

**A THREE DIMENSIONAL FINITE ELEMENT
ANALYSIS OF FORCE SYSTEM ON MAXILLARY
MOLARS BY USING TWO DIFFERENT METHODS
FOR MOLAR DISTALIZATION**

DISSERTATION

Submitted to

BABU BANARASI DAS UNIVERSITY, LUCKNOW, UTTAR PRADESH

In the partial fulfillment of the requirements for the degree

of

MASTER OF DENTAL SURGERY

In

ORTHODONTICS AND DENTOFACIAL ORTHOPAEDICS

By

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Under the guidance of

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BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW

(Faculty of Babu Banarasi Das University)

YEAR OF SUBMISSION: 2024

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LIST OF ABBREVIATIONS

S.NO	ABBREVIATED FORM	FULL FORM
1.	CBCT	Cone-beam computed tomography
2.	CAD	Computer-aided design
3.	TAD	Temporary anchorage device
4.	SAS	Skeletal Anchorage System
5.	FEM	Finite Element Method
6.	CR	Centre of resistance
7.	MPa	MegaPascal
8.	mm	Millimetre
9.	N/mm ²	Newton/millimetre ²
10.	µm	Micrometre
11.	BAPA	Bone anchored pendulum Appliance
12.	iPANDA	Indirect Palatal Miniscrew for Anchorage and Distalization Appliance
13.	MPAP	Modified Palatal Anchorage Plate
14.	CPHG	Cervical Pull Head Gear
15.	SS	Stainless Steel
16.	TMA	Titanium Molybdenum Alloy
17.	MARA	Mandibular Anterior Repositioning Appliance
18.	TPA	Trans Palatal Arch
19.	NiTi	Nickel Titanium
20.	g	Grams
21.	MIA	Mini Implant Assisted

Introduction

Molar distalization can be achieved from buccal or palatal aspect and is a common non extraction modality of gaining space. The Aim was to evaluate and compare stress and displacement during maxillary molar distalization by two commonly used methods, compressed NiTi open coil spring and K loop using finite element method.

Material and method: A maxillary arch was modelled on the basis of CBCT images. FUSION 360 software was used to convert CBCT into STL format to make CAD model of maxillary arch. Geometric Model of MBT bracket, buccal tube, .017"x.025 TMA wire, K-loop, NiTi open coil spring, mini-implant (TAD), .019"x.025" SS arch wire, ligature ties and ligature wire was generated in Solid Works software from CAD models. Hyper mesh software was used to make FEM models. Two finite element models were generated and boundary condition was applied. Group I included FEM model where molar distalization was carried out with NiTi open coil spring and Group II included K loop assisted molar distalisation and in both the FEM models anterior anchorage was reinforced by miniscrew placed buccally between 2nd premolar and 1st molar. Stress and displacement in X, Y and Z axis was measured and tabulated.

Result: Maxillary 1st molar showed displacement in mesiobuccal direction in X axis as 4.253×10^{-7} mm for group I and 7.216×10^{-7} mm in group II; (Group II > Group I), showed displacement in distal direction in Z axis as 9.217×10^{-7} mm for group I and 1.245×10^{-6} for group II; (Group II > Group I), showed displacement in occlusal direction in Y axis as 2.1605×10^{-8} for group I and 1.9866×10^{-7} mm for group II; (Group II > Group I). Mesial movement of anterior segment was not seen in both groups rather distal movement was seen. Stress in PDL, cortical bone and cancellous bone more in group II than group I but stress distribution pattern was uniform in K loop.

Conclusion: K loop was more effective in achieving molar distalization than Niti coil spring where anterior anchorage was reinforced by mini-screw.

Key words : Kloop, molar distalization, NiTi open coil spring, mini-implant (TAD)

Class II Malocclusion is a commonly encountered malocclusion in the anteroposterior plane¹ and usually presents with tooth size and arch length discrepancy². The treatment of such cases can be done by extraction of premolars or by non-extraction approach³ using expansion or molar distalization or other methods⁴. The indications for molar distalization include that patient should have class I skeletal pattern with straight profile, Angle's class II or end on molar relationship with mild maxillary dental protrusion, mild to moderate crowding, low to moderate mandibular plane angle, good facial balance and preferably unerupted second or third molar⁵. The contra-indications included protrusive profile or proclined incisors, increased overjet, hyperdivergent growth pattern and posterior crowding.

Molar distalization is a non-extraction modality of gaining space⁴ and can be done by extraoral methods (compliant) and intraoral methods (non-compliant).⁵

Atherton et al undertook a systematic review to investigate various distalization methods and found that the amount of maxillary molar distalization that could be achieved was in the range of 2 mm–2.5 mm using various methods⁶. Conventionally extraoral distalizing appliances⁷ ie. head gears were used that needed patient's cooperation. Head gear was attached via a facebow to molar bands on the maxillary first permanent molars in a high or low pull direction, depending on the type of growth pattern. Headgear delivering 150-200gm of force per side for 14 hours per day, has been routinely recommended for molar distalization. The variation in length of outer bow, direction of force with respect to centre of resistance of maxillary first molar (at trifurcation of roots), types of head gear decided magnitude and direction of moment generated for effective molar distalization in term of crown tipping, root tipping or bodily movement of maxillary first molar. Head gear achieved effective molar distalization however needed patient compliance and had never been an esthetically pleasing option for the patients.⁵

Intraoral appliances for effective molar Distalization⁸ are simple to construct and use, and are a good alternative for non compliant patients. In a systematic review by Antonarakis and Kiliaridis in 2008, it was concluded that intra-oral appliances for maxillary molar distalization were more effective than extraoral appliances.⁹

Among intraoral appliances, molar distalization can be achieved by inter-maxillary or intra-maxillary appliances⁹. Inter-maxillary appliances include Jasper jumper

¹⁰,Mandibular Anterior Repositioning Appliance (MARA)¹¹,Forsus¹²,Powerscope¹³ and Twin force,¹⁴that are commonly used as fixed functional appliances.¹⁵

Molar distalization can also be accomplished by intra-maxillary appliances,that can be attached from labial or palatal side.Different appliances that can be attached palatally include Pendulum appliance,¹⁶ Distal jet¹⁷,Goshgarian TPA¹⁸ (Trans palatal Arch), Skeletal frog appliance¹⁹, and mini-implant assisted distalizing appliance²⁰.Buccally placed intraoral appliances for molar distalization include Jones Jig²¹, K loop²², Repelling magnets²³, Wilson arch²⁴, and Niti coil spring²⁵,mini-implant²⁶ placed between first and second molar, in tuberosity region or infrazygomatic crestal region²⁷.

Intraoral methods can produce bodily or tipping movement of maxillary molars depending on direction of force vector with respect to center of resistance of maxillary molar and may cause mild anchorage loss of mesial segment.^{1,28}

The appliances that apply force from palatal aspect were more nearer to the centre of resistance, hence overcame the disadvantages of buccally placed appliances used for distalizing maxillary molars by reducing the tendency for the teeth to tip, thus producing bodily tooth movement with negligible crown tipping²⁹.Several studies have reported that the Pendulum appliance caused the maxillary first molar to distalize effectively with significant intrusion. Various modifications of Pendulum appliances like Pend-X,Pendulum -K are used for molar Distalization.³⁰

However intraoral appliance placed palatally had inherent disadvantages of being bulky ,obstructing the tongue space and making it less comfortable for patients.Hence appliances placed buccally for molar distalization are preferred as being simple, easy to use and less cumbersome.Among buccally placed appliance few are available commercially like Jones Jig³¹,repelling magnets²³,lokar distalizer³² etc that poses additional expenses to be borne by the patient.Other appliances that can be fabricated at the chair side using commonly available orthodontic inventory are preferred for molar distalization.

In 1995 Dr. Varun Kalra introduced the K Loop²² which was not dependent on patient cooperation for effective distalization of maxillary molars and was developed in accordance with biomechanical principles as outlined by Charles Burstone.Also it

gave controlled moment-to-force ratio as needed to produce bodily movement, It was easy to fabricate and place, hygienic, comfortable for the patient and was cost effective. The K-loop is made from 0.017×0.025 inch TMA wire and is positioned between the upper first molar and first premolar. Each loop of the K should be 8mm long and 1.5mm wide. The legs of the K are bent down 20° and inserted into the molar tube and the premolar bracket. The wire is marked at the mesial of the molar tube and the distal of the premolar bracket, stops are bent into the wire 1 mm distal to the distal mark and 1mm mesial to the mesial mark. Each stop should be well defined and about 1.5mm long. These bends help keep the appliance away from the mucobuccal fold, allowing a 2mm activation of the K-loop. The 20° bends in the appliance legs produce moments that counteract the tipping moments created by the force of the appliance, and these moments are reinforced by the moment of activation as the loop is squeezed into place exerting an effective force of 200 grams. Thus, this results in attaining controlled M: F ratio for bodily movement instead of tipping. Root movement continues even after the force has dissipated. If an extrusive or intrusive force against the molar is not desired, it is important to centre the K-loop between the first molar and the premolar. For additional molar movement, the appliance is reactivated 2mm after six to eight weeks.²²

Open NiTi coil spring²⁵ commonly used in orthodontic practice to gain space for crowded teeth had also been used for molar distalization by exerting force of 200-250 gms when compressed between maxillary 2nd premolar and 1st molar or between maxillary 1st molar and 1st premolar, omitting bracket placement in 2nd premolar thus increasing interbracket span between 1st molar and 1st premolar.

Open coil spring are made up of Japanese nickel-titanium alloy or stainless steel. According to literature Niti open coil spring had superior spring-back and super elastic properties and had ability to exert a very long range of constant, light, and continuous force, hence preferred over stainless steel coil springs, (Fraunhofer *et al.* (1993)³³. Current recommendations for the use of open coil springs direct that the springs be compressed approximately one third of their original length.³⁴

As K-loop, Ni-Ti open coil spring are cost effective options of molar distalization and are placed buccally, and various studies showed their efficacy in molar distalization, it was decided to distalize molar by these two commonly used methods in present study.

The potential limitation of any molar distalization is mild anchorage loss of anterior segment. Acrylic button placed in palate had been used conventionally to prevent the anterior anchorage loss with wire extension soldered to bands on premolars. Also modified Nance appliance³² had been used with extension bonded on first premolars. An additional means of anchorage reinforcement involved the incorporation of uprighting springs³⁵ to tip the crowns of these teeth distally and as a result, effective molar distalization was obtained. The use of Class II elastics³⁶ has also been recommended to avoid anterior anchorage loss. Recently TAD's (Temporary Anchorage Devices)³⁷ are used to augment anchorage of anterior segment there by negating reactive forces of molar distalization. Miniscrew placed in median and paramedian areas of palate, on buccal aspect between maxillary 1st molar and 2nd premolar prevent mesial tipping of anterior segment when anterior teeth are tied to these miniscrew for anchorage.

Hence for both the methods (K-loop and Ni-Ti coil spring) selected in the present study for molar distalization, anchorage of anterior segment was augmented by miniscrew placed on buccal aspect between second premolar and first molar of maxillary arch. Since second premolar was free from any attachment, it drifted distally via transseptal fibers during the distalization period³⁸ and thus gave additional biomechanical advantage of increased interbracket span. The anterior segment was tied to miniscrew, it was anticipated that major side effect of molar distalization i.e. anterior anchorage loss would be minimised.

Several clinical and in-vitro studies have been conducted to investigate the performance of different distalization appliances and to evaluate the type, amount, and rate of tooth movement. However, little information regarding the pattern of the mechanical stresses in the tissue surrounding teeth during molar distalization is available. As quantification of stresses in clinical studies is difficult therefore, various in-vitro methods had been proposed to quantify stresses such as- photo elastic stress analysis, mathematical models, laser holography³⁹ and finite element method⁴⁰. Among these FEM which quantitatively assess the stress and strain distribution generated in response to various biomechanical settings in orthodontics was selected in present study.⁴⁰

The FEM approach was proposed into dental biomechanical research in 1973 (Farah., *et al.*)⁴¹ and has been widely used to investigate the stress and strain fields in alveolar support structures as well as teeth . The FEM is a powerful tool for the analysis of complex structure and it is reliable for numerical approximation to all physical problems occurring clinically.^{4,42,43}

Previous FEM studies have evaluated various molar distalization methods.Kang et al concluded that modified palatal anchorage plate (MPAP) was most effective treatment option for molar distalization even after eruption of second molar in comparison to bone anchored pendulum appliance and cervical pull headgear⁴⁴.A FEM study by Tekale et al⁴⁵ concluded that mini implant supported K-loop showed large amount of distal displacement of the first molar, with negligible amount of tipping of the first molar and mesial movement of first premolar.Another FEM study by Hamanaka et al proposed a novel technique to distalize molars more efficiently by using open-coil springs.⁴⁶

However, none of the FEM or clinical studies have compared the K loop and compressed open Niti coil spring for molar distalization where anterior anchorage was reinforced using mini-implant placed between maxillary first molar and second premolar. Considering this it was decided to conduct 3-Dimensional finite element analysis of two commonly used methods of molar Distalization, K loop²² and open NiTi coil spring²³ compressed between maxillary 1ST premolar and 1st molar and anterior anchorage was reinforced by tying of first premolar to miniscrew³⁷ placed between second premolar and first molar in present study.

AIM-

To evaluate and compare stress and displacement during maxillary molar distalization by two commonly used methods, compressed NiTi open coil spring and K loop using finite element method.

OBJECTIVES-

1. To evaluate the stress and displacement around maxillary first molar and anterior segment during maxillary first molar distalization using NiTi open coil spring, where anterior anchorage was reinforced with mini implant.
2. To evaluate the stress and displacement around maxillary first molar and anterior segment during maxillary first molar distalization using K loop, where anterior anchorage was reinforced with mini implant.
3. To compare the amount of stress and displacement on maxillary first molar between two methods of molar distalisation.
4. To compare the amount of stress and displacement on maxillary anterior teeth between two methods of molar distalisation.

Chaconas et al (1984)³⁴ checked efficacy of open Ni Ti coil spring for molar distalisation and investigated the effects of wire thickness, length and radius of open coil springs on the forces produced. . Testing was performed on an Instron test machine using 0.016 inch round and 0.018 by 0.022 inch rectangular arch wires. With a constant lumen size, an increase in wire size produced an increase in force at a given activation. With a constant wire size, an increase in lumen size produced a decrease in force at a given activation. The effect of the arch wire size and shape was not significantly different for the coil springs with the smaller lumen sizes. For the larger lumen sizes, the springs used with the rectangular arch wire manifested a greater linear range than those used with the smaller arch wire. It was found that more linear force was produced in open coil spring. Open coil springs had to be compressed by about a third of its original length, producing force for movement.

AA Gianelly, J Bednar, VS Dietz, et al(1991)⁴⁷- found that Japanese NiTi superelastic coils, exerting 100 gm of force, when compressed 8 to 10mm and maintaining them by crimpable hooks or Gurin locks against the maxillary first molars and moved the molars distally 1 to 1.5 mm/month. Anchorage was obtained with a modified Nance appliance cemented onto the first premolars in conjunction with a fixed appliance. When second molars are erupted, hooks for Class II elastics were fixed on the arch wire between the lateral incisors and the canines, so that anchorage support by means of Class II elastics can be maintained.

AA Gianelly, et al(1991)⁴⁷- evaluated distal movement of the maxillary molars, and can approximately 1 mm/month when coil spring were activated by compressing them approximately 10 mm between the first premolars and the first molars, looped NiTi wires against the molars supported by a removable modified Nance appliance. The coils, in the passive state, are 10 mm longer than the space between the distal wing of the bracket on the first premolar and the molar tube. The superelastic NiTi wire also applies 100 gm of force to move molars distally with this wire, a “loop” that opens during deactivation is formed in the wire. The anchorage for the superelastic NiTi coils and superelastic NiTi wires is a modified Nance appliance. To maintain molar position, a headgear (preferably hi-pull for root uprighting) was recommended. When the molars are not severely inclined distally, a 10° to 15° active tip back is used in addition to the stop because the tip back impedes mesial movement of the crowns. If the molars are severely inclined distally, the tip back is made passive to avoid

excessive distal inclination. Additionally, the degree of difficulty and prognosis appears to be related to the stage of dental development and the age of the patient. The highest success rate with the fewest complications occurs when molars are moved distally in the mixed dentition stage of development.

Bondemark L, Kurol J, Bernhold M, et al (1994)⁷ Did a study on two force system used for molar Distalization, repelling magnet and Niti super coil spring. 18 subjects, aged 12.5 to 18.3 years were treated orthodontically using repelling rare earth magnets on one side and superelastic nickel-titanium coils on the contralateral side for simultaneous distalization of maxillary first and second molars. The magnet pair and niticoil spring are placed on sectional bar, the bar was attached to the head gear tube of the maxillary molar, activation was performed by means of ligature wire. The force values of the magnets and the coils were calibrated to 225g at the start of treatment and when reactivation was performed every fourth week. Mean distal molar movement was 3.2 mm for the supercoils and 2.2 mm for the magnets in 6 months of treatment time and found that superelastic coils were more effective than repelling rare earth magnets in achieving molar Distalization.

Dr. Kalra (1995)²² described K LOOP for molar Distalization, that is made up of .017''x .025'' TMA wire with two legs bent down at an angle of 20 degree. Each loop of the K should be 8mm long and 1.5mm wide. Stops are bent into the wire 1 mm distal to the distal mark ie mesial to molar tube and 1mm mesial to the mesial mark ie distal to premolar bracket. Each stop should be well defined and about 1.5mm long. These bends help keep the appliance away from the mucobuccal fold, allowing a 2mm activation of the K-loop. The 20° bends in the appliance legs produce moments that counteract the tipping moments created by the force of the appliance, and these moments are reinforced by the moment of activation as the loop is squeezed into place. The first molars were distalized with the K-loop without much loss of anchorage even after the eruption of the second molars

Joydeep Ghosh, and Ram S. Nanda-(1996)⁴⁹ determined the effects of the pendulum appliance on distalization of maxillary molars and the reciprocal effects on the anchor premolars and maxillary incisors. 41 subjects were treated with the pendulum appliance for bilateral distalization of the maxillary first molar teeth. The mean maxillary first molar distalization was 3.37 mm, with a distal tipping of 8.36°. The

mean reciprocal mesial movement of the first premolar was 2.55 mm, with a mesial tipping of 1.29°. The transverse width between the mesiobuccal cusps of the first molars increased 1.40 mm. The maxillary second molars were also distalized 2.27 mm, tipped distally 11.99° and moved buccally 2.33 mm. The effect of distalization on the maxillary third molars was extremely variable. The eruption of maxillary second molars had minimal effect on distalization of first molars. The lower anterior face height increased by 2.79 mm. This increase was greater in patients with higher Frankfort-mandibular plane angle measurements. The pendulum appliance is an effective and *reliable* method for distalizing maxillary molars, provided the anchor unit is adequately reinforced.

Erverdi N, Koyutürk O, Küçükkeles N.(1997)⁵⁰- compared two intra-oral molar distalization procedures Nickel-titanium coil springs and repelling magnets, involving 15 cases with Class II molar relationships. Magnetic devices were applied to the upper right first molars in each case, while nickel-titanium coil springs were used against the upper left first molars, for a period of 3 months. Although upper molar distalization was achieved with ease in both techniques were clinically acceptable, nickel-titanium coil springs were found to be the more effective in terms of movement achieved. The disadvantages of the magnets were their cost, bulky appearance and requirement for weekly activation.

