]. Some other advantages of orthodontic miniscrews include minimal anatomic limitations on placement, lower treatment costs and simpler placements with less traumatic surgery as compared to prosthetic implant.

Miniscrews are easier to place, can be placed in more varied locations, are smaller and more cost effective, and have the possibility of immediate or early loading. Miniscrews made of different materials with different lengths and diameter can be placed at various locations of maxilla and mandible depending upon the type of bone and required tooth movement .A proper angulation of insertion of miniscrew is important for anchorage, patient safety and biomechanical control. Maxillary implants need 30-90° angulation to long axis of teeth buccally and palatally ,this increases the surface contact between screw and bone and improves retention and reduces the risk of striking root[4]. Angulation of 90° gave increased stability and decreased stress concentration in bone[5] .Hence , miniscrew placed at two commonly used angulations i.e 60° and 90° will be evaluated in the present study.

En-masse retraction can be done by sliding mechanics(friction mechanics) or loop mechanics (frictionless mechanics). For anterior en-masse retraction using sliding mechanics usually miniscrew implant(MSI) are placed between maxillary first molar and second premolar, 2-8mm from the alveolar crest[6] . Forces for en-masse retraction are exerted from the powerarm placed anteriorly between lateral incisor and canine to miniscrew using Niti coil spring or E-chain. Variation in height of powerarm can alter the biomechanics of anterior teeth retraction in vertical plane as well as in sagittal plane depending on its distance from center of resistance of the anterior segment. Hence, it was decided to evaluate stress distribution at two different heights of power arm.

Studies have shown that the success of implants is dependant of the way that the stresses are transmitted from the implant to the surrounding bone[7]. Study of stress distribution allows to optimize the shape of screw, geometric parameters such as length, diameter, thread pitch ,the proper insertion angle on different bone type [8]. Hence, various authors studied these factors but the results were inconclusive. FEM enables users to analyze the effects of force systems applied to any point and in any direction, providing a quantitative assessment of the force distribution in the wire and related structures. FEM is a computerized mathematical method that can be used to simulate mechanical systems to predict stress within the object[9] and so it will be used in the present study.

Control of movement of anterior teeth is an essential requirement for the clinician to obtain an ideal result. The use of power arm enables the orthodontist for precise controlled of anterior teeth movement , altering the height of the anterior hook (power arm) can have a considerable influence on the process and significantly alter the general pattern of teeth movement [10]. None of these studies have evaluated stress distribution in bone during en-masse retraction when using power arm of variable height and using miniscrew of different length placed at variable angulation.

Few studies [10,11] evaluated biomechanics of anterior retraction with variable power arm height from miniscrew placed between 2nd premolar and 1st molar. Orthodontic mini-implants , which may often be inserted between the roots, have limitation in diameter and length. Other studies evaluated stress distribution in bone with different angulation or different diameter and length of miniscrew from power arm of uniform height.

Considering this, it was decided to conduct this in-vitro FEM study to investigate stress distribution on alveolar bone of maxilla at TAD bone interface and anterior teeth root and Pdl during anterior en-masse retraction using different length of miniscrew when placed at different angulations in combination with different height of powerarm .

Aim

To assess stress distribution on alveolar bone of maxilla at TAD bone interface, anterior teeth root and PDL during anterior en-masse retraction using different length of miniscrew when placed at different angulations in combination with different height of powerarm.

Objectives

1.To evaluate stress distribution on alveolar bone of maxilla at TAD bone interface and anterior teeth root and PDL during anterior en-masse retraction by miniscrew of 8mm length (2mm diameter) placed at two different angulations(60°, 90°) using Powerarm length 4mm and 8mm .

2.To evaluate stress distribution on alveolar bone of maxilla at TAD bone interface and anterior teeth root and PDL during anterior en-masse retraction by miniscrew of 10mm length (2mm diameter) placed at two different angulations (60°, 90°) using Powerarm length 4mm and 8mm .

3. To compare stress distribution on alveolar bone of maxilla at TAD bone interface and anterior teeth root and PDL during anterior en-masse retraction between miniscrew of two different length(8mm and 10mm) when placed at different angulations(60°,90°) with 4mm Powerarm.

4.To compare stress distribution on alveolar bone of maxilla at TAD bone interface and anterior teeth root and PDL during anterior en-masse retraction between miniscrew of two different length (8mm and 10mm) when placed at different angulations (60°,90°) using 8mm Powerarm.

5. To compare stress distribution on alveolar bone of maxilla at TAD bone interface and anterior teeth root and PDL during anterior en-masse retraction while using power arm of two different height (4mm and 8mm) for length of miniscrew (8mm and 10mm) placed at two different angulations (60° and 90°).

Petrie C.S.,John L. Williams J.L.(2005)[12] analyzed and compared systematically the relative and interactive effects of implant diameter, length, and taper on calculated crestal bone strains. Three-dimensional finite-element models were created of a 20mm premolar section of the mandible with a single endosseous implant embedded in high- or low-density cancellous bone. Oblique (200-N vertical and 40-N horizontal) occlusal loading was applied. Cortical and cancellous bone were modeled as transversely isotropic and linearly elastic. Perfect bonding was assumed at all interfaces. A two-level factorial statistical design was used to determine the main and interactive effects of four implant design variables on maximum shear strains in the crestal alveolar bone: diameter, length of tapered segment, length of untapered segment, and taper. Implant diameter ranged from 3.5 to 6mm, total implant length from 5.75 to 23.5mm, and taper from 0 to 141, resulting in 16 implant designs. Increasing implant diameter resulted in as much as a 3.5-fold reduction in crestal strain, increasing length caused as much as a 1.65-fold reduction, whereas taper increased crestal strain, especially in narrow and short implants, where it increased 1.65-fold. Diameter, length, and taper have to be considered together because of their interactive effects on crestal bone strain. The study concluded that to minimize peri-implant strain in the crestal alveolar bone, a wide and relatively long, untapered implant appears to be the most favorable choice. Narrow, short implants with taper in the crestal region should be avoided, especially in low density bone.

WilmesB., SuY.Y. DrescherD.(2008) [13] analyzed the impact of the insertion angle on the primary stability of mini-implants. A total of 28 ilium bone segments of pigs were embedded in resin. Two different mini-implant sizes (Dual-Top Screw 1.6 X 8 mm and 2.0 X 10 mm) were inserted at seven different angles (30^o, 40^o, 50^o, 60^o, 70^o, 80^o and 90^o). The insertion torque was recorded to assess primary stability. In each bone, five Dual-Top Screws were used to compensate for differences in local bone quality. The result of the study showed that the angle of mini-implant insertion had a significant impact on primary stability. The highest insertion torque values were measured at angles between 60^o and 70^o (63.8^o for Dual-Top 1.6 mm and 66.7 for Dual-Top 2.0 mm). Very oblique insertion angles (30^o) resulted in reduced primary stability. The study concluded that to achieve the best primary stability, an insertion angle ranging from 60° to 70° is advisable. If the available space between two adjacent roots is small, a more oblique direction of insertion seems to be favorable to minimize the risk of root contact.

Zhang QD., Su H.J, Xu YL, Zhong PP.(2008)[14] investigated the displacement and stress distribution of maxillary anterior teeth during retraction using the finite element method. A three-dimensional finite element model of six maxillary anterior teeth with a straight wire appliance on intermaxillary bone was established in ANSYS 8.1.The study concluded that during routine anterior tooth retraction by sliding mechanics, the crownof anterior teeth tends to tip lingually. Retraction force passing near the centre of resistance of six anterior teeth makes their displacement and stress distribution more uniform, but their translation is still undetectable. Loading on lateral incisors is greater than that on other teeth and stress concentration at its lingual apex should be considered.

Szuhanek C., Faur N. , Cernescu A.(2008)[7] evaluated the stress induced by orthodontic loading in anchorage implants and surrounding tissues. Orthodontic implants were included in this study. 3D geometrical models were constructed and material characteristics were taken from the literature. The model of Leone stainless steel orthodontic mini-implants was used.The 3D model of orthodontic implants and the surrounding bone were constructed using SOLIDWORKS software. The geometrical model was imported in ANSYS, and the 3D numerical model was obtained. Finite element models were created based on the geometry and material characteristics of the screws. Orthodontic horizontal loads of 2 N were applied, and the biomechanical parameters were evaluated by colored scales. The highest von Mises values were recorded around the implant neck area and at the bone-implant interface.

Ding X., Liao S.H, Zhu X.H, Zhang X.H., Zhang L(2009)[15] evaluated the effect of the diameter and length on the stress and strain distribution of the crestal bone around implants under immediate loading. High-quality FE models of complete range mandible was constructed from computer tomography, with three Straumann implants of various sizes embedded in the anterior zone. The implant diameter ranged from 3.3

to 4.8 mm, and length ranged from 6 to 14 mm, resulting in seven designs. The implant–bone interface was simulated by nonlinear frictional contact algorithm. For each design, vertical and oblique loadings of 150 N were applied, respectively, to each implant, and stresses and strains in the surrounding cortical bone were evaluated. The analysis resulted that the oblique loading would induce significantly higher interfacial stresses and strains than the vertical loading, while the intergroup stress difference significant levels was evaluated using *t*-tests method and the level of significance (.05) that was accepted for significance. Under both loadings, the maximal values were recorded in the 3.3 (diameter) X 10 (length) mm implant configuration, whose mean and peak values were both higher than that of others with significant statistical differences. The second maximal one is 4.1 X 6mm configuration, and the minimal stresses were recorded in 4.8 X 10 mm configuration, whose strains were also near to lowest. The study concluded that increasing the diameter and length of the implant decreased the stress and strain on the alveolar crest, and the stress and strain values notably increased under buccolingual loading as compared with vertical loading, but diameter had a more significant effect than length to relieve the crestal stress and strain concentration.

Stahl E, Keilig L, Abdelgader I, Jager A, Bourauel C (2009) [16] examined the influence of the bone quality on the efficacy of various types and sizes of implants involving various load directions using FEM . FE models of 16 implants by six different manufacturers were made in idealized jaw bone segments with the program system MSC.Marc/Mentat. Implants with length between 6.7 mm – 10 mm and diameter between 1.2 mm and 2 mm were selected. They concluded that load direction was tilted in a buccal direction, the stresses and amount of strain were reduced by as much as 35%. Further, greater cortical bone thickness leads to less exposure of cancellous bone to stress and strain and strain is reduced when load direction inclines at 45^0 angulations.

Kim Y.K, Kim Y.J, Yun P.Y, Kim J.W(2009) [17] analyzed the mechanical effects of the length and the various shapes such as cylindrical shape, taper shape, and dual-thread shape on the insertion and removal torque of mini implants. Mini-implants (diameter 1.6 mm and length 6 mm and 8 mm) consisting of cylindrical, taper, and dual-thread groups were inserted and removed in Sawbones while measuring the torque and time. Mechanical analysis was done of maximum insertion torque (MIT), maximum removal torque (MRT), torque ratio (TR; MRT/MIT), insertion angular momentum (IAM), removal angular momentum (RAM), and time of MIT. Measurements were statistically evaluated to analyze any differences of shapes and lengths. The results showed that the cylindrical shape had the lowest MIT and MRT in each length. Although taper shape showed the highest MIT in each length, dual-thread shape showed significantly higher MRT, TR, and RAM in each length (*P* _ .05). Dual-thread groups showed a gentle increase of insertion torque and a gentle decrease of removal torque in contrast to the other shape groups. However, it had higher IAM and time of MIT. The long length group showed significantly higher measurements except for TR. The study concluded that dual-thread shape provided better mechanical stability with high removal torque on the broad range than other shapes. However, dual-thread shape may need improvement for reducing the long insertion time to decrease the stress to the surrounding tissue.

Petrey JS, Saunders MM, Kluemper GT, Cunningham LL, Beeman CS (2010) [18] examined the influence of TAD insertion variables on implant retention. 330 TAD's from 3 different companies were placed at variable depths and angulations in synthetic bone replicas that were matched for the cortical and cancellous bone density in the maxillary premolar region. Clinically relevant forces were applied on them until failure of retention occurred. Results revealed that insertion depth increases the retention with 90 degrees angulation showing maximum retention and insertion at an oblique angle from the line of force reduces retention.

Woodall N., Tadepalli S.C., Qian F., Grosland N.M., Marshall S.D.,Southard T.E.(2010)[19] analyzed the screw angulation effect on screw anchorage resistance. A three-dimensional finite element models were created to represent screw placement orientations of 30°, 60°, and 90°, while the screw was displaced to 0.6 mm at a distance of 2.0 mm from the bone surface. In a parallel cadaver study, 96 titanium alloy screws were placed into 24 hemi-sected maxillary and 24 hemi-sected mandibular specimens between the first and second premolars. The specimens were randomly and evenly divided into 3 groups according to screw angulation (relative to the bone surface): 90° vs 30° screw pairs, 90° vs 60° screw pairs, and 30° vs 60° screw pairs. All screws were subjected to increasing forces parallel to the occlusal plane, pulling mesially until the miniscrews were displaced by 0.6 mm. The analysis showed that 90^o screw placement provided greater anchorage resistance than 60^o and 30^o placements. In the cadaver study, although the maximum anchorage resistance provided by screws placed at 90^o to the cadaver bone surface exceeded, on average, the anchorage resistance of the screws placed at 60^o, which likewise exceeded the anchorage resistance of screws placed at 30^o, these differences were not statistically significant. The study concluded that placing orthodontic miniscrews at angles less than 90^o to the alveolar process bone surface does not offer force anchorage resistance advantages .The alveolar process bone surface does not offer force anchorage resistance advantages.

Sung JS., Jang WG, Chun SY., Moon SY(2010)[20] examined effective en-masse retraction with orthodontic mini implant anchorage and sought to identify a better combination of the above factors using finite element analysis. The study showed that the tooth displacement tendencies were similar in all 3 models. The height of the anterior retraction hook and the placement of the compensating curve had limited effects on the labial crown torque of the central incisors for en-masse retraction.

Farnsworth D,Rossouw E.P, CeenF.R, Buschang H.P(2011) [21] assessed the purpose of age ,sex and regional differences in the cortical bone thickness of commonly used maxillary and mandibular miniscrew implant placement sites. CBCT images taken at 0.39-mm voxel size, of 52 patients, including 26 adolescents and 26adults were evaluated . The CBCT data were imported into a 3-d software to measure cortical thickness at 16 sites - 3 paramedian sites, 1infrazygomatic crest site, 4 buccal interradicular sites of the mandible and 4 buccal, 4 lingual interradicular sites in maxilla. This study showed no significant differences in cortical bone thickness between the sexes. However, miniscrew implant placement sites were thicker in adults than in adolescents, also there were differences in cortical bone thickness between and within regions of the jaws that must be considered when placing miniscrew implant.

Lee JK, Park CY, Hwang JC, Kim JY, Choi HT, Yoo MH, Kyung HS(2011)[22] clinically evaluated the anteroposterior and vertical displacement patterns of the maxillary teeth in sliding mechanics depending on the position of interradicular miniscrews afterthe extraction of premolars. For the study, thirty-six women requiring maximum incisor retraction because of bialveolar protrusion were divided into 2 groups: group A (n 5 18), miniscrew between the premolar and the molar, and group B (n 5 18), miniscrew between the premolars. In both groups, the result of the study showed significant incisor retraction with intrusion of the root apex was noted, with no significant change in the first molar position. The study concluded that miniscrews provided firm anchorage for anterior retraction. Selection of the placement site appeared to be an important determinant for the resultant displacement patternof the incisor segment.

Ansari TA, Mascarenhas R, Husain A, Salim M (2011)[23] evaluated the effectiveness of the power arm in bringing about bodily movement and to determine the ideal length and locationof the power arm. A geometric model of the maxillary right canine was constructed and subsequently converted to a finite element model. The study concluded that the attachment of the power arm at the cervical third brought about maximum bodily movement, followed by the middle and incisal thirds. Variations in length of the power arm at different sites of attachment did not bring any change in the outcome.

Vijayalakshmi PS, Veereshi AS, Jayade VP, Dinesh MR, Kumar M(2012) [24] analysed the stress and strain distribution patterns in the bone surrounding a mini-implant and investigated the deformation of bone around the implant in their finite element study. A patient with severe bimaxillary protrusion malocclusion and initial anchorage requirement was selected and the implants were placed between 2nd premolar and 1st molar region and screwed at an angle of 60 degrees between teeth and occlusal plane. Loads of 200 and 250 grams produced strains in the optimal stage of bone maintenance. Finite element models showed the area with the highest stress and strain to be around the neck of the implant and the surrounding bone at the cervical margin and the implant should be preferably placed entirely in the cortical bone.

DuaibisR, KusnotoB, Natarajan R, Zhao L,Evans C(2012)[25] evaluated various types of stress in cortical bone around miniscrew implants using the finite element analysis. Twenty-six 3-D assemblies of miniscrew models that were placed in an alveolar bone blocks were constructed using Abaquas, a commercial finite element analysis software package. The model variables included implant design factors and bone-related factors. All miniscrew implants were loaded in mesial direction with a linear force of 2N .The study concluded that the miniscrew implant diameter, head length, thread size as well as the elastic modulus of cancellous bone affect the stresses in cirtical bone layer surrounding the miniscrew implant and may affect the stability.

Omar A ,IshakM.I, HarunM.N, SulaimanE,Kasim N.H.A(2012)[26] evaluated stress in an orthodontic mini-implant and bones using the finite element analysis with variations of insertion angles and to identify their optimal angle for implant placement. A 3D model of a left maxillary posterior bone section was constructed on a CT image dataset. The model consist of cortical bone, cancellous bone, second premolar, first molar teeth. The miniscrews were inserted at 30°, 40°, 50°, 60°, 70°, 80° and 90°. The study concluded that different insertion angles of orthodontic mini-implant give a significant influence on the stress values and distributions recorded in bones and implant. The optimal angle for orthodontic mini-implant placement in the bone model is 90° to the alveolar bone crest.

Jasmine I.F, YezdaniA.A, Tajir F, Venu R.M(2012)[5] investigated the actual impact of different insertion angulation on stability. Finite element models of maxilla and mandible with types D3 and D2 bony quantity and microimplants with diameter 1.3mm and lengths 8 and 7mm were generated for the finite element study. Microimplants were inserted at 30°, 45°, 60° and 90° to the bone surface. A simulated orthodontic force of 200g was applied to the centre of the microimplant head and stress distribution and magnitude were analysed. It resulted that the maximum von Mises stresses in the microimplant and cortical bone decreased as the insertion angle increased. This study concluded that the placement of microimplant at a 90°angulation in the bone reduced the stress concentration increasing the implant stabilization. Perpendicular insertion offered more stability to the orthodontic loading.

Singh S, Mogra S, ShettyV.S, Shetty S, Philip P(2012)[27] examined the stress distribution and displacement patterns that develop in an orthodontic miniscrew implant and its surrounding osseous structures for 2 implant material under horizontal and torsional loading with no osseointegration. The finite element method was used to determine the stress and displacement of the various components at a given time after miniscrew implant application. The study showed that there was no significant difference in stress distribution between the 2 implant material. Stress values were increased at the neck of the implant and surrounding cortical bone.

Liu TC, Chang CH, Wong TY, Liu JK(2012)[28] investigated the roles of bone quality, loading conditions, screw size, and implant depth on orthodontic miniscrews by using finite element analysis. A 3-D model with a bone block integrated with a miniscrew was constructed to simulate the various properties. To determine the screw size effect, 3 screw (outer) diameters (1.2, 1.5, and 2.0 mm) and 5 screw lengths (7-15 mm at 2-mm intervals) were investigated. Results revealed that both stress and displacement increased with decreasing cortex thickness, whereas cancellous bone density played a minor role in the mechanical response. The indices showed highest values when the force was perpendicular to the long axis of the screw. A wider screw provided a superior mechanical advantage.

Chang.J.Z.C J, Chen Y.J, Tung Y.Y, Chiang Y.Y, Lai E.H.H, Chen W.P, Chun-Pin Lin C.P(2012)[29] investigated the influence of various mini-implants design factors, including thread depth, degree of taper, and taper length on insertion torque, pullout strength, stiffness, and screw displacement before failure were investigated. Finite element analyses were conducted first for identification of optimal design parameters. Four types of mini-implants with different design parameters were then custom manufactured and tested mechanically. All mechanical tests were performed in artificial bone with homogenous density to remove the variability associated with bone. Finite element results showed that, for mini-implants with a fixed external diameter of 2 mm, a thread length of 9.82 mm, and a pitch of 0.75 mm, those with greater thread depths, smaller taper degrees, and shorter taper lengths generated higher maximum stresses on the bone and thread elements. These mini-implants also had larger relative displacements. Maximum pullout resistance was attained with a core/external diameter ratio of 0.68. All mechanical results were compatible with the findings in the finite element analyses. The study concluded that modification of the mini-implant design can substantially affect the mechanical properties.

Jung Y.R, Kim S.C, Kang K.H, Cho J.H, Lee E.H, Chang N.Y , Chae J.M(2012)[30] evaluated the effect of placement angles on the success rate of orthodontic microimplants and other factors with cone-beam computed tomography images. The study examined 228 orthodontic microimplants implanted into the maxillary buccal alveolar bone of 130 patients (33 men, 97 women) with malocclusion. Vertical placement angle, horizontal placement angle, root proximity, and cortical bone thickness were measured, and the correlations between these measurements and orthodontic microimplant success rates and the correlations among the measurements were evaluated.The overall success rate was 87.7%. The orthodontic microimplant success rate significantly increased as root proximity (distance from the orthodontic microimplant to the root surface) increased but there were no statistical significances between placement angles and success rates, and cortical bone thickness and success rate Correlations between placement angles and root proximity showed no statistical significance. The study concluded that the success rate of orthodontic microimplants is not affected by placement angles and is more significantly affected by root proximity than by cortical bone thickness. Cortical bone thickness is affected by placement angles, but root proximity is not affected by placement angles.

Kojima Y, Kawamura J, Fukui H.(2012)[31] investigated the relationship between force directions and movement patterns. By using the finite element method, orthodontic movements were simulated based on the remodeling law of the alveolar bone. The study concluded that when the power arm was lengthened, rotation of the entire dentition decreased. The posterior teeth were effective for preventing rotation of the anterior teeth. In cases of the high-position miniscrew, bodily tooth movement was almost achieved. The vertical component of the force produced intrusion or extrusion of the entire dentition.

Lee J, Kim J.Y, ChoiY.J, KimK.H, Chung C.J(2013)[32] evaluated the influence of placement angle and direction of orthopaedic force application on the stability of miniscrews. Finite element analysis using miniscrews which were inserted into supporting bone at angles of 90°,60° and 30°. An orthopaedic heavy force 800g was applied to the heads of the miniscrew in four upward or lateral directions. This study showed that miniscrew with a placement angle of 30°and 60° had an increase in von Mises stress as compared to 90°, this study concluded that the placement of miniscrew perpendicular to the cortical bone is advantageous in biomechanical stability also placement angles of less than 60 can reduce the stability of miniscrews when orthopaedic forces are applied in various directions.

Lin T.S, Tsai F.D, Chen C.Y, Lin L.W(2013)[33] investigated using the finite element approach and factorial analysis to determine the biomechanical effects of exposure length of the mini-implant, the insertion angle, and the direction of orthodontic force. Twenty-seven finite element models were constructed to simulate the biomechanical response of the alveolar bone adjacent to the mini-implant. Factorial analysis was performed to investigate the comparative influence of each factor. The results of the study showed that the simulation results showed that the exposure length of the mini-implant had a statistically significant influence on bone stress, with a contribution of 82.35%. Increased exposure length resulted in higher bone stress adjacent to the mini-implant. Whereas all factors investigated had a statistically significant influence on cancellous bone stress, the stress values associated with cancellous bone were much less than those of cortical bone. The study concluded that with increased exposure lengths resulted in higher bone stresses adjacent to the mini-implant. The percentage of contribution of the insertion angle of themini-implant (6.03%) was also statistically significant but much less than that of the exposure length (82.35%).The direction of orthodontic force had no significant effect on cortical bone stress.

Ashekar S.S, Deshpande R.S, Shetty P., Lele S., Patil S.S(2013)[34] examined effective *en masse* retraction with orthodontic mini-implant anchorage and sought to identify the position and height of the mini-implant and the height of the anterior retraction hook for Intrusive and Bodily Movement of Anterior Teeth in Sliding mechanics using the finite element analysis. Base models were constructed from a measurements given in the Wheeler's dental anatomy book. The center of resistance for the 6 anterior teeth in the base model was calculated. The working archwires were assumed to be 0.019" × 0.025" in stainless steel. The amount of tooth displacement after finite element analysis was measured.The study concluded that in low orthodontic mini-implant (6 mm) anteriors showed tipping movement. Mid implant condition (8 mm) showed more of bodily movement during retraction as the force passes near or through the CRs of all the six anterior teeth. In high orthodontic mini-implant (10 mm) and 0 mm ARH condition, all the six anterior teeth showed intrusion with retraction

Machado G.L (2014)[35] evaluated the effects of orthodontic miniscrew placement angle and structure in terms of length and diameter on stress distribution at the bone miniscrew interface using FEM.. 10 finite models were created representing miniscrews and was inserted in the buccal alveolar bone between the maxillary first molar and second premolar to simulate varying angulations of miniscrew placement (90°, 60°, 45°, 30°) to the long axis of the maxillary first molar, varying length (6mm,8mm, 10mm, 12mm) and varying diameter (1.2mm, 1.3mm, 1.4mm, 1.5mm). In order to simulate retraction forces an identical force of 200 g was applied perpendicular to the long axis of the miniscrew in all the models. The study resulted that the minimum and maximum stress in the miniscrew was generated at placement angles of 30° and 90° respectively. In the bone minimum and maximum stress was found at placement angles of 90° and 30° respectively. On increasing the miniscrew diameter stress in both the miniscrew and the bone decreased. There was no difference found in the stress distribution patterns with varying miniscrew length. The study concluded that based on stress patterns, biomechanical stability of the miniscrew is enhanced by a placement angle of 90° to the long axis of the first maxillary molar and a diameter of 1.5mm for the site selected.

Ozaki H., Tominaga J.Y, Hamanaka R., Sumi M., Chiang P.C, Tanaka M., Koga Y., Yoshida N.(2014)[36] determined the optimal length of power arms for achieving controlled anterior tooth movement in segmented arch mechanics combined with power arm using FEM. The type of tooth movement, namely, the location of center of rotation of the maxillary central incisor in association with power arm length, was calculated after the retraction force was applied. When a 0.017 × 0.022-in archwire was inserted into the 0.018-in slot bracket, bodily movement was obtained at 9.1 mm length of power arm, namely, at the level of 1.8 mm above the center of resistance. In case a 0.018 × 0.025-in full-size archwire was used, bodily movement of the tooth was produced at the power arm length of 7.0 mm, namely, at the level of 0.3 mm below the center of resistance. Segmented arch mechanics required shorter length of power arms for achieving any type of controlled anterior tooth movement as compared to sliding mechanics. Therefore, this space closing mechanics could be widely applied even for the patients whose gingivobuccal fold is shallow. The segmented arch mechanics combined with power arm could provide higher amount of moment-to-force ratio sufficient for controlled anterior tooth movement without generating friction, and vertical forces when applying retraction force parallel to the occlusal plane. It is, therefore, considered that the segmented power arm mechanics has a simple appliance design and allows more efficient and controllable tooth movement.