Bondemark L, Kurol J⁷. 1998- investigated the efficacy of magnets and superelastic coils of Class II correction, the study comprised 18 patients, mean age 14.7 years at the start of treatment, with Class II malocclusion, deep overbite and space deficiency in the maxillary arch. The first phase of the treatment consisted of 6 months simultaneous distal movement of maxillary first and second molars with repelling samarium-cobalt magnets on one side and a superelastic nickel-titanium coil on the contralateral side together with an anterior biteplane to achieve bite opening (2.6 mm). For the second phase of the treatment, a straight-wire appliance was used for an average treatment time of 1.3 years. The treatment resulted mainly in dental changes. The dental Class II molar relation was corrected to Class I by bodily distal movement of maxillary molars and by mesial movement of the mandibular molars. The correction of molar relation was significantly greater on coil sides than on magnet sides, mean 3.4 mm, and 3.0 mm, respectively. Despite anchorage loss associated with

the maxillary molar movement, i. e. mesial movement of the maxillary incisors(mean 1.8 mm), the net overjet was reduced, mean 2.5 mm, by the use of Class II elastics.¹⁷

Keles A, Sayinsu K,etal (2000)⁵¹- introduced a new appliance, Intraoral bodily molar distalizer to achieve bodily molar distalization, avoid distal tipping of molars, eliminate the need for patient cooperation (no headgear, no elastics, and no esthetic and social concern), and finally to minimize the treatment period and maximize the treatment efficiency.15 patients (mean age of 13.53 years),where second molars were erupted, and the lower dental arch was well aligned.The intraoral bodily molar distalizer (IBMD) was composed of 2 parts: the anchorage unit and the distalizing unit. The anchorage unit was a wide Nance button, and the active unit consisted of distalizing springs. The springs had 2 components: the distalizer section of the spring applied a crown tipping force, while the uprighting section of the spring applied a root uprighting force on the first molars, 230 g of distalizing force was used on both sides. Maxillary first molars were moved distally by an average of 5.23 mm without tipping or extrusion. Maxillary first premolars were moved 4.33 mm mesially , tipped 2.73° distally and extruded by 3.33 mm.Maxillary central incisors were proclined by an average of 4.7 mm and tipped 6.73° labially.

Timothy J. Bussick, James A. McNamara, Jr.(2000)⁵²- conducted a study to examine the dentoalveolar and skeletal effects of the pendulum appliance in Class II patients(no-101) at varying stages of dental development and with varying facial patterns (high, neutral,and low mandibular plane angles) The average maxillary first molar distalization was 5.7 mm, with a distal tipping of 10.6°. The anchoring anterior teeth moved mesially,1.8-mm,with a mesial tipping of 1.5°. The maxillary first molars intruded 0.7 mm, and the first premolars extruded 1.0 mm. Lower anterior facial height increased 2.2 mm; there was no significant difference in lower anterior facial height increase between patients of high, neutral, or low mandibular plane angles. In patients with erupted maxillary second molars, there was a slightly greater increase in lower anterior face height and in the mandibular plane angle and a slightly greater decrease in overbite in comparison to patients with unerupted second molars. Similar findings were observed in patients with second premolar anchorage versus those with second deciduous molar anchorage. The results of this study suggest that the pendulum appliance is effective in moving maxillary molars posteriorly during orthodontic treatment. For maximum maxillary first molar distalization with minimal

increase in lower anterior facial height, this appliance is used most effectively in patients with deciduous maxillary second molars for anchorage and unerupted permanent maxillary second molars, although significant bite opening was not a concern in any patient in this study.

Bolla E, Muratore F, Carano A, Bowman SJ,etal (2002)⁵³evaluated efficacy of Distal Jet with other contemporary methods for maxillary molar distalization on 20 consecutively treated and growing subjects.The crowns of the maxillary first molars were distalized an average of 3.2 mm and tipped distally an average of 3.18⁰, however, the amount of tipping in each case was influenced by the state of eruption of the second molar. In subjects whose second molars had erupted only to the level of the apical third of the first molar roots, distal tipping was almost twice that seen when the second molar had completed their eruption. The center of resistance of the maxillary first molar is close to the trifurcation of the roots, but when the germ of the second molar is an obstacle to distal movement, the center of resistance tends to move superiorly and may lead to greater tipping.

Keles A, Erverdi N, Sezen S.et al(2003)⁵⁴ investigated that palatal implants can be used effectively for anchorage maintenance and in space-gaining procedures.The implant, (4.5 mm diameter,8 mm length)was placed in the palatal region for anchorage. For molar distalization, the Keles Slider appliance was modified ,on the palatal side of the first molar bands, tubes of 0.045-inch diameter were soldered A stainless steel wire of 0.040-inch diameter was attached to the palatal implant and the wire oriented about five mm apical to the gingival margin of the first molars, whichpassed through the tube and oriented parallel to the occlusal plane.A Ni-Ti coil spring, two cm length, 0.045-inch diameter, and 0.010-inch thickness, was placed in between the lock on the wire and the tube in full compression,molars were distalized bodily at 5 month,This method can be used effectively to achieve distalization of molars bodily without anchorage loss.

Gelgor I E,Buyukyilmaz T,Karaman A I Y,Dolanmaz D,Kalayci A (2004)⁵⁵ conducted a clinical study on 25 subjects (11.3 to 16.5 years of age) to investigate the efficiency of intraosseous screws for anchorage in maxillary molar distalization and the sagittal and vertical skeletal, dental, and soft tissue changes after maxillary molar distalization using buccally placed distalizing appliance supported by intraosseous

screw (diameter is 1.8 mm,, lengh is 14-mm) placed 5 mm behind the incisive canal at a safe distance from the midpalatal suture(three mm to the right or left of the raphe.) The screws immediately loaded after healing. A 0.036-inch (0.9 mm) stainless steel transpalatal arch (TPA) was prepared between the first premolars, with a“U” bend touching the screw, The TPA was soldered to premolar band,and u bend was bonded to the intraoral neck section of the screw using light-cured composite resin.Bilateral sectional arches (0.016x0.022-inch stainless steel) and 0.036-inch nickel-titanium open-coil springs were inserted between the first premolar and molar with a continuous force of ;250 g per side to distalize upper first molars or the second molars when they were present, the upper first molars were tipped 8.8° and moved 3.9 mm distally on average. On the dental casts, the mean distalization was 5 mm (in 4.6 months). The upper molars were rotated distopalatally, there was no change in overjet, overbite, or mandibular plane angle. Study found that the, immediately loaded intraosseous screw–supported anchorage unit was successful in achieving sufficient molar distalization without major anchorage loss.md

Park HS, Lee SK, Kwon OW et al,(2005)⁵⁶- evaluated the success rate and clinical considerations for the use of the microcrew implants and know the efficacy of microcrew and sites of miniscrews placement for Group Distal Movement for anchorage.13 patients who had undergone distalization of the posterior teeth using forces applied against microcrew implants were selected. Among them, 11 patients had mandibular micro- screw implants and 4 patients had maxillary implants, including two patients who had both maxillary and mandibular ones at the same time. The first premolar and first molars showed significant distal movement, with no significant distal movement of the anterior teeth was observed. The microscrews placed in the maxillary interradicular bone and mandibular retromolar area provided absolute anchorage for the en- masse distal movement of posterior teeth.The success rate for the microcrew implants was 90% over a mean application period of 12.3 +5.7 months.

Kinzingera Gero S. M; Heiner Wehrbeinb; Peter R. Diedrichc(2005)⁵⁷- did a study on Molar Distalization to investigate whether the Pendulum K is suitable for the translatory Distalization of upper molars, Pendulum K is a Modified Pendulum Appliance— incorporation of a distal screw into the Nance button and the initial application of an uprighting and a toe-in bend in the region of the pendulum

springs. In-vitro analysis of the Force System revealed that all forces and moments remained virtually constant over a three-mm simulated distalization increment and In-vivo study was conducted on children and adolescents and found that molar Distalization was 73.53% of the total movement, Pendulum K allows a virtual translatory molar distalization with slight tippings of 4.75° to the palatal plane and 4.25° to the anterior basal plane, therapeutically desirable mesial outward molar rotation and a transversal expansion of the dental arch had occurred. The quality and quantity of molar Distalization and of reactive incisor protrusion are in direct correlation with the patient's dental age. For example, the values for upper molar distalization and tipping are comparatively higher in the early mixed dentition than in the permanent dentition, whereas mesial incisor movement is less pronounced, the Pendulum K helps prevent undesirable side effects such as pronounced distal tipping and palatal movements of the molars.

Karlsson I, Bondemark L. (2006)⁷-performed a clinical study to evaluate the maxillary molar distalization and anchorage loss in two groups, one before (MD -1 group, mean age-11.4) and one after (MD- 2 group, mean age-14.6 years) eruption of second maxillary molars. 20 patients were taken for each group, and use of an intra-arch NiTi coil appliance with a Nance appliance to provide anchorage. The main outcome measures to be assessed were: treatment time, time in months to achieve a normal molar relation, distal movement of maxillary first molars, and anterior movement of maxillary incisors (anchorage loss). The amount of distal movement of the first molars was significantly greater and the anchorage loss was significantly lower in the group with no second molars erupted. The molar distalization time was also significantly shorter in first group, and thus the movement rate was two times higher. It is more effective to distalize the first maxillary molars before the second molars have erupted.

Gelgor I E, Buyukyilmaz T, Karaman A I Y, Dolanmaz D, Kalayci A (2007)⁵⁸ conducted a clinical study on 40 subjects to evaluate the efficacy of intra osseous screws and also compared the effects of 2 distalization systems supported by intraosseous screws (1.8 mm in diameter and 14 mm in length) which were placed behind incisive canal at a safe distance from the midpalatal suture for augmenting anchorage during molar distalization. In the first group, 20 patients (11.6-15.1 years of age) were treated appliance with the vestibular force vector, prepared with bilateral

sectional arches (0.016 x 0.022-in stainless steel) and 0.036-in nickel-titanium open-coil springs were placed between the first premolar and the molar with a continuous force of 250 g per side and premolar was attached palatally with using modified nance holding arch to intraosseous screws. In the second group, 20 patients (12.3-15.4 yrs of age) were treated with an appliance like Keles appliance in this 0.045-in diameter tubes were soldered on the palatal side of first molar bands, main line extending from 5mm apical to the gingival margin. The mean distal movements were 3.95 mm in group 1 and 3.88 mm in group 2. On the dental casts, the mean distalization amounts were 4.85 mm in 4.6 months for group 1 and 3.70 mm in 5.4 months for group 2, first molars were tipped 9.05° in group 1 and 0.75° in group 2. The study concluded that immediately loaded intraosseous screw-supported anchorage units were successful for molar distalization in both groups. Although both the groups had somewhat same distalization amount, but distalization times were longer and hygiene was poorer in group 2.

Kinzinger GS, Diedrich PR. et al-(2007)⁵⁹-did a vitro study to analyse biomechanics of the acting forces and moments induced by a special orthodontic appliance, the Pendulum K modified by integrating a distal screw into its base and by special preactivation of the pendulum springs, for molar distalization, and suitability of this appliance by conducting vivo study in children and adolescents. The purpose-designed test set-up (artificial maxilla with anchorage unit and two electro-thermodynamic molars, an electronic measuring unit, a unit with force – moment sensor, an analogue/digital converter, and a data read-out unit) allowed simulation of *in vivo* conditions on the one hand and precise determination of the force systems on the other. The appliances investigated were three specimens of the Pendulum K. The in-vitro measurement of the resulting force systems revealed that all forces and moments remained virtually constant over a 3-mm simulated distalization increment (10 activations/mm. The transverse force, F_x , increased from 2 to 11 cN and the weakly intrusively acting force, F_y , from 6 to 8 cN, but these increases were not statistically significant. The distalization force, F_z , initially 201 cN, was still 199 cN after a three-mm Distalization increment. The mesially acting moment, M_y , rose from 1654 to 1834 cN mm, whereas the palatally acting moment, M_z , declined slightly from 229 to 164 cN mm. The slight, consistent distoinclinator moment, M_x , initially 306 cN mm, was 310 cN mm after 3 mm. In parallel in-vivo study with its collective

of 66 patients confirmed that the Pendulum K allows a virtually translatory molar distalization with slight tippings of 4.75° to the palatal plane and 4.25° to the anterior basal plane. This is achieved by continuous adjustment of an incorporated distal screw and by specific pre-activations of the Pendulum springs, all forces and moments remained almost constant over a simulated distalization increment of 3 mm, the addition of a distal screw, and the initial application of uprighting activation and toe-in bends at the end of the Pendulum. The proportion of molar distalization in the total movement was 73.53%. These modifications were aimed at preventing palatal movements and distal tipping of the first molars, md

Kuroda S, Sugawara Y, Deguchi T, Kyung HM, Takano-Yamamoto T.(2007)⁶⁰ evaluated the clinical usefulness of miniscrews as orthodontic anchorage by conducting study on 75 patients, 116 titanium screws of 2 types, and 38 miniplates were retrospectively examined their success rates, analyzed factors associated with their stability, and evaluated patients' postoperative pain and discomfort with a retrospective questionnaire. The success rate for each type of implant was greater than 80%. The analysis of 79 miniscrews with a 1.3-mm diameter showed no significant correlations between success rate and these variables: age, sex, mandibular plane angle, anteroposterior jaw-base relationship, control of periodontitis, temporomandibular disorder symptoms, loading, and screw length. Most patients receiving titanium screws or miniplates with mucoperiosteal flap surgery reported pain, but half of the patients receiving miniscrews without flap surgery did not report feeling pain at any time after placement. In addition, patients with miniscrews reported minimal discomfort due to swelling, speech difficulty, and difficulty in chewing. They concluded that miniscrews placed without flap surgery have high success rates with less pain and discomfort after surgery than miniscrews placed with flap surgery or miniplates placed with either procedure.

Choi NC, Park YC, Lee HA, Lee KJ et al(2007)⁶¹ presented a case report, in which distal movement of the maxillary first molars was done using nickel-titanium coil springs and indirect mini-screw was used for anchorage, along with extraction of the first premolars and maxillary second molars was planned. After the distal molar movement phase was complete, the maxillary first molars had moved 8.0 mm to the distal, and the first premolars, which were splinted to the miniscrews, had moved 0.5 mm to the mesial. To ensure efficient distal maxillary molar movement and prevent

undesirable side effects, miniscrews (7.0 mm length, 1.8 mm diameter) were placed in the maxillary alveolar buccal bone between the second premolar and first molar on both sides, NiTi open-coil springs, guided by a 0.018 _ 0.025-inch stainless steel wire, were used between the maxillary first premolar and the first molar on both sides with a magnitude of 200 to 250gms for applying the distal force. During distal molar movement, additional crimpable hooks were attached loosely, and continuous distal force was applied with an elastomeric chain. After 5 months, the maxillary first molars had moved approximately 4.0 mm distally. After 8 months, distal maxillary molar movement of 8.0 mm was completed. They concluded the advantages of miniscrew anchorage and NiTi coil springs over conventional mechanics using Nance button to reinforce anterior anchorage.

Ruhi Nalçacı, Ali Altuğ Biçakçı, Fatih Ozan (2010)⁶²- investigated efficiency of a screw supported intraoral distalization appliance on 21 subjects. Two screws were inserted behind the incisive foramen and immediately loaded to distalize the upper first molars. SS wire was extended about 7 mm distal to the tube and a “U” bend was made (0.040 inch stainless steel rod) at the level of distal surface of the second molar was performed and extended into the acrylic part of the appliance to enhance its stability. A superelastic heavy open-coil spring is compressed along the rod and activated by Gurin lock, in order for easy intraoral application, a second Gurin lock was placed just behind the tube. Teucher tubes of 0.045-inch diameter were soldered on the palatal side of the first molar bands at the level of the centre of resistance of the first molars. A 1.1 mm diameter stainless steel (SS) wire was oriented parallel to the occlusal plane and passed through the tube. A Ni-Ti coil spring of 25 mm length, 0.055-inch diameter, and 0.014-inch thickness was placed. Upper molars were distalized 3.95 mm on average and a Class I molar relationship was achieved without any anchorage loss. The upper molars were tipped only 1.49° and found that screw supported noncompliance distalization appliance was found to be an effective device for achieving bodily molar distalization without any anchorage loss.

Acar AG, Gürsoy S, Dinçer M. et al (2010)⁶³-The aim of this study was to evaluate the dentoalveolar effects of a pendulum appliance supported buccally by a K-loop, and to compare these with a cervical headgear (CHG) group. The records of 30 patients with skeletal Class I and dental Class II malocclusions were divided into two groups: Patients in group 1 (mean age-15.0 ± 3.4 years) were treated with a pendulum

appliance supported with a K-loop buccally, while in group 2 (mean age- 14.2 ± 2.9 years), the patients were treated with CHG. The mean amount of distalization was 4.53 ± 1.46 mm in group 1 and 2.23 ± 1.68 mm in group 2. The mean amount of distal tipping for group 1 was 5.13 ± 4.90 degrees; the mean amount of mesial tipping for group 2 was 0.80 ± 2.27 degrees. Intrusion and mesiobuccal rotation of the maxillary molars were achieved in both groups. In group 1, the amount of labial protrusion and tipping of the maxillary incisors was not statistically significant. In group 2, palatoversion and retrusion of the maxillary incisors was statistically significant. After insertion of the appliances, the patients were monitored every 3 weeks and the K-loop was activated every 6 weeks. The patients in group 2 were instructed to wear their appliances for 16–20 hours a day and were motivated at each visit. The mean treatment time for both groups was 12 ± 2.9 weeks. In the CHG group, long outer bows were used, which were parallel to the occlusal plane, exerting a force of 400 g. There was no change in the mandibular plane angle. However, in group 2, the maxilla moved backward by 1 mm. The mean amounts of distalization achieved with the pendulum appliance K-loop combination and CHG were 4.53 ± 1.46 mm and 2.23 ± 1.68 mm, respectively. The major advantages of the pendulum appliance K-loop combination were prevention of anchorage loss on the anterior teeth and significantly less distal tipping at the maxillary molars. However, the amount of distal tipping of the molar teeth was still greater than with CHG.

Allyson Bourke, John Daskalogiannakis, Bryan Tompson, et al (2010)⁶⁴ - did an in-vitro study to quantify the properties of commercially available nickel titanium springs. 11 open-coil springs from 3 manufacturers were tested 5 times over a 12-week period. A universal testing machine was used to measure the force generated when open-coil springs were compressed to half of their original length and then gradually allowed to decompress. The results showed that average forces generated at the initial recording session for uniformly wound springs from GAC International (Bohemia, NY) and 3M Unitek (Monrovia, Calif) were 19.3% to 42.7% and 9.7% to 38.8% below the manufacturers' labeled force levels, respectively. GAC's uniformly wound light (100 g) coils generated the lowest load-deflection ratios (23.7 g/mm) and they concluded that open coils might need to be compressed by more than one-third of their original length to produce the labeled forces. Uniformly wound coils generally produce lower load-deflection ratios and maximum forces, which were generally more acceptable for tooth movement. Changes in maximum force magnitude for

uniformly wound coils might be unpredictable. There are significant differences between the opencoil springs from different manufacturers (3M Unitek and GAC International), as well as between uniformly wound and stop-wound springs. All springs had relatively high load-deflection ratios, indicating non superelastic behavior.

Yu IJ, Kook YA, Sung SJ, Lee KJ, Chun YS, Mo SS et al (2011)⁶⁵ - mechanically evaluated the distalization modalities through the application of skeletal anchorage using finite element analysis and compared tooth displacement in molar distalization between buccal mini-implants and palatal plate. Base models were constructed from commercial teeth models. A finite element model was created and three treatment modalities were modified to make 10 models. Modalities 1 and 2 placed mini-implants in the buccal side, and modality 3 placed a plate on the palatal side. Distalization with the palatal plate in modality 3 showed bodily molar movement and insignificant displacement of the incisors. Placing mini-implants on the buccal side in modalities 1 and 2 caused the first molar to be distally tipped and extruded, while the incisors were labially flared and intruded. Distalization with the palatal plate rather than mini-implants on the buccal side provided bodily molar movement without tipping or extrusion. They recommended to use their findings as a clinical guide for the application of skeletal anchorage devices for molar distalization.

Vata L I, Stirbu C, Zetu I, Parcurar M et al (2012)⁶⁶ -described a finite element analysis for upper molar Distalization and found that the rotational axis of first molar was displaced when applying a palatal force for distalisation from buccally – apex to palatal – crown and compressive stress was located on cervical region of distobuccal root. For bodily movement, the moment/force ratio at the molar centre of resistance must be zero, so it is necessary to reduce the moment on the molar band using a counterbalancing couple (CBC) with effects in vertical plane. The displacement of upper molar rotational axis during distalisation is proved by molar rotation and explains the second molar role as a fulcrum, when is not erupted.. On applying palatal force for distalization from buccal aspect, the axis of molar was displaced distally. As per authors bodily movement during distalization could be obtained when centre of rotation is at infinite and compressive stress is homogenously distributed in the periodontal ligament.f

Venkateswaran S, George AM, Anand MK, Devi VRS, Vora SR, Krishnaswamy NR et al (2013)⁶⁷ presented three case report where mini-implants were placed in the maxillary tuberosity region for molar distalization. The most potent advantage of the maxillary tuberosity implants was that implants had no interference with root and any other anatomic structure during placement of mini-implant and there was negligible interference from the roots during tooth movement and method was proved to be efficient for molar distalisation in all the three subjects.

Suzuki EY, Suzuki B et al, (2013)⁶⁸-performed this study to introduce the clinical application of the indirect Palatal miniscrew Anchorage and Distalization Appliance (iPanda) and to describe the dental and skeletal effects obtained with this innovative appliance. Pretreatment (TO), postdistalization (T1), and posttreatment (T2) lateral cephalometric radiographs and dental casts of 20 consecutively treated adult patients (mean age 23.2 ± 4.7 years) with Class II molar relationship were analyzed. I-panda was fabricated on dental cast which includes long teardrop loop of 2mm wide and 10 mm long bend made up of .09 mm round ss wire, bend loop produce custom made self locking system between the heads of two miniscrews and i-panda appliance, in this additional loop wire incorporated bilaterally at the extended arm to allow connection to the light wire single round tubes with hooks that were bonded on the lingual side of maxillary first molar. The distalizing force was delivered through the Niti closed coil springs inserted bilaterally, maxillary first molars were significantly distalized by an average 4.5 ± 1.5 mm in a mean period of 3.2 ± 0.6 months and were intruded by a mean of $1.0 \text{ mm} \pm 0.8 \text{ mm}$. if simultaneous second molar Distalization is planned This study demonstrated that the innovative iPanda is effective way to distalize the maxillary molars bodily and to provide maximum anchorage.

Carla Scanavini Croci¹, Paulo Henrique Ferreira Caria(2015-) evaluated the correlation between the maxillary molar rotation center and the direction of the maximum tooth movement according to the force direction using three-dimensional finite element analysis (3D-FEA). Computed tomography of a human tooth was used to build a finite element model, which comprised the cancellous and cortical bones, the periodontal ligament and the tooth, a 1 N force was applied to the mesial and lingual faces of the maxillary molar to simulate buccal and distal tipping forces on the tooth. The initial displacement of the maxillary first molar was greater for distal tipping than for buccal tipping. The rotation axis for distal tipping in this simulation

was located on the furcation of the first molar. For buccal tipping this axis was on the cervical and middle third of the buccal roots of the maxillary first molar. They concluded that applied movement interferes in molars' crest location. Higher molar tipping is expected when distal movement is applied rather than buccal movement thanks to the close distance between crest and location of the force applied to this movement.

Shashidhar N, Reddy S R K and Madhukar Reddy (2016) compared the K loop molar distalisation with that of Pendulum appliance by performing a clinical study on two groups of 15 each: In Group 1 (nine females and six males; mean age, 16.0 ± 2.6 years) patients were treated with K-Loop molar distalization supported palatally by Nance button, while in Group 2 (seven females and eight males; mean age, 15.4 ± 4.7 years), the patients were treated with conventional pendulum appliance. The results showed no statistically significant difference in the amount of molar distalization in either of the appliance groups: the mean amount of molar distal movement of 5.1 ± 0.8 mm and 4.93 ± 1.68 mm was observed in the Group 1 and 2 respectively. The incisors moved mesially by 1.3 ± 0.63 mm in Group 1 and 1.57 ± 0.58 mm in Group 2 and concluded that K loop molar distalizing appliance had similar skeletal and dento-alveolar effects as that of pendulum appliance.

Noorollahian S, Alavi S, Shirban F. et al (2016)⁷¹ presented a case report to evaluate the clinical effectiveness of bone-anchored mini-screw-supported modified Hyrax appliance for molar Distalization using SAS system presented for bodily and *en-masse* bilateral posterior teeth distalization, in this study mini-screws in paramedian of anterior palate, with acrylic button were used, the appliance was positioned near the palatal vault, 13 mm apical to the occlusal surface of maxillary molars. Anterior legs of Hyrax were bent into eyelet form and attached to the anterior palate with two miniscrews (2×10 mm). Posterior legs of Hyrax were welded to first maxillary molar bands. Hyrax opening rate was 0.8 mm per month. The screw was activated once a week, and produced 3.5-mm bodily distal movement of all posterior teeth simultaneously without anchorage loss was obtained in 5 months, rate of *en-masse* distalization was 0.7 mm per month and faster than *enmasse* distalization with the SAS system.md

Kang J M, Park J H, Bayome M, Park C O, Kook Y A, Mo SS (2016)⁴⁴ conducted a FEM study to evaluate the effects of maxillary second and third molar eruption status on distalization of first molar using modified palatal anchorage plate(MPAP),bone anchored pendulum appliance and cervical head gear.Three eruption stages were established: an erupting second molar at the cervical one-third of the first molar root (Stage 1), a fully erupted second molar (Stage 2), and an erupting third molar at the cervical one-third of the second molar root (Stage 3).The MPAP results showed greater root movement of the first molar than crown movement and this was more noticeable in Stages 2 and 3. The bone-anchored pendulum resulted in distalization, distal and buccal tipping, and intrusion.When the bone anchored pendulum appliance was used in Stage 2,extrusion and increased buccal tipping of the first molar resulted. distal tipping were also seen with headgear. Transversely,mesial out rotation was seen with head gear and mesial in rotation occurred with other devices.Vertically intrusion occurred with MPAP and with other devices caused extrusion of first molar.As per authors application of The second molar eruption stage had an effect on molar distalization, but the third molar follicle had no effect. MPAPwas effective treatment option for maxillary molar distalisation.

Marure PS, Patil RU, Reddy S, Prakash A, Kshetrimayum N, Shukla R. (2016)⁷²- evaluated effectiveness of pendulum, K-loop, and distal jet distalization techniques in growing children and its effects on anchor unit.66 children of mean age 14.13 years requiring molar distalization were divided into three groups: Group I (pendulum appliance), Group II (K-loop), and Group III (distal jet).In overall treatment changes among the three groups, the anteroposterior skeletal changes were not statistically significant, vertically FMA angle increased by $1.79^{\circ} \pm 2.25^{\circ}$ and overbite reduced by 2.38 ± 1.83 mm.The maxillary first molars were distalized by an average of 4.70 ± 3.01 mm in 5 months, the distal movement of maxillary first molars in the Group I was 6.4 mm, In Group II, the mean molar distalization was 2.25 mm. In Group III, the average molar distalization was 3.9 mm.The maxillary central incisor labial tipping increased to an average of 1.61 ± 2.73 mm and cant of upper lip increased by $3.40^{\circ} \pm 5.88^{\circ}$ are statistically significant ($P < 0.05$).All three distalization techniques in growing children produced significant effects on anchor unit.

Singh DP, Arora S, Yadav SK, Kedia NB. et al,(2017)³² presented a case series using newer distalizing appliances, like the Jones Jig, Lokar distalizer and Carrière distalizer, in patients (age range of 15-17 years). First case of the series used the modified nance palatal arch i.e., Jones jig where distalization of molars occurred with the minimum amount of anchor loss, whereas in second case, Lokar distalizer was used where the rest of the bonded upper arch acted as the anchorage unit for the distal molar tooth movement. In the last case, Carrière distalizer was implemented and anchorage was taken from the lower first molars with augmentation of anchorage potential with the help lingual arch placed on the lower jaw. These distalizing appliances which comprised of compact designs, placed buccally and cause minimal discomfort to the patient with limited drawbacks such as anchorage loss resulting in incisor proclination and increased overjet, which can be reversed in phase II /multi-bracket treatment phase.

JH Park, YA Kook, YS Park et al,(2017)⁷³ -conducted a study to evaluate the dental and skeletal effects of the modified C-palatal plate (MCP) 2 The appliances were fitted on dental casts to adapt to the shape of the palatal surface, with their arms extending into the area between the first molars and second premolars. This was fixed with three miniscrews measuring 8 mm in length and 2.0 mm in diameter. Then, a palatal bar with two hooks extending along the gingival margins of the teeth was cemented on the right and left maxillary first molars. Immediately after placement, distalization was initiated by engaging elastics or nickel-titanium closed coil springs between the MCP arm notches and the hooks on the palatal bar, with an approximate force of 300 g per side for total arch distalization in adult patients with Class II malocclusion and compare the findings with those of cervical pull headgear. The mean amount of distalization at the crown and root levels of the maxillary first molar and the amount of distal tipping was 4.2 mm, 3.5 mm, and 3.9o in the MCP group, and 2.3 mm, 0.6 mm, and 8.6o in the headgear group, respectively. Maxillary first molar intrusion was observed in the MCP group, whereas slight extrusion was observed in the headgear group. In both groups, the distal movement of the upper lip and the increase in the nasolabial angle were statistically significant, MCP is an effective treatment modality with improved root control for maxillary molar or total maxillary arch Distalization in comparison to cervical headgear.

Tan, Jun Ming; Liu, Yi-Min; Chiu, Hung-Cheng; and Chen, Yi-Jane et al(2017)⁷⁴- the purpose of this study was to review the papers on methods of molar distalization with use of TADs, potential side effects, and possible range of distalization. In this review, they concluded that the range of molar distalization were 1.4~5 mm in maxillary molars, and 1.6~7 mm in mandibular molars. Maximum maxillary molar distalization of 5 mm and maximum mandibular molar distalization of 7 mm were shown in case reports. Although TADs do help in molar distalization, we still need to consider either extraction or non-extraction method is the best and least time-consuming way to achieve the goals of orthodontic treatment.³

Sanap S, Swami V, Patil A, Deshmukh S, Bhosale V.(2020)⁷⁵- analysed efficacy of infrazygomatic screws and miniscrew in maxillary arch distalization by measuring and comparing the amount of maxillary arch distalization and its effects, on adjacent teeth, by varying the positions of mini-implants by Finite Element Analysis. 3 FEM models were prepared. Model-1: the miniscrews were placed bilaterally between maxillary first and second premolar and between second premolar and first molar at the height of 5 mm from alveolar crest. Miniscrews were inserted at the midpoint between adjacent teeth with 45° angulations relative to the occlusal plane and on the mucogingival junction. Model-2: Infrazygomatic screws were placed between upper first and second molar bilaterally at an angle of 55-70° to maxillary occlusal plane at height of 11 mm from alveolar crest. Model-3: Infrazygomatic screws were placed on the mesio-buccal root of upper first molar bilaterally at an angle of 55-70° to maxillary occlusal plane at height of 11 mm from alveolar crest. The displacement of each tooth was calculated on x, y, and z axes when 200 gm of force was applied on each side from Niti-coil spring for maxillary arch distalization. Maximum amount of maxillary arch distalization was seen when infrazygomatic screws were placed between upper first and second molar in model-2. Whereas maximum amount of maxillary arch intrusion and less distalization was observed when miniscrews were placed between upper first premolar and second premolar and in between second premolar and upper first molar in model-1. There was no bucco-palatal rotation of teeth observed among all three finite element models. Thus infrazygomatic screws and miniscrews are the effective means of maxillary arch distalization for the correction of Class II malocclusion.

Kalpakuri R.,Pisarla M.,Kala T.,Kumar J.S.,Lakshmi B.J.,Kumar B.P. (2021)⁷⁶ did a FEM study to analyze three dimensional movement of first molar during distalization using mini implants , and also compare the buccal and palatal placement of mini implant and their resultant movement.mini implant with 1.2mm,7mm were placed buccally at an angle 90 degree in between second and first molar,on palatal side miniimplants were placed between the buccal roots and molar distalized with MIA-TPA, the molar showed mesial buccal rotation,intrusion with uncontrolled distal tipping on application of 150 gms,on application of 200gms the molar showed buccal rotation,intrusion with uncontrooled distal tipping and extrusion of mesial cusps.on palatal side the molar showed mesio palatal rotation,distal displacement and intrusion of distal cusps and extrusion of mesial cusps which were same on application of 150 and 250 gms of force but the movements were more with 250gms. They concluded that palatal placement shows more distalization and less tipping as it is closer to centre of resistance in comparison to buccal placement of implant but visibility and ease of placement, buccal implant was easier compared to palatal implant.

Suzuki EY, Suzuki B, et al (2021)⁷⁷- did a comparative study of one versus two maxillary molars distalization with iPanda: a finite element analysis and found that for one molar, the stress was concentrated at the furcation and along the distal surface in all roots with a large amount of distalization and distobuccal crown tipping,For two molars, the stress in the first molar was 10 times higher than in the second molar with a great tendency for buccal tipping and a minimal amount of distalization. Moreover, the stress concentration on the distal miniscrew was six times higher than in the mesial miniscrew with an extrusive and intrusive vector, respectively,they concluded that individual molar distalization provides the most effective stress distribution and displacement patterns with reduced force levels. In contrast, the en-masse distalization of two molars results in increased force levels with undesirable effects in the transverse and vertical direction.

Tekale P D,Patil H A,Garg K,Kerudi V V, et al (2022)⁴⁵ conducted a study to assess the stress and displacement effects of mini implant supported K loop for maxillary molar distalisation,mini implant (length-6 mm;diameter-1.4 mm) was placed between roots of maxillary right first molar and right second premolar.A 3D model of the maxilla with all teeth, periodontal ligament, bone, mini-implants, brackets, and archwire was used in this study. The distobuccal movement on the first

molar and second molar were 0.26864 and 0.00833mm respectively. A total of 0.25 mm intrusion movement was seen on distal cusp of the first molar and 0.14 mm extrusion movement seen on mesial cusp of the first molar. Large amount of distal displacement of the first molar was seen, also negligible amount of tipping of the first molar and mesial movement of first premolar was observed.

Hamanaka R, Yamaguchi R, Kuga D, Jinnai S, Komaki H, Tominaga J, Yoshida et al (2022)⁴⁶- analysed a finite element method to assess the efficiency of the proposed technique of molar distalization using Coil Springs and Mini Screws, it is demanded in orthodontics to shorten treatment times by improving force distribution to distalize molars more efficiently. A three dimensional finite element model of an upper dental arch with brackets and an archwire was constructed based on cone-beam computed tomography and analyzed two distalization methods: a conventional grouped distalization technique (NoSp model), and proposed technique using open coils (Sp model). Finite element analyses were performed to evaluate long-term tooth movement in both techniques. The distalization force was more evenly distributed in the Sp model than in the NoSp model. Moreover, less concentration of compressive stress in the periodontal ligament (PDL) was observed in the Sp model. The force systems of the two models became more similar as the distalization progressed. However, the NoSp model still showed higher stress concentration at the end of the simulation. Inserting open-coil springs between distalized teeth improved the distribution of the force significantly. The conventional grouped distalization method might cause stress concentration at the first premolar, indicating risks of the hyalinization of the PDL and root resorption. In this proposed novel technique to distalize the molars efficiently. Inserting open-coil springs between the posterior teeth significantly improved the distribution of the distalization force, and was able to achieve greater amounts of distalization than the conventional grouped distalization in the finite element analysis. The results suggest that the conventional grouped distalization method causes stress concentration at premolars, improvement for more efficient distalization can be achieved by modifying the spring rates between teeth.

Bondemark L, Kurol J, Bernhold M.et al(1994)⁸¹-Did a study on two force system used for molar Distalization,repelling magnet and Niti super coil spring.18 subjects, aged 12.5 to 18.3 years were treated orthodontically using repelling rare earth magnets on one side and superelastic nickel-titanium coils on the contralateral side for simultaneous distalization of maxillary first and second molars.The magnet pair and niticoil spring are placed on sectional bar, the bar was attached to the head gear tube of the maxillary molar, activation was performed by means of ligature wire.The force values of the magnets and the coils were calibrated to 225g at the start of treatment and when reactivation was performed every fourth week. Mean distal molar movement was 3.2 mm for the supercoils and 2.2 mm for the magnets in 6 months of treatment time and found that superelastic coils were more effective than repelling rare earth magnets in achieving molar Distalization.

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 AnaMac Design, FEM Lab Gaziabad, to evaluate and compare stress and displacement in anterior and posterior segments during maxillary molar distalization by two commonly used methods K loop and compressed NiTi open coil spring using finite element method .

The approval was taken from the Ethical Committee of Babu Banarasi Das College of Dental Sciences, before conducting the study. 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. For construction of CAD model-

- A Cone Beam Computed Tomography (CBCT) scan of an adult skull, for maxillary jaw was taken. **(Figure:1)**
- A maxillary arch with all permanent teeth, bone, periodontal ligament (PDL) was modelled with the help of CBCT images.
- CBCT output was converted into a Stereolithographic (STL) file and was sent for further processing.
- Using the data from CBCT scans, two CAD model were constructed for fabrication of finite element model for two methods of molar distalization.

2. Brackets and tube (Figure:2)

- a) MBT brackets of 0.022" X 0.028" slot (Gemini metal bracket, 3M Unitek)
- b) Bondable buccal tubes (triple slot) on first molar with main slot dimension of 0.022" x 0.028" for both right and left side.

3. Elastic modules (ligature tie) (Figure:3)

4. Ligature wire -Soft stainless steel wire of 0.009" diameter (fig 2)

5. Materials used for molar Distalization (Figure:3,4)

- a. Open NiTi coil spring (lumen size-.030")
- b. **Archwire** - 0.019"X 0.025" Rectangular Stainless steel (SS) arch wire, sectional arch wire attached from canine to canine(in K loop mechanics)

c. 0.017x.025” TMA(Titanium molybdenum alloy) wire for K loop fabrication.

6. **Miniscrews** -Mini screw of Titanium of length 6mm and diameter 1.4 mm

Used for reinforcement of anterior anchorage. **(Figure:5)**

7. Software used for creating and analyzing FEM (Finite Element Method)

a. Fusion 360

- Fusion 360 was used to convert CBCT scan into STL format.
- Fusion 360 modeling software was used for the construction of geometric model of maxillary arch from its STL file.

b. Solid works.

- Geometric model of the MBT brackets, SS arch wire, TMA arch wire with K loop, mini-implant, ligature wire and NiTi open coil spring was made using solid works software

c. HYPERMESH 2019

- It was utilized to generate mesh models and number of nodes and elements count.

d. Ansys software

- It was used –
- To integrate the model of the maxilla with the periodontal ligament (PDL), bone, and other components.
- To carry out the simulation of applied loads after applying boundary condition.
- To simulate the finite element results, create result images, and extract information about stress and displacement. The results of the FEA are individual values without any statistical spread, so statistical significance analyses were not performed.

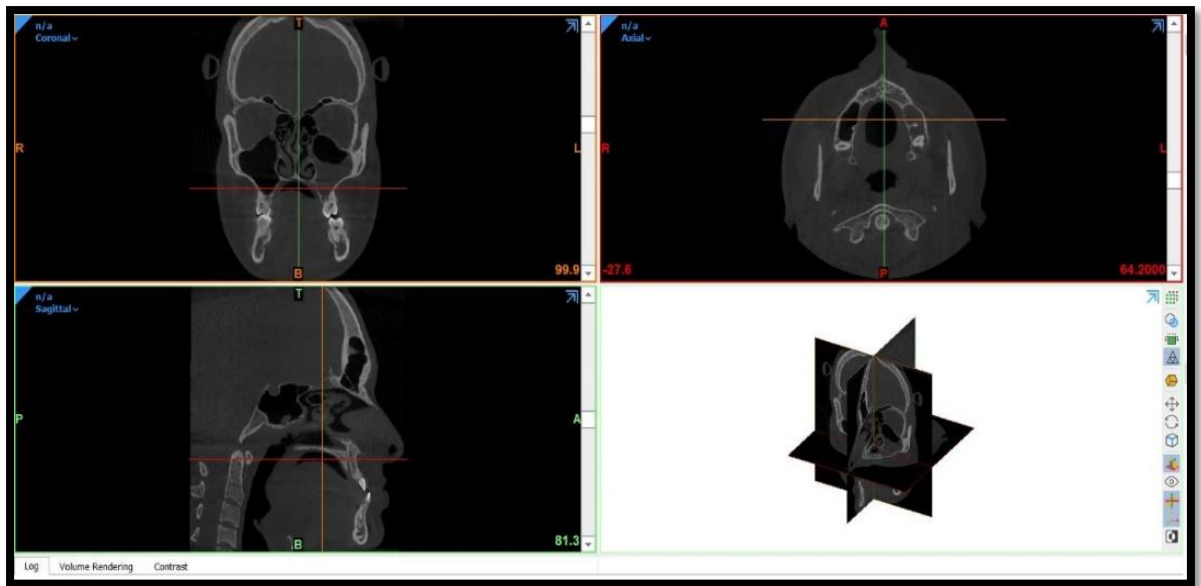


Figure: 1: CBCT images of the maxilla used for the study.