Marimuthu V.K, Kumar K., Sadhasivam N., Arasappan R., Jayamurugan A., RathinasamyR.(2015)[37] investigated the biomechanical effects of implant insertion angle and direction of orthodontic force on maxilla and mandible by finite element approach and factorial analysis. A three-dimensional finite element bone block models of maxilla and mandible with type D3 and D2 bone quality were constructed. Mini implants were inserted at 30°, 60°, and 90° and orthodontic force was applied to the center of the mini implant head at 60°, 90°, and 120° angulation. ANSYS software was used to evaluate the stress on implant, stress on bone and displacement of bone. The study resulted that maximum von Mises stress was observed at 30° insertion angle. The stress on implant, stress on bone and displacement of bone increased as the insertion angle decreased from 90° to 30° and was statistically significant in both maxilla and mandible. The direction of orthodontic force had no statistically significant effect on stress and displacement around mini‑ implant in both maxilla and mandible. The stress on bone and displacement of bone was greater in maxilla compared to that of mandible and was statistically significant.

Lu Y.J, Chang S.H, Ye J.T, Ye Y.S, Yu Y.S(2015)[38] compared the stress on the bone surrounding a micro-implant after application of a single force (SF) of 200 g or a composite force (CF) of 200 g and 6 N.mm torque.Finite element models were developed for micro-implant diameters of 1.2, 1.6, and 2.0 mm, and lengths of 6, 8, 10, and 12 mm and either a SF or CF was applied. The maximum equivalent stress (Max EQS) of the bone surrounding the micro-implant was determined, and the relationships among type of force, diameter, and length were evaluated. The study resulted that the Max EQS of the CF exceeded that of the SF (P< 0.05). The effect of force on stress was related to implant diameter, but not to implant length. The larger CF led to greater instability of the micro-implant and the effect was most pronounced at an implant diameter of 1.2mm. The use of implant diameters of 1.6 mm and 2.0 mm produced no significant difference in implant stability when either a CF or SF was applied. The study concluded that when considering the use of an implant to perform three-dimensional control on the teeth, the implant diameter chosen should be > 1.2 mm.

Rokutanda H, Koga Y, Yanagida H, Tominaga YJ, Fujimura Y, Yoshida N (2015)[39] investigated the hypothesis that the type of anterior tooth movement is correlated with the height level of the power arm with respect to the center of resistance (CRes) of a tooth, but not with the power arm length itself in sliding mechanics using three-dimensional (3D) model analysis. The study concluded that anterior tooth movement during retraction varied with the anatomical parameters of individual patients, even if the same power arm length was employed. The present findings suggested that the height level of the power arm relative to CRe is the most influential factor determining the tooth movement, while the power arm length itself has less impact on subsequent tooth movement.

Sivamurthy G., Sundari S. (2016)[40] evaluated the stress patterns produced in mini-implant and alveolar bone, for various implant dimensions, under different directions of simulated orthodontic force, using a three-dimensional finite element method. Eight finite element (FE) models of mini-implant and bone were generated with insertion angles of 30° and 60°, diameters of 1 and 1.3 mm, and lengths of 6 and 8 mm. A simulated constant orthodontic force of 2 N was applied to each of these FE models in three directions simulating anterior retraction, anterior intrusion and retraction, and molar intrusion. The study concluded that 1mm diameter mini-implants are not safe to be used clinically for orthodontic anchorage. The 1.3 × 6 mm dimension mini-implants are recommended for use during anterior segment retraction and during simultaneous intrusion and retraction, and the 1.3× 8 mm dimension mini-implant is recommended for use during molar intrusion. All mini-implants should be inserted at a 30° angle into the bone for reduced stress and improved stability.

Choi S.H, Kim S.J, Lee K.L, Sung S.J, Chun Y.S., Hwang C.J(2016)[41] analyzed stress distributions in the roots, periodontal ligaments (PDLs), and bones around cylindrical and tapered miniscrews inserted at different angles using a finite element analysis. A three-dimensional (3D) maxilla model of a dentition with extracted first premolars was created and used 2 types of miniscrews (tapered and cylindrical) with 1.45 mm diameters and 8mm lengths. The miniscrews were inserted at 30°, 60°, and 90° angles with respect to the bone surface. A simulated horizontal orthodontic force of 2 N was applied to the miniscrew heads. Then, the stress distributions, magnitudes during miniscrew placement, and force applications were analyzed with a 3D finite element analysis. The study resulted that the stresses were primarily absorbed by cortical bone. Moreover, very little stress was transmitted to the roots, PDLs, and cancellous bone. During cylindrical miniscrew insertion, the maximum von Mises stress increased as insertion angle decreased. Tapered miniscrews exhibited greater maximum von Mises stress than cylindrical miniscrews. During force application, maximum von Mises stresses increased in both groups as insertion angles decreased. The study concluded that for both cylindrical and tapered miniscrew designs, placement as perpendicular to the bone surface as possible is recommended to reduce stress in the surrounding bone.

Hedayati Z., Shomali M.(2016) [42] determined the type of anterior tooth movement during the time when force was applied from different mini screw placements to the anterior power arm with various heights. Two appropriate positions for mini screw in the mesial and distal of the second premolar were designed as fixed nodes. Forces were applied from the mini screw to four different levels of anterior hook height: 0, 3, 6, and 9 mm. Initial tooth movement in eight different conditions was analyzed and calculated with ANSYS software. The study resulted that rotation of anterior dentition was decreased with a longer anterior power arm and the mesial placement of the mini screw. Bodily movements occurred with the 9-mm height of the power arm in both mini screw positions. Intrusion or extrusion of the anterior teeth segment depended on the level of the mini screw and the edge of the power arm on the Z axis.

Song WJ., Lim KJ. Lee JK, Sung JS, Chun SY, Mo SS (2016)[43] examined the ideal biomechanics during maxillary incisor retraction by varying the length in the anterior retraction hook (ARH) and OMI position. Two extraction models were constructed to analyze the three dimensional finite element: a first premolar extraction model (Model 1, M1) and a residual 1-mm space post-extraction model (Model 2, M2). This study observed and concluded that orthodontic tooth movement according to the OMI position and ARH height, and M2 under high OMI traction with short ARH showed retraction with maxillary incisor intrusion.

Doshi D.S, Pradhan J.M(2017)[11] analyzed the change in maxillary anterior teeth displacement and stress distribution using different compensating curves in the arch wire and varying power arm length in first premolar extraction case during sliding mechanics. For the study , 6geometric models were created using ANSYS software. This geometric model was converted into a finite element model with the help of software HYPERMESH 11.0. Bilaterally mini-implants were placed in the bone between the roots of maxillary second premolar and first molar. Power arms were placed at two heights – 3 mm and 5.5mm. Compensatory curves were placed in the archwire (0, 3mm or 5mm) and a force of 150 gms was applied using NiTi coil springs bilaterally. Stresses in bone and tooth displacements were analyzed. More bodily movement of the teeth using the longer power arms was observed. Incorporating a compensatory curve further helped to reduce tipping. The tooth that showed most bodily movement was the lateral incisor followed by central incisor and least by the canine. There was increased intrusion of the incisors and extrusion of canine with increase in power arm height.

Brar L.S., Dua V.S.(2017) [44] investigated the ideal force system for en-masse retraction using mini implant and to determine most favorable angle for implant insertion. DENTASCAN was used to fabricate a three dimensional finite element model of the maxilla. Three models were constructed with different implant angulations, i.e., 45°, 60°, and 75°. Each model was applied 150, 200, 250, and 300 g of load. The results were analyzed using ANSYS software. The study showed result that maximum stress was observed at the head of implant at the point of attachment with the retraction spring. In cortical bone and cancellous bone, stress was distal to bone‑ implant interface. In PDL, maximum stress developed at the apex of lateral incisor root. The study concluded that for en masse retraction, the most favorable angulations for implant placement are 60°, and ideal force system is in the range of 200–250 g. Force levels above 300 g will possibly produce deleterious effects on PDL, cancellous bone, and teeth.

Jain A., Hattarki R., Patel P., Khandelwal V., Sapre J.(2017)[45] investigated the stress distribution in bone and miniscrew and displacement pattern of maxillary anterior teeth with two methods of en-masse retraction i.e.NiTi coil spring and elastomeric chain, with miniscrews placed at various heights using finite element analysis was compared. A total of four models were created i.e. two models with retraction by elastomeric chain and two models with retraction by NiTi coil spring with the help of implant placed at 3 mm and 5 mm height from alveolar crest. The study showed that the retraction with elastomeric chain produces lesser amount of von Mises stress on the bone as well as mini-implant as compared to that with NiTi coil spring. Retraction with elastomeric chain produced more sagittal and vertical displacement of canines as compared to its effect on incisors. The overall displacement of anterior teeth in both vertical as well as in sagittal direction was found to be more with elastomeric chain as compared with NiTi coil spring. Both the methods for retraction resulted in same amount of palatal root movement irrespective of the force vector.

Bohara P., Kumar M., Sharma H., Jayprakash KP, Misra V., Savana K.(2017)[46] evaluated the stress distribution and displacement of maxillary anterior teeth. Four different finite element models of maxillary arch were constructed to understand the nature of stresses and displacement patterns of anterior teeth during en masse intrusion and retraction on force application with different combinations of miniimplants and retraction hooks.The study concluded that the nature of stresses changes from tensile to compressive from cervical area to apical area. Various tooth displacements suggest that different combinations of miniimplants and retractionhooks affect the direction of the tooth movement.

Namburi M, Nagothu S, Kumar CS, Chakrapani N, Hanumantharao CH , Kumar SK(2017)[47] investigated the effects of consolidation in two implant and three implant combinations of retraction and intrusion. A three-dimensional FEM model of maxillary teeth and periodontal ligament housed in the alveolar bone with the first premolars extracted is generated with appropriate number of elements and nodes. The models were broadly divided into two groups according to the no. of implants. The study concluded that consolidation is better than non- consolidation during en-masse retraction and intrusion.

Ghadge A.,Shah A.,Karandikar G.,Gangurde P.,Gaikwad S.,Jadhav B. (2019) [48] determined and evaluated the efficiency of the varying positions and heights of power arm (PA) as well as the effect of varying locations of Temporary Anchorage Devices (TADS) on en-masse retraction of maxillary anterior teeth in sliding mechanics by employing a Finite Element Method. A 3D Finite Element Method (FEM) was used to simulate en-masse anterior teeth retraction in sliding mechanics. The study concluded that to achieve better controlled movement during sliding mechanics use of powerarm by varying height and positions and by varying locations of TADs speeds orthodontic results. Use of power arm makes the unit more stable and stronger. Use of TADs achieved maximum anchorage than conventional method during maxillary anterior teeth retraction.

Park JH, Kook YA, Kojima Y, Yun S, Chae JM.(2019)[49] investigated the mechanics of tooth movement in palatal en-masse retraction of segmented maxillary anteriorteeth by using anchor screws and lever arms. A three-dimensional finite element method was used to simulate overall orthodontic tooth movements. The study concluded that the movement pattern of the anterior teeth changed depending on the combination of lever arm height and anchor screw position. However, this pattern may be unpredictable in clinical settings because the movement direction is not always equal to the forcedirection.

Feng Y., Kong D.W, Cen J.W, Zhou Z.X, Zhang W, Li TQ, Guo YH. Yu WJ(2019)[50] evaluated the tooth movement tendency during space closure in maxillary anterior teeth with the use of miniscrew anchorage in customized lingual orthodontics with various power arm locations. Three-dimensional finite element models of the maxilla were created with miniscrews and power arms; the positions were varied to change the force directions. The study concluded that in customized lingual orthodontic treatment, power arms located at the distal sideof the canines are unfavorable for anterior teeth torque control and intercanine width control.

Aghera D, Shyagali R.T, Kambalya P(2019)[51] evaluated and compared the stress and displacement pattern between conventional and micro-implant supported retraction in lingual orthodontic system. A finite element model of the maxilla, teeth, periodontal ligament, lingual-orthodontic ap. The study concluded that Within the limitations of this research, the 8 mm micro-implant model displayed high initial stresses and greater initial displacement of the anterior teeth in the X-Y-Z coordinates in comparison to conventional retraction method.

Reddy M.C, Mohan S. , Raghav P., Jain S. , Jain S.(2020)[52] evaluated the stress distribution in bone at varying lengths and diameters of the micro-implant. A 3-D Finite element models of maxilla, mandible, and micro-implants with varying lengths and diameters were generated for the study. The micro-implants were inserted 90° to the bone surface. A force of 200 g was applied from the micro-implant to the power arm. The results showed that with increased diameter of micro-implant, significant negative correlation with the stress generated. The maximum von Mises stress was found for implant of diameter 1.2 mm and least for implant of diameter 1.8 mm. The study concluded that with increasing the diameter of the micro-implant reduces the stress concentration in bone, thereby increasing the likelihood of implant stabilization.

Cozzani M., Nucci L. , Lupini D. , Dolatshahizand H. , Fazeli D., Barzkar E. , Naeini E., Jamilian A.(2020)[53] investigated an optimal insertion angle for Jeil, Storm, and Thunder miniscrews on stress distribution at the bone miniscrew interface. A 3-dimensional finite element model with a bone block was constructed with type D2 of bone quality, and with miniscrews of Storm, Thunder, Jeil, with the diameter of 2, 1.5. 1.6 mm and length 15.9, 12.4, 14.4 mm respectively. The miniscrews were inserted at 15°, 30°, 45°, 60°, 75° and 90° to the bone surface. A simulated horizontal orthodontic force of 200 gram was applied to the centre of the miniscrews head in all models, and stress distribution and its magnitude were evaluated with a 3-dimensional finite element analysis program. The study showed the result that in the cancellous bone, minimum stress was found at placement angles of 90◦ for Jeil and Storm, which was 0.37 and 0.39 MPa respectively, and 15◦ for Thunder, which was 0.85 MPa. The maximum von Mises stresses in the cancellous bone for Jeil was at 608, which was 0.92 MPa, and for Thunder at 90◦, which was 1.3 MPa. The study concluded that each miniscrew has an ideal insertion angle, optimal insertion positions were found within 90◦ for Jeil and for Storm but 15◦ for Thunder.

Qie H., Kong L., Zhang F., Li C., Lu L., Dou C., Shan L(2020)[54] examined the biomechanical effects of combined loading of maxillary anterior and posterior implants using thesliding method on en-masse retraction of the anterior teeth and to quantify the loading ratio (LR) of anterior and posterior implants to achieve controlled retraction of the maxillary anterior teeth. A three-dimensional finite element model of the maxilla-upper dentition appliance was constructed. Implants were placed on the distal (A) and mesial (B) sides of the lateral incisors as well as on the mesial (C) side of the first molar and different amounts of force were loaded between the implants using 2- or 5-mm traction hooks. The result of the study suggested that 2- mm traction hooks can cause labial crown inclination, translation tendency during retraction, or lingual crown inclination of the central incisors due to alterations in the LR of the anterior and posterior implants.

Agrawal A. , Subash P.(2021)[55] evaluated the effectiveness of en-masse retraction design with mini-screw with respect to the retraction hook and mini-implant position and height.. The selected studies were assessed for the risk of bias using the Cochrane Collaboration risk of bias tool. The "traffic plot" and "weighted plot" risk of bias distribution were designed using the ROBVIS tool. The authors extracted and analyzed the data. The study came with the conclusion that according to the currently available literature review for successful bodily en-masse tooth movement, the force vector should pass through the center of resistance, which can be achieved by the clinical judgment of placing a miniscrew and an anterior retraction hook. The force from an implant placed at a higher level from the anterior retraction hook will cause intrusion; an implant placed at the medium level shows bodily movement; and an implant placed at a lower level shows tipping forces in consolidated arches.

Ghannam M, Kamiloglu B.(2021)[56] analyzed different points of force application during miniscrew supported en masse retraction of the anterior maxillary teeth to identify the best line of action of force in lingual orthodontic treatment. Three-dimensional (3D) finite element modelswere created to stimulate en masse retraction with different heights and positions of the miniscrew length (10.7mm) . The study concluded that all miniscrew heights and lever arm positions showed initial lingual crown tipping and labial root tipping with occlusal crown extrusion. However, the 8mm miniscrew height and the lever arm located between the lateral incisor and canine showed fewer amounts of these tipping patterns than a 4.5mm miniscrew height and lever arm located distal to the canines.

Ali MJ , Bhardwaj A, Khan MS , Alwadei F. , Gufran K. , Alqahtani AS , Alqhtani NR, Alasqah M., Alsakr AM. and Alghabban RO (2022)[57] estimated the distribution of stress generated by the forces on the maxillary anterior teeth during orthodontic retraction using the bilateral miniscrew implant. Finite element models were generated from the three-dimensional (3D) reconstruction of the maxillary arch via cone–beam computed tomography (CBCT). These models imitate the retraction of maxillary anterior teeth with the mini screw placed as the skeletal anchorage. The study concluded that the length of the power arm shows no significant difference in stress distribution pattern on the left and right sidesexcept for stresses moving from the canine region to the lateral incisor region with the increase in power arm height.

Sreenivasagan S, Subramanian AK, Chae JM, Venugopal A, Marya A(2022)[58] evaluated the initial displacement of the maxillary anterior teeth during distalization of the whole maxillary dentition and en-masse retraction of the maxillary anterior teeth using interradicular MIs (IRMIs) and infrazygomatic crest mini-implants (IZCMI) with varying power arm heights. The study is a finite element (FE) study. Two FE models were created for total distalization of the maxillary dentition and en masse retraction of the maxillary six anterior teeth. The study concluded that a careful consideration of the MI location and the power arm height should be preceded to obtain a desired tooth movement when planning to retract or distalize themaxillary dentition.

MATERIAL AND METHOD

This in-vitro FEM study was conducted in the department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi das college of dental Sciences, Lucknow in collaboration with FEA Solution Mumbai, in order to evaluate the stress distribution on alveolar bone of maxilla at TAD bone interface and anterior teeth root and PDL during anterior en-masse retraction using different length of miniscrew when placed at different angulations in combination with different height of powerarm .

The approval was taken from the Ethical Committee of Babu Banarasi Das College of Dental Sciences, before conducting the study and since the FEM study is an in-vitro study patient consent was not required for conducting the study.

MATERIALS :

In this study , the following material were used:

1. **Model**

   A maxillary arch with extracted right and left first premolars will be modeled on the basis of their CBCT images.

   - A Cone Beam Computed Tomography (CBCT) scan of an adult skull, including both the maxillary and mandibular jaws was taken.(**Figure 1**)
   - CBCT output was converted into an Stereolithographic (STL) file and was sent for further processing.(**Figure 2**)
   - Using the data from CBCT scans, a CAD model was constructed in order to create a finite element model.(**Figure 3**)

2. **Bracket**

   MBT prescription with 0.022’’ X 0.028’’ bracket slot .(Gemini:3M,St Paul, Minnesota,USA)(**Figure 4**)

3. **Archwire**

   0.019’’X 0.025’’ Rectangular Stainless steel (SS)arch of ovoid shape wire were used for anterior en-masse retraction .(Gemini:3M,St Paul, Minnesota, USA) (**Figure 5**)

4. **Powerarm**

   Preformed powerarm of height - 4 and 8mm made of 0.021X 0.025 crimpable hook (Libral Traders, New Delhi. India)(**Figure 7**)

5. **Miniscrew**

   Titanium miniscrew of length 8 and 10mm of diameter 2 mm(**Figure 8**) along with MBT prescription with 0.022'' X 0.028'' bracket slot , 0.019''X 0.025'' Rectangular SS arch wire and Preformed power arm of height - 4 and 8mm were scanned using laser scanning system & CAD model were obtained.

6. **Laser scanner software used for creating and analyzing FEM(Finite Element Method)**

   - MIMICS will be used to convert CBCT into STL format
   - Laser scanning of the TAD, MBT bracket slot,SS arch wire and preformed power arm were scanned to make the CAD model and 3-D modeling will be done.
   - GEOMAGIC modeling software was used for the construction of geometric model.
   - ALTAIR HYPERMESH by Altair Engineering Inc.(Troy , Michigan, United States) software was utilized to generate mesh models. (**Figure 9**)
   - ALTAIR HYPERMESH developed by Altair Engineering Inc.(Troy , Michigan ,United States) for windows was used to integrate the model of the maxilla with the periodontal ligament(PDL), bone, and other components.
   - ALTAIR OPTISTRUCT developed by Altair Engineering Inc.(Troy, Michigan, United States) Finite Element (FE) solver was used to carry out the simulation.
   - ALTAIR HYPERVIEW created by Altair Engineering Inc.(Troy, Michigan, United States) was employed to visualize the finite element results, create result images, and extract stress data information from the simulation.

The results of the FEA are individual values without any statistical spread, so statistical significance analyses were not performed.

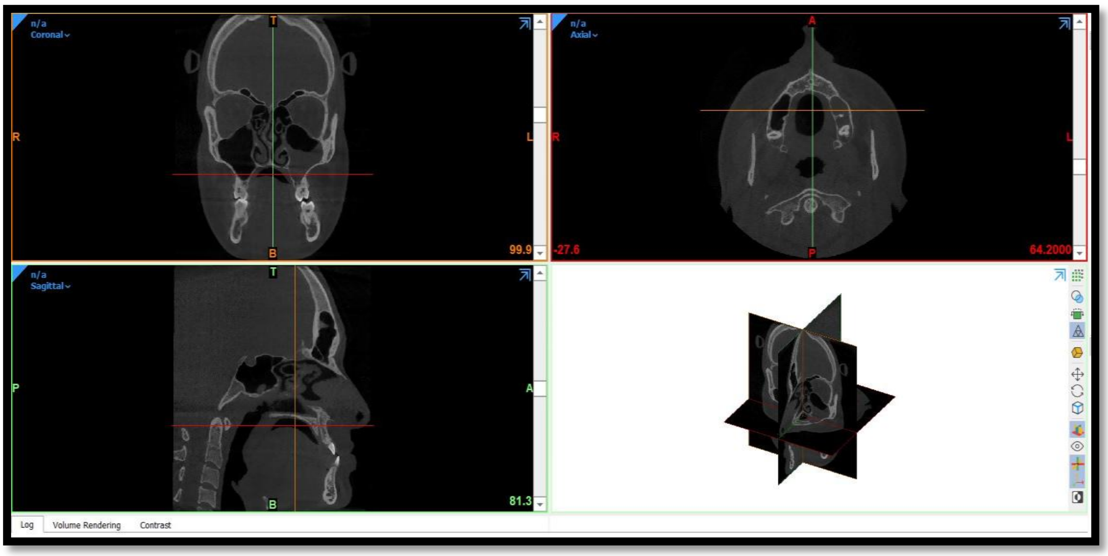


Figure 1: CBCT images of the maxillary and mandibular jaw

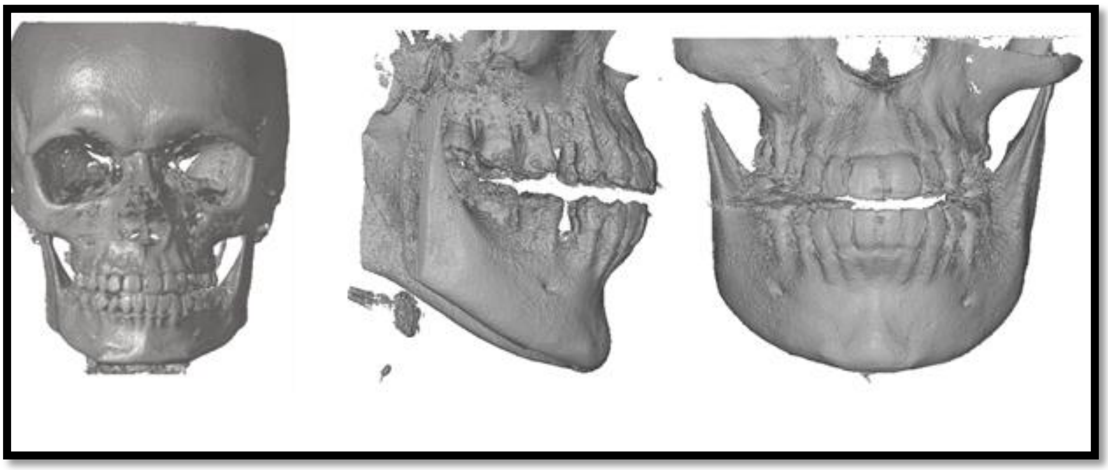


Figure 2 : Raw STL File output of the human skull from the CAD model

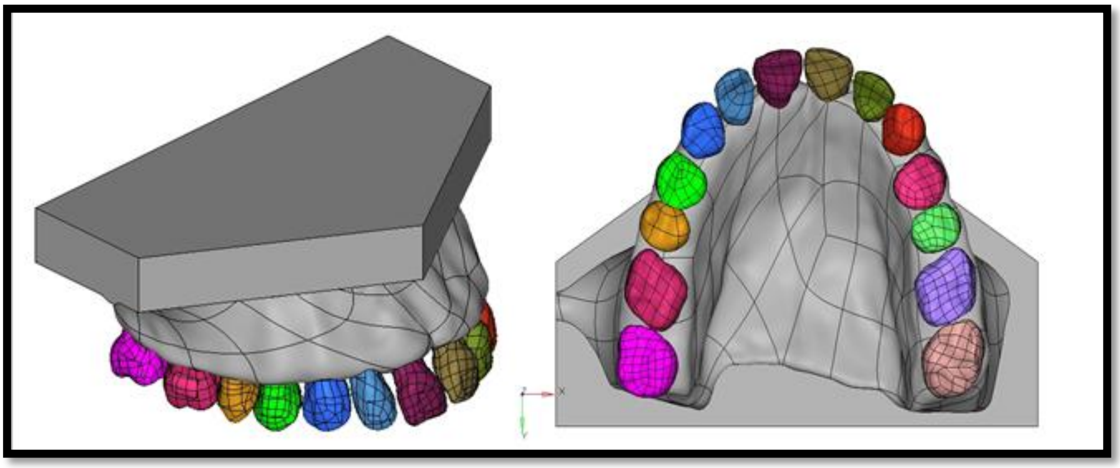


Figure 3: Final finite element model of the maxillary arch

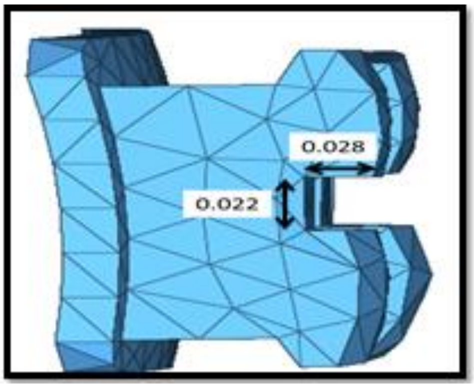


Figure 4 : Bracket of MBT slot size 0.022”X 0.028”

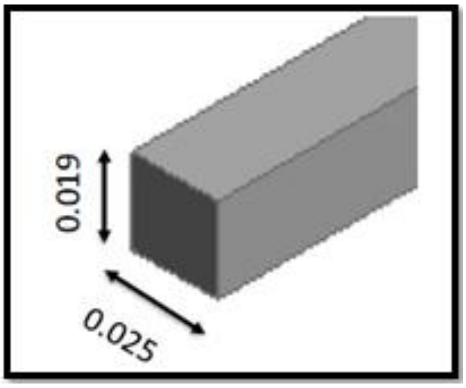
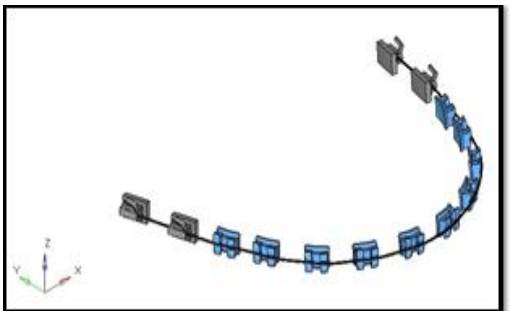


Figure 5: 0.019’’X0.025’’ SS archwire



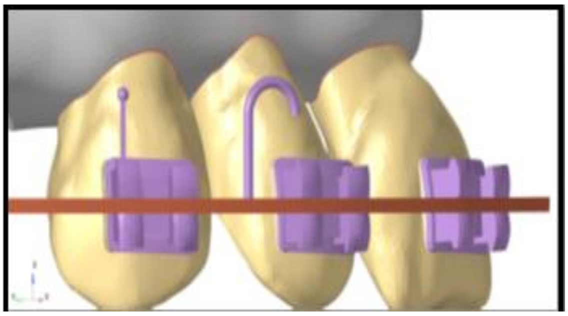


Figure 6: Bracket and Archwire assembled in a single curve

Figure 7: Preformed powerarm attached on the archwire

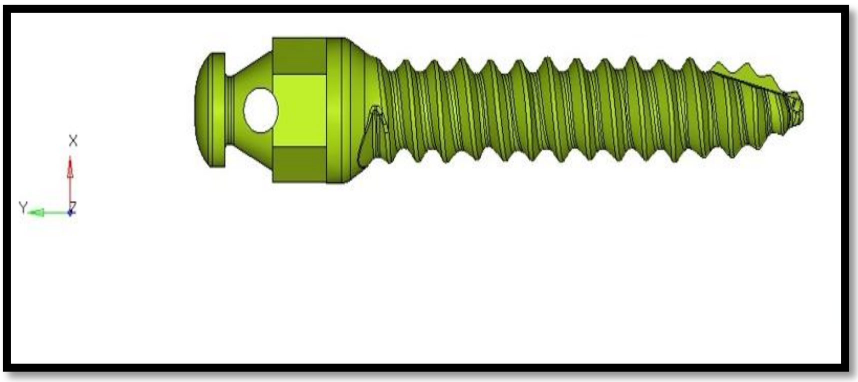


Figure 8 : Screw model

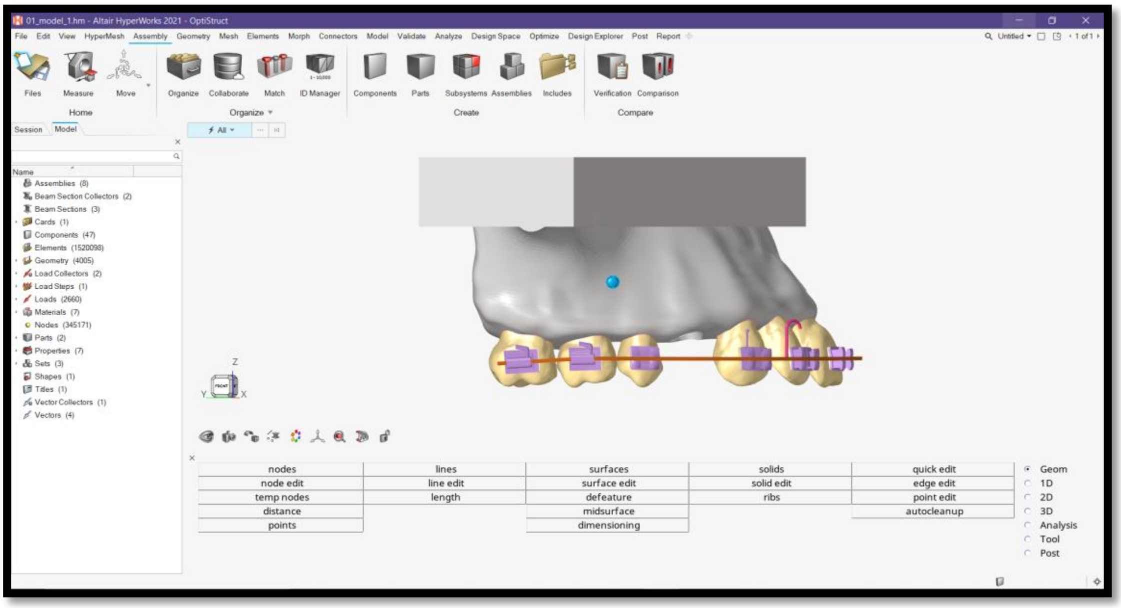


Figure 9 : Image from Altair HyperWorks

Methdology

In the present study ,the following steps will be involved for the finite element study:

- Generation of the CAD Model
- Construction of the geometric model of the maxillary bone around the TAD and complete the assembly.
- Conversion of the geometric models to a finite element model
- Incorporation of material properties of tooth structure and periodontium
- Defining boundary condition
- Loading configuration
- Translation of results and interpretation

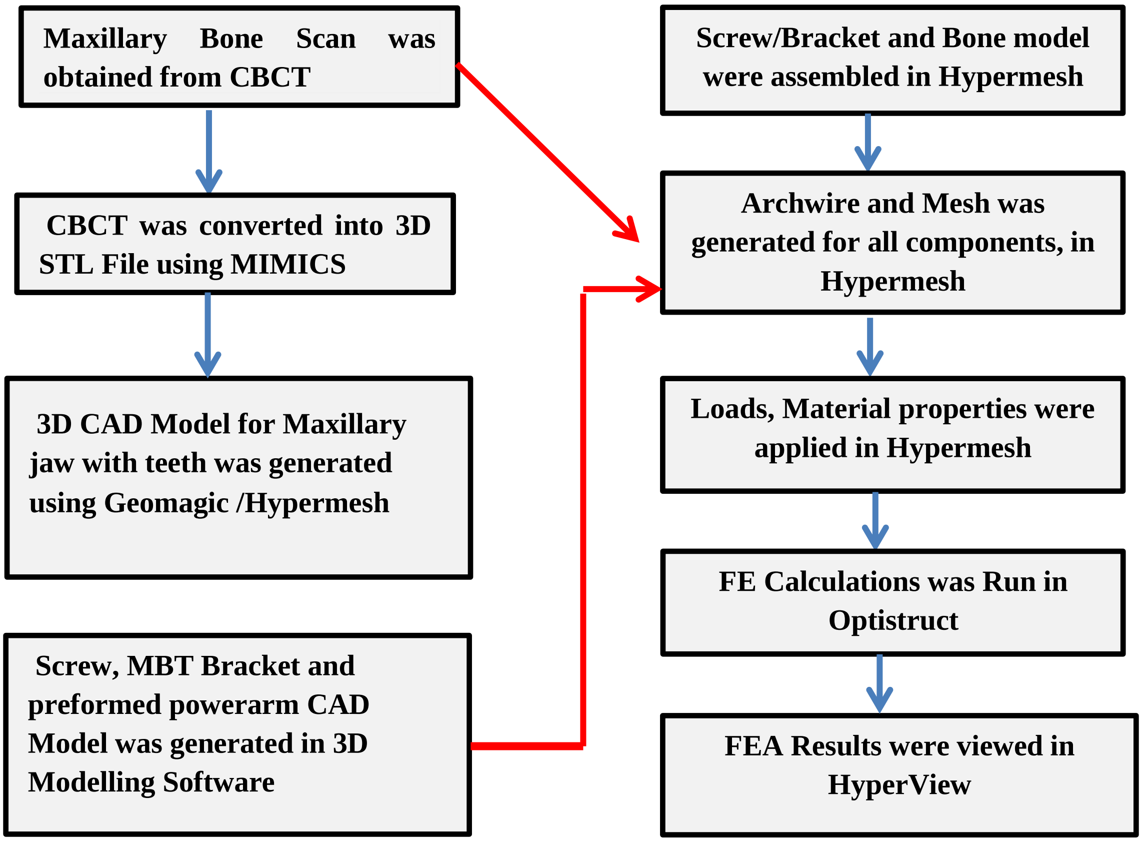


Figure 10: Schematic flowchart showing the steps involved in the study

1. **Generation of CAD Model of maxilla**

CBCT scans of normal adolescent skull without any skeletal defects, trauma, lesions, and with all of teeth up to second molars, were obtained from the archives of a reputed CBCT scan center at 0.5-mm intervals, parallel to the Frankfort plane in the axial orientation, sequential CT images were taken. DICOM files were the output of the scan. These DICOM files were at each scan interval. All DICOM files were then imported into MIMICS Software to develop a 3D model. A software program that mimics moving the data facilitates 3D interpretation and helps with determining the CT scan's specifics. Different parts like teeth, jawbone etc. were then extracted from MIMICS by separating then based on bone density in MIMICS. Stereo-lithography (STL) file was exported from MIMICS. This file was a constructed 3D representation of all DICOM slices. Files in stereo-lithography (STL) format were converted into CAD model as shown in (**Figure 3)** STL file was imported into Geomagic software where STL was converted into Surface CAD model. In Geomagic complete assembly of the model was generated. This CAD model was then exported as a *.Step file. Step file was imported into FEM software; Altair Hyper Mesh in this case. The FEM is made up of a collection of minor components that work together to adequately characterise the subject's geometry. It's known as "creating the mesh" or "meshing." (**Figure 11)**

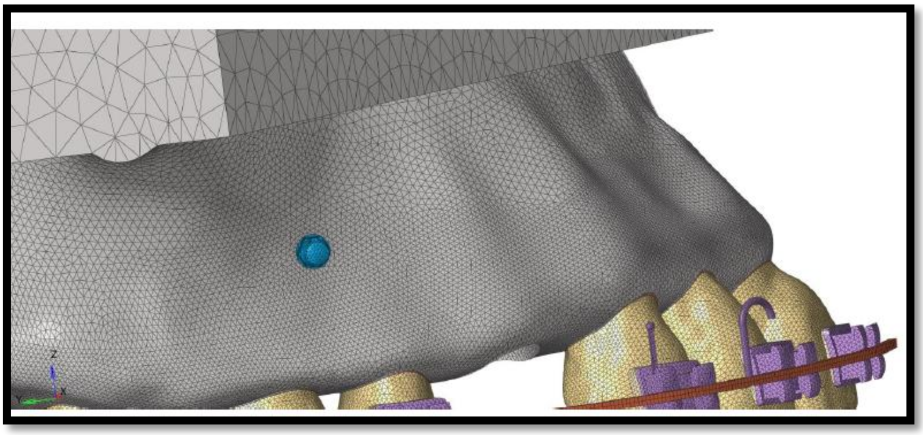


Figure 11: Meshed Model

2. **Construction of the geometric model of the maxillary bone**

   In this study, the geometry of 3D finite element model of Maxillary Bone anatomy was generated through CT Scan. This data were exported to 3D image processing and editing software- 3D-Doctor (Able Software Corp., Lexington, Massachusetts, USA), and image obtained as stereolithographic (STL format).

Thus, bone model was imported in Altair HyperMesh (Troy, Michigan, United States) and complete model was assembled in Altair HyperMesh software. **(Figure 9)**

3. **Construction of geometric model of maxillary bone with the whole assembly for the study – Brackets, Wires, J-hook and TAD's**

TAD with 8mm & 10 mm length were scanned using laser scanning system & CAD model for the same was obtained. (**Figure 12**)

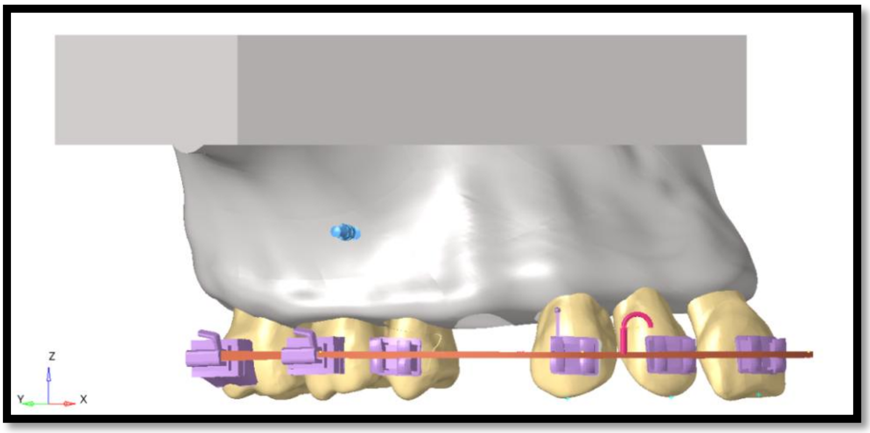


Figure 12: Geometric model of maxillary bone with the assembly

3 . **Conversion of the geometric models to a finite element model**

With the help of Altair HyperMesh Software, the geometric models were converted into finite element models and this process is called meshing or mesh generation. The finite element model represents geometry in terms of finite elements and the nodes that could be tetrahedron, pyramid, triangulat Prism and Hexahedron . This process is called "discretization." In this study, to model the irregular geometry of the teeth, maxilla, wire, bracket, power arm and TAD, 4-noded tetrahedral shape was selected as the finite element and for modeling a 3-D Quad mesh was used. (**Figure 13**)

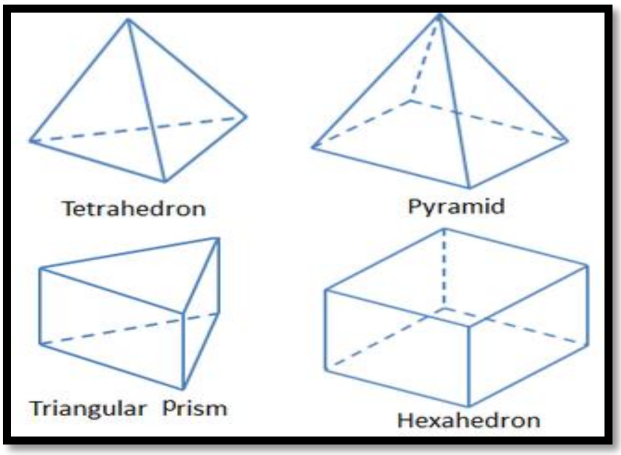


Figure 13: Different geometric shapes that can be used for generation of a model

Meshing Details

Meshing is nothing but to discretize, or divide, the complex geometry into a collection of manageable, smaller "elements" with finite dimensions (2D or 3D). The intersections of two or more distinct components are known as nodes or nodal points. The perimeter nodes are the main primary exterior nodes.

The additional nodes that show up on an element's edges are called secondary external nodes.

Compared to corner nodes, the secondary nodes have less movement.

Collection of nodes and elements leads to the creation of an element mesh that can take the form of a hexahedron or tetrahedron pyramid.

The element's quantity, dimensions, and sort are chosen. To reduce the number of elements to a minimum conducive to acceptable outcomes, practical knowledge and judgement are required. (**Table 1**)

Table 1: The number of nodes and elements in FEM model

Component	No. of Nodes	No. of elements
Teeth	105714	522566
Periodontal Ligament (PDL)	111782	183943
Jaw bone	148986	749379
Brackets	8500	30990
TAD	2801	10821
Arch Wire	2223	980

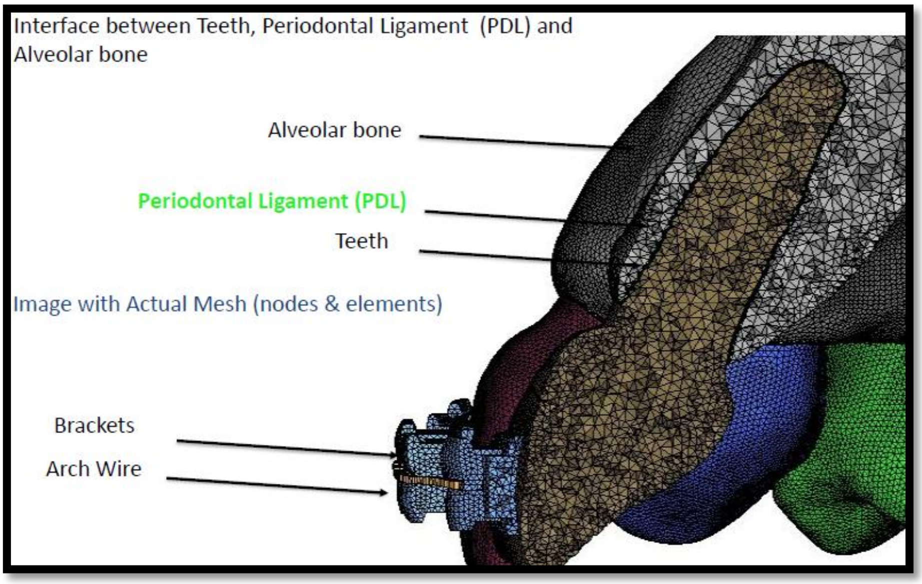


Figure 14: Meshing detail of dentoalveolar structure with bracket and archwire

5 . Incorporation of material properties of tooth structure and periodontium

The material properties of teeth, cortical bone, cancellous bone, screw/implant/TAD were the average values reported in literature [14,25,31,59,60,61] . All materials employed for the finite element model study were taken to be isotropic, homogenous, and linearly elastic and material properties are shown in(**Table 2**)

Table 2: Table showing the material properties[14,25,31,59,60,61]

MATERIALS	YOUNG'S MODULUS (MPa)	POISSON'S RATIO
Teeth	**20,000**	**0.30**
Periodontal ligament	**0.05**	**0.30**
Alveolar bone	**2000**	**0.30**
Titanium mini-implant	**110,000**	**0.35**
Cortical bone	**13,700**	**0.30**
Cancellous bone (D3)	**1,600**	**0.30**
Bracket/arch-wire/molar hook	**200,000**	**0.30**

6. **Defining boundary condition**

In this step the fixing location, fixing surface of the model or bone is decided. It is decided as per clinical significance of the study. For example in this study the top base of the maxilla will be locked in all degrees of freedom.

Boundary Conditions:

Validation of Model:

This step served as a FEA trial run. It served as a testing ground for constituent quality. In order to enhance the element quality, the model's Warpage, Aspect Ratio, and tet Collapse element qualities were examined.

The Finite Element Model's general mesh quality might benefit from local re-meshing in some places. All of this was done to make sure the generated mesh/element quality is within the FEA Solver's permissible range. Both Maxilla models underwent this procedure.

Application of Boundary Conditions

Boundary Conditions define the way model is held or fixed in the FE space & the way forces are applied on the model.

- ***Fixing the Model:***

Model need to be fixed at a point in FEA. Following images gives details on how the model was fixed in this study.

As per FEM, nodes on the selected surfaces were locked in all Degrees of Freedom. This restricted the displacement of these nodes in all direction. This way model was locked / fixed in the FEA space for solving.

Model was locked in all Degree of freedom as shown below.

Force Application:

A vertical load on the incisal edge of the midline to simulate vertical loading while biting and lingual loading from the labial surface of the teeth to simulate protrusive jaw movement during mastication

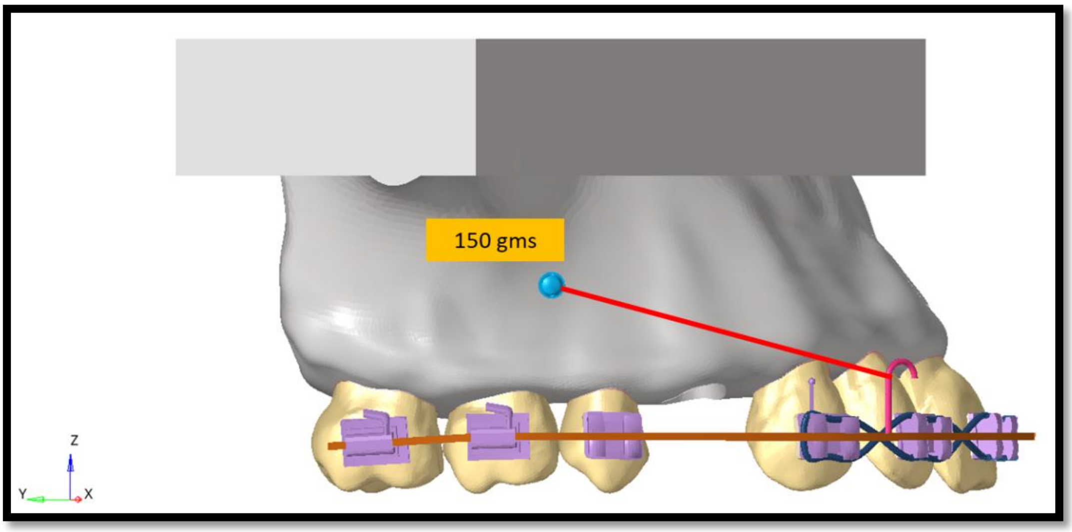


Figure 15: Image showing boundary Condition for all models with 4mm Power Arm height

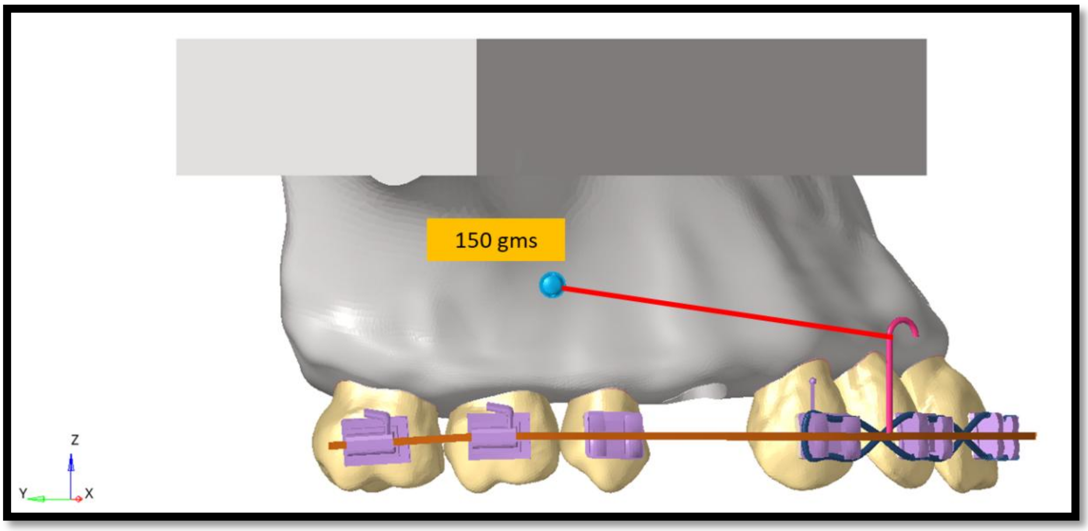


Figure 16: Image showing boundary Condition for all models with 8mm Power Arm height

6. Loading Configuration

In this step all the types of forces experienced by the model are understood, converted into numerical values with force direction and magnitude. This force is then applied on the model.

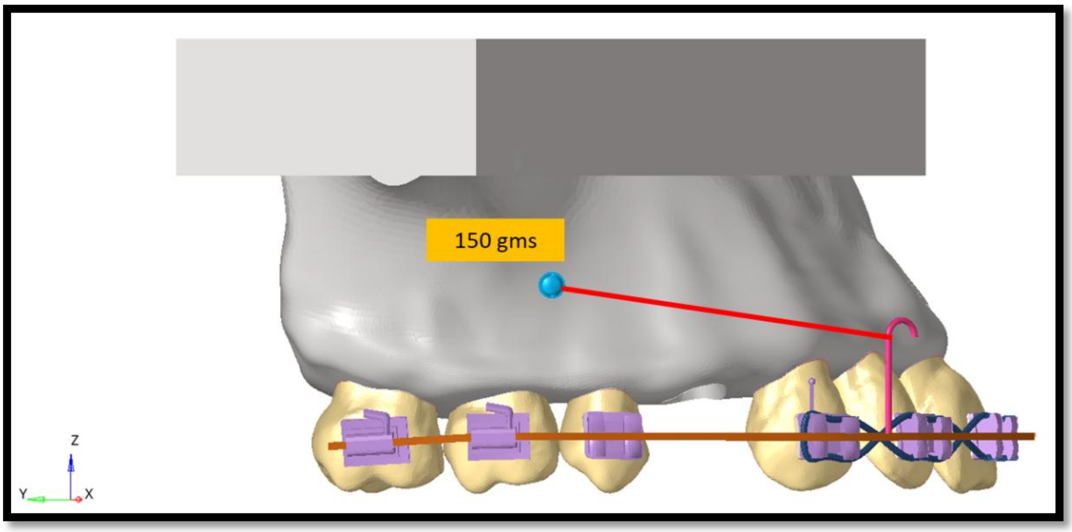


Figure 17: Image showing a loading force of 150gms applied for anterior en-masse retraction

7. Translation of results and interpretation

At this stage the FEA results are checked, tabulated and understood in form of results. These results are then interpreted and converted into proper discussion of results which resembles clinical significance.

The following stages were used in the construction of the finite element model.

1.**Pre-processing:** It is the procedure carried out before FEA calculations are performed, as the term implies. The model was created at this stage. Mesh was produced.

Boundary constraints were then used. Altair Hypermesh was the programme used during the pre-processing step.

2. **FEA Solver**: This programme processes data and computes outcomes for the FEM. At the solver step, Altair Optistruct was the programme used.

3. **Post-Processing**: This step involved viewing, extracting, reviewing, and storing the results.

At this stage, results like reaction force and displacements are all analysed and extracted.

Altair Hyperview was the programme utilised for data post-processing.