Figure 2: Materials used for bonding on Typhodont

- a)- Typhodont b)- Brackets c)-Buccal tube d)-Bonding materials
e)- bracket holding forcep f)-MBT gauze g)- pencil h)-Curing light



Figure 3 :Materials used for molar distalization using NiTi coil spring on Typhodont a)- NiTi open coil spring, b)Arch wire19x25 SS c) scale, marker, divider d) light wire cutter e)-Mathew forcep f)-Tucker g)-Ligature wire h) Ligature tie

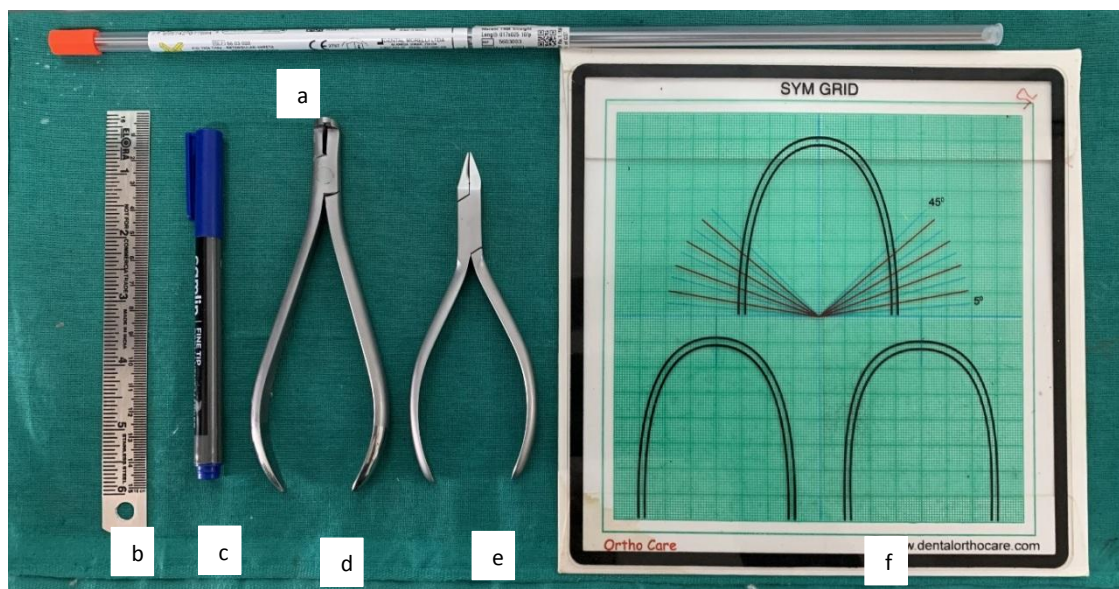


Figure 4 : Materials used for molar distalization using K loop fabrication on Typhodont -17X25 TMA Straight wire b) -Scale c)-Marker d)- Cutter e)-Bird beak plier f) Sym grid



Figure 5 Mini Implant with implant screw driver

Methodology

Construction of Finite Element Model generally involves the following steps:

1.Pre-Processing (Meshing):

- Finite element modelling will be done using suitable element type & size.
- Respective material properties will be assigned.
- Stringent element quality parameters will be followed for the better accuracy of the result
- Boundary Conditions , respective Load & constraints will be applied.

2. Finite Element Solution / Solver:

- FE model will be solved for Structural analysis.

3. Result Interpretation/ Post-processing:

- Pictorial and/or Tabular representation of the stresses. The stress flow in each component will be plotted.

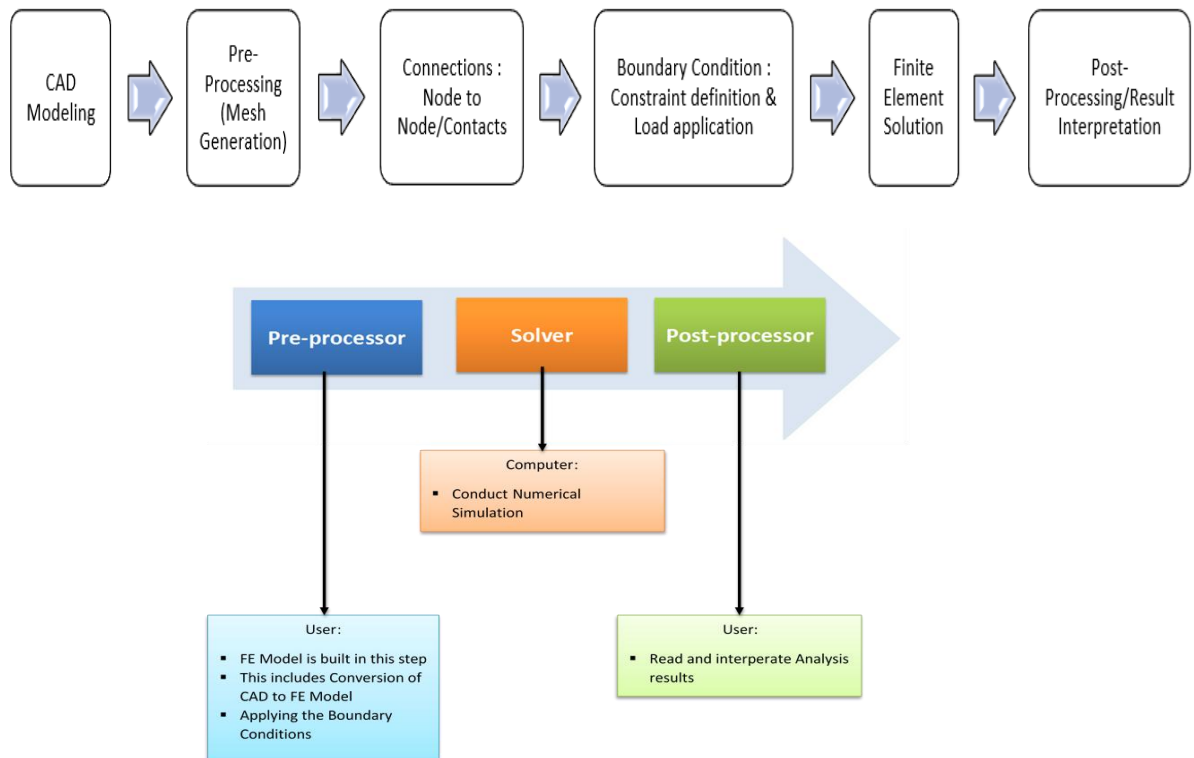


Figure 6: Flow chart showing construction of finite element and processing of results.

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

1. Generation of the CAD Model
2. Construction of the geometric model.
3. Conversion of the geometric models to a finite element model.
4. Incorporation of material properties.
5. Defining boundary condition.
6. Loading configuration.
7. Translation of results and interpretation.

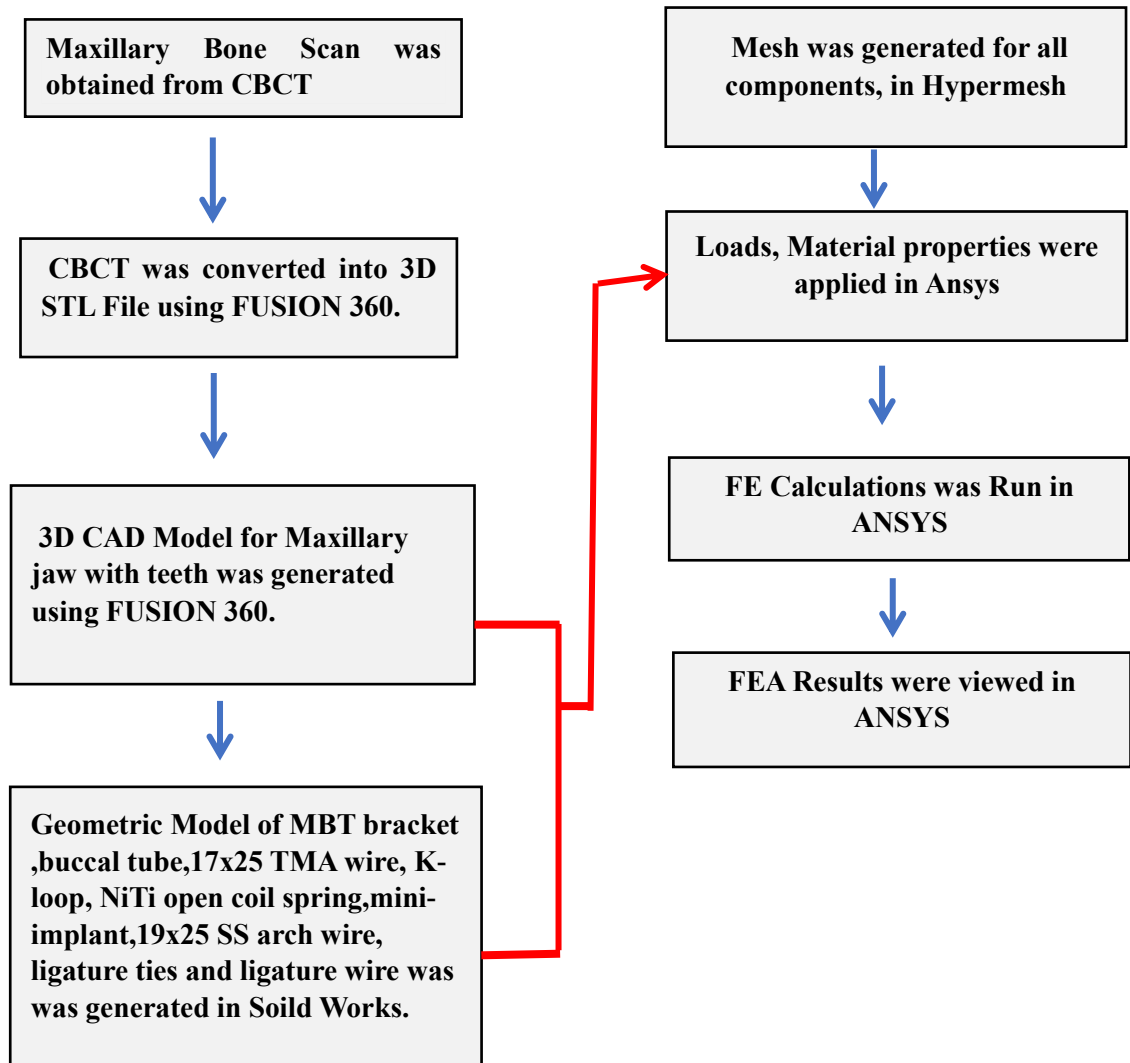


Figure 7- Schematic flowchart showing the steps involved in the study.

1. Generation of STL file of maxilla.

CBCT scan of normal adolescent skull without any skeletal defects, trauma, lesions, and with all of teeth up to second molars,taken, parallel to the Frankfort plane in the axial orientation was obtained from the archives of a reputed CBCT scan centre,.DICOM files were the output of the scan at 0.5 mm interval. These files were imported into Fusion 360 Software to develop a 3D model (Stereolithography (STL) file). Different parts like teeth, jawbone etc. were then extracted from fusion 360 Software by separating them based on bone density. This Stereolithographic (STL) file was exported from fusion 360 Software. **(Figure-8)**

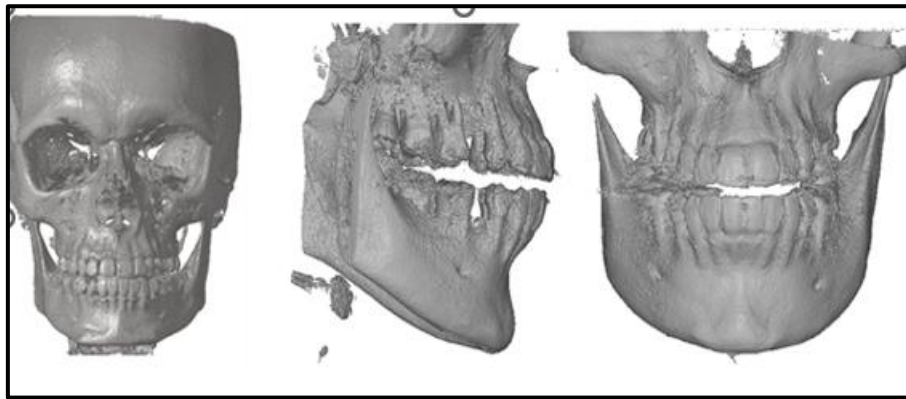


FIGURE 8: STL file of maxilla.

2.Construction of the CAD model of the maxillary arch

Files in stereo-lithography (STL) format were converted into CAD model of maxilla(figure7) using Fusion 360 software. CAD model was exported to 3D image processing and editing software- 3D-Doctor (Able Software Corp., Lexington, Massachusetts, USA), This bone model was then imported in HyperMesh for incorporation of material properties and creating finite element model . **(Figure- 9)**

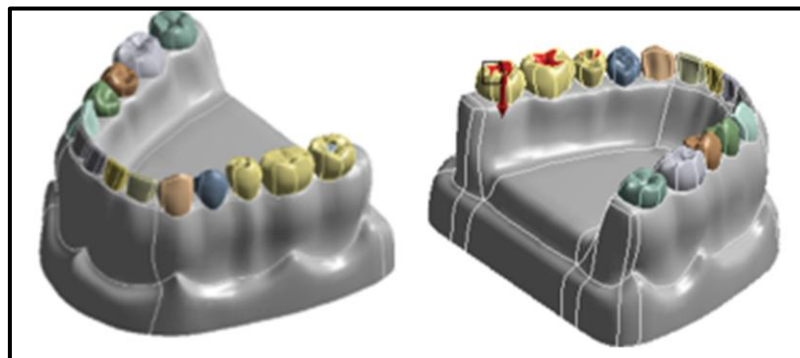


FIGURE 9: CAD model of the maxillary arch

3. Construction of the 2 geometric models of maxillary bone with the whole assembly for the study.

Before fabrication of FEM model , molar distalization using both the methods was explained on typhodont.

(A) Molar distalization using Niti coil spring on typhodont-

1. Maxillary Typhodont was taken
2. MBT brackets were placed from right first premolar to left first premolar, omitting placement bracket on second premolar and placement of buccal tube of maxillary molar.
3. All the teeth of anterior segment from right first premolar to left first premolar were ligated with the ligature wire in figure of eight manner.
4. 0.019'' X 0.025'' SS arch with a open NiTi coil spring compressed three times of interbracket span between first premolar's bracket and first molar's buccal tube was placed on typhodont.
5. Anterior anchorage was reinforced by mini-implant placed between maxillary second premolar and first molar.
6. Complete assembly of 19x 25 SS wire with open Niti coil spring is shown on typhodont. (Figure:10)



Figure 10

Figure 10: Typhodont showing NiTi coil spring and miniscrew

(B) Molar distalization using K loop on typhodont-

- 1 For molar distalization using K loop, sectional 0.019'' X 0.025''SS arch wire was placed from right canine to left canine on the same Typhodont.
2. K loop was fabricated and explained following these steps-(fig-11)
 - a).Start with a straight 0.017" x .025" TMA(Titanium Molybdenum wire), with each loop 8mm long and 1.5mm wide.

- b). Use bird beak plier to give 20° bent down in legs of K loop at sym grid.
 - c). Wire marked at mesial of molar tube and distal of premolar bracket
 - d). Using Bird beak plier bends placed 1 mm mesial to mesial mark and 1 mm distal to distal mark.
 - e). Each stop should be well defined and about 1.5mm long. These bends help keep the appliance away from the mucobuccal fold, allowing a 2mm activation of the K-loop.
- The fabricated K loop was placed on typhodont and miniscrew was placed at same position in group I. (Figure 12)
- f). K loop was compressed between maxillary first premolar and first molar on typhodont.



Figure 12

Figure 12: Typhodont showing K loop and miniscrew

STEP TO FABRICATE K LOOP



Figure 11 a). K-Loop made of .017" x .025" TMA wire, with each loop 8mm long and 1.5mm wide.

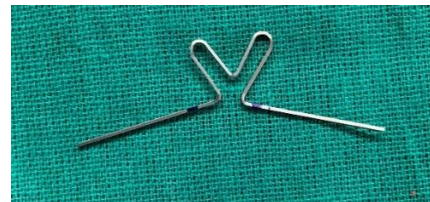


Figure 11 b). Legs of appliance bent down 20°



Figure 11 c). Marking to make stop

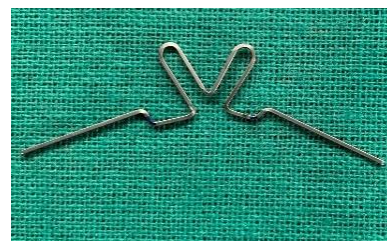


Figure 11 d). Bends placed 1 mm mesial to mesial mark and 1 mm distal to distal mark.

Figure 11: Steps to fabricate K loop

Geometric model of all components as used in both the groups for molar distalization were modelled using FUSION 360 software to make two CAD models that are grouped as follows-(fig 10)

Group I-include CAD model of maxillary arch with assembly of MBT brackets,buccal tube ,19x25 SS arch wire, NiTi open coil spring,ligature wire, and ligature tie used for molar distalization using NiTi open coil spring compressed between first premolar bracket and first molar buccal tube,where anterior anchorage was reinforced by mini screw placed between second premolar and first molar.

(Figure 13)

Group II- include CAD model of maxillary arch with assembly of MBT brackets,buccal tube ,19x25 SS arch wire,Kloop,ligature wire, and ligature tie used for molar distalization using K loop compressed between first premolar bracket and first molar buccal tube,where anterior anchorage was reinforced by mini screw placed between second premolar and first molar.

(Figure 14)



Figure 13: Geometric Model of maxillary arch for molar distalisation using Niti coil spring and mini-implant.



Figure 14: Geometric Model of maxillary arch for molar distalisation using K loop and mini implant

4. Conversion of the geometric models to a finite element model (Figure-11 A,B)

With the help of HyperMesh Software, the geometric models were converted into finite element models and this process is called meshing or mesh generation.

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. As compared to corner nodes, the secondary nodes have less movement.

The finite element model represents geometry in terms of finite elements and the nodes that could be tetrahedron, pyramid, triangular Prism and Hexahedron. This process is called "discretization." In this study, to model the irregular geometry of the teeth, maxilla, wire, bracket, Kloop, mini-implant and NiTi open coil spring, 4-noded tetrahedral shape was selected as the finite element and for modeling a 3-D Quad mesh was used.

Figure 15 and 16 shows FEM model of Group I and II respectively.

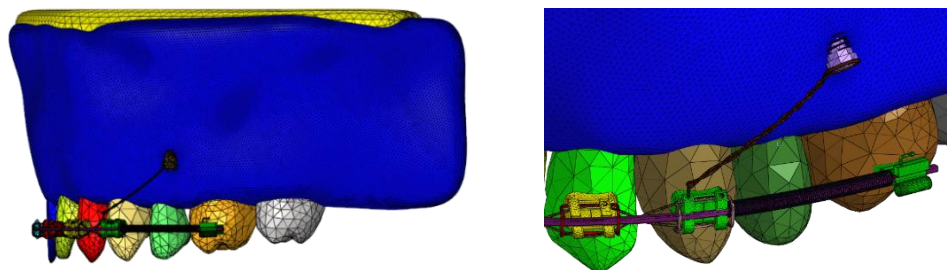


FIGURE 15: FEM Model of maxillary arch for molar distalisation using using Niti coil spring and mini-implant.