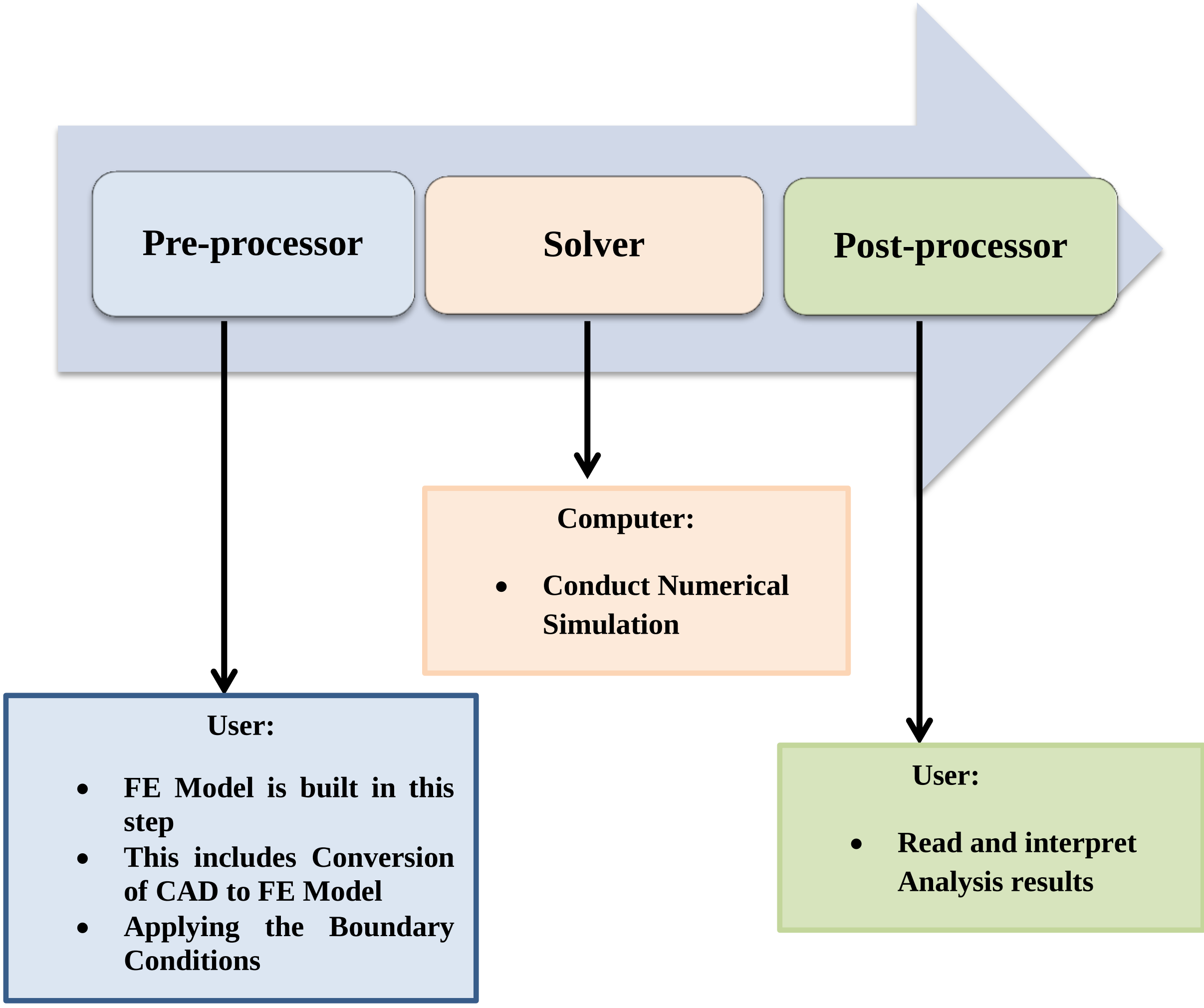


Figure 18: Schematic flowchart showing the 3 Steps in Finite Element Method.

FEM

ESSENTIAL STEPS IN FEM:

- Select the type of analysis
- Discretization
- Develop element matrices and equating
- Derivation of overall equations/matrices
- Imposition of boundary status
- Application of loads
- Post processing of results

CALCULATION

The FE Model was submitted to Altair Optistruct Software for Finite Element Calculation.

Develop Element Matrices And Equating

- Specify material properties to the elements and obtain algebraic equation defining stiffness for each element.
- The stiffness matrix (K) will connect the forces operating on the structure to the displacement brought on by those forces in the manner described below.

$$[K]\{u\} = \{F\} \Longrightarrow \{u\} = [k]^{-1}\{F\}$$

K = Stiffness matrix; **u** = Deflection; **F** = Force

Derivation of overall equations/matrices

- Displacement at a node has to be same for all the adjacent elements.
- Combine element matrices to obtain one master equation called Global stiffness matrix
- By connecting elements, the piecewise polynomial interpolation concept is used by FEM to piecewise interpolate the field quantity over the full structure.

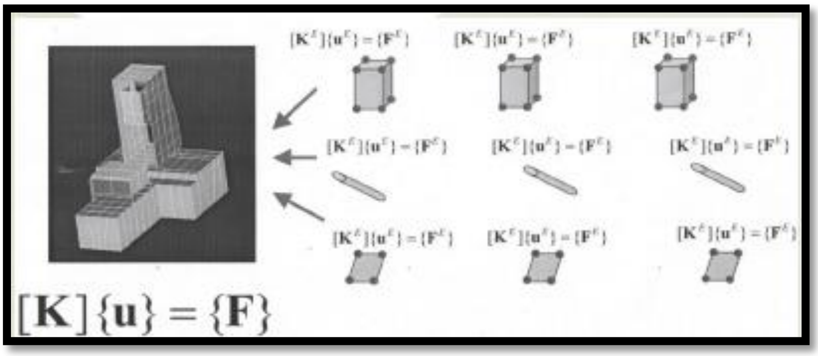


Figure 19: Global Stiffness

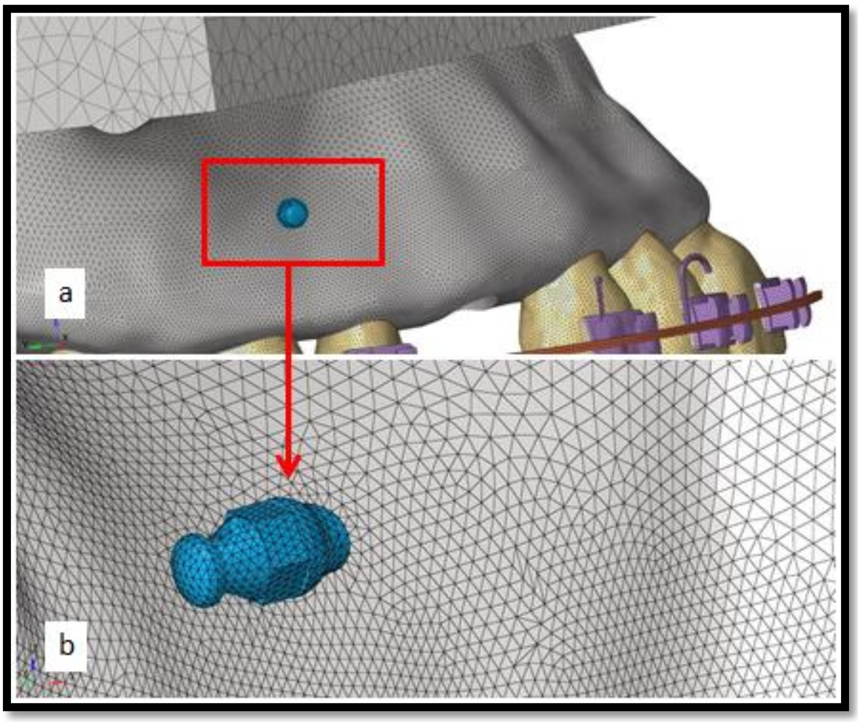


Figure 20: a. Meshed model of miniscrew

b. Zoomed image of the Meshed model of miniscrew

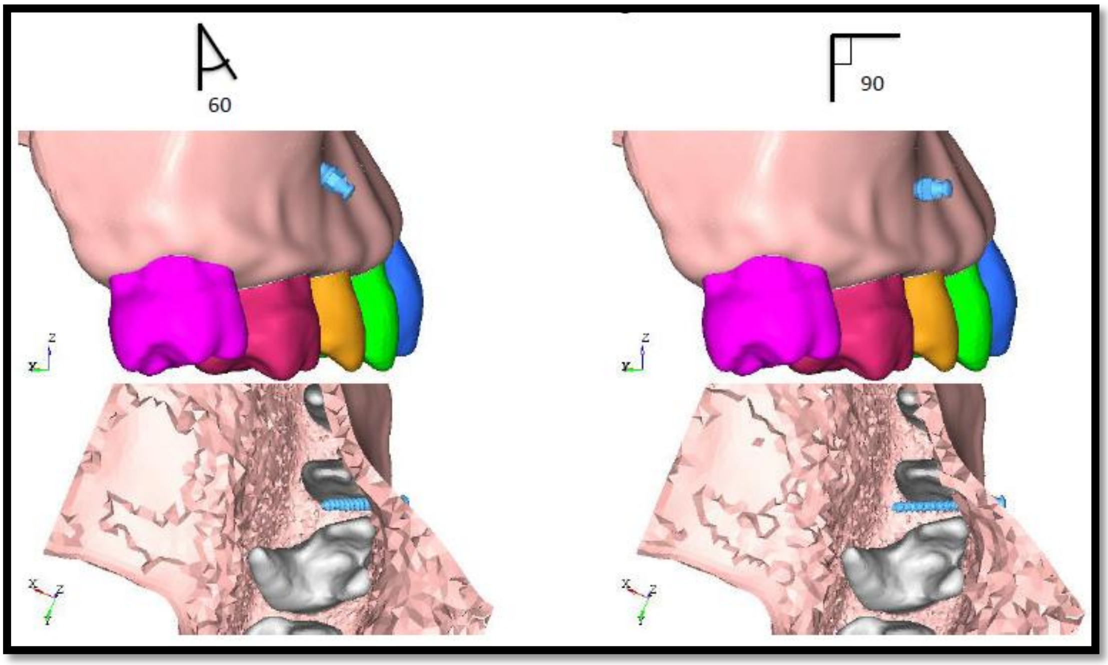


Figure 21: Finite element model showing the miniscrew insertion angles 60◦ and 90 ◦

Table 3: Finite Element model details

Models	TAD Length(mm)	Powerarm height (mm)	Angulation(Deg.)
1	**8**	**4**	**60**
2			**90**
3		**8**	**60**
4			**90**
5	**10**	**4**	**60**
6			**90**
7		**8**	**60**
8			**90**

A total of 8 finite element model was generated and boundary conditions was applied.

The FE model will be then submitted to Altair Optistruct Software for the Finite Element Calculation

Results

Post –processing was done in **Altair Hyperview Software**.

Table 4 : Software used for the study:

Stage	Software Name
FEA Pre-processing	Altair HyperMesh
FEA Solver	Altair Optistruct
FEA Post-processor	Altair HyperView

The obtained Von Mises stress were tabulated and compared to each other for all combinations to compare the stress distribution in the TAD bone interface and in the roots and PDL in the anterior segment.

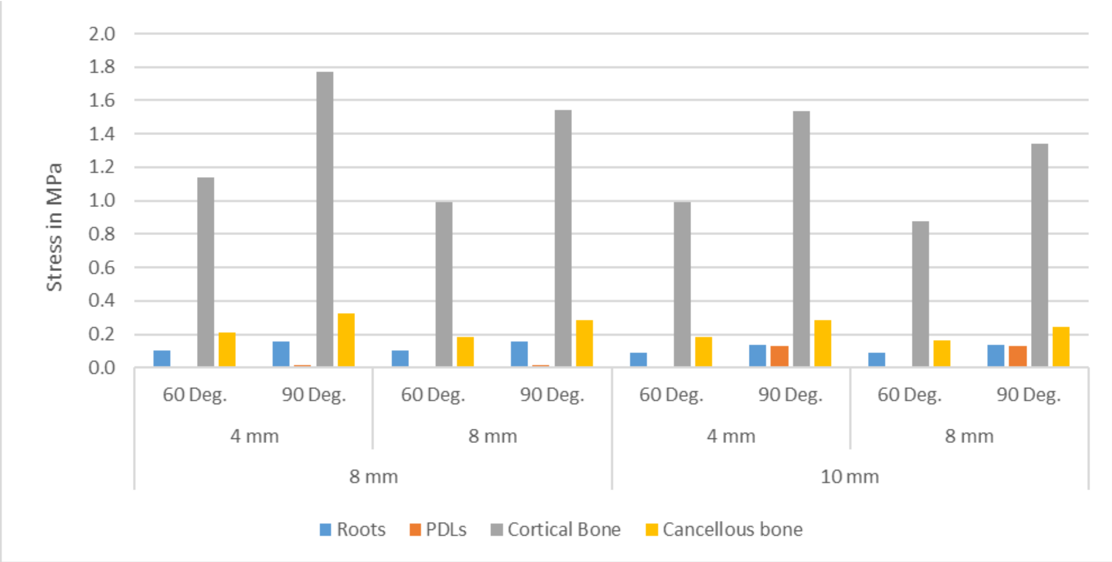
In order to assess and compare the stress distribution in alveolar bone during en-masse retraction, this research study was carried out at the Department of Orthodontics and Dentofacial Orthopaedics of BBD University in collaboration with FEA solution, Mumbai .Anterior en-masse retraction was carried out using miniscrews of length **(MSL)*** 8mm and 10mm with a diameter of 2mm. The miniscrews were placed at two different angulations of 60◦ and 90◦ and along with it power arm **(PA)**** of height 4 and 8mm were used for the en-masse retraction with a force application of 150gms.

A colour scale consisting of 9 stress values was used to evaluate the stress value for our present study. This colour scale for the stress distribution (Von Mises stress in MPa) runs from lowest stress values i.e. blue colour to the highest values i.e. red colour .The stress distribution in the TAD- bone interface in the posterior segment i.e. the stress generated around the cancellous and cortical bone and also the stress generated in the root and PDL in the anterior segment during retraction have been generated for different combination of TAD length, angulation and power arm in the maxilla.

Table 5: Descriptive data for the stress distribution (Von. Mises stress) in MPa in different structures (roots and PDL)in the anterior segment and Cancellous and Cortical bone in the posterior segment around the TAD .

Stress in all Components of the Model (Mpa)								
Miniscrew Length (MSL)	8 mm				10 mm			
PowerArm Height (PA)	4 mm		8 mm		4 mm		8 mm	
	ANGULATION				ANGULATION			
Structure	60 Deg.	90 Deg.	60 Deg.	90 Deg.	60 Deg.	90 Deg.	60 Deg.	90 Deg.
Roots	0.101	0.156	0.101	0.156	0.087	0.135	0.087	0.135
PDLs	0.009	0.014	0.009	0.014	0.008	0.130	0.008	0.130
Cortical Bone	1.142	1.770	0.994	1.545	0.994	1.535	0.876	1.339
Cancellous bone	0.210	0.326	0.183	0.284	0.183	0.282	0.161	0.246

Stress in MPa



Bar diagram 1 : Showing the stress distribution in MPa in different structures in the anterior and posterior segment for different combinations of placement angulation , miniscrew length and power arm .

The results of the study for different situations are discussed below in details.**8** different FEM models with different set of combinations with a loading force of 150 gm of force for en-masse retraction were generated.

8mm Miniscrew length (MSL) with 4mm power arm (PA) placed at 60◦ angulation the Von Mises stress generated in the anterior segment for the root area was 0.101 MPa , in PDLs was 0.009 MPa . In the posterior segment (around the TAD- bone interface) the stress generated in the cortical bone was 1.142 MPa and in the Cancellous bone was 0.210 MPa.

8mm Miniscrew length (MSL) with 4mm power arm (PA) placed at 90◦ angulation the Von Mises generated in the anterior segment for the root area was 0.156 MPa , in PDLs was 0.014 MPa . In the posterior segment (around the TAD- bone interface)the stress generated in the cortical bone was 1.770 MPa and in the Cancellous bone was 0.326 MPa.

8mm Miniscrew length (MSL) with 8mm power arm (PA) placed at 60◦ angulation the Von Mises generated in the anterior segment for the root area was 0.101 MPa , in PDLs was 0.009 MPa . In the posterior segment(around the TAD- bone interface) the stress generated in the cortical bone was 0.994 MPa and in the Cancellous bone was 0.183 MPa.

8mm Miniscrew length (MSL) with 8mm power arm (PA) placed at 90◦ angulation the Von Mises generated in the anterior segment for the root area was 0.156 MPa , in PDLs was 0.014 MPa .In the posterior segment(around the TAD-bone interface) the stress generated in the cortical bone was 1.545 MPa and in the Cancellous bone was 0.284 MPa.

10mm Miniscrew length (MSL) with 4mm power arm (PA) placed at 60◦ angulation the Von Mises generated in the anterior segment for the root area was 0.087 MPa , in PDLs was 0.008 MPa .In the posterior segment(around the TAD-bone interface) the stress generated in the cortical bone was 0.994 MPa and in the Cancellous bone was 0.183 MPa.

10mm Miniscrew length (MSL) with 4mm power arm (PA) placed at 90◦ angulation the Von Mises generated in the anterior segment for the root area was 0.135 MPa , in PDLs was 0.130 MPa .In the posterior segment(around the TAD-bone interface) the stress generated in the cortical bone was 1.535 MPa and in the Cancellous bone was 0.282 MPa.

10mm Miniscrew length (MSL) with 8mm power arm (PA) placed at 60◦ angulation the Von Mises generated in the anterior segment for the root area was 0.087 MPa , in PDLs was 0.008 MPa . In the posterior segment (around the TAD-bone interface)the stress generated in the cortical bone was 0.876 MPa and in the Cancellous bone was 0.161 MPa.

10mm Miniscrew length (MSL) with 8mm power arm (PA) placed at 90◦ angulation the Von Mises generated in the anterior segment for the root surface area was 0.135 MPa , in PDLs was 0.130 MPa . In the posterior segment (around the TAD- bone interface) the stress generated in the cortical bone was 1.339 MPa and in the Cancellous bone was 0.246 MPa

Table 6: Comparison of the stress distribution (Von. Mises Stress in MPa) in all components of the Model when miniscrew placed at angulations of **60◦and 90◦**

COMPARISON GROUPS					
VARIABLE		STRUCTURE			
		Stress in anterior segment		**Stress in posterior segment around TAD**	
Angulation	Combination	Roots	PDL	Cortical bone	Cancellous bone
60◦	8mmMSL and 4mm PA	0.101MPa	0.009MPa	1.142MPa	0.210 MPa
	8mmMSL and 8mm PA	0.101 MPa	0.009MPa	0.994MPa	0.183 MPa
	10mmI L and 4mmPA	0.087 MPa	0.008MPa	0.994MPa	0.183 MPa
	10mmMSL and 8mmPA	0.087 MPa	0.008MPa	0.876MPa	0.161 MPa
90◦	8mmMSL and 4mm PA	0.156 MPa	0.014 MPa	1.770MPa	0.326 MPa
	8mmMSL and 8mm PA	0.156 MPa	0.014 MPa	1.545MPa	0.284 MPa
	10mmMSL and 4mmPA	0.135 MPa	0.130 MPa	1.535MPa	0.282 MPa
	10mmMSL and 8mmPA	0.135 MPa	0.130 MPa	1.339MPa	0.246 MPa

MSL* stands for Miniscrew length and PA** stands for height of the Power arm

Table 6 shows :

At **60◦ angulation** , **8mm Miniscrew length** with **4mm Power arm** showed stress at root was 0.101 MPa and at PDL was 0.009 MPa . Similar stress distribution was obtained with **8mm Powerarm**. Whereas in the posterior segment at 60◦ angulation , **8mm Implant length** showed 1.142 MPa   stress in cortical bone with **4mm Powerarm** and 0.994 MPa stress at **8mm Power arm** . In Cancellous bone , 0.210

MPa with **4mm** and 0.183 MPa stress at **8mm Powerarm** .It was observed that long power arm (8mm) showed less stress in comparison to 4mm around TAD bone interface.

At **60◦ angulation** , **10mm Miniscrew length** with **4mm Powerarm** showed stress at root was 0.087 MPa and at PDL was 0.008 MPa .Whereas in the posterior segment at 60◦ angulation , **10 mm Implant length** showed 0.994 MPa stress in cortical bone at **4mm Powerarm** and 0.876 MPa stress at **8mm Power arm.** In Cancellous bone , 0.183 MPa at **4mm** and 0.161 MPa at **8mm Powerarm**. .It was observed that long power arm (8mm) showed less stress in comparison to 4mm around TAD bone interface.

At **90◦ angulation**, **8mm Miniscrew length** with **4mm Powerarm** showed stress at root 0.156MPa and at PDL was 0.135 MPa . Whereas in the posterior segment at **90◦ angulation** , **8 mm Implant length** showed 1.770 MPa stress in cortical bone at **4mm Powerarm** and 1.545 MPa at **8mm Power arm**. In Cancellous bone , 0.326 MPa at **4mm** and 0.284 MPa at **8mm Powerarm** . It was observed that long power arm (8mm) showed less stress in comparison to 4mm around TAD bone interface.

At **90◦ angulation** , **10mm Miniscrew length** with **4mm Powerarm** showed stress at root 0.135MPa and at PDL was 0.130 MPa. Whereas in the posterior segment at **90◦ angulation** , **10 mm Implant length** showed 1.535 MPa stress in cortical bone at **4mm Powerarm** and 1.339 MPa at **8mm Power arm** .In Cancellous bone,0.282 MPa at **4mm** and 0.246 MPa at **8mm Powerarm.** It was observed that long power arm (8mm) showed less stress in comparison to 4mm around TAD bone interface.

Table 7 : Comparison of the stress distribution (Von. Mises Stress in MPa) in all components of the Model with Miniscrew length (MSL)* of **8mm and 10mm .**

COMPARISON GROUPS					
VARIABLE		STRUCTURE			
		Stress in anterior segment		**Stress in posterior segment around TAD**	
Miniscrew Length(MSL)*	Combination	Roots	PDL	Cortical bone	Cancellous bone
8mmMSL	60◦ and 4mm PA	0.101MPa	0.009MPa	1.142MPa	0.210 MPa
	60◦ and 8mm PA	0.101MPa	0.009MPa	0.994MPa	0.183 MPa
	90◦ and 4mm PA	0.156MPa	0.014MPa	1.770MPa	0.326 MPa
	90◦ and 8mm PA	0.156MPa	0.014MPa	1.545MPa	0.284MPa
10mmMSL	60◦ and 4mm PA	0.087MPa	0.008MPa	0.994MPa	0.183 MPa
	60◦ and 8mm PA	0.087MPa	0.008MPa	0.876MPa	0.161 MPa
	90◦ and 4mm PA	0.135MPa	0.130MPa	1.535MPa	0.282 MPa
	90◦ and 8mm PA	0.135MPa	0.130MPa	1.339MPa	0.246 MPa

MSL* stands for Miniscrew length and PA** stands for height of the Power arm

Table 7 shows :

8mm Miniscrew length, with **4mm Powerarm** placed at **60◦ angulation** showed 0.101 MPa stress at root and 0.009 MPa at PDL in the anterior segment . Similar stresses were observed with **8mm Powerarm .** Whereas in the posterior segment **8mm Implant length** , placed at **60◦ angulation** showed stress in cortical bone 1.142 MPa at **4mm** and 0. 994 MPa at **8mm Power arm**. In Cancellous bone, 0.210 MPa with **4mm** and 0.183 MPa stress at **8mm Powerarm.** It was observed that long power arm (8mm) showed less stress in comparison to 4mm around TAD bone interface.

8mm Miniscrew length, with **4mm Powerarm** when placed at **90◦ angulation** showed 0.156 MPa stress at root and 0.014 MPa at PDL in the anterior segment . Similar stress were observed with **8mm Powerarm**. Whereas in the posterior segment **8mm Miniscrew length** , placed at **90◦ angulation** showed stress in cortical bone 1.770 MPa at **4mm** and 1.545 MPa at **8mm Power arm**. In Cancellous bone , 0.326 MPa with **4mm** and 0.284 MPa stress at **8mm Powerarm** . It was observed that long power arm (8mm) showed less stress in comparison to 4mm around TAD bone interface.

10mm Miniscrew length, with **4mm Powerarm** when placed at **60◦ angulation** showed 0.087 MPa stress at root and 0.008 MPa at PDL in the anterior segment . Similar stress were observed with **8mm Powerarm**. Whereas in the posterior segment **10 mm Miniscrew length** , placed at **60◦ angulation** showed stress in cortical bone 0.994 MPa at **4mm** and 0.876 MPa at **8mm Power arm** .In Cancellous bone , 0.183 MPa with **4mm** and 0.161 MPa stress at **8mm Powerarm.** It was observed that long power arm (8mm) showed less stress in comparison to 4mm around TAD bone interface.

10mm Miniscrew length , with 4mm Powerarm when placed at **90◦ angulation** showed 0.135 MPa stress at root and 0.130 MPa at PDL in the anterior segment. Similar stress were observed with **8mm Powerarm**. Whereas in the posterior segment **10 mm** Implant length , placed at **90◦ angulation** showed stress in cortical bone 1.535 MPa with **4mm** and 1.339 MPa at **8mm Power arm**. In Cancellous bone,0.282 MPa at **4mm** and 0.246 MPa stress at **8mm Powerarm .** It was observed that long power arm (8mm) showed less stress in comparison to 4mm around TAD bone interface.

Table 8 : Comparison of the stress distribution (Von. Mises Stress in MPa) in all components of the Model with Powerarm (PA)** height of **4mm and 8mm .**

COMPARISON GROUPS					
VARIABLE		STRUCTURE			
		Stress in anterior segment		**Stress in posterior segment around TAD**	
Powerarm height (PA)**	Combination	Roots	PDL	Cortical bone	Cancellous bone
4mm PA	8mmMSL and 60◦	0.101MPa	0.009MPa	1.142MPa	0.210 MPa
	8mmMSL and 90◦	0.156MPa	0.014MPa	1.770MPa	0.326 MPa
	10mmMSLand 60◦	0.087MPa	0.008MPa	0.994MPa	0.183 MPa
	10mmMSLand 90◦	0.135MPa	0.130MPa	1.535MPa	0.282 MPa
8mm PA	8mmMSL and 60◦	0.101MPa	0.009MPa	0.994MPa	0.183 MPa
	8mmMSL and 90◦	0.156MPa	0.014MPa	1.545MPa	0.284 MPa
	10mmI L and 60◦	0.087MPa	0.008MPa	0.876MPa	0.161 MPa
	10mmMSLand 90◦	0.135MPa	0.130MPa	1.339MPa	0.246 MPa

MSL* stands for Miniscrew length and PA** stands for height of the Power arm

Table 8 shows :

At anterior segment for **4mm Power arm** , **8mm Miniscrew length** inserted at **60◦angulation** showed 0.101MPa stress at root and 0.009MPa at PDL**.** Whereas for **4mm Power arm , 8mm Miniscrew length** inserted at **90◦ angulation** showed 0.156 MPa stress at root and 0.014 MPa at at PDL. At posterior segment for **4mm Power arm** ,**8 mm Miniscrew length** inserted at **60◦angulation** showed 1.142MPa stress in cortical bone and 0.210 MPa at Cancellous bone. Whereas for **4mm Power arm ,**

8mm Miniscrew length inserted at **90◦ angulation** showed 1.770 MPa stress at Cortical bone and 0.326MPa stress at Cancellous bone.It was observed that 60 ◦ showed less stress in comparison to 90◦ around TAD bone interface.

At anterior segment for **4mm Power arm** , **10mm Miniscrew length** inserted at **60◦angulation** showed 0.087 MPa stress at root and 0.008MPa at PDL. Whereas for **4mm Power arm, 10mm Miniscrew length** inserted at **90◦ angulation** showed 0.135 MPa stress at root and 0.130 MPa at PDL. At posterior segment for **4mm Power arm** , **10 mm Miniscrew length** inserted at **60◦angulation** showed 0.994MPa stress in cortical bone and 0.183 MPa at Cancellous bone. Whereas for **4mm Power arm , 10mm Miniscrew length** inserted at **90◦ angulation** showed 1.535 MPa stress in Cortical bone and 0.282 MPa at Cancellous bone. It was observed that 60 ◦ showed less stress in comparison to 90◦ around TAD bone interface.

At anterior segment for **8mm Power arm** , **8mm Miniscrew length** inserted at **60◦angulation** showed 0.101 MPa stress at root and 0.009MPa at PDL. Whereas for**8mm Power arm , 8mm Miniscrew length** inserted at **90◦ angulation** showed 0.156 MPa stress at root and0.014 MPa at **PDL** .At posterior segment for **8mm Power arm** ,**8mm Miniscrew length** inserted at **60◦angulation** showed 0.994MPa stress in cortical bone and 0.183 MPa at Cancellous bone. Whereas for **8mm Power arm , 8 mm Miniscrew length** inserted at **90◦ angulation** showed 1.545 MPa in Cortical bone and and 0.284 MPa at Cancellous bone. It was observed that 60 ◦ showed less stress in comparison to 90◦ around TAD bone interface.

At anterior segment for **8mm Power arm**, **10mm Miniscrew length** inserted at **60◦angulation** showed 0.087 MPa stress at root and 0.008MPa stress at PDL. Whereas for**8mm Power arm , 10mm Miniscrew length** inserted at **90◦ angulation** showed 0.135 MPa stress at root and 0.130 MPa at PDL. At posterior segment for **8mm Power arm** , **10mm Miniscrew length** inserted at **60◦angulation** showed 0.876MPa stress in Cortical bone and 0.161 MPa at Cancellous bone. Whereas for**8mm Power arm , 10mm Miniscrew length** inserted at **90◦ angulation** showed 1.339 MPa stress at Cortical bone and 0.246 MPa at Cancellous bone **.** It was observed 60 ◦ showed less stress in comparison to 90◦ around TAD bone interface.

Dental protrusion characterised by dentoalveolar flaring of maxillary and mandibular anterior teeth is common in many ethnic groups around the world with resultant protrusion of the lips and convex profile. This protrusion is treated by extracting all the first premolars, followed by anterior tooth retraction to obtain the desired dental and soft-tissue profile changes[2]. Adequate anchorage control has made it possible to prevent undesirable tooth movement in all three planes of space. In recent years, miniscrews have gained immense popularity among orthodontic practitioners for space closure using sliding mechanics in maximum anchorage cases, where the forces on the reactive unit would generate adverse side effects. Advantages include ease of insertion and removal of the screws, immediate/early loading, low cost, and adequate anchorage support for orthodontic tooth movement[62]. Cortical anchorage, patient safety, and biomechanical regulation all depend on the correct angle of microimplant insertion. However, it is unclear how specific insertion angulations will actually affect stability. Furthermore, the pattern of stress-strain distribution on the periodontal ligament (PDL), alveolar bone, and teeth needs to be assessed[44].

En-masse retraction can be done by sliding mechanics (friction mechanics) or loop mechanics (frictionless mechanics). Forces for en-masse retraction are exerted from the powerarm placed anteriorly between lateral incisor and canine to miniscrew using Niti coil spring or E-chain. Variation in height of powerarm can alter the biomechanics of anterior teeth retraction in vertical plane as well as in sagittal plane depending on its distance from center of resistance of the anterior segment. Sliding mechanics is less technique sensitive and known as frictional mechanics of space closure . To reinforce anchorage in maximum anchorage requirement, TAD had been used. Stability of TAD by varying length, diameter , angulation had been evaluated in various studies . The effect of combination of variation in Powerarm height during sliding mechanics along with variation in miniscrew length, its angulation during sliding mechanics had not been evaluated in any of the previous study

The use of a rigid rectangular wire with a power arm placed near the center of resistance (Cres) of the anterior teeth enables one to achieve more predictable space closure. By varying the height of the power arm, it is possible to vary the line of action of the force bringing it closer to or away from the Cres[11]. A lot of factors contribute to the success of Orthodontic space closure like selection of the miniscrew length, its placement angulation and the height of powerarm, amount of force[63] etc. Steigman and Michaeli[64] and Young II Chang et al[65]., in their studies evaluated the force levels for retraction of anterior teeth which varied between 20 and 500 g. Stress levels developed in an object should not be greater than the yield strength of the object, as irreversible changes may occur. In another study , by Gracco et al[8]. when 200g of force was applied the stress levels developed were very close to the yield strength of soft bone. Brar et al[44]. in their study evaluated that at 75◦ force of 150g was ideal force. In other FEM studies by Zhang et al[14], Kojima et al[31] , Ashekar et al[34] , Chetan et al[2] , Abhishek et al[66] , Hedayati et al[10],. Doshi et al[11]., etc. a load of 150gms had been recommended . Hence, it was decided to use force of 150gm retraction force in the present study .

The reactionary stresses developed on various intraoral tissues in response to these loading forces were evaluated on animals, therefore the results may vary. In vivo measurement of these stresses is difficult, thus the development of an effective model for analyzing them is required. One such approach is the finite element method (FEM), which is used to examine structural stress . In FEM studies calculation of stress is done on the basis of the physical properties of structures being analyzed[44].

In the present study, the whole model was generated and analyzed for obtaining stresses produced .However some other studies by Jasmine et al[5] , Duaibis et al[25] and Marimthu et al[37] who have conducted the study on a bone block representing the section of the inter-radicular bone or a portion of the jaw instead of analyzing the whole model.

Considering this in the present study , the magnitude and pattern of stress distribution on alveolar bone of maxilla around miniscrew and anterior teeth during anterior en-masse retraction using power arm of different heights , miniscrews of different length, placed at various insertion angles was evaluated and compared.
For the present study, a FEM model of maxillary arch with extracted right and left first premolars was prepared on the basis of CBCT images with MIMICS software. A

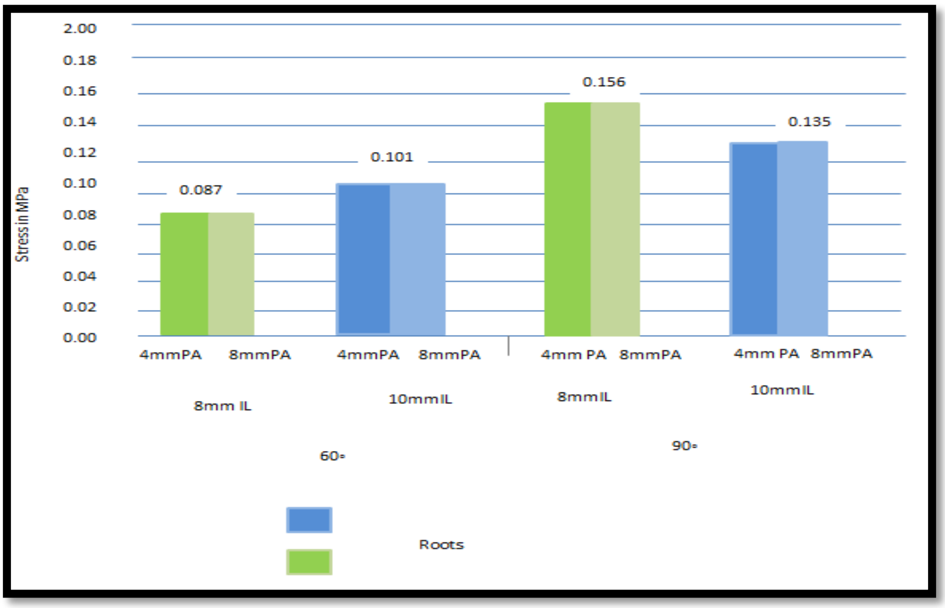
MBT appliance system with bracket slot of 0.022''x 0.028'' inch , 0.019 x 0.025'' rectangular SS wire with powerarm of 4mm and 8mm , titanium miniscrew of 8mm and 10mm length (diameter of 2mm) were scanned using laser scanner to make CAD model. This was used to make geometric model. GEOMAGIC modeling software that was used to make mesh models using ALTAIR HYPERMESH software It was developed by Altair Engineering Inc.(Troy , Michigan ,United States) for windows. A total of 8 FEM models were made with the different combination of miniscrew length (10mm and 8mm) and insertion angles (60^o and 90^o) and powerarm height (4mm and 8mm) . A force of 150gm were used for en-masse retraction of the anterior teeth with closed Niti coil spring was simulated using the FEM software.Von Mises Stress (MPa) generated on both the anterior segment (in the roots and PDL of anterior teeth) as well as the TAD bone interface at posterior segment were measured.

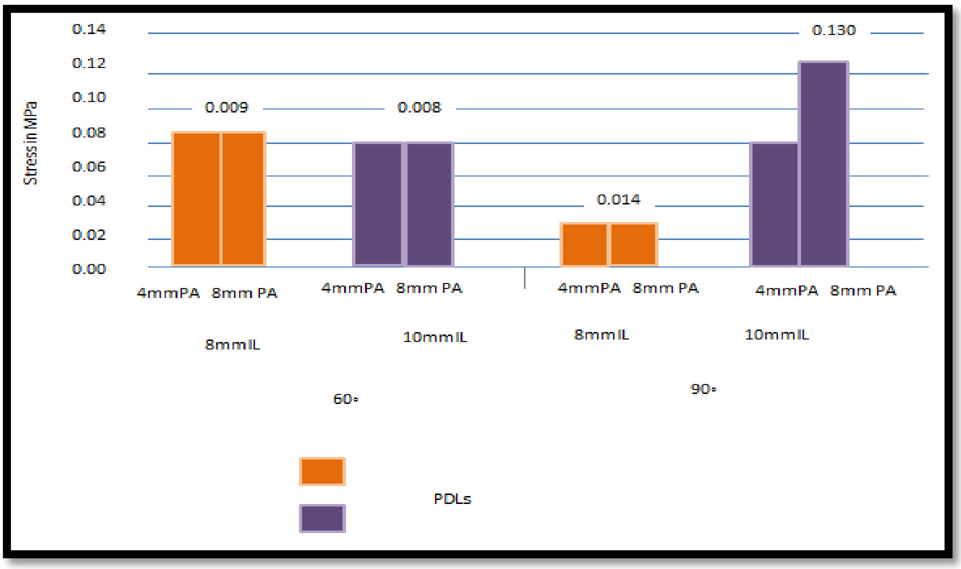
The results of the present study showed that magnitude of stress and pattern of stress distribution varied with different implant lengths, different implant insertion angles and length of power arm.

Magnitude and distribution of stress around TAD-bone interface and anterior segment at 60◦ and 90◦ angulation of miniscrew.

In the present FEM study, 60^o insertion angle of miniscrew showed less magnitude of stress as compared to 90^o with the various combinations of miniscrew and powerarm length around the structures of anterior segment and at TAD-bone interface. In the anterior segment ,at 60^o angulation stress generated around anterior teeth roots was i.e. (0.101 MPa) and at PDL was (0.009 MPa) for both (8mm MSL x 4mm PA) combination . For the above combinations at 90^o, stress of (0.156 MPa) was generated at anterior teeth roots and 0.014 MPa at PDL (8mm MSL x 4mm PA) and (8 mm MSL x 8mm PA) .

Combination of 10 mm MSL with 4mm and 8mm PA , 0.087 MPa of stress was developed at the roots and 0.008 MPa at PDL inserted at 60^o. At 90^o angulation, above combinations of produces , stress of 0.135 MPa at roots and 0.130 MPa at PDL . (**Table no: 6 , Figure :22A-25A , Bar Diagram: 2A**)

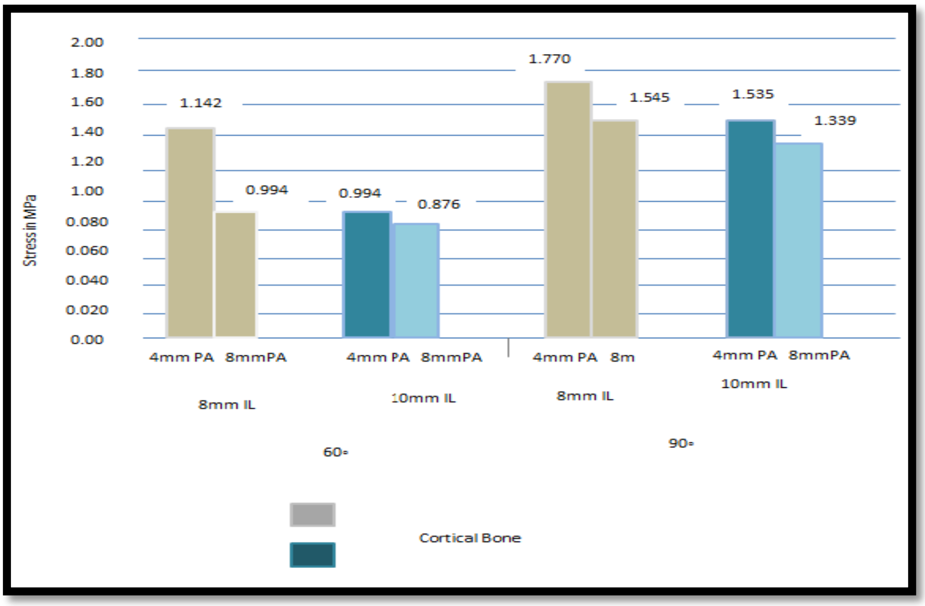


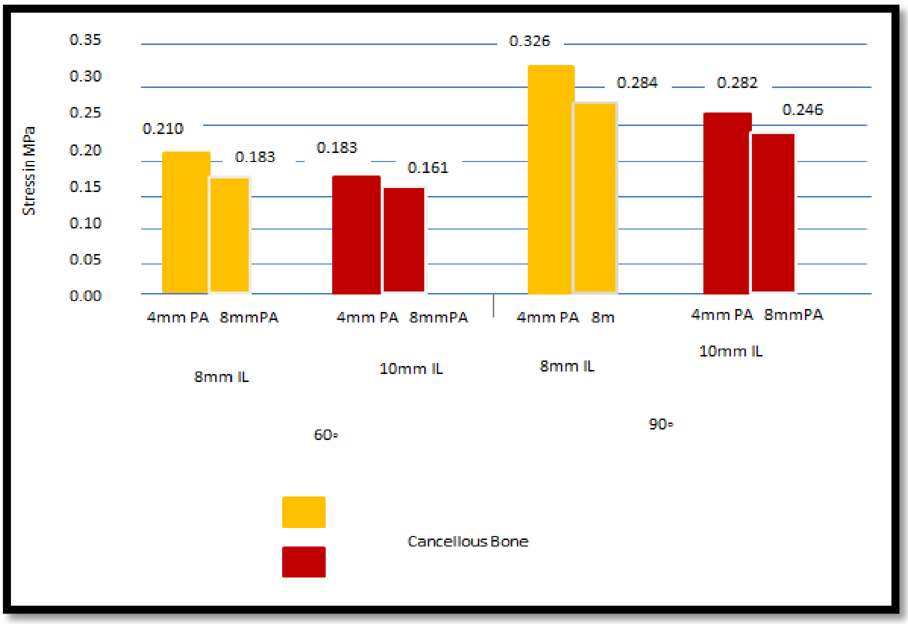


Bar Diagram 2A: Stress distribution at Roots and Pdl with 60◦ and 90◦insertion angle of Miniscrew

At TAD - bone interface, at 60^{o} angulation stress generated at Cortical bone was 1.142MPa at (8mm MSL x 4mm PA) , 0.994MPa at (8mm MSL x 8mm PA and 10mm MSL x 4mm PA) and 0.876 MPa at (10mmMSL x 8mm PA). At Cancellous bone the stress generated was , 0.210MPa at (8mm MSL x 4mm PA) , 0.183MPa at (8mm MSL x 8mm PA and 10mm MSL x 4mm PA) and 0.161 MPa at (10mmMSL x 8mm PA).

For 90^o angulation stress generated at Cortical bone was 1.770 MPa at (8mm MSL x 4mm PA) , 1.545 MPa at (8mm MSL x 8mm PA) ,1.535MPa at (10mm MSL x 4mm PA) and 1.339 MPa at (10mmMSL x 8mm PA). At Cancellous bone the stress generated was , 0.326 MPa at (8mm MSL x 4mm PA) , 0.284 MPa at (8mm MSL x 8mm PA) , 0.282 MPa at (10mm MSL x 4mm PA) and 0.246 MPa at (10mmMSL x 8mm PA). (**Table no : 6 , Figure : 22B -25B, Bar Diagram : 2B**)





Bar Diagram 2B: Stress distribution at Cancellous and Cortical bone with 60◦ and 90◦ insertion angle of Miniscrew .

In the present study it was seen that for a given load; the stress values were lower for 60^o angulations. This is in agreement with Benedict et al[13] and Brar et al[44], Paul et al[68] study on insertion angle of implant which concluded that 60^o-70^o is the ideal range for implant placement.

Brar et al[44] in his FEM study , assessed ideal force system (**150,** 200, 250, 300 g) for en-masse retraction using mini implants and determined the most favorable angle of placement(45^o, **60^o** and 75^o). The results are in accordance to the present study as their results showed that for a given load of 150g , stress was lowest at **60**◦ angulation as compared to the stress generated at other angulations of the study. The maximum and minimum stress generated at **60^o** (with 150g of force with implant of 1.5mm X 9 mm) , at cortical bone was 9.35MPa and 1.04 MPa ; for Cancellous bone was 0.68MPa and 0.076MPa; for the teeth was 3.18MPa and 0.353 MPa ; for PDL was 0.022MPa and 0.002 MPa . The stresses observed by them were more as compared to the present study. The variation may be due to the variation in the analysis.

They also stated that if stresses are greater than the yield strength of that object, then irreversible changes can take place. The yield strength taken by them for PDL was 6.89×10^{-5} (0.0689 MPa), tooth 20.7 GPa (20700 MPa), cortical bone 14.7 GPa(14700 MPa) and cancellous bone 1.5 GPa (15000MPa). Similarly in the present study, the yield strength of PDL was 0.05 MPa, teeth was 20,000MPa, Cortical bone was 13,700MPa and Cancellous bone was 1,600MPa. The maximum values of stress generated at PDL (0.009 MPa) , roots(0.101 MPa) , cortical bone (1.142 MPa) , cancellous bone(0.210 MPa) at 60^o MI angulation .The stress generated at PDL was (0.130 MPa), roots (0.156 MPa), cortical bone(1.770 MPa), cancellous bone(0.326 MPa) at 90^o MI angulation. Stress values for both the MI angulations in the present study were lesser as compared to the yield strength of the material so, no adverse effect would be seen with this combination of miniscrew length, angulations and force.

However stress distribution pattern was contrary to our study which showed that at **60°** angulations, the stresses were distal, mesial, and apical to miniscrew .The stresses uniformly decreased in the form of concentric rings as the implant was moved away and reached the upper and lower crest of the cortical bone. At 45° reached only lower crest at **60°** and did not reach upper or lower crest at 75^o. In the present study stress were distributed around the implant in the mesial, distal and apical direction in concentric rings at both at **60**◦ and **90**◦ both for the cortical bone and Cancellous bone . (**Table no:6, Figure no : 22B - 25B**).

The pattern of stress distribution on implant was in agreement with studies conducted by Ammar et al[67], Gracco et al[8], Crismani et al[68] and Wilmes et al[13] but with a difference that the implant was not placed with different angulations in their studies.

The result of the present study are also in agreement in a study by Benedict et al[13]., inserted at different angulations(30◦,40◦,50◦,**60**◦,70◦,80◦ and **90**◦) ; in 28 ilium bone segments evaluated stress generated with variable implant sizes (**1.6 X 8mm and 2.0 X 10mm**); using a precision potentiometer. It has angle sensor, a torque sensor, and a driver shaft. They concluded that **60**◦ **-** 70◦ is the ideal range for implant placement for the primary stability as they found highest insertion torque value (63.8^{o} for Dual –Top 1.6mm and 66.7^{o} for Dual –Top 2.0mm) for these angulations.

Results of the present study are also favoured by FEM study by Paul et al[69] , where evaluation of stress pattern was studied in the mini-implant(MI) and the infrazygomatic crest(IZC) at different angulations(50◦, **60**◦, 70◦, 80◦ and **90**◦) implant of (2mmX 12mm) with force of (8, 9, 10, 11 and 12 oz). They also found that von mises stress in the mini-implant and bone was maximum at 90^{o}, least stresses were observed at 50^{o} and 60^{o} angulations. As force magnitude increased, von Mises stress increased linearly.

Similarly , in another FEM study by Sivamurthy et al[40] where stress pattern produced in mini-implant and alveolar bone, for various implant dimensions (diameters 1 and 1.3 mm and **length** 6 and **8mm**) with insertion angles (30◦ and **60**◦) at 2 N applied in three direction which stimulates anterior retraction, and anterior intrusion and retraction, and molar intrusion was evaluated. When results of stress generation in 8mm MSL was compared to the results of our study , it was observed that similar to our findings the higher stress values were obtained with increasing the insertion angle from 30^{o} – 60^{o}. As they found that stresses increased on increased angulation from (30^{o} to 60^{o}) , it can be anticipated that stress will be more at 90^{o} which is in agreement to the results of the present study.

The results of the present study are contradicted by studies done by CK Ching et al[70], Genevive L.et al[35] , Omar et al[26] , Jasmine et al[5] where they found more stress generated at **60°** angulation as compared to **90°** angulation of miniscrew.

A FEM study by CK Ching et al[68] was done to evaluate maximum principal stress (Max PS) , minimum principal stress (Min PS) and Von mises stress (von MS) with variations of miniscrew insertion angulations(**90°,60°** and 45°) with different implant materials(titanium, composite and stainless steel) in a posterior segment model of maxillary arch with well, established borders and miniscrew (**8mm X 1.6mm**) with a force of **150 gm** was applied to the miniscrew. No power arm was specified in this study; a **150 grams** loading force to the mesial was then applied to the miniscrew to simulate distalization of anterior teeth. The von mises generated for the titanium material in this study at 45◦ on the bone miniscrew interface was **12.89 MPa at 60**◦ , 15.13 MPa and decreased to 9.43 MPa at 90◦. An angulation of **60°** was more favourable than either 45° or **90°** for all the three stress types generated relative to the stress on the miniscrew.

Genevive L. Machado et al[35], who evaluated the effects of miniscrew placement angle (**90**◦**, 60**◦, 45◦, 30◦) and structure in terms of varying length (6mm, **8mm, 10mm**, 12mm) and varying diameter (1.2mm, 1.3mm, 1.4mm, 1.5mm) at the bone miniscrew interface by FEM. The miniscrew was inserted in the buccal alveolar bone between the maxillary first molar and second premolar. They found that lesser stresses was generated at **90**◦ angulation (9.134 MPa) at the bone screw interface as compared to **60**◦ (14. 41 MPa) and this finding was contradictory to the findings of our study. They also concluded that at a constant miniscrew length and diameter with increasing placement angle, stress values in the bone decreased, while stress values in the miniscrew increased.

Omar et al[26] also in his FEM study simulated seven different angles of insertions: 30◦, 40◦, 50◦, **60**◦**,** 70◦, 80◦ and **90**◦; with 7mm MI length and **1.6mm** diameter and a force of **1.5N** was applied .The maximum Equivalent von Mises stress(EQV) recorded on the cortical bone were **76.25MPa**, and **71.70MPa** consecutively from angulations **60◦ and 90◦**. While the maximum EQV stress on the Cancellous bone were **32.66MPa** and **32.76 MPa** respectively for angulations **60◦ and 90◦**. The results were contradictory to findings of our study where stress at **90°** was more as compared to stresses as **60°** MI angulation .

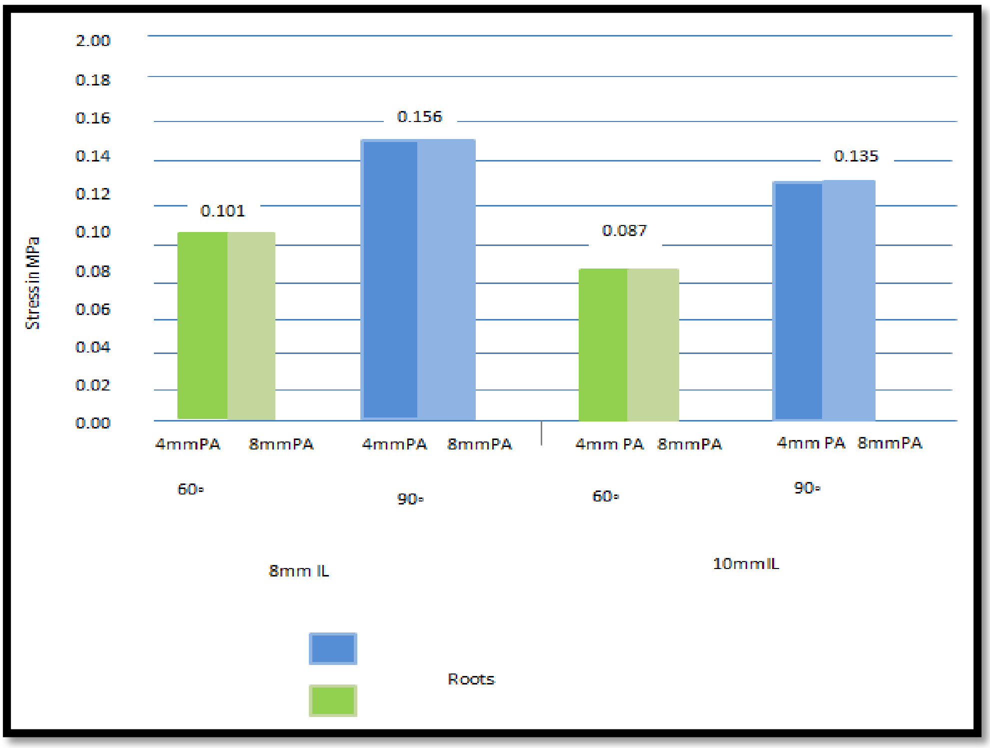
Jasmine et al[5] in order to analyse bone and microimplant stress during the en-masse retraction of maxillary and mandibular anterior teeth with various insertion angulations, performed a 3-dimensional finite element analysis research. With different insertion angulations (30°,45°, **60°** and **90°**); lengths (**8** and 7 mm) with diameter 1.3 mm with an orthodontic force of 200 g. The von mises generated at maxillary cortical bone at **60°** was more (32.59 MPa) as compared to **90°**(12.50 MPa); however in Cancellous bone stresses were less at 60°(0.30 MPa) than **90°**(0.47 MPa) . They came to the conclusion that placing an 8mm miniscrew in the maxilla at a **90°** angle in the bone increases the chance that the implant will stabilize. Their findings demonstrated that the stress was largely absorbed by the cortical bone and barely transferred to the cancellous bone. However, the results are not in accordance to our study as we did not found much difference in Cortical and Cancellous bone stress.