FIGURE 16: FEM Model of maxillary arch for molar distalisation K loop and mini-implant.

Collection of nodes and elements leads to the creation of an element mesh that can take the form of a hexahedron or tetrahedron pyramid and nodes ,elements of present study are shown in(Table:1)

Component	No. of Nodes	No. of elements
Teeth	39176	163640
Periodontal Ligament (PDL)	61781	183928
Cortical bone	251254	1084641
Brackets	19805	79148
TMA Wire for K loop	567	985
SS Arch Wire	15222	60080
NiTi open coil spring	6592	28248
Ligature wire	2462	6732
Ligature tie	39176	163640
Mini-implant	18987	81649

TABLE 1 : Number of nodes and elements in present study

5. Incorporation of material properties-

The material properties of teeth, cortical bone, cancellous bone, SS wire, TMA wire, NiTi open coil spring, mini-implant, brackets and buccal tube were taken as per the average values reported in literature. 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)

MATERIALS	YOUNG'S MODULUS (Mpa)	POISSON'S RATIO
Teeth	20,000	0.30
Periodontal ligament	0.05	0.30
Alveolar bone	2,000	0.30
Cortical bone	13,700	0.30
Cancellous bone	1,600	0.30
Stainless steel MBT bracket / molar tube/ arch wire .	2,00,000	0.30
TMA arch wire	42,840	0.30
NiTi open coil spring	80000	0.30
Mini-implant	1,10,000	0.35

TABLE 2 : Material properties as used in present study

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:

For both groups force of 200 grams was simulated using soft ware for molar distalization.

7. Loading Configuration

In this step forces experienced by the model are understood, converted into numerical values with force direction and magnitude.

Stress and displacement in anterior and posterior are obtained by software during simulation of molar distalization was tabulated.

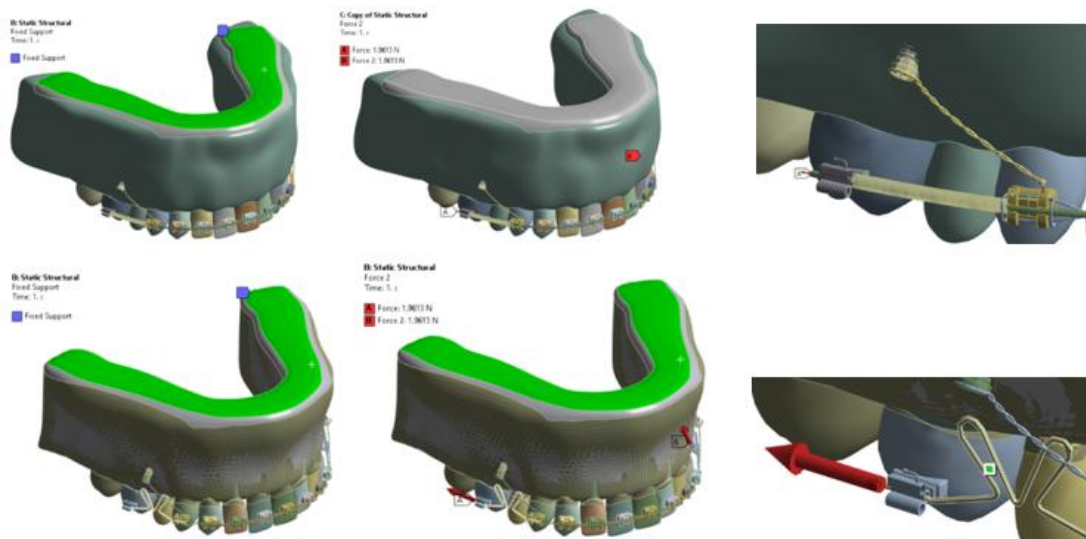


Figure 17: Loading and Boundary Conditions

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. Stresses and displacement were calculated for all FEM models and tabulated.

OBSERVATION AND RESULT - This study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences in collaboration with Anamac FEM LAB Gaziabad with an aim to evaluate and compare stress and displacement in anterior and posterior segments during Maxillary molar distalization by two commonly used methods (compressed NiTi open coil spring and K loop) using finite element method where anterior anchorage was reinforced by miniscrew.

In this study the FEM models were divided in 2 groups based on molar Distalization method as follows. Group I included FEM model where molar distalization was carried out with NiTi open coil spring. Group II included FEM model where K loop assisted molar distalisation was accomplished. In both the models anterior anchorage was reinforced by miniscrew.

FEM analysis results were obtained as displacement of anterior segment including central incisor, lateral incisor, canine, first premolar and posterior segment including second premolar, first molar, second molar and Von Mises stresses of teeth, PDL and bone using contour plots.

The x-axis correspond to the bucco-palatal direction, the y-axis occluso-gingival direction, and the z-axis the antero-posterior direction. A +x value was defined as the labial/ buccal direction, +y as the apical direction, and +z as the mesial direction.

The result of present study for both the groups are tabulated as follows-

Table 3 : Total displacement in anterior and maxillary first molar in both groups

Table 4 : Displacement of anterior and maxillary first molar in X,Y,Z Axis in both groups

Table 5 : Descriptive data of Maximum and minimum Von mises stress for different anatomical structure of both groups

Table 6 : Von Mises stresses over Teeth(MPa)

The result of total displacement seen in anterior and maxillary first molar in both groups of present study are tabulated in **Table: 3**

TABLE: 3

Total Displacement (mm)		
Mechanics	Group I (Niti coil spring)	Group II (K loop)
Segment		
Anterior segment	9.5012×10^{-7} mm	1.1017×10^{-6} mm
Maxillary first molar	1.5273×10^{-6} mm	2.3291×10^{-6} mm

Table 3: Total displacement in anterior and Maxillary first molar in both groups

The amount of distal displacement of Maxillary 1st molar was more in group II than group I with no mesial movement of anterior segment in both groups (figure 18).

The amount of total movement in Maxillary first molar group I and group II, suggestive of molar distalization was 1.5273×10^{-6} mm, 2.3291×10^{-6} mm respectively. In anterior segment amount of distal displacement in group I and II, was 9.5012×10^{-7} mm and 1.1017×10^{-6} mm respectively. (**Group II > Group I**) (Figure 22).

The result of displacement of anterior segment and Maxillary first molar in X,Y,X axes in both groups of present study are tabulated in Table: 5

TABLE:4

Displacement of anterior and Maxillary first molar in X,Y,Z Axis(mm)							
		Group I(Niti coil spring)			Group II(K loop)		
		X-(Trans)	Y-(Vertical)	Z-(A/P)	X-(Trans)	Y-(Vertical)	Z-(A/P)
	Anterior segment	1.472×10^{-7}	1.9242×10^{-7}	9.1793×10^{-7}	1.9175×10^{-7}	2.5125×10^{-7}	8.535×10^{-6}
	Maxillary 1st Molar	4.253×10^{-7}	2.1605×10^{-8}	9.217×10^{-7}	7.2167×10^{-7}	1.9866×10^{-7}	1.2459×10^{-6}

Table:4 Displacement of anterior segment and Maxillary first molar in X,Y,Z Axis in both groups

Anterior segment -The Maximum displacement in Z axis was more in group II (8.535×10^{-7} mm) than in group I (9.1793×10^{-7} mm) in distal direction.

The Maximum displacement in X axis was more in group II (1.9175×10^{-7} mm) was more than group I (1.472×10^{-7} mm).

The Maximum displacement in Y axis, was more in group II (2.5125×10^{-7} mm) than group I (1.9242×10^{-7} mm). (Figure 19,20,21)

Maxillary first molar-

The uniform displacement of Maxillary 1st molar was seen in group II in comparison to group I in Z axis as crown and root showed uniform color codes from group II than group I.

Molar distalization achieved as seen by displacement of Maxillary first molar in group II in Z-axis was more in group II (1.2459×10^{-6} mm) than group I (9.217×10^{-7} mm).

The Maximum displacement in X axis was more in group II (7.2167×10^{-7} mm) than group I (4.253×10^{-6} mm) in mesio-buccal direction.

The Maximum displacement in Y axis was more in group II (1.9866×10^{-7} mm) than group I (2.1605×10^{-8} mm) in apical direction. (Figure 23,24,25)

DISPLACEMENT IN ANTERIOR SEGMENT IN GROUP- I AND GROUP II

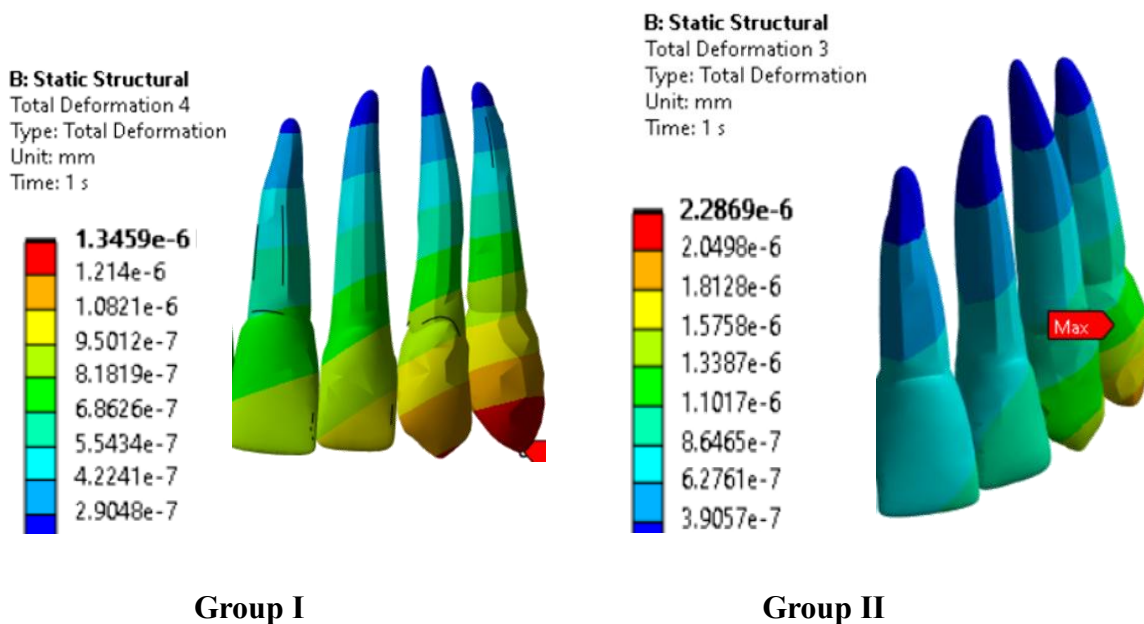
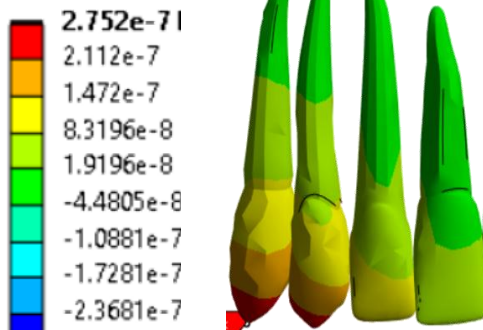


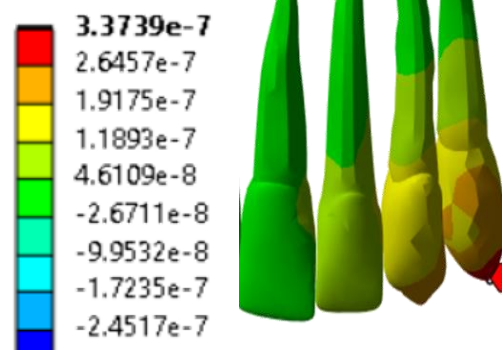
Figure- 18 Total Displacement in Group- I and Group II

B: Static Structural
 Directional Deformation 7
 Type: Directional Deformation
 Unit: mm
 Global Coordinate System
 Time: 1 s



Group I

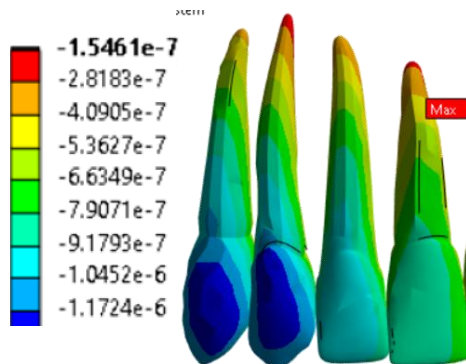
B: Static Structural
 Directional Deformation 7
 Type: Directional Deformation
 Unit: mm
 Global Coordinate System
 Time: 1 s



Group II

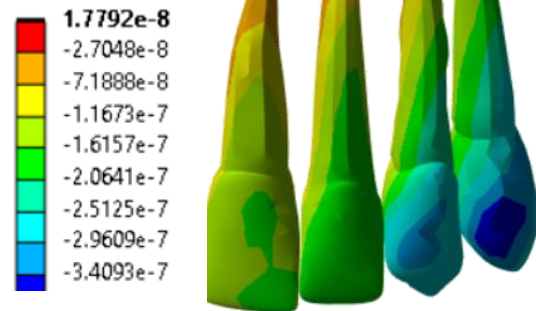
Figure- 19 Displacement In X-Axis (Transverse) In Group- I And Group II

B: Static Structural
 Directional Deformation 9
 Type: Directional Deformation
 Unit: mm
 Global Coordinate System
 Time: 1 s



Group I

B: Static Structural
 Directional Deformation 8
 Type: Directional Deformation
 Unit: mm
 Global Coordinate System
 Time: 1 s

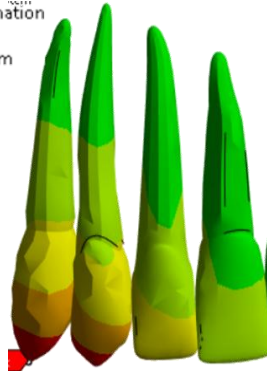


Group II

Figure- 20 Displacement in Y-axis (Vertical) in Group- I and Group II

B: Static Structural
 Directional Deformation 9
 Type: Directional Deformation
 Unit: mm
 Global Coordinate System
 Time: 1 s

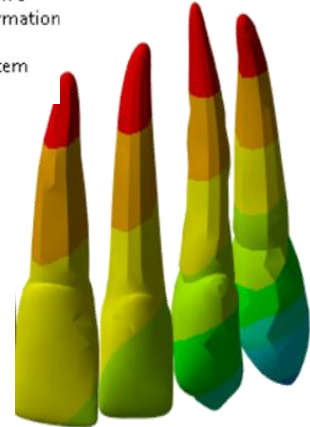
-1.5461e-7
 -2.8183e-7
 -4.0905e-7
 -5.3627e-7
 -6.6349e-7
 -7.9071e-7
 -9.1793e-7
 -1.0452e-6
 -1.1724e-6



Group I

B: Static Structural
 Directional Deformation 9
 Type: Directional Deformation
 Unit: mm
 Global Coordinate System
 Time: 1 s

-1.5004e-7
 -3.8453e-7
 -6.1902e-7
 -8.5351e-7
 -1.088e-6
 -1.3225e-6
 -1.557e-6
 -1.7915e-6
 -2.026e-6



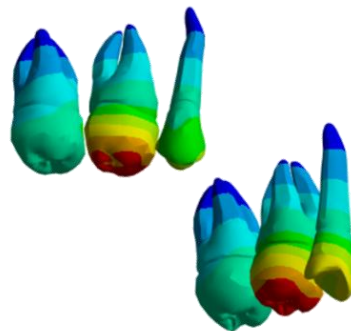
Group II

Figure- 21 Displacement In Z-Axis (Antero Posterior) In Group I And Group II

DISPLACEMENT IN MAXILLARY FIRST MOLAR

B: Static Structural
 Total Deformation 5
 Type: Total Deformation
 Unit: mm
 Time: 1 s

2.0868e-6
 1.9003e-6
 1.7138e-6
 1.5273e-6
 1.3408e-6
 1.1543e-6
 9.6782e-7
 7.8133e-7
 5.9484e-7

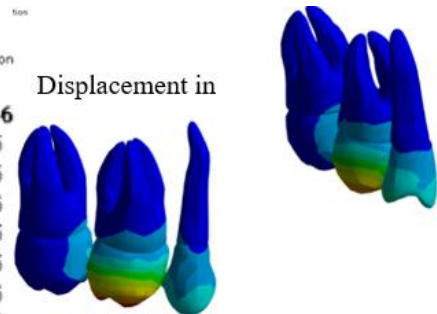


Group I

B: Static Structural
 Total Deformation 2
 Type: Total Deformation
 Unit: mm
 Time: 1 s

9.0218e-6
 8.0657e-6
 7.1096e-6
 6.1535e-6
 5.1974e-6
 4.2413e-6
 3.2852e-6
 2.3291e-6
 1.373e-6

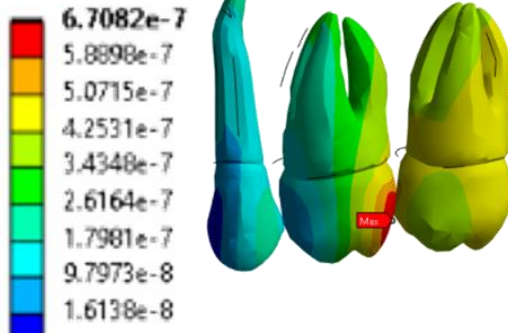
Displacement in



Group II

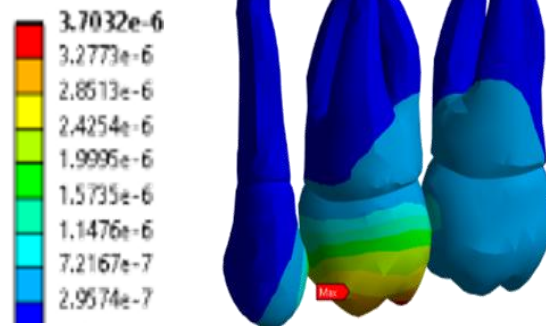
Figure- 22 Total Displacement In Group- I and Group II

B: Static Structural
Directional Deformation 4
Type: Directional Deformation
Unit: mm
Global Coordinate System
Time: 1 s



Group I

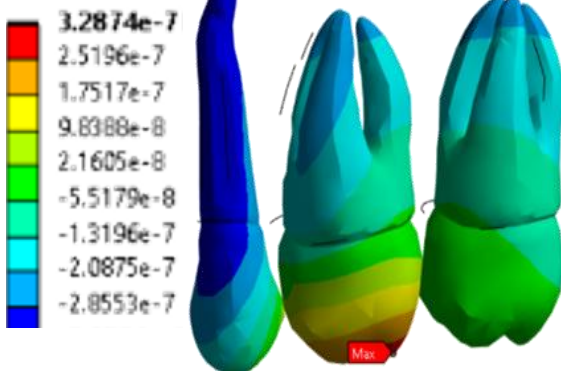
B: Static Structural
Directional Deformation 4
Type: Directional Deformation
Unit: mm
Global Coordinate System
Time: 1 s



Group II

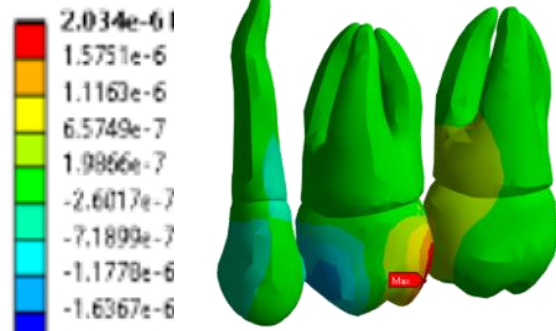
Figure- 23 Displacement in X-axis (Transverse) Group- I and Group II

B: Static Structural
Directional Deformation 5
Type: Directional Deformation
Unit: mm
Global Coordinate System
Time: 1 s