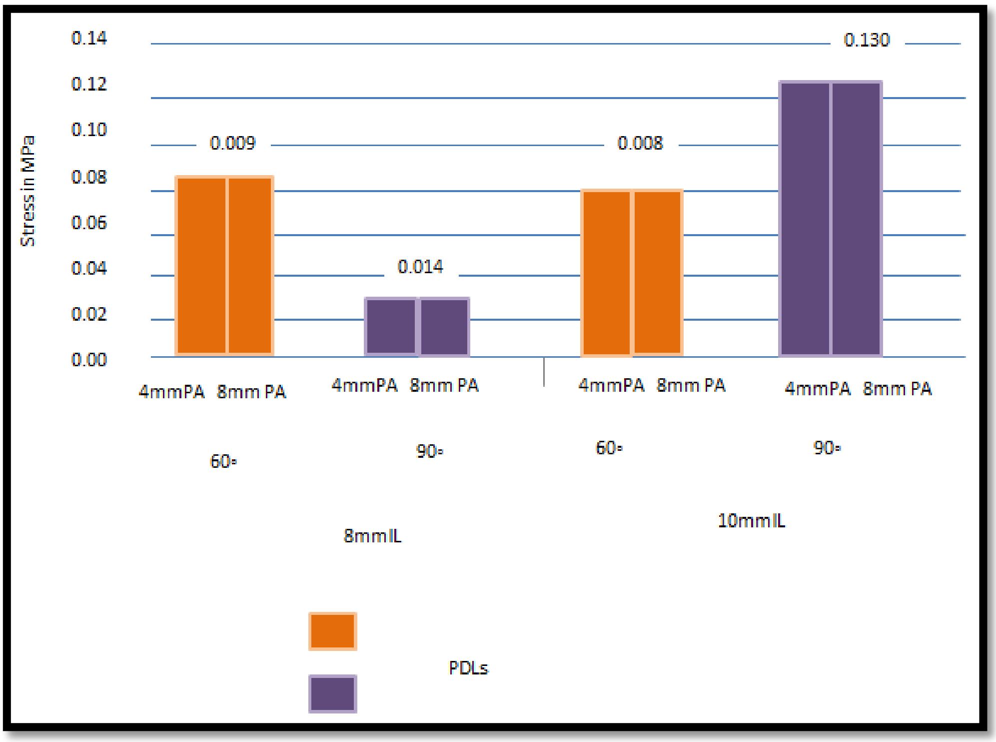
Magnitude and distribution of stress around TAD-bone interface and anterior segment for 8mm and 10mm miniscrew length.

In the present FEM study, **10 mm MSL** showed less magnitude of stress around the structures of anterior segment and at TAD-bone interface as compared to **8mm MSL** with the various combinations of angulations and powerarm height. In the anterior segment , with **8mm MSL** stress generated was 0.101 MPa at roots and 0.009 MPa at PDL for 60° x 4mm PA and 60° x 8mm PA combination . Stress generated with 90° x 4mm PA and 90° x 8mm PA combination was 0.156 MPa at roots and 0.014 MPa at PDL.

With **10 mm MSL**, stress generated was 0.087 MPa at roots and 0.008MPa at PDL for both 60° x 4mm PA and 60°x 8mm PA combination. Stress generated with 90° x

4mm PA and 90° x 8mm PA combination was 0.135 MPa at roots and 0.130 MPa at PDL. (**Table no: 7 , Figure : 22A -25A , Bar Diagram : 3A**).

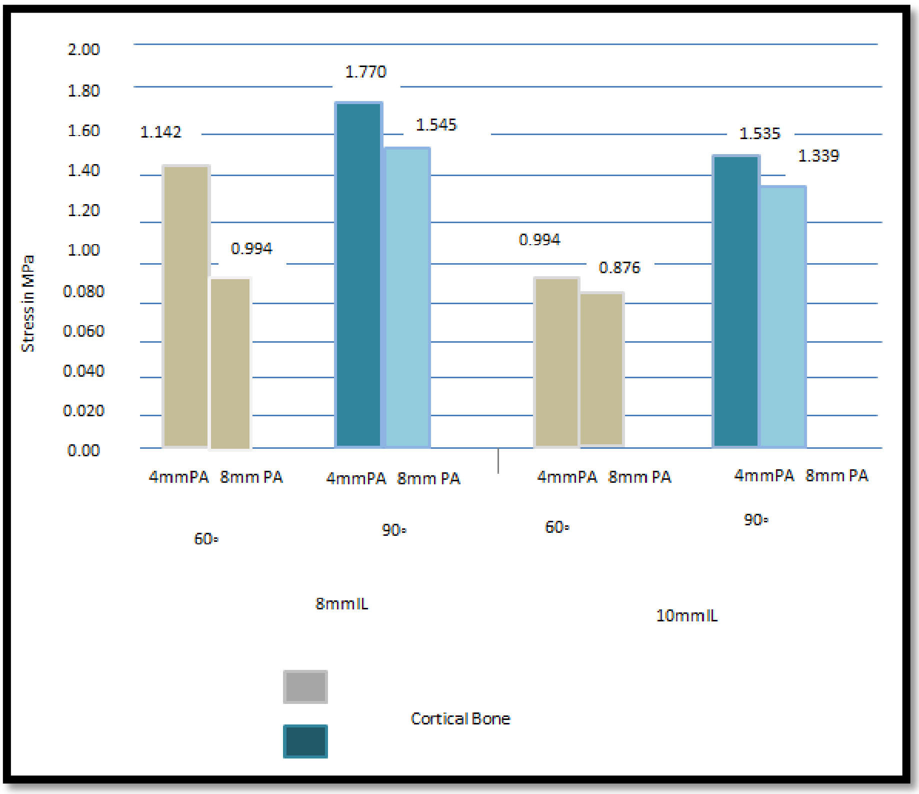


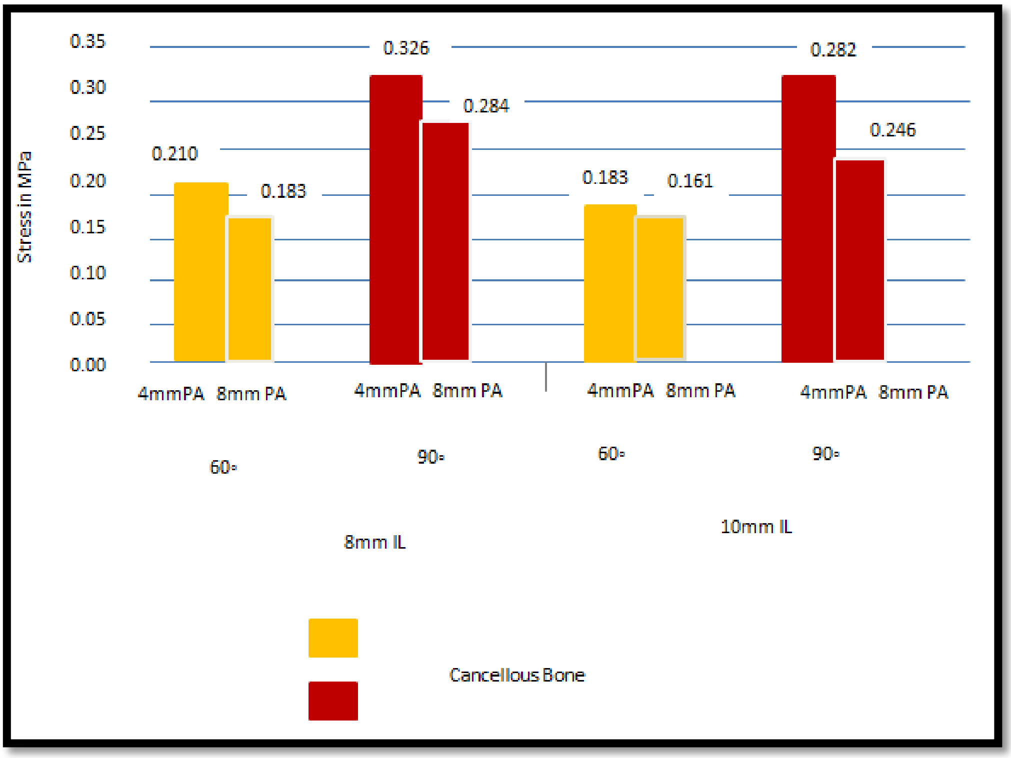


Bar Diagram 3A: Stress distribution at Roots and PDl with 8mm and 10mm miniscrew

At TAD - bone interface with **8mm MSL** stress generated at Cortical bone was 1.142MPa for (60° angulation x 4mm PA), 0.994 MPa at (60° angulation x 8mm PA) ; 1.770 MPa at (90° angulation x 4mm PA) and 1.545 MPa at (90° angulation x 8mm PA). Whereas at Cancellous bone, the stress generated was , 0.210MPa at (60° angulation x 4mm PA) , 0.183 MPa at (60° angulation x 8mm PA) ; 0.326 MPa at (90° angulation x 4mm PA) , 0.284 MPa at (90° angulation x 8mm PA) .

With **10mm MSL** stress generated at Cortical bone was 0.994 MPa for (60° angulation x 4mm PA), 0.876 MPa at (60° angulation x 8mm PA) ; 1.535 MPa at (90° angulation x 4mm PA) and 1.339 MPa at (90° angulation x 8mm PA). At Cancellous bone, the stress generated was, 0.183 MPa at (60° angulation x 4mm PA) , 0.161 MPa at (60° angulation x 8mm PA) ; 0.282 MPa at (90° angulation x 4mm PA) , 0.246 MPa at (90° angulation x 8mm PA) . (**Table no: 7, Figure : 22B-25B, Bar Diagram:3B**)





Bar Diagram 3B: Stress distribution at Cortical and Cancellous bone with 8mm and 10mm miniscrew.

In the present study, length of MI was inversely related with the amount of stress generated around structures. As the length of the MI was increased the mean stress was reduced thereby having reduced chances of side effects to the neighboring living tissues. In accordance to this Xi Ding et al[15] also concluded that increasing the diameter and length of the implant decreased the stress and strain on the alveolar crest, but the diameter had a more significant effect than the length. Whereas Munish C Reddy[52] , Genevive L. Machado[35] , Ying Juan Lu et al[38] and Crismani et al[68] , Duaibis et al[25] found no difference in stress generated with varying miniscrew length. However, advantage of using a long MI with in the clinical limits, is its ability to distribute the forces applied over a greater area of bone with less production of bone stresses.

Xi Ding et al[15] has done a mechanical analysis using the finite element(FE). This study was done to evaluate the effect of the diameter(ranged from 3.3 to 4.8mm) and length ranged from (6 to 14mm) on the stress and strain distribution of the crestal bone around implants under immediate loading of force 150 N . The study concluded that increasing the diameter and length of the implant decreased the stress and strain on the alveolar crest, but diameter had a more significant effect than length to relieve the crestal stress and strain concentration. Another mechanical analysis by Lum LB[71] also supported the view that increasing implant length may only increase the success rate to a certain extent.

Munish C Reddy et al[52] conducted an FEM study to evaluate stress distribution in bone with MI having varying lengths(6mm,7mm,**8mm**,9mm) and varying diameters (1.2 mm, 1.4 mm, 1.6 mm, 1.8 mm) inserted at an angulation of **90^{o}** with a force of 200g . The results of their study showed that rather than the length, diameter affected the stress generation. The stresses generated was 4.33 MPa ,4.34 MPa, **4.24 MPa** and 4.28 MPa for miniscrew lengths of 6mm,7mm,**8mm** and 9mm respectively. They found 4.24 MPa of stress with **8mm MI** and 1.8mm diameter with 5.5mm powerarm . But in the present study with **8mm MI** with 2mm diameter at **90^{o}** with 4mm PA showed stress of 1.770 MPa at cortical bone and 0.326 MPa at cancellous bone. At **90^{o}** with 8mm PA showed stress of 1.545 MPa and 0.284 MPa at Cancellous bone. Results of the stress value was more as compared to the present study, this may be due to the difference in the analysis. The study concluded that the maximum von Mises stress generated do not have any correlation with the various lengths of TAD's. Rather, with decreasing implant diameter the stress generated was lesser, stress was found higher for implant of diameter 1.2 mm and least for implant of diameter 1.8 mm .

Genevive L. Machado[35], who conducted FEM study to assess the effects of orthodontic miniscrew placement angle and structure on the stress distribution at the bone miniscrew interface. Varying angulations of miniscrew placement(**90**◦, **60**◦,45◦,30◦), varying length (6mm, **8mm, 10mm**, 12mm) and varying diameter(1.2mm, 1.3mm,1.4mm,1.5mm) with a retraction force of **200g** was considered for the study. The stress generated for the varying length 6mm, **8mm, 10mm**, 12 mm was a constant stress value of 20.41 and 20.44 MPa in the bone and miniscrew respectively . However, in the present study the stress generated for various combinations of length and angulations were different to each other.

Ying Juan Lu et al[38] who compared the stress on the bone surrounding a micro-implant after application of a single force (SF) of 200 g or a composite force (CF) of

200 g and 6 N.mm torque with micro-implant diameters of (1.2, 1.6, and **2.0 mm**)and lengths of (6, **8, 10** and 12 mm) . They also concluded that the effect of force on stress was related to implant diameter, but not to implant length.

Crismani et al[68]., also concluded that changing the length of the TAD did not have a considerable effect on the maximum von Mises stress generated in bone at TAD site . Eckert et al and Douglass et al in their studies indicated that the use of longer implant did not necessarily receive the stress concentration in the bone around implant.

Studies by Motoyoshi et al[72], Upadhaya et al.[73] suggested that 8mm length implant are preferable , because they are stable and minimize the risk of root damage. Baek et al[74] suggested use of longer mini-implants in areas of thicker cortical bone, for increased primary stability. Seon et al[75] also concluded that stability of mini-implant is more dependent on the length.

A FEM study by Lin et al[33], where factorial analysis was done to determine the biomechanical effects of exposure length of the mini-implant, the insertion angle, and the direction of orthodontic force. It suggested that cortical bone stress increases in association with increase in exposure length.

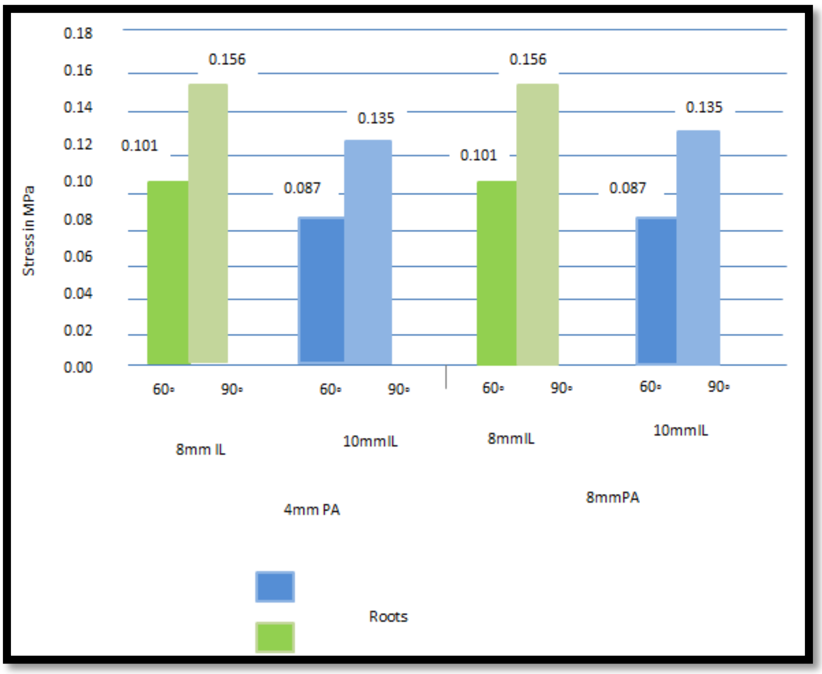
Varied results of the present study as well as previous studies regarding the effect of length of MI on the stress generated suggest that length of MI to be used should be determined by depth and quality of the bone, miniscrew insertion angulation, transmucosal thickness and adjacent vital structures.

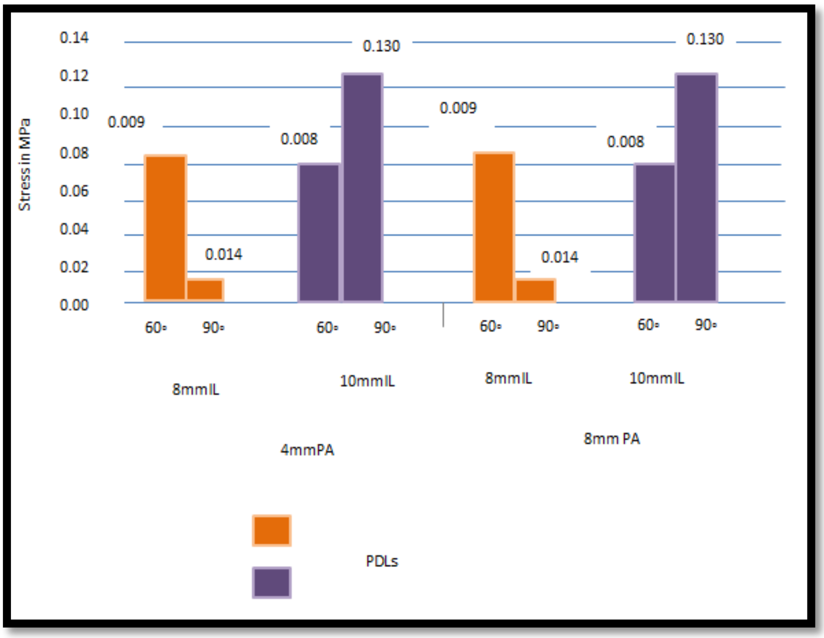
Magnitude and distribution of stress around TAD-bone interface and anterior segment at 4mm and 8mm height of powerarm.

In the present FEM study, 8 mm PA showed less magnitude of stress as compared to 4 mm PA with the various combinations of miniscrew length and placement angulations around the structures of anterior segment and at TAD-bone interface. In the anterior segment ,at 4mm PA the amount of stress was generated around anterior teeth roots and PDL was 0.101 MPa and 0.009 MPa at (8mm MSL x 60^{o}

angulation) and 0.156 MPa and 0.014 MPa at (8 mm MSL x 90^0angulation) . At 4mm PA , the amount of stress generated at roots and PDL was 0.087 MPa and 0.008 MPa (10 mm MSL x 60^o angulation) and 0.135 MPa and 0.130 MPa at (10 mm MSL x 90^0angulation) was generated. (**Table no : 8, Figure : 22A-25A,Bar Diagram: 4A**).

Same amount of stresses were observed with 8mm PA and different combinations of MSL and angulation.

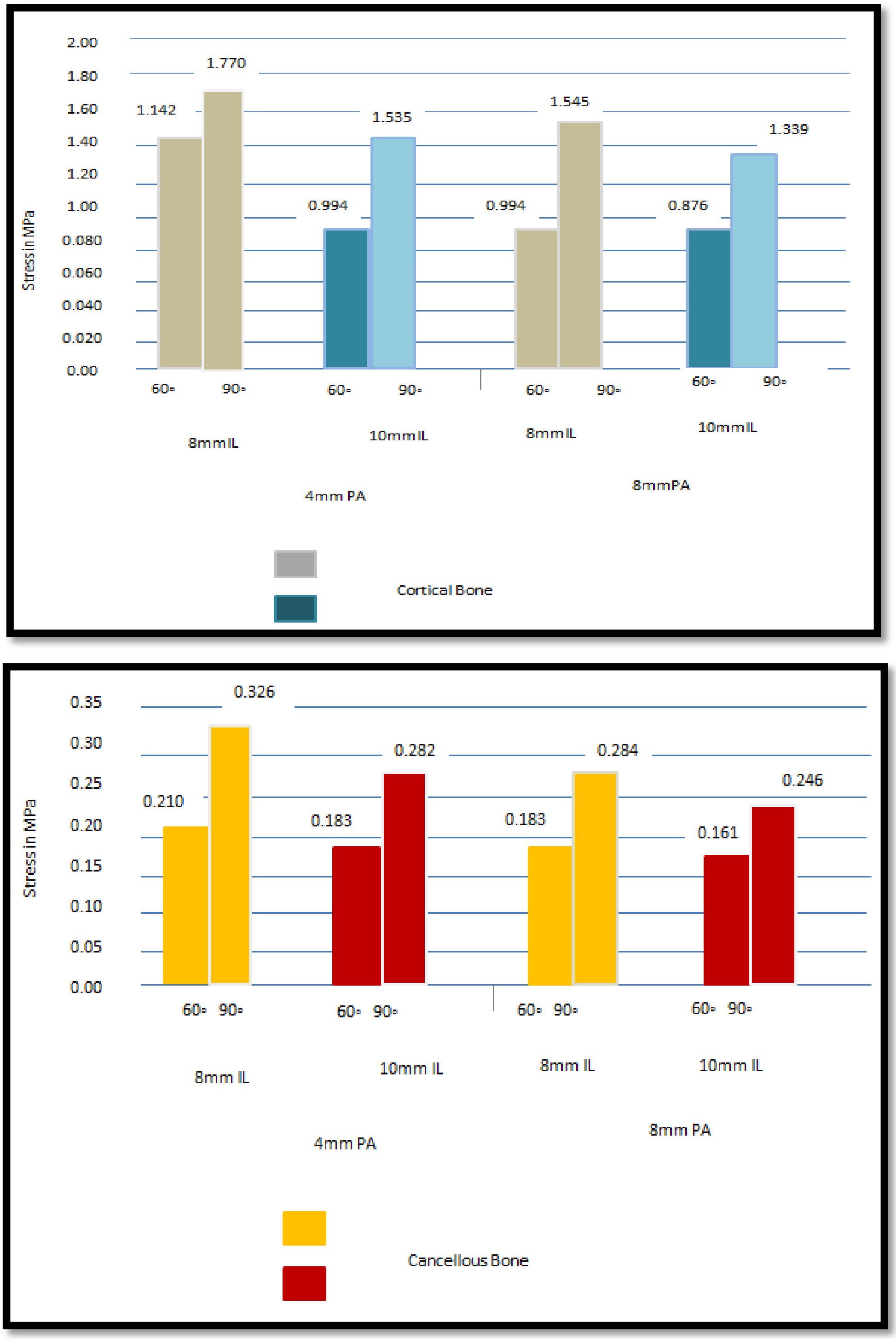




Bar Diagram 4A: Stress distribution at Roots and Pdl with 4mm and 8mm Powerarm length.

At TAD - bone interface, at 4mm PA stress generated at Cortical bone was 1.142MPa at (8mm MSL x 60^o angulation) , 1.770 MPa at (8mm MSL x90^0angulation) ; 0.994 MPa at (10mm MSL x60^o angulation) and 1.535 MPa at (10mmMSL x 90^0angulation). At Cancellous bone, the stress generated was , 0.210MPa at (8mm MSL x60^o angulation) , 0.326 MPa at (8mm MSL x 90^0angulation) ; 0.183 MPa at (10mm MSL x60^o angulation) and 0.282 MPa at (10mmMSL x 90^0angulation).

However with 8mm PA stress generated at Cortical bone was 0.994 MPa at (8mm MSL x60^o angulation), 1.545 MPa at (8mm MSL x 90^0angulation) ; 0. 876 MPa at (10mm MSL x 60^o angulation) and 1.339 MPa at (10mmMSL x 90^0angulation). At Cancellous bone the stress generated was , 0.183 MPa at (8mm MSL x 60^o angulation) , 0.284 MPa at (8mm MSL x 90^0angulation) ; 0.161 MPa at (10mm MSL x 60^o angulation) and 0.246 MPa at (10mmMSL x 90^0angulation). (**Table no : 8, Figure no: 22B-25B, Bar Diagram: 4B**).



Bar Diagram 4B: Stress distribution at Cortical bone and Cancellous bone with 4mm and 8mm Powerarm length.

Studies by Hedayati et al[10] , Kojima et al[31] , Doshi et al[11] evaluated the efficiency of varying positions and height of PA as related to type of tooth movement. None of the studies have evaluated effect of the height of powerarm on the stress on bone or implant quantitatively. Hence , direct quantitative comparisons are not possible.

Hedayati et al[10]., in this FEM study determined the type of anterior tooth movement when force of 150gr/side was applied from different miniscrews placed 6mm above the arch wire in two different positions and using anterior power arm of various heights (0mm, 3mm,6mm,and 9 mm). The use of power arms enables the orthodontist to achieve controlled movement of the anterior teeth . Force applied from the mini screw can displace and rotate the anterior teeth during retraction in the sagittal and vertical planes. Changing the height of the anterior hook (power arm) alters the whole biomechanics paradigm and greatly affect the pattern of teeth movement. They observed that with increasing the length of the anterior power arm decreased the uncontrolled tipping of the anterior dentition, and with 9 mm of the power arm, bodily movement occurred.

Kojima et al[31]. carried out a FEM study to clarify the relationship between force directions and movement patterns. The power arm length and the miniscrew position low position at 4mm or in a high position of 8mm gingivally to the archwire ; positions were varied to change the force directions, a force of 1.5N was considered in this study. To change the force direction, the length of the power arms was varied from 1, **4**, and **8 mm**. They found in that in cases of the low position miniscrew
(4 mm), when lengthening the power arm from **1 mm to 4 mm,** rotation of the entire dentition decreased with decrease in distance of line of force to Cres of anteriors. With high position miniscrew irrespective of the position of **8mm** Powerarm , the anterior teeth moved bodily.

Doshi et al[11] concluded that increase in power arm height causes a decrease in the tipping tendency and increased bodily movement during en masse retraction of anterior teeth using mini‑implant anchorage.
Other studies like Ashekar et al[34], Sung et al[20], Ruchira et al[76] , Aditi ghadge et al[48] also concluded that increasing the length of Powerarm reduces the tipping of tooth and provide more bodily tooth movement.

A FEM study by Parag Bohara et al[46] where they evaluated the stress distribution and displacement of maxillary anterior teeth using different combinations of mini-implants (1.3mm x 7mm) and retraction hook (6mm and 2mm) using different amount of retraction force (150g, 60g, 50g) .The stresses generated in this study was hard bone is (22.29, 20.872, 10.012 and 12.27 MPa) for model 1,2,3 and 4 respectively. Soft bone (1.58, 1.546, 0.857, 1.135 MPa) for model 1,2,3 and 4 respectively. PDL(0.004 , 0.004, 0.006 and 0.006 MPa) for model 1,2,3 and 4 respectively. This study concluded that the length of power arm could be considered the main influencing factor in determining the degree and couse of movement on sliding mechanics. The teeth showed bodily movement and controlled lingual crown tipping at 6 mm retraction hook and at 2 mm more amount of lingual crown tipping can be observed.

In contrast to the results of the present study and above studies a study by Sreenivasagan et al[58] who evaluated initial displacement of maxillary anterior teeth during distalization. 2 FE models were created for total distalization of the maxillary dentition along with en-masse retraction of the six anterior teeth. Mini- implants were placed at interradicular (IRMIs) and infrazygomatic (IZCMI) with varying power arm of heights 5 mm , **8 mm** and 12mm , distalization force of 3N and en-masse force of 2N. They stated height of power arm showed no significance in their study.

The construction of a human model that is both realistic and of sufficient detail to clinically valuable is one of the primary interest in FEM. Comparing the results of among the various studies to other orthodontic studies using FEA is challenging due to several differences between models[77].

The length of power arm could be considered the main influencing factor in determining the degree and course of movement of anterior teeth during sliding mechanics retraction. Thus, the retraction hook height could be the most easily modifiable clinical factor in determining and achieving the most desirable direction of anterior teeth displacement during intrusion and retraction of anterior teeth. The clinical application of these findings relates to the chair-side simple estimation of the location of the center of resistance and height of retraction force on power arm in relation to pre-programmed tooth movement.

PATTERN OF STRESS DISTRIBUTION AROUND TAD-BONE INTERFACE AND ANTERIOR SEGMENT WITH VARIOUS COMBINATIONS

A colour scale with 9 stress values served to evaluate the stress distribution quantitatively in the anterior segment i.e. roots and PDL and the TAD-bone interface i.e. cortical and cancellous bones. The stress scale runs from blue to red, where blue shows the lowest von mises stress and red shows the highest von mises stress.

From (**Figure :22A-25A,22B-25B**) , where direction of force simulated anterior segment retraction, it is evident that the distribution of stress was concentrated in the mesial aspect of cervical region of all combinations and the cortical bone was subject to higher stresses as compared to the cancellous bone.

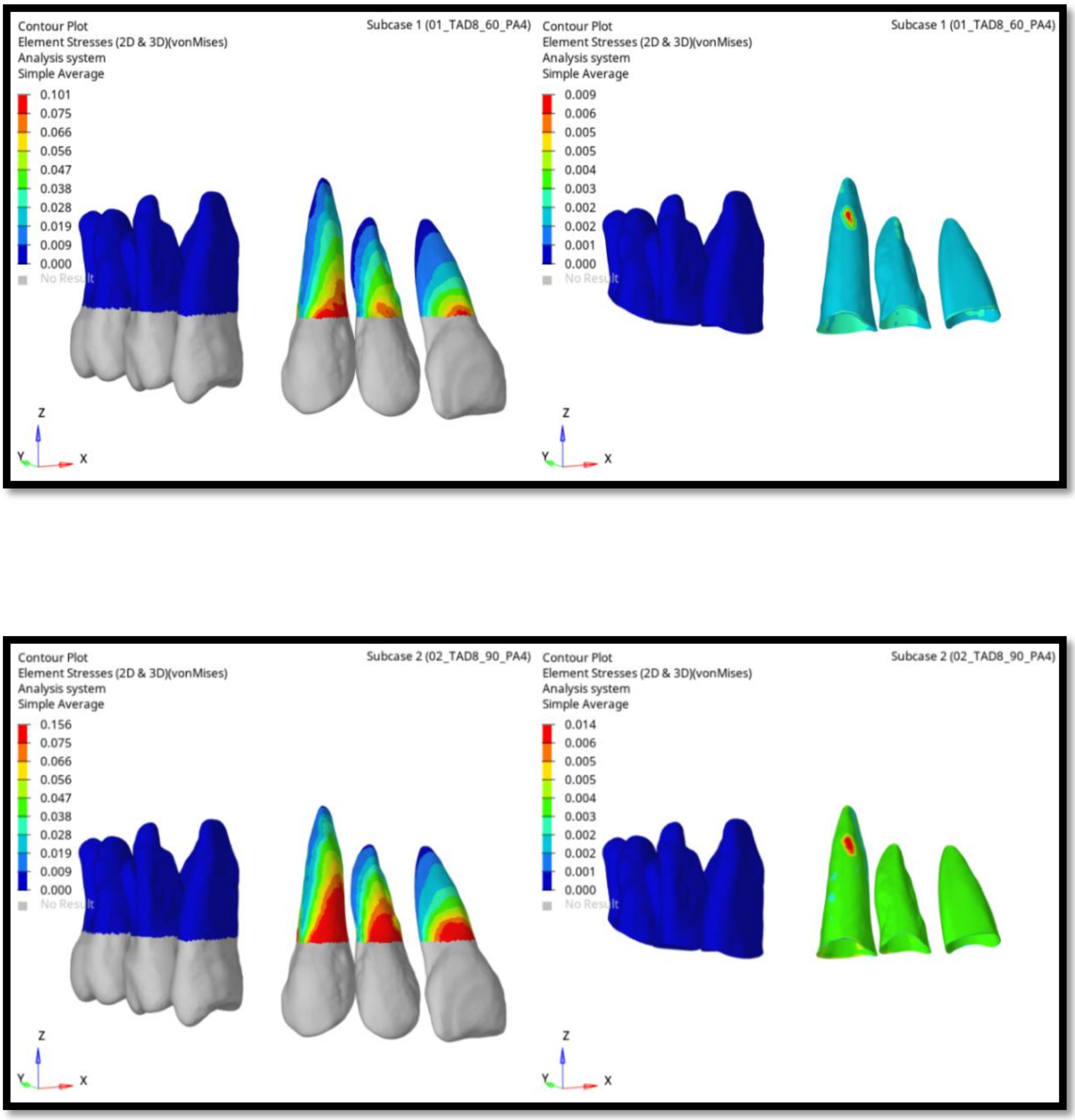


Figure 22 A: Stress distribution on root and PDL for combination (8mm MSL X 4mm PA) miniscrew placed at 60◦(above) and 90◦ angulation (below).

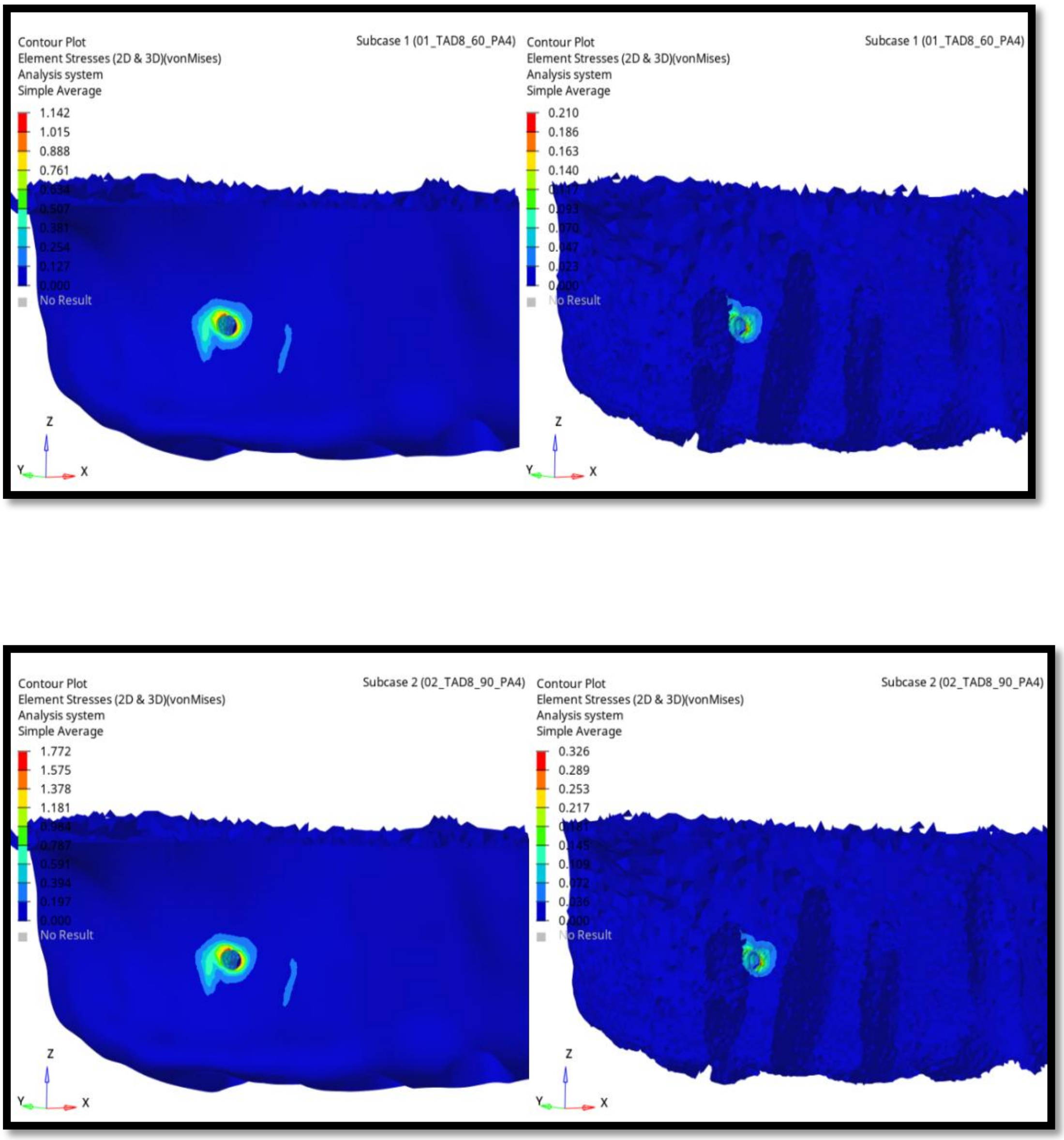


Figure 22 B: Stress distribution on Cortical (right side) and Cancellous bone (left side) for combination (8mm MSL X 4mm PA) miniscrew placed at 60◦(above) and 90◦ angulation (below).

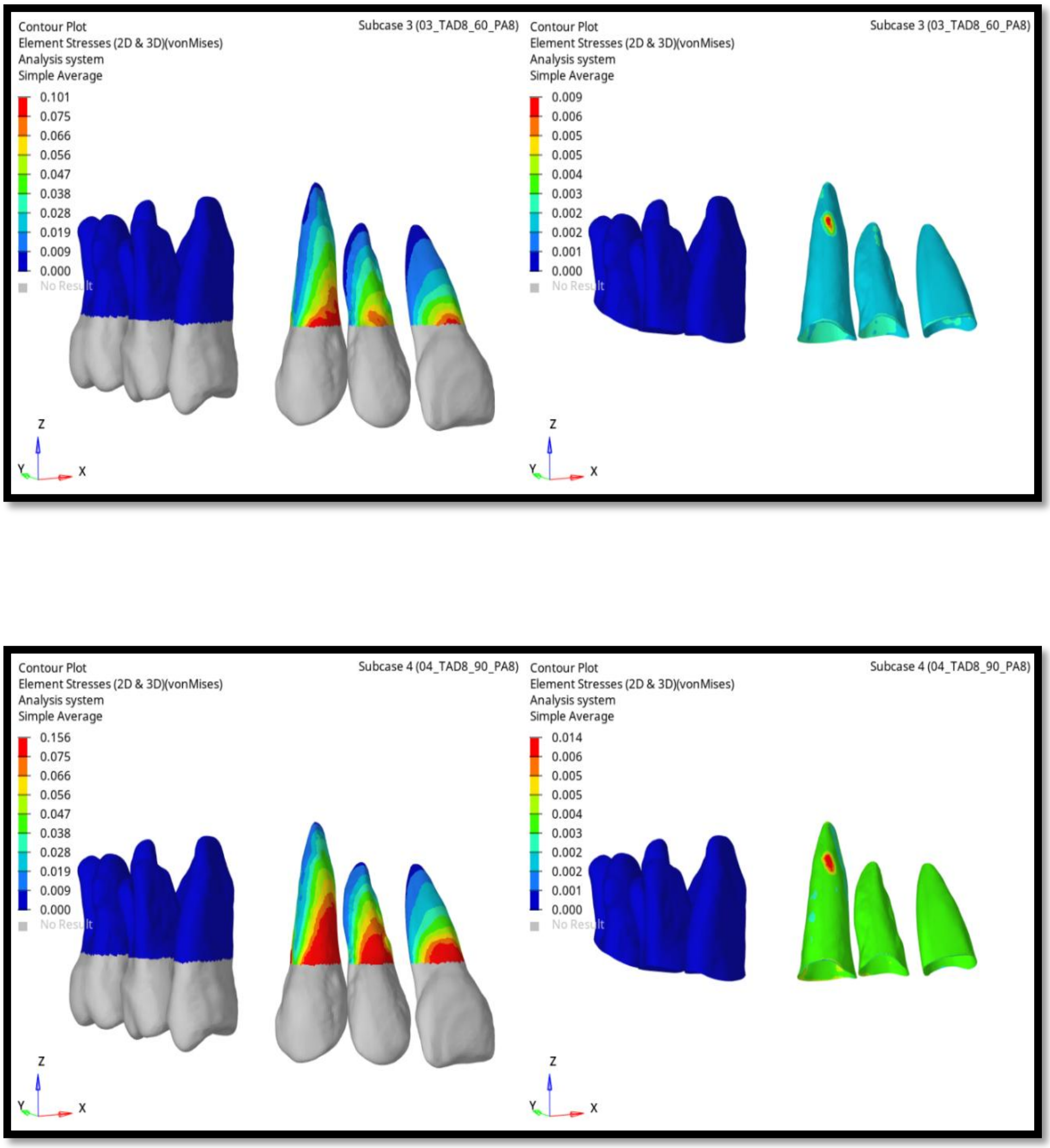


Figure 23 A: Stress distribution on root and PDL for combination (8mm MSL X 8mm PA) miniscrew placed at 60◦(above) and 90◦ angulation (below).

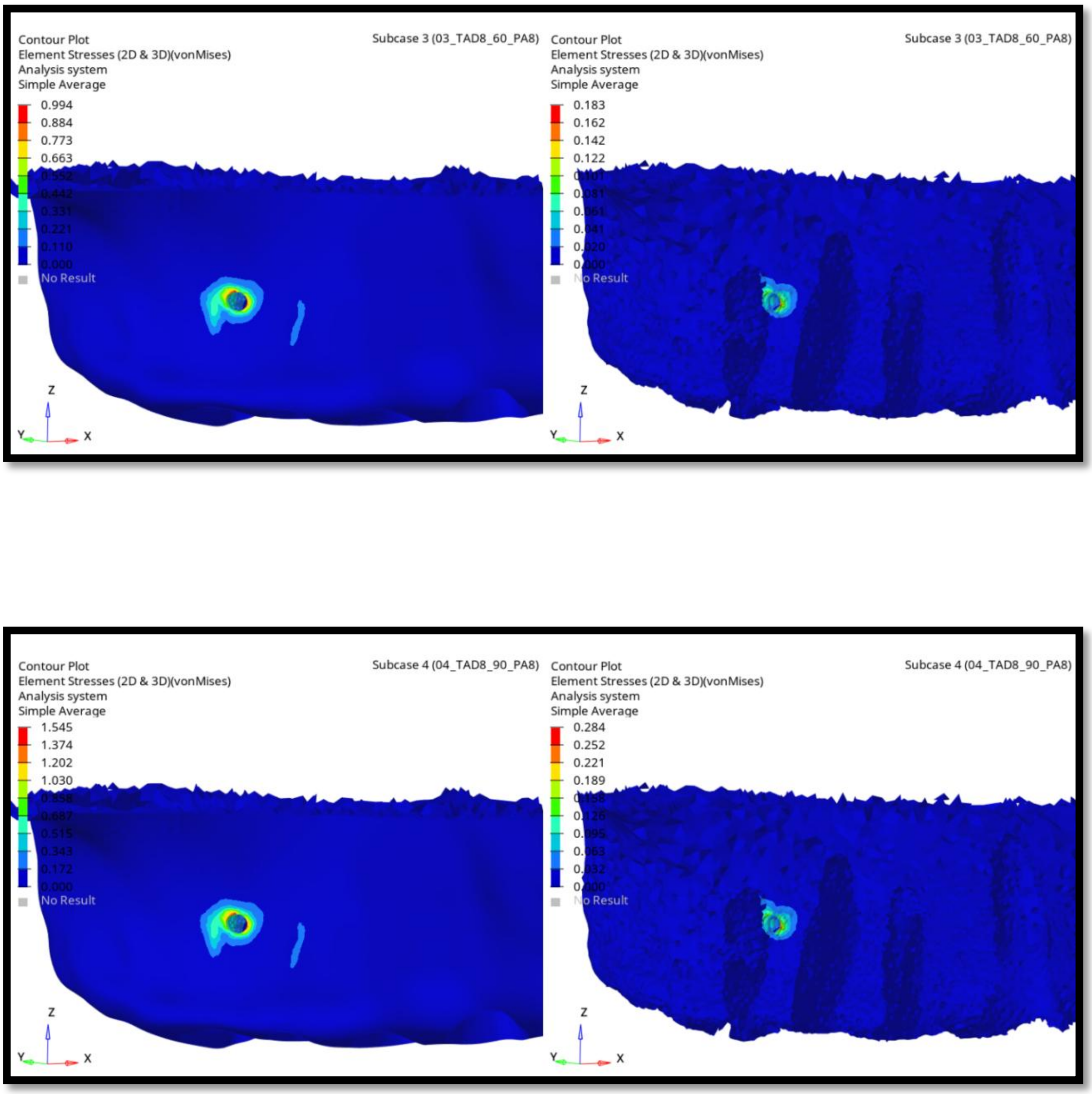


Figure 23B: Stress distribution on Cortical (right side) and Cancellous bone (left side) for combination (8mm MSL X 8mm PA) miniscrew placed at 60◦(above) and 90◦ angulation (below).

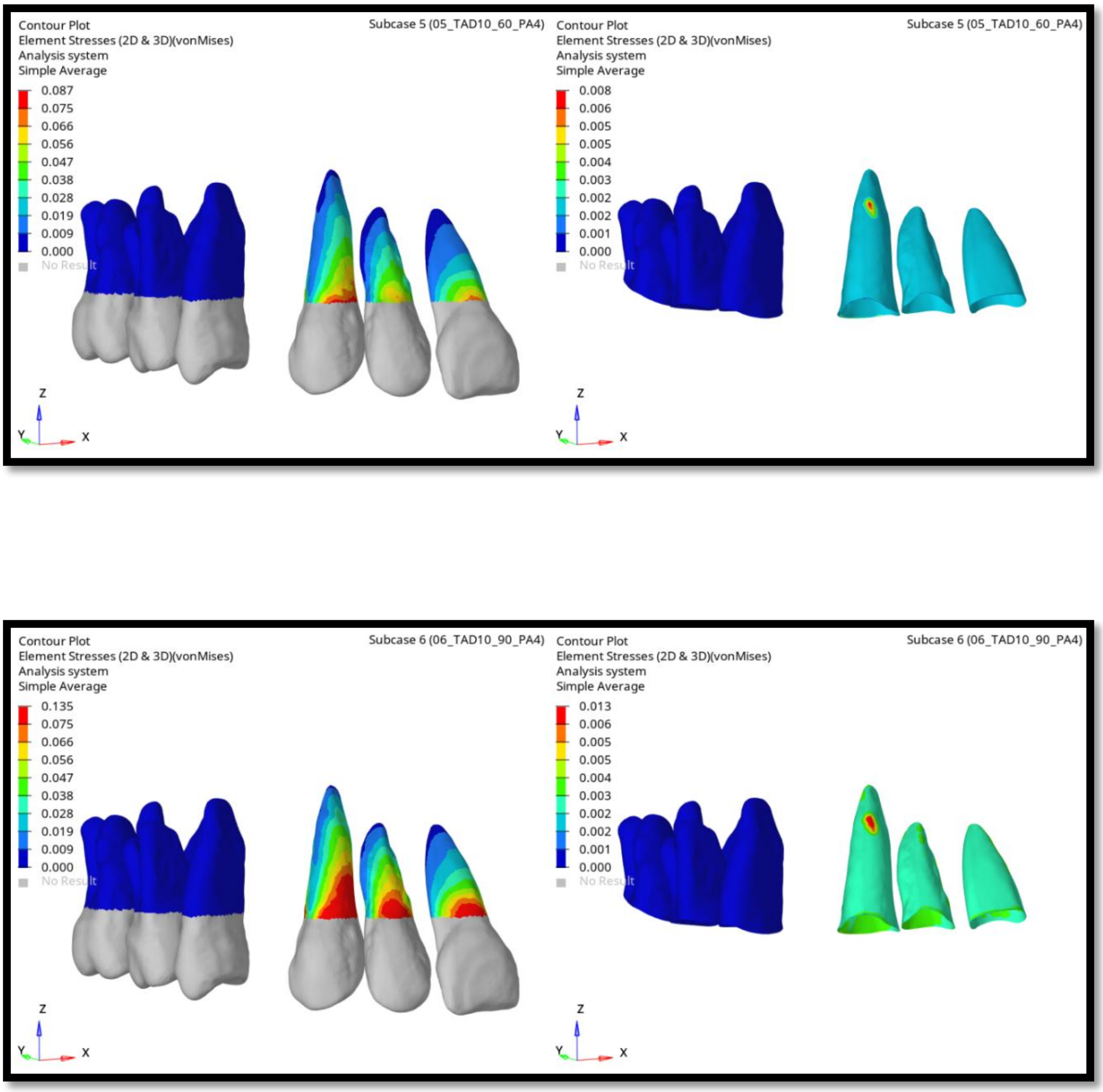


Figure 24A: Stress distribution on root and PDL for combination (10mm MSL X 4mm PA) miniscrew placed at 60◦(above) and 90◦ angulation (below).

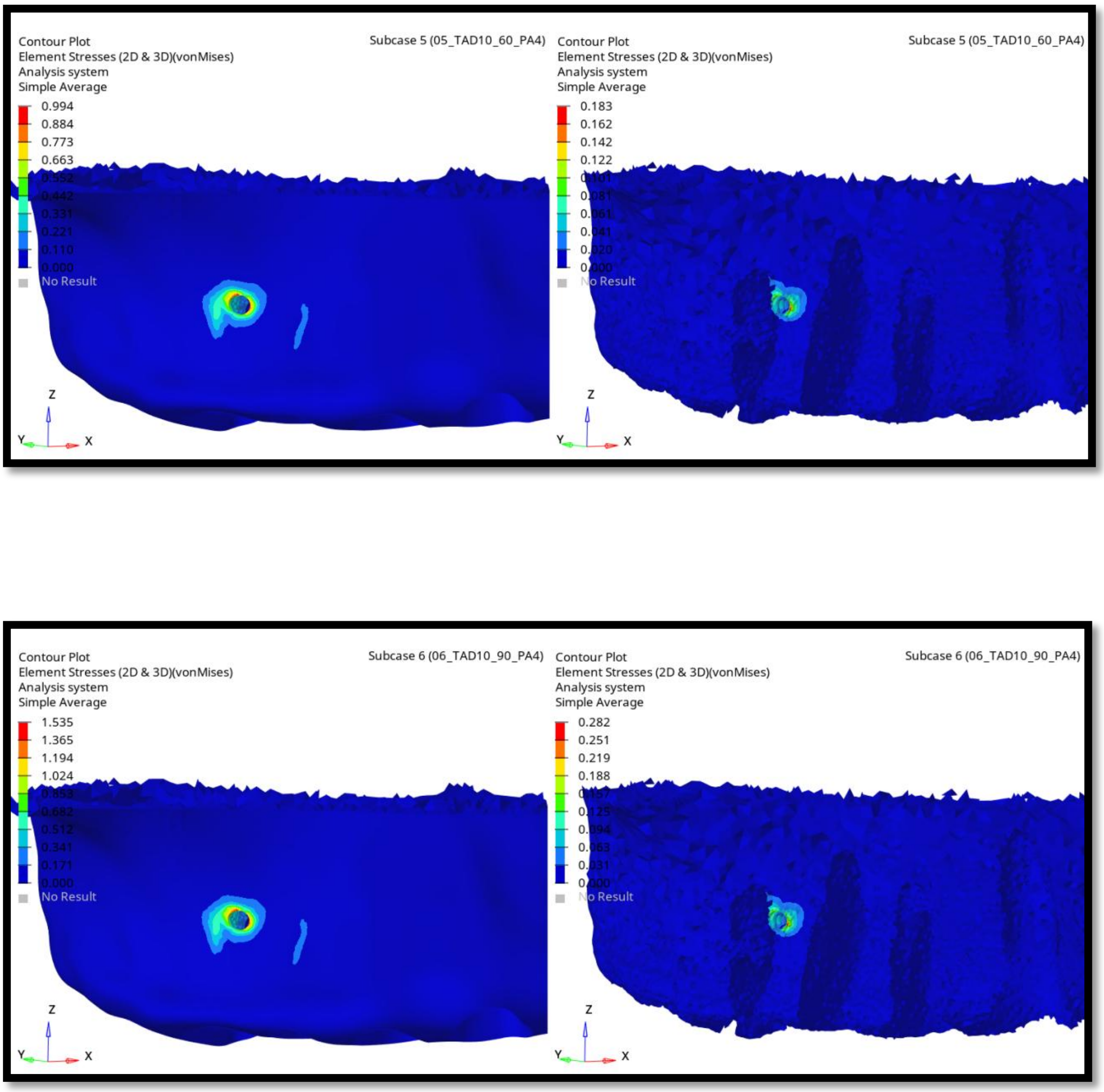


Figure 24 B: Stress distribution on Cortical (right side) and Cancellous bone (left side) for combination (10mm MSL X 4mm PA) miniscrew placed at 60◦(above) and 90◦ angulation (below).

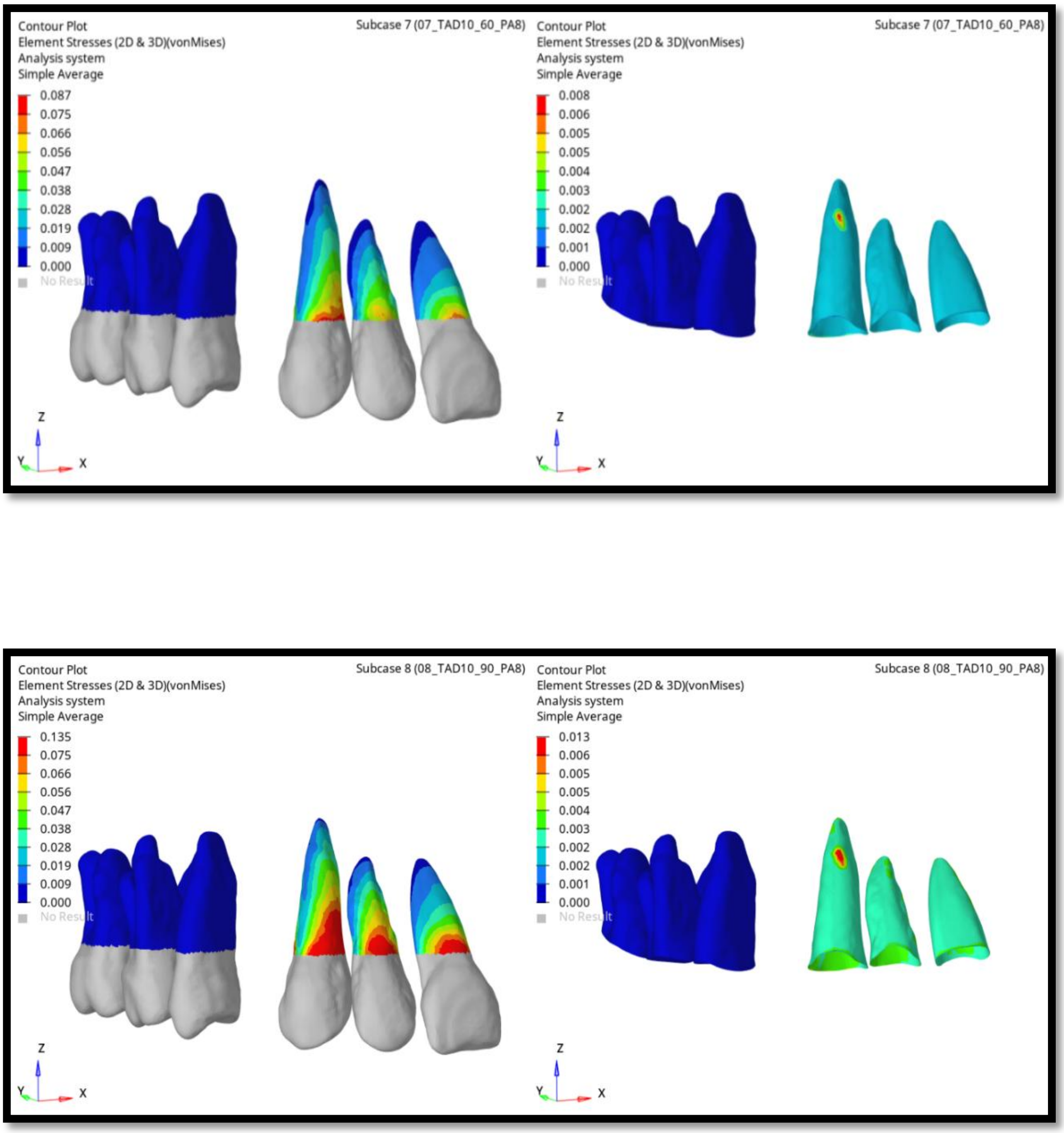


Figure 25 A: Stress distribution on root and PDL for combination (10mm MSL X 8mm PA) miniscrew placed at 60◦(above) and 90◦ angulation (below).