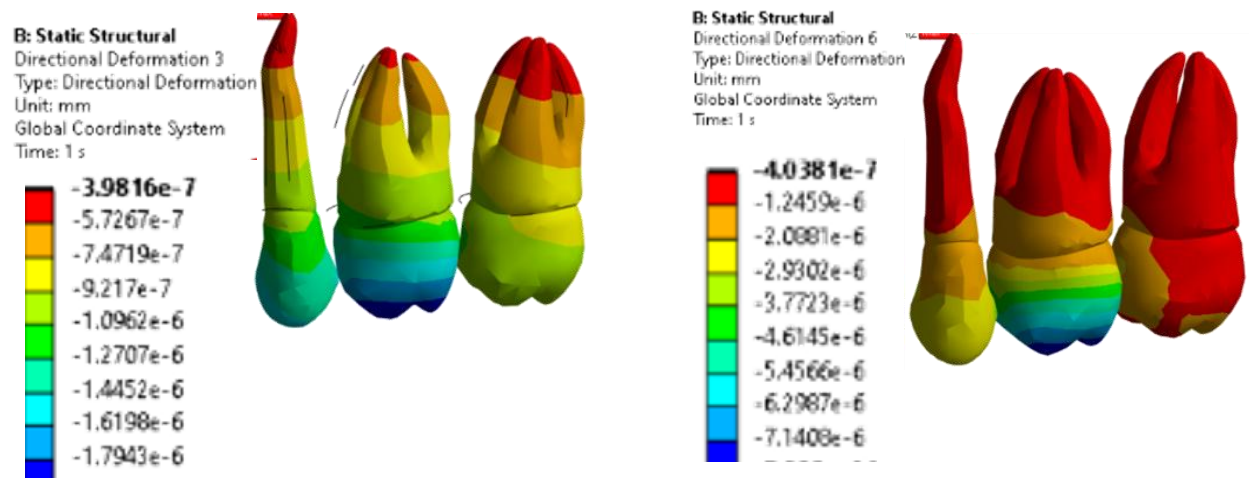
Group I

B: Static Structural
Directional Deformation 5
Type: Directional Deformation
Unit: mm
Global Coordinate System
Time: 1 s
(Y Axis)



Group II

Figure- 24 Displacement in Y-axis (Vertical) Group- I and Group II



Group I

Group II

Figure- 25 Displacement in Z axis(Antero Posterior) Group- I and Group II

The result of Maximum and minimum Von mises stress in different anatomical structure in both the groups of present study are tabulated in Table:

TABLE: 5

VON MISES STRESS(MPa)								
Anatomical structure	Group I(Niti coil spring)				Group II (K loop)			
	Maximum stress	Region	Minimum stress	Region	Maximum stress	Region	Minimum stress	Region
Teeth	0.038512	Mesial portion of 1 st molar	.004279	Anterior segment (CI to canine)	0.027658	Mesial portion of 1 st molar	.003073	Anterior segment(CI to 1 st PM)
Root	0.015775	Palatal aspect of 1 st molar	.001755	Anterior segment from CI to canine	1.9714x10 ⁻⁷	Palatal aspect of root	2.19x10 ⁻⁸	Anterior segment except 1 st PM
PDLs	0.033018	Between 2 nd pre-molar , 1 st molar	.00366	Anterior segment including 1 st PM	0.1351	At mesial aspect over 1 st molar	.0150	Anterior segment
Cortical bone	0.019963	Buccal cortical plate between 1 st molar and 2 nd molar	.002315	Anterior segment except 1 st PM	0.025197	Buccal and palatal alveolar cortical plate of 2 nd premolar 1 st molar	.00288	Anterior segment except 1 st PM
Cancellous bone	0.024969	Buccal aspect of 1 st premolar,	.00286	Anterior segment except 1 st PM	0.047512	Distal and mesial interradicular bone of first molar and mesial interradicular bone of second molar Furcation area of 1 st molar	.00537	Anterior segment except 1 st PM

TABLE 5: Discriptive data of Maximum and minimum Von mises stress for different anatomical structure of both groups

Von Mises Stress for different anatomical structures of both the groups:

1)TEETH- For teeth,Maximum vonmises stress had higher value in group I (**0.038512Mpa**) than group II (**0.027658MPa**) and was on mesial aspect of 1st molar for group I as well as group II.

For teeth minimum Von Mises Stress had higher value in group I (**.004279MPa**) than group II (**.003073 MPa**) and was seen in anterior segment (incisors to canine) in group I , in anterior segment(incisors to 1st premolar) in group II. (Figure 26)

2)ROOT-For root Maximum von mises stress had higher value in group I than group II.

Von Mises Stress had Maximum value of on palatal aspect of 1st molar for both group . ,group I (**0.015775MPa**) , for group II (**1.9714x10⁻⁷MPa**). (Figure 27)

For root minimum von mises stress had higher value in group I than group II.

Von Mises Stress had minimum value of on anterior segment (incisors to canine)for both groups,group I (**1.9714x10⁻⁷ MPa**) , for group II(**2.19x10⁻⁸ MPa**).

3)PDL- For PDL Maximum von mises stress had higher value in group II than group I.

Von Mises Stress had Maximum value between 2nd premolar and 1st molar for ,group I (**0.033018 MPa**) , for group II at at palatomesial aspect over 1st molar (**0.1351MPa**) and homogenous stress surrounding the molars.

For PDL minimum von mises stress had higher value in group II than group I.

Von Mises Stress had minimum value of on anterior segment (incisors to 1st premolar)for both groups,group I (**.00366MPa**) , for group II(**.0150MPa**). (Figure 28)

4)CORTICAL BONE- For cortical bone Maximum von mises stress had higher value in group II than group I.

Von Mises Stress had Maximum value at Buccal, lingual cortical plate of 2nd premolar and 1st molar and interradicular bone of 2nd premolar , 1st molar and 2nd molar for ,group I (**0.019963MPa**) , for group II , Buccal and palatal alveolar cortical plate of 2nd premolar and 1st molar (**0.025197MPa**).

For cortical bone minimum von mises stress had higher value in group II than group I.

Von Mises Stress had minimum value of on anterior segment (incisors to canine)for both group, group I (**.002315 MPa**) for group II (**.00288MPa**). (Figure 29)

5) CANCELLOUS BONE-for cancellous bone Maximum von mises stress had higher value in group II than group I.

Von Mises Stress had Maximum value at distal and mesial interradicular bone of first molar and mesial interradicular bone of second molar for group I (**0.024969 MPa**) for group II at distal and mesial interradicular bone of first molar and mesial interradicular bone of second molar Furcation area of 1st molar(**.047512 MPa**).

For cancellous bone minimum von mises stress had higher value in group II than group I.

Von Mises Stress had minimum value of on anterior segment (incisors to canine)for both group, group I(**.00286MPa**) for group II(**.00537MPa**). (Figure 30)

Von mises stress of both the groups over the teeth in anterior and posterior segment are tabulated in Table :-

TABLE: 6

Von Mises stresses over teeth (MPa)				
Segment		Region	Group I	Group II
Anterior segment		Apex	.0042793	.0030733
		Occlusal	.0042793	.0030733
Posterior segment	2nd premolar	Apex	.0042793	.0030733
		Occlusal	.0042793	.0030733
	1st molar	Apex	.0042793	.0030733
		Occlusal	.017117	.012292

TABLE: 6 Von Mises stresses over Teeth(MPa)

For both the groups ,von mises stress at apex and occlusal surface was same for all anterior teeth(incisors,canineand 1st premolar),von mises stress for group I was (**.0042793 MPa**) both at apex and occlusal reference point,whereas for group II lesser values of(**.0030733MPa**) was seen both for apex and occlusal reference point.

In posterior segment, 2nd premolar had lesser stress values for group II (**.0030733 MPa**), both at apex and occlusal surface than group I (**.0042793MPa**) both apex and occlusal surface.

For 1st molar higher von mises stresses have been seen at occlusal surface in comparison to apex for both the group I and group II.

For group I von mises stress at apex (**.0042793MPa**) had lesser values than at occlusal surface (**.017117MPa**).

For group II von mises stress at apex (**.0030733 MPa**) had lesser values than at occlusal surface (**.012292MPa**)

On inter group comparison, von mises stress both at apex and occlusal surface of 1st molar was more in group I than group II.

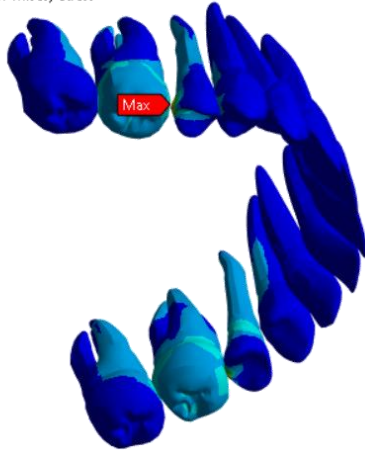
VON MISES STRESS FOR GROUP I AND II

Maximum Stress in Teeth is 0.038512 MPa

Maximum Stress in Teeth is 0.027658 MPa

B: Static Structural
Equivalent Stress 5
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s

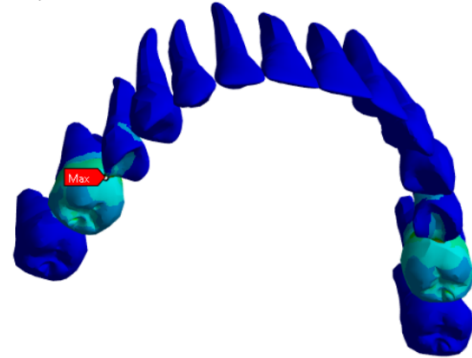
0.038512 Max
0.034233
0.029954
0.025675
0.021396
0.017117
0.012837
0.0085584
0.0042793
2.3461e-7 Min



Group I

B: Static Structural
Equivalent Stress 6
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s

0.027658 Max
0.024585
0.021512
0.019439
0.015366
0.012292
0.0092194
0.0061463
0.0030733
2.2364e-7 Min

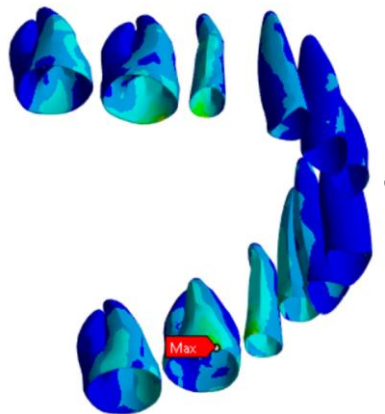


Group II

Figure- 26 Maximum Stress in Teeth in Group I and Group II

Maximum Stress in root is 0.015775 MPa

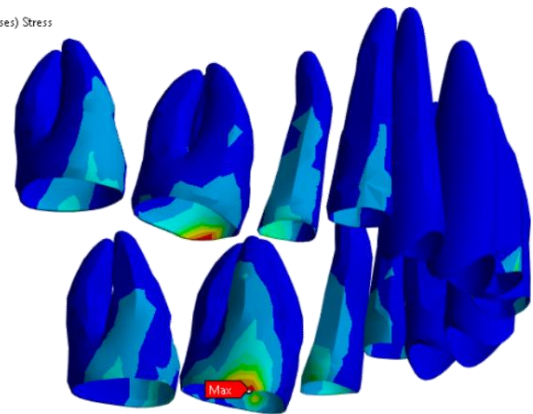
Maximum Stress in root is 1.9714e-7 MPa



Group I

B: Static Structural
Equivalent Stress 5
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s

1.9714e-7 Max
1.7524e-7
1.5333e-7
1.3143e-7
1.0953e-7
8.7623e-8
6.572e-8
4.3816e-8
2.1913e-8
9.8875e-12 Min



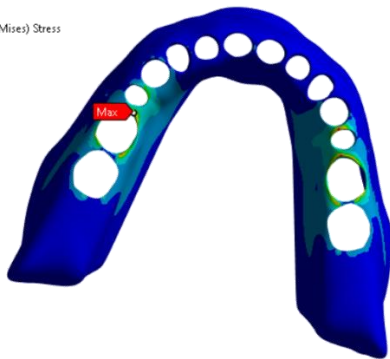
Group II

Figure- 27 Maximum Stress in root in Group I and Group II

Maximum Stress in PDL is 0.033018 MPa

B: Static Structural
Equivalent Stress 2
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s

0.033018 Max
0.02935
0.025681
0.022012
0.018944
0.014675
0.011006
0.0073375
0.0036688
6.4337e-8 Min

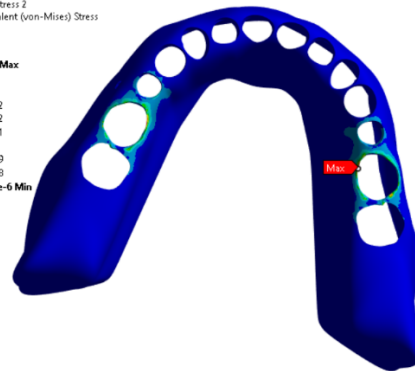


Group I

Maximum Stress in PDL is 0.1351 MPa

B: Static Structural
Equivalent Stress 2
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s

0.1351 Max
0.12009
0.10508
0.090072
0.075062
0.060051
0.045044
0.030039
0.015018
7.6244e-6 Min



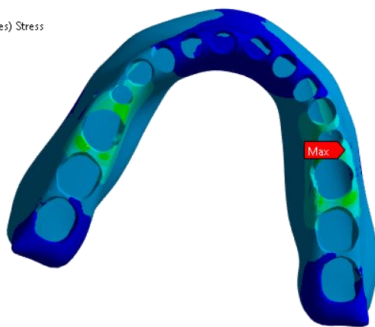
Group II

Figure- 28 Maximum Stress in PDL in Group I and Group II

Maximum Stress in cortical bone is 0.019963

B: Static Structural
Equivalent Stress 3
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s

0.019963 Max
0.017757
0.015551
0.013345
0.011139
0.0089333
0.0067274
0.0045214
0.0023155
0.00010953 Min

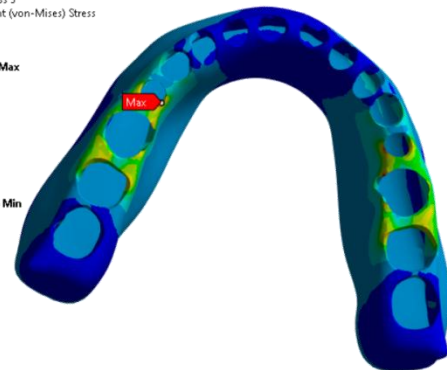


Group I

MPa Maximum Stress in cortical bone is 0.025197 MPa

B: Static Structural
Equivalent Stress 3
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s

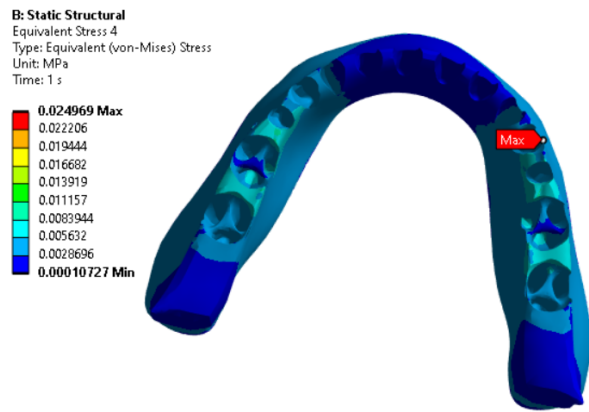
0.025197 Max
0.022408
0.019619
0.016831
0.014042
0.011253
0.0084644
0.0056757
0.0028869
9.8176e-5 Min



Group II

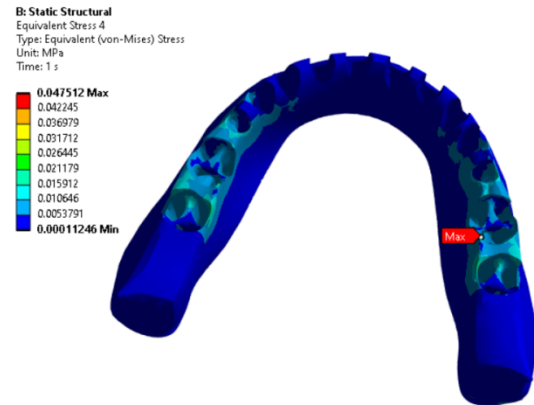
Figure- 29 Maximum Stress in cortical bone in Group I and Group II

Maximum Stress in cancellous bone is 0.024969 Mpa



Group I

Maximum Stress in cancellous bone is 0.047512 MPa



Group II

Figure- 30 Maximum Stress in cancellous bone in Group I and Group II

Class II Malocclusion is a commonly encountered malocclusion in the anteroposterior plane¹ and usually presents with tooth size and arch length discrepancy². The treatment of such cases can be done by extraction of premolars or by following non-extraction treatment modalities like expansion or molar distalization^{3,4}.

The indications for molar distalization include that patient should have class I skeletal pattern with straight profile, Angle's class II or end on molar relationship with mild maxillary dental protrusion, mild to moderate crowding, low to moderate mandibular plane angle, good facial balance and preferably unerupted second or third molar. The contra-indications included protrusive profile or proclined incisors, increased overjet, hyperdivergent growth pattern and posterior crowding.⁵

Molar distalization can be done by extraoral methods (compliant) and intraoral methods (non-compliant).^{4,5}

Among extraoral methods head gear achieved effective molar distalization however needed patient compliance and had never been an esthetically pleasing option for the patients¹¹. Intraoral appliances for effective molar distalization, are simple to construct and use, and are a good alternative for non-compliant patient. Among intraoral appliances⁷, molar distalization can be achieved by inter-maxillary and intra maxillary appliances¹¹. Intra-maxillary appliances, that can be attached from labial side (Jones Jig,²¹ K loop²², Repelling magnets²³, Wilson arch, and Niti coil spring²⁵, mini-implant)²⁶ or palatal side (Pendulum appliance, Distal jet¹⁷, Goshgarian TPA¹⁸, Skeletal frog appliance¹⁹, and mini-implant²⁶).

Intraoral methods can produce bodily or tipping movement of maxillary molars depending on direction of force vector with respect to center of resistance of maxillary molar and may cause mild anchorage loss of mesial segment.^{1,28}

The appliances that apply force from palatal aspect were more nearer to the centre of resistance, hence overcame the disadvantages of buccally placed appliances used for distalizing maxillary molars by reducing the tendency for the teeth to tip, thus producing bodily tooth movement with negligible crown tipping²⁹.

However intraoral appliance placed palatally had inherent disadvantages of being bulky, obstructing the tongue space and making it less comfortable for patients. Hence

appliances placed buccally for molar distalization are preferred as being simple, easy to use and less cumbersome. Among buccally placed appliance few are available commercially like Jones Jig, repelling magnets, Lokar distalizer etc that poses additional expenses to be borne by the patient whereas other appliances that can be fabricated chair side using commonly available orthodontic inventory like Niti coil spring and K loop were used in present study.

The potential limitation of any molar distalization is mild anchorage loss of anterior segment. Acrylic button placed in palate had been used conventionally to prevent the anterior anchorage loss. Recently TAD's (Temporary Anchorage Devices) are used to augment anchorage of anterior segment thereby negating reactive forces of molar distalization.²⁶

Hence for both the methods (K-loop and Ni-Ti coil spring) selected in the present study for molar distalization, anchorage of anterior segment was augmented by miniscrew placed on buccal interradicular bone between second premolar and first molar of maxillary arch.

Several clinical and in-vitro studies have been conducted to investigate the performance of different distalization appliances and to evaluate the type, amount, and rate of tooth movement. However, little information regarding the pattern of the mechanical stresses in the tissue surrounding teeth during molar distalization is available. As quantification of stresses in clinical studies is difficult therefore, various in-vitro methods had been proposed to quantify stresses such as- photo elastic stress analysis, mathematical models, laser holography and finite element method. Among these FEM which quantitatively assess the stress and strain distribution generated in response to various biomechanical settings in orthodontics was selected in present study.³⁸

Considering this it was decided to do 3-Dimensional finite element analysis of two commonly used methods of molar distalization, K loop²² and open NiTi coil spring²⁵ compressed between maxillary 1ST premolar and 1st molar and anterior anchorage was reinforced with miniscrew placed between second premolar and first molar in present study.

This comparative 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 AnaMac Design, FEM Lab Gaziabad.