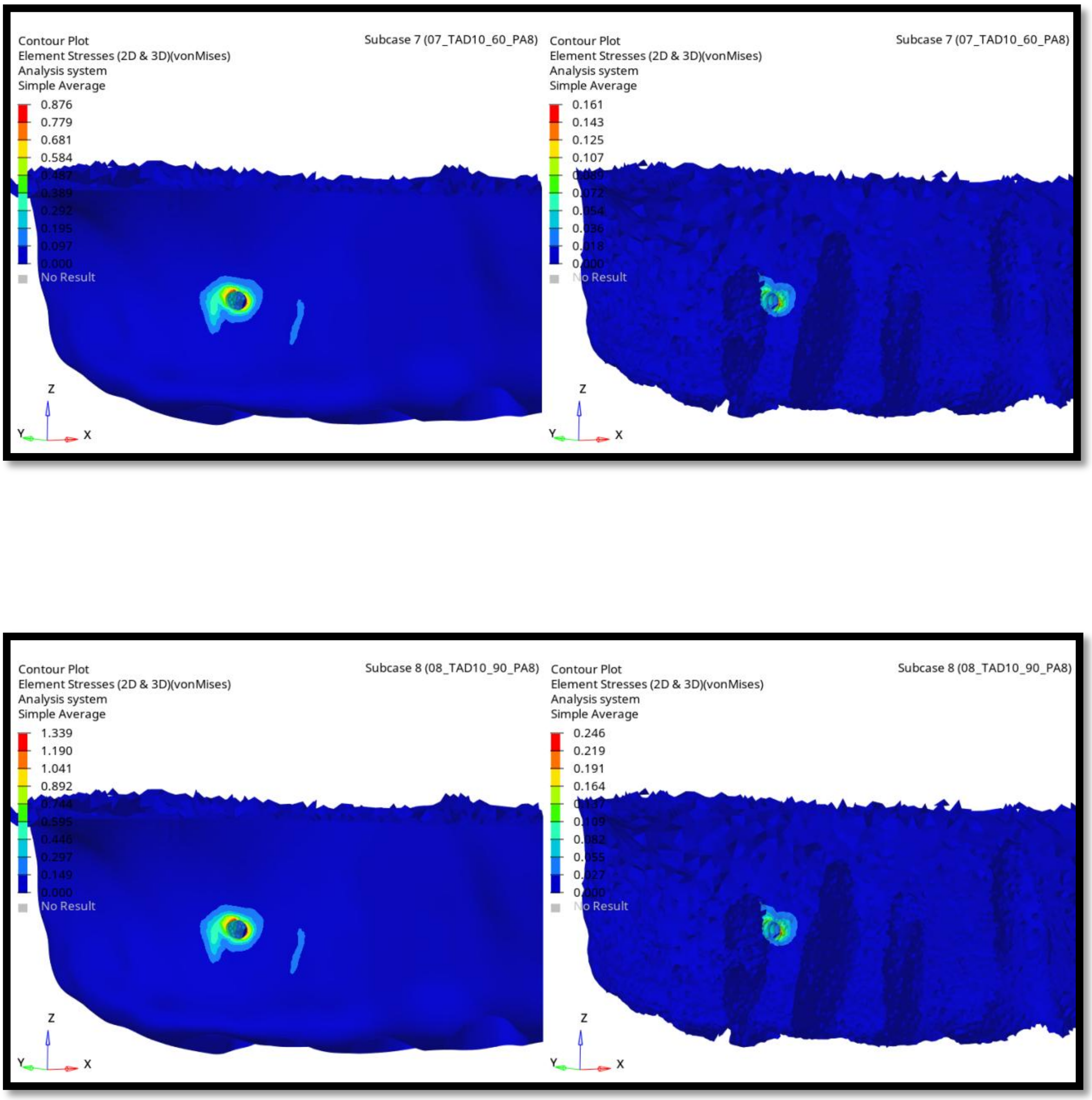


Figure 25B: Stress distribution on Cortical (right side) and Cancellous bone (left side) for combination (10mm MSL X 8mm PA) miniscrew placed at 60◦(above) and 90◦ angulation (below).

In the present study, stress were distributed around the implant in the mesial, distal and apical direction in concentric rings at both at **60**◦ and **90**◦ both for the Cortical bone and Cancellous bone (**Table no: 6, Figure no: 22B - 25B**) . However , in a study by Brar et al[44] , stress distribution pattern was contrary to the present study which showed that at **60°** angulations, the stresses were distal, mesial, and apical to implant. The stresses uniformly decreased in the form of concentric rings as the implant was moved away and reached the upper and lower crest of the cortical bone. At 45° reached only lower crest at **60°** and did not reach upper or lower crest at 75^o.

Stress distribution as seen on the contour plot was maximum on the mesial aspect of cervical region for all combinations (Canine > Lateral incisor > Central incisor) and relatively uniform distribution was seen in remaining part of tooth. On considering angulation higher stress in cervical region was seen for 90^o in comparison to 60^o irrespective of length of powerarm or miniscrew. On considering powerarm higher stress in cervical region was seen with 4mm in comparison to 8mm irrespective of miniscrew angulation or length. On considering miniscrew length higher stress in cervical region was seen on 8mm in comparison to 10mm irrespective of miniscrew angulation or powerarm.

Thus, a miniscrew of length 10mm when inserted at an angulation of 60^o for en-masse retraction with a 8mm powerarm during sliding mechanics provided more uniform distribution of stress at distal aspect of teeth. This will closely simulate the situation of biologic tooth movement as seen clinically . However, the stress generated at the root, PDL, cortical, and cancellous bone were less than the corresponding material properties as incorporated in the FEM model for the present study. Hence, it can be suggested that all of the combinations examined in the current research are clinically acceptable for the en-masse retraction of anterior teeth using sliding mechanics based on individual case requirement. The cases where combination of tipping and bodily teeth movement of anterior teeth is desirable , any combination could be used. However, in cases where retraction has to be mainly by bodily tooth movement as tipping might hamper facial esthetics PA height of 8mm should be used. Longer screws of 10mm inserted at 60^o would be preferred generally because, they generated uniform stress distribution.

Finite element studies have provided the orthodontist with new concepts on the behavior of the oral and dental tissues in response to the forces. Although it is not possible to simulate the biological environment of oral cavity (tissue fluids, cells, blood, and blood pressures). Despite of this, results obtained from finite element studies have been found to be highly reliable. However, the stress levels that actually causes biologic response i.e. resorption and remodeling of the bone are not comprehensively known. Therefore , the data of stress provided from FE analysis need substantiation by further clinical research.

Major limitation of the finite element analysis technique is that it is based on several assumptions. The structures in the model were all assumed to be homogenous and isotropic with linear elasticity [9,11], whereas the properties of the materials, particularly the living tissues were different. For instance, it is well documented that the alveolar bone of the maxilla and mandible is non-homogenous, the mechanical properties of the materials are nonlinear and complicated, and it might be impossible to include ideal properties in the model[5]. This makes the problem even more complex. The stress distribution patterns simulated also might be different, depending on the materials and properties assigned to each layer of the model used in the experiments. These are inherent limitations of this study.

Future studies with FEM model could analyze a variety of factors related to stress generation, such as the variable combination of miniscrew, length, diameter, and power arms during retraction. Additionally, stress distribution during retraction using different loop designs could be compared to those of a sliding mechanics using FEM. Also results should be with corroborated with clinical findings.

The present study was carried out at the Department of Orthodontics and Dentofacial Orthopaedics of BBD University in collaboration with FEA solution, Mumbai . The aim of the present study was to assess stress distribution on alveolar bone of maxilla at TAD bone interface and anterior teeth root and PDL during anterior en-masse retraction using different length of miniscrew when placed at different angulations in combination with different height of powerarm.

The following conclusions were drawn from the study:

1. The results showed that magnitude of stress and pattern of stress distribution varied under different miniscrew length, insertion angulation and powerarm length.

2. Von mises stress was found lesser in miniscrew placed at 60^0 angulation as compared to 90^0 angulation for various combinations of miniscrew length, angulation and power arm during en-masse retraction of anterior teeth.

3. Von mises stress was found lesser with 10 mm miniscrew length as compared to 8 mm miniscrew length for various combinations of miniscrew length, angulation and power arm during en-masse retraction of anterior teeth.

4. Von mises stress was found lesser with 8 mm PA in comparison to 4 mm PA for various combinations of miniscrew length, angulation and power arm during en-masse retraction of anterior teeth.

5. Stress generated for root, PDL, cortical and cancellous bone were lesser than the respective material properties as incorporated in FEM model for present study, hence it can be suggested that all combinations analyzed in the present study are clinically acceptable for en-masse retraction of anterior teeth.

Dental protrusion characterised by dentoalveolar flaring of maxillary and mandibular anterior teeth is common in many ethnic groups around the world with resultant protrusion of the lips and convex profile . The extraction of all the first premolars, followed by anterior tooth retraction to obtain the desired dental and soft-tissue profile is a common procedure in such cases .Controlled orthodontic tooth movements without undesirable reciprocal effect in the anchorage unit are difficult to achieve without reinforcement of anchorage .

Recently, miniscrews were introduced as absolute anchorage devices in Orthodontic treatment with the advantage of patient compliance. Excellent treatment results have been reported by using miniscrews for orthodontic anchorage in various malocclusions.

Miniscrews are easier to place, can be placed in more varied locations, smaller and more cost effective, and have the possibility of immediate or early loading. It is made of different materials with different lengths and diameter can be placed at various locations of maxilla and mandible depending upon the type of bone and required tooth movement.

En-masse retraction can be done by sliding mechanics (friction mechanics) or loop mechanics (frictionless mechanics). Forces for en-masse retraction are exerted from the powerarm placed anteriorly between lateral incisor and canine to Miniscrew using Niti coil spring or E-chain. Variation in height of powerarm can alter the biomechanics of anterior teeth retraction in vertical plane as well as in saggital plane depending on its distance from center of resistance of the anterior segment. Sliding mechanics is less technique sensitive and known as frictional mechanics of space closure . To reinforce anchorage in maximum anchorage requirement, TAD had been used. Stability of TAD by varying length, diameter , angulation had been evaluated in various studies . The effect of combination of variation in Powerarm height during sliding mechanics along with variation in miniscrew length, its angulation during sliding mechanics had not been evaluated in any of the previous study , hence it was decided to evaluate the same in the present study . Study of stress distribution allows to optimize the shape of screw, geometric parameters such as length, diameter, thread pitch ,the proper insertion angle on different bone type. However quantification of stresses clinically is difficult.

FEM enables users to analyze the effects of force systems applied to any point and in any direction, providing a quantitative assessment of the force distribution in the wire and related structures. Hence, FEM, computerized mathematical method that can be used to simulate mechanical systems to predict stress within the object was considered for the present study . Considering this , the aim of the study was to assess stress distribution on alveolar bone of maxilla at TAD bone interface and anterior teeth root and Pdl during anterior en-masse retraction using different length of miniscrew when placed at different angulations in combination with different height of powerarm.

This study had been conducted in the Department of Orthodontics and Dentofacial Orthopaedics of BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW in collaboration with FEA Solution Mumbai .

For the present study, a FEM model of maxillary arch with extracted right and left first premolars was prepared on the basis of CBCT images with MSLMSLCS software. A MBT appliance system with bracket slot of 0.022’’x 0.028’’ inch , 0.019 x 0.025’’ rectangular SS wire with powerarm of 4mm and 8mm , titanium miniscrew of 8mm and 10mm length (diameter of 2mm) were scanned using laser scanning to make CAD model. This was used to make geometric model. GEOMAGIC modeling software that was used to make mesh models using ALTAIR HYPERMESH software It was developed by Altair Engineering Inc.(Troy , Michigan ,United States) for windows. A total of 8 FEM models were made with the different combination of Miniscrew length (10mm and 8mm) and insertion angles (60^o and 90^o) and powerarm height (4mm and 8mm) . A force of 150gm were used for en-masse retraction of the anterior teeth with closed Niti coil spring was simulated using the FEM software. Von Mises Stress (MPa) generated on both the anterior segment (in the roots and PDl of anterior teeth) as well as the TAD bone interface at posterior segment were measured.

The following conclusions were drawn from the study:

1. The results showed that magnitude of stress and pattern of stress distribution varied under different miniscrew length, insertion angulation and powerarm length.

2. Von mises stress was found lesser in miniscrew placed at 60^0 angulation as compared to 90^0 angulation for various combinations of miniscrew length, angulation and power arm during en-masse retraction of anterior teeth.

3. Von mises stress was found lesser with 10 mm miniscrew length as compared to 8 mm miniscrew length for various combinations of miniscrew length, angulation and power arm during en-masse retraction of anterior teeth.

4. Von mises stress was found lesser with 8 mm PA in comparison to 4 mm PA for various combinations of miniscrew length, angulation and power arm during en-masse retraction of anterior teeth.

5. Stress generated for root, pdl, cortical and cancellous bone were lesser than the respective material properties as incorporated in FEM model for present study, hence it can be suggested that all combinations analyzed in the present study are clinically acceptable for en-masse retraction of anterior teeth.

Future studies with FEM model could analyze a variety of factors related to stress generation, such as the more combination of miniscrew length, diameter, and the effect of power arms during retraction. Additionally, different loop designs with varying dimensions and material properties, as well as the mechanical properties of various retraction methods, could be compared to those of a sliding mechanism.

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ANNEXURE-I

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES
(FACULTY OF BBD UNIVERSITY), LUCKNOW

INSTITUTIONAL RESEARCH COMMITTEE APPROVAL

The project titled "**Comparision of Stress Distribution in Alveolar Bone during Anterior En-Masse Retraction using Miniscrews– A Fem Study**" submitted by **Dr Haobam Minerva** Post graduate student from the Department of **Orthodontics and Dentofacial Orthopaedics** as part of MDS Curriculum for the academic year 2020-2023 with the accompanying proforma was reviewed by the Institutional Research Committee present on **12th October 2021** at BBDCODS.

The Committee has granted approval on the scientific content of the project. The proposal may now be reviewed by the Institutional Ethics Committee for granting ethical approval.

Prof. Vandana A Pant
Co-Chairperson

Prof. B. Rajkumar
Chairperson

ANNEXURE-II

Babu Banarasi Das University
Babu Banarasi Das College of Dental Sciences,
BBD City, Faizabad Road, Lucknow – 226028 (INDIA)

Dr. Lakshmi Bala
Professor and Head Biochemistry and
Member-Secretary, Institutional Ethics Committee

Communication of the Decision of the IX[th] Institutional Ethics Sub-Committee

IEC Code: 25 **BBDCODS/04/2022**

Title of the Project: Comparision of Stress Distribution in Alveolar Bone during Anterior En-Masse Retraction using Miniscrews– A Fem Study.

Principal Investigator: Dr Haobam Minerva **Department:** Orthodontics and Dentofacial Orthopaedics

Name and Address of the Institution: BBD College of Dental Sciences Lucknow.

Type of Submission: New, MDS Project Protocol

Dear Dr Haobam Minerva,

The Institutional Ethics Sub-Committee meeting comprising following four members was held on 07[th] April, 2022.

1.	Dr. Lakshmi Bala Member Secretary	Prof. and Head, Department of Biochemistry, BBDCODS, Lucknow
2.	Dr. Amrit Tandan Member	Prof. & Head, Department of Prosthodontics and Crown & Bridge, BBDCODS, Lucknow
3.	Dr. Rana Pratap Maurya Member	Reader, Department of Orthodontics, BBDCODS, Lucknow
4.	Dr. Akanksha Bhatt Member	Reader, Department of Conservative Dentistry & Endodontics, BBDCODS, Lucknow

The committee reviewed and discussed your submitted documents of the current MDS Project Protocol in the meeting.
The comments were communicated to PI thereafter it was revised.

Decisions: The committee approved the above protocol from ethics point of view.

Forwarded by:

Lakshmi Bala

Member-Secretary
Institutional Ethic Committee
BBD College of Dental Sciences
BBD University
Faizabad Road, Lucknow-226028

(Dr. Lakshmi Bala)
Member-Secretary
IEC

(Dr. Puneet Ahuja)
Principal
BBDCODS

PRINCIPAL
Babu Banarasi Das College of Dental Sciences
(Babu Banarasi Das University)
BBD City, Faizabad Road, Lucknow-226028

ANNEXURE -III

FEA
SOLUTIONS

Document ID:FEA-S-2022-003-10

Date: 4th Dec. 2022

To Whomsoever It May Concern

We at FEA Solutions are very pleased to inform the successful completion of Finite Element Analysis simulation on dental model for Dr. **Haobam Minerva**

Project Title : "COMPARISON OF STRESS DISTRIBUTION IN ALVEOLAR BONE DURING ANTERIOR EN-MASSE RETRACTION USING MINISCREWS- A FEM STUDY".

Start Date: 15th Nov. 2022

End Date: 4th Dec. 2022

We were completely involved in the above mentioned study for the mentioned period.

Thanking You,

P. Naik

For FEA Solutions.

FEA Solutions | First Floor, Mohan, Nandanvan, Louiswadi, Thane (W) | www.fea.co.in

ANNEXURE -IV

Babu Banarasi Das College of Dental Sciences

(Babu Banarasi Das University)

BBD City, Faizabad Road, Lucknow – 227105 (INDIA)

Guidelines for Devising a Participant / Legally Acceptable Representative InformationDocument (PID) in English

1. **Study Title**
   Comparision of stress distribution in alveolar bone during anterior en-masse retraction using miniscrews-A FEM STUDY

2. **Invitation Paragraph**

   You are being invited to take part in a research study. Before you decide it is important for you to understand why the research/study is being done and what it will involve. Please take time to read the following information carefully and discuss it with friends, relatives and your treating physician/family doctor if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

3. **What is the purpose of the study?**
   the purpose of the study is to assess stress distribution on alveolar bone of maxilla during anterior en-masse retraction using power arm at different heights to miniscrews of different length, placed at various insertion angles

4. **Why have I been chosen?**
   No patient is required as it is an in vitro study

5. **Do I have to take part?**
   Not applicable.

6. **What will happen to me if I take part?**
   Not applicable.

7. What do I have to do?
Not applicable.

8. What is the procedure that is being tested?

The procedure will involve to evaluate stress distribution on alveolar bone of maxilla during anterior en-masse retraction using power arm at different heights to miniscrews of different length, placed at various insertion angles

9. What are the interventions for the study?

- To evaluate stress distribution on alveolar bone of maxilla during anterior en-masse retraction with power arm at height of 4 & 8mm by miniscrew of length 8mm with diameter 1.5mm placed at two different angulations(60°,90°).
- To evaluate stress distribution on alveolar bone of maxilla during anterior en-masse retraction with power arm at height of 4 & 8 mm by miniscrew of length 10mm of diameter 1.5mm placed at two different angulations(60°,90°).
- To compare stress distribution on alveolar bone of maxilla during anterior en-masse retraction from power arm at height 4mm between miniscrew of two different length(8mm and 10mm) of diameter 1.5mm when placed at different angulations(60°,90°).
- To compare stress distribution on alveolar bone of maxilla during anterior en-masse retraction from power arm at heigh t 8mm by miniscrew of two different length(8mm and 10mm) of diameter 1.5mm when placed at different angulations (60°,90°).
- To compare stress distribution on alveolar bone of maxilla during anterior en-masse retraction between power arm at two different height (4mm and 8mm) from two different variables-length of miniscrew(8mm and 10mm) and angulations of miniscrew placement (60° and 90°).

10. What are the side effects of taking part?
Not applicable

11. What are the possible disadvantages and risks of taking part?
Not applicable

12. What are the possible benefits of taking part?
Not applicable

13. What if new information becomes available?

Sometimes during the course of a research project, new information becomes available about the research being studied. If this happens, your researcher will tell you about it and discuss with you whether you want to continue in the study. If you decide to withdraw, your researcher/investigator will make arrangements for your withdrawal. If you decide to continue in the study, you may be asked to sign an updated consent form.

14. What happens when the research study stops?

If the study stops/finishes before the stipulated time, this will be explained to the patient/volunteer.

15. What if something goes wrong?

If any severe adverse event occurs, or something goes wrong during the study, the

complaints will be handled by reporting to the institution (s), and Institutional ethical

community.

16. Will my taking part in this study be kept confidential?

Not applicable as it is an in vitro study

17. What will happen to the results of the research study?

The results of the study will be used to be compare stress distribution on alveolar bone.

18. Who is organizing the research?

This research study is organized by the academic institution (BBDCODS).

19. Will the results of the study be made available after study is over?

Yes

20. Who has reviewed the study?

The study has been reviewed and approved by the Head of the Dept, and the IEC/IRC of

the institution.

21. Contact for further information

Dr. HAOBAM MINERVA
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Babu Banarasi College of Dental Sciences.
Lucknow-227105

Mob- 8279844510

Dr. Sneh Lata Verma (Reader)
Department of Orthodontics and Dentofacial Orthopaedics
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Dr. Rohit Khanna (HOD)
Department of Orthodontics and Dentofacial Orthopaedics
Babu Banarasi College of Dental Sciences.
Lucknow-227105
Mob-9415037011

Signature of PI………………………………

Name………………………………………….

Date……………………………………………..

ANNEXURE -V

Babu Banarasi Das College of Dental Sciences

(Babu Banarasi Das University, Lucknow)

BBD City, Faizabad Road, Lucknow – 227105 (INDIA)

प्रतिभागी के लिए सूचना पत्र

1.अध्ययन शीर्षक

दातों को मिनीस्क्रू द्वारा पीछे ले जानी की प्रक्रिया में हड्डी पर तनाव का मूल्याकन - फ इ म द्वारा

2. निमंत्रण अनुच्छेद

मान्य नहीं ।

3. अध्ययन का उद्देश्य क्या है ?

अध्ययन का उद्देश्य मिनीस्क्रू के विभिन्नकोणों पर रखे गए और विभिन्न लंबाई का अलग-अलग ऊंचाई पर पावर आर्म के उपयोग द्वारा दातों को पीछे ले जाने की प्रक्रिया में हड्डी में तनाव का मूल्यांकन करना है।

4. मुझे इस अध्ययन के लिए क्यों चुना गया है?

किसी रोगी की आवश्यकता नहीं है।

5. क्या इसमें मुझे भाग लेना चाहिए ?

मान्य नहीं।

6. मुझे क्या होगा यदि मैं इस अध्ययन में भाग लेता हूं।

मान्य नहीं।

7. मुझे क्या करना है?

मान्य नहीं।

8. किस प्रक्रिया का अध्ययन किया जा रहा है?

अध्ययन का उद्देश्य मिनीस्क्रू के विभिन्नकोणों पर रखे गए और विभिन्न लंबाई का अलग-अलग ऊंचाई पर पावर आर्म के उपयोग द्वारा दातों को पीछे ले जाने की प्रक्रिया में हड्डी में तनाव का मूल्यांकन करना है।

9. इस शोध में कौन से हस्तक्षेप दिए जाएंगे?

मान्य नहीं।

10. इस अध्ययन में भाग लेने के क्या दुष्प्रभाव हैं ?

मान्य नहीं।

11. इस अध्ययन में भाग लेने के संभावित जोखिम और नुकसान क्या है?

मान्य नहीं।

12. अध्ययन में भाग लेने के संभावित लाभ क्या है?

मान्य नहीं।

13. क्या होगा यदि कोई नई जानकारी उपलब्ध हो जाती है ?

मान्य नहीं।

14. क्या होता है जब अध्ययन / शोध परीक्षण बंद हो जाता है।

मान्य नहीं।

15. क्या होगा अगर कुछ गलत हो जाता है?

मान्य नहीं।

16. क्या इस अध्ययन में मेरा हिस्सा गोपनीय रखा जाएगा?

मान्य नहीं।

17. अध्ययन / शोध परीक्षण के परिमाण का क्या होगा?

मिनी -स्क्रू कौन सी लंबाई या कोन ,हड्डी में सबसे कम तनाव देगा ।

18. इस अध्ययन को कौन आयोजित कर रहा है और इस परीक्षण के लिए धन कहां से आएगा।

यह शोध अध्ययन शैक्षणिक संस्थान (बीबीडीसीओडीएस) द्वारा आयोजित किया जाता है।

19.क्या सेवाएं शोध खत्म हो जाने के बाद उपलब्ध रहेगी या नहीं?

हां।

20. अध्ययन की समीक्षा किसने की है?

अध्ययन की समीक्षा की गई है और विभाग के प्रमुख, और आईईसी/आईआरसी के द्वारा अनुमोदित किया गया है। निम्न लोगों से संपर्क करें

21.अधिक जानकारी के लिए संपर्क करें ।

डॉ. हाओबम मिनर्वा
ऑर्थोडोंटिक्स और डेंटोफेशियल ऑर्थोपेडिक्स विभाग
बाबू बनारसी कॉलेज ऑफ डेंटल साइंसेज।
लखनऊ-227105
मोब- 8279844510

डॉ स्नेह लता वर्मा (रीडर)
ऑर्थोडोंटिक्स और डेंटोफेशियल ऑर्थोपेडिक्स विभाग
बाबू बनारसी कॉलेज ऑफ डेंटल साइंसेज।
लखनऊ-227105
मोब-8960943326

डॉ रोहित खन्ना (एचओडी)
ऑर्थोडोंटिक्स और डेंटोफेशियल ऑर्थोपेडिक्स विभाग
बाबू बनारसी कॉलेज ऑफ डेंटल साइंसेज।
लखनऊ-227105
मोब-9415037011

bbdcods.iec@gmail.com

पीआईकाहस्ताक्षर ....

नाम ....

दिनांक………………………………

ANNEXURE -VI

Document Information

Analyzed document	merge file 8-3-2023.pdf (D160433180)
Submitted	3/8/2023 2:52:00 PM
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Sources included in the report

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