A maxillary arch was modelled on the basis of CBCT images. FUSION 360 software was used to convert CBCT into STL format to CAD model of maxillary arch. Geometric Model of MBT bracket, buccal tube, 17x25 TMA wire, K-loop, NiTi open coil spring, mini-implant, 19x25 SS arch wire, ligature ties and ligature wire was generated in Solid Works software from CAD models. Hyper mesh software was used to create mesh models and also used to fuse the model of maxilla with PDL, bone and complete assembly of brackets, molar tube, arch wire, NiTi open coil spring, crimpable hook, stainless steel archwire of 0.019"x0.025" inch and K-loop (made with 17x25 TMA wire) etc. to make FEM model. Material properties were incorporated for teeth, PDL, bone, stainless steel and TMA. Two finite element models were generated and boundary condition was applied. Group I included FEM model where molar distalization was carried out with NiTi open coil spring and Group II included K-loop assisted molar distalization, in both the FEM models anterior anchorage was reinforced by miniscrew placed buccally between 2nd premolar and 1st molar. The displacement of each tooth was calculated on x, y, and z axes, and the von Mises stress distribution was visualized using color-coded scales on application of 200 grms of force to achieve molar distalization using Hypermesh software.

The displacement in mm and stress distribution patterns of the anterior segment (which include incisors, canine and 1st premolar) and maxillary 1st molar with regard to distalizing force vectors applied from K-loop and NiTi coil spring where anterior anchorage was reinforced by interdental miniscrews placed between 2nd premolar and 1st molar was measured and tabulated.

The result of the present study showed greater amount of molar distalization in group II (K-loop) than group I (Niti coil spring). Mini screw assisted augmentation of anterior anchorage helped in preventing anterior anchorage loss and both the groups showed distal movement of anterior segment (Group II > Group I).

Displacement-**Maxillary First molar**

The uniform displacement of maxillary 1st molar was seen in group II in comparison to group I in Z axis as crown and root showed uniform color codes from group II than group I.

Molar distalization achieved as seen by displacement of posterior segment in group II in Z-axis was more in group II ($1.2459 \times 10^{-6} \text{ mm}$) than group I ($9.217 \times 10^{-7} \text{ mm}$). The maximum displacement in X axis was more in group II ($7.2167 \times 10^{-7} \text{ mm}$) than group I ($4.253 \times 10^{-6} \text{ mm}$) in mesio-buccal rotation. The maximum displacement in Y axis was more in group II ($1.9866 \times 10^{-7} \text{ mm}$) than group I ($2.1605 \times 10^{-8} \text{ mm}$) in apical direction.

Anterior segment -The maximum displacement in Z axis was more in group II ($8.535 \times 10^{-7} \text{ mm}$) than in group I ($9.1793 \times 10^{-7} \text{ mm}$) in distal direction. The maximum displacement in X axis was more in group II ($1.9175 \times 10^{-7} \text{ mm}$) was more than group I ($1.472 \times 10^{-7} \text{ mm}$). The maximum displacement in Y axis, was more in group II ($2.5125 \times 10^{-7} \text{ mm}$) than group I ($1.9242 \times 10^{-7} \text{ mm}$).

The result of present study were compared to previous FEM studies and that evaluated distalization of molar using variable force, with different treatment modalities.

In a study by **Tekale et al**,⁴⁵ the displacement of maxillary 1st molar was 0.268 mm in disto buccal direction in X axis; was 0.008 mm for root and was 0.706 mm for crown in distal direction in antero posterior plane was 0.14 mm on mesio buccal cusp in occlusal direction, 0.25 mm apical movement of disto buccal cusp in occluso gingival plane.

In anterior segment they found mesial movement of 1st premolar as 0.006 mm for crown and 0.003 mm for root.

In a study by **Hamanaka et al**,⁴⁶ FEM model with sectional Niti coil spring placed between 1st premolar and 2nd premolar (force applied was 3 N), 2nd premolar and 1st molar (force applied was 2 N), 1st molar and 2nd molar (force applied was 1 N) had more distalisation than conventional (no spring model), where E-chain was used from 1st premolar to miniscrew placed between 1st and 2nd molar and exerting force of 4 N.

Distalization achieved was 1.5 times more in group with Niti coil spring (0.57mm,0.54mm,0.36mm,0.33mm for 1st premolar, 2nd premolar, 1st molar and 2nd molar respectively) and in group when Niti coil spring was not used displacement was 0.59mm, 0.52mm, 0.31mm and 0.22mm for 1st premolar, 2nd premolar, 1st molar and 2nd molar respectively.

Kang et al⁴⁴ compared 3 molar distalizing methods modified palatal anchorage plate (MPAP) Bone-anchored pendulum appliance and Cervical-pull headgear (CPHG) using FEM. The model where 2nd molar was fully erupted would be compared to the present study.

They found distal displacement of maxillary 1st molar as 3.94×10^{-6} mm in Y axis; 3.24×10^{-6} mm in X axis and 8.85×10^{-6} mm in apical direction in Z axis for MPAP; for bone anchored pendulum appliance distal displacement was 0.99×10^{-6} mm in Y axis, was 3.57×10^{-6} mm in X axis and 0.01×10^{-6} in apical direction in Z axis; for CPHG distal displacement was 2.55×10^{-6} mm in Y axis, was 10.20×10^{-6} mm in X axis and 3.78×10^{-6} in apical direction in Z axis.

For anterior segment mesial displacement of incisal edge of central incisor was seen to be same (0.06×10^{-6} mm) for MPAP and bone anchored pendulum appliance whereas no mesial movement was seen for CPHG. They found MPAP had greatest distalization among these 3 groups.

On comparing results with present study, molar distalization achieved with K loop was similar to that achieved by appliances placed palatally. (MPAP and bone anchored pendulum appliance) however we did not find any mesial movement of anterior segment in both the groups, rather slight distal movement was seen (Group II > Group I) in our study.

Il-Jun Yu et al⁶⁵ compared three molar distalization modalities having buccal implant on buccal side between canine and 1st premolar in model 1 and model 2 had mini implant between 2nd premolar and 1st molar; model 3 had palatal implant using FEM and 150 gms of force was used. Niti open-coil spring were placed between 1st premolar and first molar in model 1 and 2. However only model 2 was similar to our study. In this modality the distal movement of 1st molar in Y axis, 1.75×10^{-1} mm, in X axis 4.6×10^{-2} and in Z axis 5.45×10^{-2} mm which showed distalisation, mesial-out rotation and extrusion of 1st molar. Incisors moved 1.52×10^{-5} mm in Y axis, by 4.52×10^{-2} mm in X axis and intruded by 2.09×10^{-2} in Z axis which showed incisor tipped anteriorly and intruded.

Khanehmasjed et al.⁷⁹ compared the displacement of maxillary teeth in three dimensions under the influence of total arch distalization with the help of miniscrews. In model 1 the single midpalatal miniscrew assisted molar distalization using TPA and in Model 2, palatal interradicular miniscrew assisted molar distalization using TPA. Force was applied by compressing Niti coil spring. Displacement in X axis for left 1st molar 2.96e-3 mm in Y axis 1.19e-3mm and in Z axis 5.14e-3 mm (3.63e-3mm, 2.003e-3 mm, 2.99e-3 mm) for right 1st molar. In model 2 Displacement in X axis for left 1st molar was 5.44e-3 mm in Y axis 2.73e-3mm and in Z axis 9.19e-3 mm, in X axis for right 1st molar was 7.13e-3mm, in Y axis 4.28e-3mm, in Z axis 4.98e-3mm. In all measurements, the amount of movement in Model 2 was more than that in Model 1. In the Y-axis, displacement values are higher in model 2 but mainly tipping was seen in the first molar, in Model 1, bodily movement of the first molar was more evident.

Kalpakuri et al⁷⁶ on applying 200grms force for maxillary 1st molar Distalization where anterior anchorage was reinforced by mini-screw placed between 2nd premolar and 1st molar on buccal aspect found 0.001 mm mesial buccal rotation, 0.003 mm uncontrolled distal tipping, 0.001 mm intrusion of distal cusp and extrusion of mesial cusp.

When mini-implant was placed between 2nd premolar and 1st molar on palatal aspect, mini-implant assisted molar distalization using TPA and 200 grms of force showed 0.002 mm mesio-palatal rotation, 0.004 mm distal displacement, 0.001 mm intrusion of distal cusps and 0.001 mm extrusion of mesial cusps.

Sanap et al⁷⁵ compared three methods of full arch distalization - model 1 had two implants placed between 1st premolar and 2nd premolar, 2nd premolar and 1st molar; model 2 had IZC screw placed between 1st molar and 2nd molar; model 3 had IZC screw placed above mesio-buccal root of maxillary first molar. When 200 grms of force was applied from mini-screw with Niti coil spring, they found maximum distalization of maxillary arch with values 1.199mm in model 2 > 1.068 mm in model 3 > 0.768mm in model 1.

They found intrusion as 0.624 mm in model 1 > 0.223 mm in model 3 > 0.158 mm in model 2.

They found bucco palatal rotation as 0.091mm in model 1 > 0.084mm in model 2 > 0.081 mm in model 3. All the models showed intrusion and distalisation with no labiopallatal rotation in anterior teeth.

The conclusion drawn from above mentioned studies is that, distal tipping of maxillary first molar as observed in present study for both the groups was also evident from previous studies. Mini-implant supported molar distalization using K loop gave almost similar distal movement of maxillary molars as achieved in previous studies using different method of molar distalization from buccal and palatal aspect and was effective method of molar distalization in comparison to NiTi coil spring. Also mesio buccal rotation as seen in previous FEM studies was also seen in our study in both groups. Mesial movement or unwanted tipping of anterior segment was not seen in present study. As anterior anchorage was reinforced by mini implant. Hence slight distal movement of anterior segment was seen being tied by figure of eight ligature wire in our study.

Stress-

In present study Von mises stress both at apex and occlusal region of 1st molar was more in group I than group II.

For PDL maximum von mises stress of **0.033018MPa** was seen between 2nd premolar and 1st molar in group I and of **0.0150 MPa** on mesial aspect of 1st molar in group II. Minimum von mises stress in PDL was in anterior segment in both groups as **0.00366 MPa** in group I and as **0.0150 MPa** for group II (**Group II > Group I**)

For cortical bone maximum von mises stress had higher value in group II (**0.025197MPa**) than group I (**0.019963MPa**). Minimum von mises stress had higher value in group II (**0.00288MPa**) than group I (**0.002315 MPa**).

For cancellous bone maximum von mises stress had higher value in group II (**0.047512 MPa**), than group I (**0.024969 MPa**). Minimum von mises stress had higher value in group II (**0.00537MPa**), than group I (**0.00286MPa**)

The result of present study were compared to previous FEM studies, that evaluated stresses during distalization of molar using variable force, with different treatment modalities used for molar distalization.

Tekale et al⁴⁵ found maximum von mises stress on buccocervical region of maxillary 1st molar as 0.346 MPa and minimum von mises stress was at apex of distobuccal root of maxillary 1st molar as 0.056 MPa. The adjacent 2nd premolar experienced maximum stress of 0.0036 MPa on furcation area and minimum von mises stress at its apex as 0.00032 MPa.

Hamanaka et al⁴⁶ found minimum von mises of 0.0159 MPa in model without coil spring, and was 0.082 MPa in model with coil spring, that was lesser among then the other model. Both models had minimum stress in premolar region as also seen in present study for both the groups.

Ioana et al⁶⁶ found during individual distalisation of maxillary 1st molar alone ,that compressive stress was located at cervical region of disto buccal cusp of maxillary 1st and suggested that for bodily translation, rotation of axis must be at infinite with homogeneous distribution of stress in PDL.

Sujaritwanid et al⁷⁷ compared the stress distribution on 1st and 2nd molars when distalization were carried out with iPanda (indirect palatal implant anchored distalizing appliance), an arrangement made up of mid palatal screw with palatal bar) using FEM, at varying forces of 50,100,200 grms. For 200grms force, stress over 1st molar was at different surfaces was (Mesial-.0006 MPa ,Distal-.001 MPa,Buccal-.001 MPa,Palatal-.001 MPa Furcation area-.0003 MPa). Also found higher stress on molar with 200 grms force than other forces .

Similar results were seen by **Suzuki et al**⁶⁸ for molar distalization using same appliance as **Sujaritwanid et al** .

The overall conclusion drawn from above mentioned studies is that stress distribution and values varied among different studies as different methods were employed for molar distalization and had variable distance from center of resistance of maxillary 1st molar.

Stress in PDL, cortical bone and cancellous bone more in group II than group I but stress distribution pattern was uniform in K loop. Also difference between stress at apical and occlusal was less in Group II than Group I suggestive of less distal tipping than Gr I. Thus K loop being frictionless mechanics and segmental mechanics had biomechanical advantages in achieving molar distalization with lesser stresses on teeth

K loop provided better molar distalization with increased stresses on anterior and posterior segment however stresses were within limits of yield strength of cancellous and cortical bone.

The results of present study were corroborated with respect to clinical studies that evaluated efficiency of NiTi coil spring or K loop for maxillary molar distalization.

Reddy et al⁷⁰ compared the skeletal and dentoalveolar effects on lateral cephalogram using two methods of molar distalization ; K-loop and pendulum appliance and found statistically no significant difference between the two groups .The distal movement of maxillary molar 5.1 ± 0.8 mm and 4.93 ± 1.68 mm in K-loop appliance and in pendulum appliance respectively .The incisors moved mesially by 1.3 ± 0.63 mm in k loop and by 1.57 ± 0.58 mm in pendulum appliance. They found minimal tipping with increased distalization with K loop as moment-force ratio to produce all types of tooth movements in different plane could be controlled.

A study by **Marure et al**⁷² showed similar molar distalization with of pendulum, K-loop, and distal jet distalization techniques in growing children,as anteroposterior skeletal changes were not statistically significant, among the three groups .There was nostatically significant incisor proclination and distal tipping of molar noticed in the pendulum and K loop, so either can be used effectively for molar distalization.

Bondemark⁸¹ did a study on two force system used for molar Distalization - mrepelling magnets and Niti super coil spring. The distal molar movement was 3.2 ± 1.09 mm for the Niti open coil spring and $2.2 \pm .94$ mm for the magnets in time duration of 6 months and found that Niti open coil spring were significantly more effective than repelling rare earth magnets in achieving molar distalization.

In a clinical study done by **Acar AG et al** compared dentoalveolar effects of a pendulum appliance placed palatally and supported buccally by a K-loop, with cervical headgear group (CHG) .In pendulum and K loop combination ,amount of distalization was 4.53 ± 1.46 mm and was more than CHG group (amount of distalization -2.23 ± 1.68 mm. Intrusion and mesiobuccal rotation of the maxillary molars were achieved in both groups. In pendulum and K loop combination , the amount of labial protrusion and tipping of the maxillary incisors was not statistically significant. In CHG group, palatoversion and retrusion of the maxillary incisors was statistically significant.

Gelgor et al conducted a clinical study to compared two distalization systems supported by mid palatal intraosseous screws in first group the molar distalization was attempted by bilateral sectional arch with nickel-titanium open-coil springs placed between the 2nd premolar and 1st molar with a continuous force of 250 g per side. In the second group, appliance consist of palatal rod attached to Keles 1st molar band and

Niti coil spring was compressed between band and anteriorly placed composite resin. The mean maxillary molar distal movements was significantly more in group 1 (3.95 ± 1.68 mm) than group 2 (3.88 ± 1.47 mm), but crown of maxillary 1st molar significantly tipped distally more in group 1 than group 2. Also anterior anchorage loss was significantly more in group 1 than group 2.

The overall conclusion drawn from clinical studies was that k loop was equally effective as pendulum appliance in terms of distal movement of maxillary 1st molar with minimal anterior anchorage loss in most of the studies. This can be corroborated to findings of present study where k loop assisted molar distalization was higher than that achieved by NiTi open coil spring. Anterior anchorage was reinforced by miniscrew, hence no mesial movement of anterior segment was noted rather distal movement was seen. As with any loop mechanics, initial crown tipping is achieved on activation and when loop is kept in place without further activations, moment to force ratio increases, thereby achieving root movement. However with FEM, we could see only initial displacement but root movement achieved clinically after keeping K loop in place for months could not be visualized.

With in the limitation of present study, it can be stated that K loop was more effective for molar distalisation, than NiTi coil spring with lesser distal tipping. This study had limitation as certain factors could not simulated in FEM, like complex and dynamic forces existing in the oral environment. As Finite element method is based on several assumptions like properties of homogeneity and isotropic with linear elasticity of the materials, however the vital tissues are different having different mechanical properties of the nonlinear structures, and it might be impossible to include ideal properties of vital structures in the model making more complex condition. 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. Also, force are applied for limited time i.e. around seconds in FEM studies, whereas clinically force is applied over a longer duration of time. Therefore the result of FEM studies must be validated by clinical studies.

The main clinical implication of study is that side effects of molar distalization, that is anterior anchorage loss could be controlled effectively with the help of reinforcement of anterior anchorage by mini-screw. Among two methods of molar

distalization evaluated in present study maxillary molar Distalization with K loop would be a better choice being a segmental mechanics.

Further studies should aim at comparing other buccal method of molar distalization with that of palatal methods . Also force levels and bracket prescription can be varied. The results of FEM studies should be validated by conducting clinical studies on large sample sizes.

Following conclusions are drawn from the present study conducted with an aim to evaluate and compare stress and displacement during maxillary molar distalization by two commonly used methods, compressed NiTi open coil spring and K loop.-

Within the limitation of FEM study following conclusions can be drawn-

- K loop was more effective than Niti coil spring in achieving molar distalization in terms of distal movement of maxillary first molar.
- Mesio-buccal rotation of maxillary molar was more in K loop than Niti coil spring.
- Distal tipping of maxillary molar was lesser in K loop than Niti coil spring.
- Anchorage reinforcement of anterior segment with miniscrew eliminated mesial movement of anterior segment, rather distal movement of anterior segment was seen for both the methods of molar distalization
- Stress at PDL, cortical and cancellous bone was more in K loop than Niti coil spring. Also stress distribution was more uniform with K loop suggestive of lesser distal tipping of maxillary first molar.

K loop was more effective in achieving molar distalization than Niti coil spring where anterior anchorage was reinforced by miniscrew.

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Class II Malocclusion is a commonly encountered malocclusion in the anteroposterior plane¹ and usually presents with tooth size and arch length discrepancy. The treatment of such cases can be done by extraction of premolars or by non-extraction approach using expansion or molar distalization or other methods.

Molar distalization is a non-extraction modality of gaining space and can be done by extraoral methods (compliant) and intraoral methods (non-compliant).

The indications for molar distalization include that patient should have class I skeletal pattern with straight profile, Angle's class II or end on molar relationship with mild maxillary dental protrusion, mild to moderate crowding, low to moderate mandibular plane angle, good facial balance and preferably unerupted second or third molar. The contra-indications included protrusive profile or proclined incisors, increased overjet, hyperdivergent growth pattern and posterior crowding.

Effective molar distalization with extraoral appliance needed patient compliance and had never been an esthetically pleasing option for the patients.

Intraoral appliances for effective molar Distalization, are simple to construct and use, and are a good alternative for non compliant patient. Various methods like Jones Jig, K loop, Repelling magnets, Wilson arch, and Niti coil spring, mini-implant) or palatal side (Pendulum appliance, Distal jet, Goshgarian TPA, Skeletal frog appliance, and mini-implant.

Intraoral methods can produce bodily or tipping movement of maxillary molars depending on direction of force vector with respect to center of resistance of maxillary molar and may cause mild anchorage loss of mesial segment.

The appliances that apply force from palatal aspect were more nearer to the centre of resistance, hence overcame the disadvantages of buccally placed appliances used for distalizing maxillary molars by reducing the tendency for the teeth to tip, thus producing bodily tooth movement with negligible crown tipping.

However intraoral appliance placed palatally had inherent disadvantages of being bulky, obstructing the tongue space and making it less comfortable for patients. Hence appliances placed buccally for molar distalization are preferred as being simple, easy to use and less cumbersome. Among buccally placed appliance few are available commercially like Jones Jig, repelling magnets²², lokar distalizer etc that poses

additional expenses to be borne by the patient where as other appliances that can be fabricated chair side using commonly available orthodontic inventory are preferred for molar distalization.

As K-loop, given by Dr. Varun Kalra¹⁵, Ni-Ti open coil spring commonly used in orthodontics are cost effective options of molar distalization and are placed buccally, and various studies showed their efficacy in molar distalization, it was decided to distalize molar by these two commonly used methods in present study.

The potential limitation of any molar distalization is mild anchorage loss of anterior segment. Acrylic button placed in palate had been used conventionally to prevent the anterior anchorage loss. Recently TAD's (Temporary Anchorage Devices) are used to augment anchorage of anterior segment there by negating reactive forces of molar distalization.

Hence for both the methods (K-loop and Ni-Ti coil spring) selected in the present study for molar distalization, anchorage of anterior segment was augmented by miniscrew placed on buccal interradicular bone between second premolar and first molar of maxillary arch.

Several clinical and in-vitro studies have been conducted to investigate the performance of different distalization appliances and to evaluate the type and amount of tooth movement. However, little information regarding the pattern of the mechanical stresses in the tissue surrounding teeth during molar distalization is available. As quantification of stresses in clinical studies is difficult therefore, various in-vitro methods had been proposed to quantify stresses such as- photo elastic stress analysis, mathematical models, laser holography^{32y} and finite element method. Among these FEM which quantitatively assess the stress and strain distribution generated in response to various biomechanical settings in orthodontics was selected in present study.

Considering this it was decided to do 3-Dimensional finite element analysis of two commonly used methods of molar distalization, K loop and open NiTi coil spring compressed between maxillary 1ST premolar and 1st molar and anterior anchorage was reinforced with miniscrew placed between second premolar and first molar in present study.

This comparative 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 AnaMac Design, FEM Lab Gaziabad.

A maxillary arch was modelled on the basis of CBCT images. FUSION 360 software was used to convert CBCT into STL format to CAD model of maxillary arch. Geometric Model of MBT bracket, buccal tube, 17x25 TMA wire, K-loop, NiTi open coil spring, mini-implant, 19x25 SS arch wire, ligature ties and ligature wire was generated in Solid Works software from CAD models. Hyper mesh software was used to create mesh models and also used to fuse the model of maxilla with PDL, bone and complete assembly of brackets, molar tube, arch wire, NiTi open coil spring, crimpable hook, stainless steel archwire of 0.019"x0.025" inch and Kloop(made with 17x25 TMA wire) etc. to make FEM model. Material properties were incorporated for teeth, PDL, bone, stainless steel and TMA. Two finite element models were generated and boundary condition was applied. Group I included FEM model where molar distalization was carried out with NiTi open coil spring and Group II included K loop assisted molar distalisation, in both the FEM models anterior anchorage was reinforced by miniscrew placed buccally between 2nd premolar and 1st molar. The displacement of each tooth was calculated on x, y, and z axes, and the von Mises stress distribution was visualized using color-coded scales on application of 200 grms of force to achieve molar distalization using Hypermesh software.

We observed stress distribution and displacement patterns of the anterior and posterior segments in maxillary arch with regard to distalizing force vectors applied from K loop and NiTi coil spring. Anterior anchorage was reinforced by interdental miniscrews. The Von Mises stresses were in megapascals (MPa) and displacement was in millimeters.

The result of present study are as following-

Displacement –

In present study maxillary 1st molar showed displacement in distobuccal direction in X axis as 4.253×10^{-7} mm for group I and 7.216×10^{-7} mm in group II; (Group II > Group I), showed displacement in distal direction in Z axis as 9.217×10^{-7} mm for group I and 1.245×10^{-6} for group II; (Group II > Group I), showed displacement in occlusal direction in Y axis as 2.1605×10^{-8} for group I and 1.9866×10^{-7} mm for group II; (Group II > Group I).

The result of the present study showed amount of molar distalization is more in group II than group I.

Von mises Stress-In present study maximum von mises stress of 0.033018MPa was seen between 2nd premolar and 1st molar for PDL in group I and of 0.0150 MPa on mesial aspect of 1st molar in group II.

In present study minimum von mises stress in PDL was in anterior segment in both groups as 0.00366 MPa in group I and as 0.0150 MPa for group II (Group II > Group I)

K loop provide more better molar distalization with increased stress on anterior and posterior segment however stress were with in the limit of cancellous and cortical bone.

Following conclusion are drawn from the present study conducted with an aim to evaluate and compare stress and displacement during maxillary molar distalization by two commonly used methods, compressed NiTi open coil spring and K loop.-

- K loop was more effective than Niti coil spring in achieving molar distalization in terms of distal movement of maxillary first molar.
- Distobuccal rotation of maxillary molar was more in K loop than Niti coil spring.
- Distal tipping of maxillary molar was lesser in K loop than Niti coil spring.
- Anchorage reinforcement of anterior segment with miniscrew eliminated mesial movement of anterior segment, rather distal movement of anterior segment was seen.
- Stress at PDL, cortical and cancellous bone was more in K loop than Niti coil spring, also stress distribution was more uniform with K loop suggestive lesser distal tipping of maxillary first molar

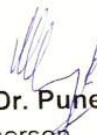
K loop was more effective in achieving molar distalization than Niti coil spring where anterior anchorage was reinforced by miniscrew.

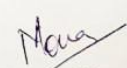
ANNEXURE-I

**BABU BANARASI DAS UNIVERSITY**
BBD COLLEGE OF DENTAL SCIENCES, LUCKNOW**INSTITUTIONAL RESEARCH COMMITTEE APPROVAL**

The project titled "A Three Dimensional Finite Element Analysis Of Force System For Maxillary Molar Distalization Using Two Different Methods" submitted by Dr Jaya Shukla Postgraduate student in the Department of Orthodontics & Dentofacial Orthopaedics for the Thesis Dissertation as part of MDS Curriculum for the academic year 2021-2024 with the accompanying proforma was reviewed by the Institutional Research Committee in its meeting held on 14th September, 2022 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. Dr. Puneet Ahuja
Chairperson


Dr. Mona Sharma
Co-Chairperson

ANNEXURE-II



BABU BANARASI DAS UNIVERSITY

BBD COLLEGE OF DENTAL SCIENCES, LUCKNOW

BBDCODS/IEC/09/2022

Dated: 16th September, 2022Communication of the Decision of the Xth Institutional Ethics Sub-Committee Meeting

IEC Code: 15

Title of the Project: A Three Dimensional Finite Element Analysis Of Force System For Maxillary Molar Distalization Using Two Different Methods.

Principal Investigator: Dr Jaya Shukla **Department:** Orthodontics & Dentofacial Orthopaedics

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

Type of Submission: New, MDS Project Protocol

Dear Dr Jaya Shukla,

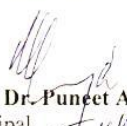
The Institutional Ethics Sub-Committee meeting comprising following members was held on 15th September, 2022.

- | | |
|---|--|
| 1. Dr. Lakshmi Bala
Member Secretary | Prof. and Head, Department of Biochemistry |
| 2. Dr. Praveen Singh Samant
Member | Prof. & Head, Department of Conservative Dentistry & Endodontics |
| 3. Dr. Jiji George
Member | Prof. & Head, Department of Oral Pathology & Microbiology |
| 4. Dr. Amrit Tandan
Member | Professor, Department of Prosthodontics and Crown & Bridge |
| 5. Dr. Rana Pratap Maurya
Member | Reader, Department of Orthodontics & Dentofacial Orthopaedics |

The submitted documents of the current MDS Project Protocol is exempted for review in the meeting.

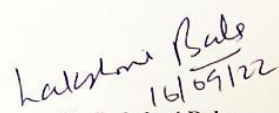
Decision: The MDS Protocol is exempted for review by the Institutional Ethics Sub-Committee.

Forwarded by:


Prof. Dr. Puneet Ahuja
 Principal
 BBD College of Dental Sciences
 BBD University, Lucknow

PRINCIPAL

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


Dr. Lakshmi Bala
 Member-Secretary
 Institutional Ethics Sub-Committee (IEC)
 BBD College of Dental Sciences
 BBD University, Lucknow

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

ANNEXURE -III

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
Information Document (PID) in English**

1. Study Title

**A THREE DIMENSIONAL FINITE ELEMENT ANALYSIS OF FORCE
SYSTEM ON MAXILLARY MOLARS BY USING TWO DIFFERENT
METHODS FOR MOLAR DISTALIZATION**

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 evaluate and compare stress and displacement during maxillary molar distalization by two commonly used methods, compressed NiTi open coil spring and K loop using finite element method.

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 comparative evaluation of stress and displacement during maxillary molar distalization by two commonly used methods, compressed NiTi open coil spring and K loop using finite element method.

9. What are the interventions for the study?

- To calculate the stress and displacement around maxillary first molar and anterior segment during maxillary first molar distalization using NiTi open coil spring, where anterior anchorage was reinforced with mini implant.
- To calculate the stress and displacement around maxillary first molar and anterior segment during maxillary first molar distalization using K loop, where anterior anchorage was reinforced with mini implant.
- To compare the amount of stress and displacement on maxillary first molar between two methods of molar distalisation.
- To compare the amount of stress and displacement on maxillary anterior teeth between two methods of molar distalisation.
 - To make inter group comparison of stress and stress and displacement during maxillary molar distalization by two commonly used methods, compressed NiTi open coil spring and K loop using finite element method.

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 compare displacement and stress distribution during maxillary molar distalization by two commonly used methods, compressed NiTi open coil spring and K loop using finite element method.

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. Jaya Shukla

Department of Orthodontics and Dentofacial Orthopaedics

Babu Banarasi College of Dental Sciences.

Lucknow-226010

Mob- 9452355110

Dr. Tripti Tikku (Professor)

Department of Orthodontics and Dentofacial Orthopaedics

Babu Banarasi College of Dental Sciences.

Lucknow-226010

Mob- 9452355110

Dr. Rohit Khanna (HOD)

Department of Orthodontics and Dentofacial Orthopaedics

Babu Banarasi College of Dental Sciences.

Lucknow-226010

Mob- 9452355110

Signature of PI.....

Name.....

Date.....

ANNEXURE -IV**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**

मोलर डिस्टलाइजेशन के लिए दो अलग-अलग तरीकों का उपयोग करके मैक्सिलरी मोलर्स पर बल प्रणाली का तीन आयामी परिमित तत्व विश्लेषण

2. निमंत्रण अनुच्छेद

आपको एक शोध अध्ययन में भाग लेने के लिए आमंत्रित किया जा रहा है। निर्णय लेने से पहले आपके लिए यह समझना महत्वपूर्ण है कि शोध/अध्ययन क्यों किया जा रहा है और इसमें क्या शामिल होगा। कृपया निम्नलिखित जानकारी को ध्यान से पढ़ने के लिए समय निकालें और यदि आप चाहें तो दोस्तों, रिश्तेदारों और अपने इलाज करने वाले चिकित्सक/पारिवारिक डॉक्टर के साथ इस पर चर्चा करें। हमसे पूछें कि क्या ऐसा कुछ है जो स्पष्ट नहीं है या यदि आप अधिक जानकारी चाहते हैं। यह तय करने के लिए समय लें कि आप भाग लेना चाहते हैं या नहीं।

3. अध्ययन का उद्देश्य क्या है?

अध्ययन का उद्देश्य आमतौर पर उपयोग की जाने वाली दो विधियों, संपीडित NiTi ओपन कॉइल स्प्रिंग और परिमित तत्व विधि का उपयोग करके K लूप द्वारा मैक्सिलरी मोलर डिस्टलाइजेशन के दौरान तनाव और विस्थापन का मूल्यांकन और तुलना करना है।

4. मुझे क्यों चुना गया है?

किसी रोगी की आवश्यकता नहीं है क्योंकि यह एक इन विट्रो अध्ययन है

5. क्या मुझे भाग लेना होगा?

लागू नहीं।

6. यदि मैं भाग लूंगा तो मेरा क्या होगा?

लागू नहीं।

7. मुझे क्या करना होगा?

लागू नहीं

8. वह कौन सी प्रक्रिया है जिसका परीक्षण किया जा रहा है?

इस प्रक्रिया में आमतौर पर उपयोग की जाने वाली दो विधियों, संपीड़ित NiTi ओपन कॉइल स्प्रिंग और परिमित तत्व विधि का उपयोग करके K लूप द्वारा मैक्सिलरी मोलर डिस्टलाइजेशन के दौरान तनाव और विस्थापन का तुलनात्मक मूल्यांकन शामिल होगा।

9. अध्ययन के लिए क्या हस्तक्षेप हैं?

- NiTi ओपन कॉइल स्प्रिंग का उपयोग करके मैक्सिलरी फर्स्ट मोलर डिस्टलाइजेशन के दौरान मैक्सिलरी फर्स्ट मोलर और पूर्वकाल खंड के आसपास तनाव और विस्थापन की गणना करने के लिए, जहां पूर्वकाल एंकरेज को मिनी इम्प्लांट के साथ मजबूत किया गया था।

- के लूप का उपयोग करके मैक्सिलरी फर्स्ट मोलर डिस्टलाइजेशन के दौरान मैक्सिलरी फर्स्ट मोलर और पूर्वकाल खंड के आसपास तनाव और विस्थापन की गणना करने के लिए, जहां पूर्वकाल एंकरेज को मिनी इम्प्लान्ट के साथ मजबूत किया गया था।
- मोलर डिस्टलाइजेशन के दो तरीकों के बीच मैक्सिलरी फर्स्ट मोलर पर तनाव और विस्थापन की मात्रा की तुलना करना।
- मोलर डिस्टलाइजेशन की दो विधियों के बीच मैक्सिलरी पूर्वकाल के दांतों पर तनाव और विस्थापन की मात्रा की तुलना करना।
- आमतौर पर उपयोग की जाने वाली दो विधियों, परिमित तत्व विधि का उपयोग करके संपीड़ित NiTi ओपन कॉइल स्प्रिंग और K लूप द्वारा मैक्सिलरी मोलर डिस्टलाइजेशन के दौरान तनाव और तनाव और विस्थापन की अंतर समूह तुलना करना।

10. भाग लेने के दुष्प्रभाव क्या हैं?

लागू नहीं

11. भाग लेने के संभावित नुकसान और जोखिम क्या हैं?

लागू नहीं

12. भाग लेने के संभावित लाभ क्या हैं?

लागू नहीं

13. यदि नई जानकारी उपलब्ध हो जाए तो क्या होगा?

कभी-कभी किसी शोध परियोजना के दौरान, अध्ययन किए जा रहे शोध के बारे में नई जानकारी उपलब्ध हो जाती है। यदि ऐसा होता है, तो आपका शोधकर्ता आपको इसके बारे में बताएगा और आपसे चर्चा करेगा कि क्या आप अध्ययन जारी रखना चाहते हैं। यदि आप वापस लेने का निर्णय लेते हैं, तो आपका शोधकर्ता/अन्वेषक आपकी वापसी की व्यवस्था करेगा। यदि आप अध्ययन जारी रखने का निर्णय लेते हैं, तो आपसे एक अद्यतन सहमति प्रपत्र पर हस्ताक्षर करने के लिए कहा जा सकता है।

14. जब शोध अध्ययन बंद हो जाता है तो क्या होता है?

यदि अध्ययन निर्धारित समय से पहले रुकता/समाप्त होता है, तो यह रोगी/स्वयंसेवक को समझाया जाएगा।

15. अगर कुछ गलत हो गया तो क्या होगा?

यदि अध्ययन के दौरान कोई गंभीर प्रतिकूल घटना घटती है, या कुछ गलत होता है, तो

शिकायतों का निपटारा संस्था (संस्थानों) को रिपोर्ट करके किया जाएगा, और संस्थागत नैतिकता

समुदाय।

16. क्या इस अध्ययन में मेरी भागीदारी को गोपनीय रखा जाएगा?

लागू नहीं है क्योंकि यह एक इन विट्रो अध्ययन है।

17. शोध अध्ययन के परिणामों का क्या होगा?

अध्ययन के परिणामों का उपयोग आमतौर पर इस्तेमाल की जाने वाली दो विधियों, संपीड़ित NiTi ओपन कॉइल स्प्रिंग और K लूप द्वारा परिमित तत्व विधि का उपयोग

करके मैक्सिलरी मोलर डिस्टलाइजेशन के दौरान विस्थापन और तनाव वितरण की तुलना करने के लिए किया जाएगा।

18. अनुसंधान का आयोजन कौन कर रहा है?

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

19. क्या अध्ययन के परिणाम अध्ययन समाप्त होने के बाद उपलब्ध कराए जाएंगे?

हाँ

20. अध्ययन की समीक्षा किसने की है?

अध्ययन की समीक्षा और अनुमोदन विभाग के प्रमुख और संस्थान के आईईसी/आईआरसी द्वारा किया गया है।

21. अधिक जानकारी के लिए संपर्क करें

डॉ जया शुक्ला

ऑर्थोडॉन्टिक्स और डेंटोफेशियल ऑर्थोपेडिक्स विभाग

बाबू बनारसी कॉलेज ऑफ डेंटल साइंसेज।

लखनऊ-226010

मोब- 9452355110

डॉ. तृप्ति टिक्कू (प्रोफेसर)

ऑर्थोडॉन्टिक्स और डेंटोफेशियल ऑर्थोपेडिक्स विभाग

बाबू बनारसी कॉलेज ऑफ डेंटल साइंसेज।

लखनऊ-226010

मोब- 9452355110

डॉ. रोहित खन्ना (एचओडी)

ऑर्थोडॉन्टिक्स और डेंटोफेशियल ऑर्थोपेडिक्स विभाग

बाबू बनारसी कॉलेज ऑफ डेंटल साइंसेज।

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पीआई के हस्ताक्षर.....

नाम.....

तारीख.....

ANNEXURE -V

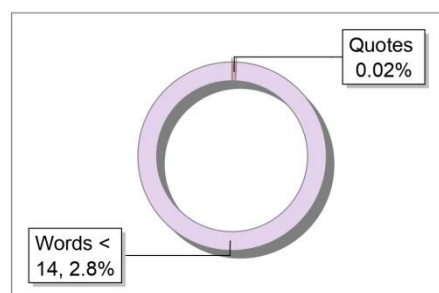
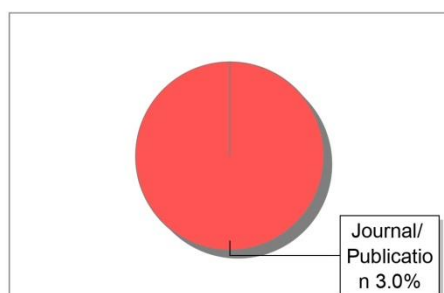


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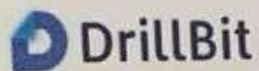
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ANNEXURE -V



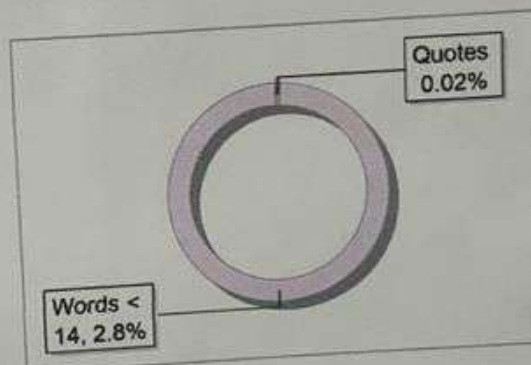
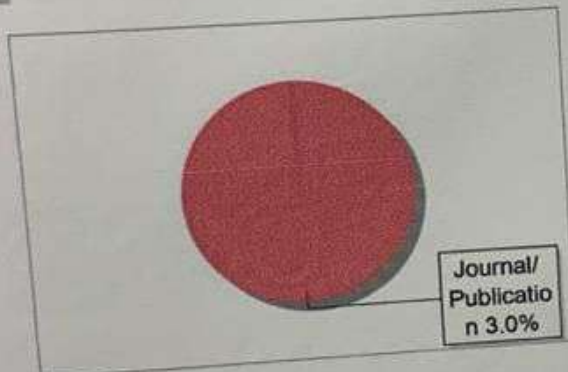
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