COMPARATIVE EVALUATION OF INTRUSION OF FOUR MAXILLARY INCISORS USING TWO DIFFERENT MECHANICS - A FEM STUDY

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

Dr. Bivek Bijoy Senapati

Under the guidance of

Dr. Tripti Tikku

Professor

Department of Orthodontics and Dentofacial Orthopaedics

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW

(Faculty of Babu Banarasi Das University)

YEAR OF SUBMISSION: 2023 **BATCH: 2020-2023**

CERTIFICATE BY THE GUIDE/CO-GUIDE

This is to certify that the dissertation entitled "***COMPARATIVE EVALUATION OF INTRUSION OF FOUR MAXILLARY INCISORS USING TWO DIFFERENT MECHANICS - A FEM STUDY***" is a bonafide work done by **Dr. Bivek Bijoy Senapati**, under my direct supervision and guidance in partial fulfilment of the requirement for the degree of MDS in Department of Orthodontics and Dentofacial Orthopaedics.

Date:

Tripti Tikku

GUIDE

Dr. Tripti Tikku
Professor
Department of Orthodontics and Dentofacial Orthopaedics
BBDCODS, BBDU
Lucknow

Kamna

CO-GUIDE

Dr. Kamna Srivastava
Reader
Department ofOrthodontics and Dentofacial Orthopaedics
BBDCODS, BBDU
Lucknow

ENDORSEMENT BY THE HOD / HEAD OF THE INSTITUTION

This is to certify that the dissertation entitled "***COMPARATIVE EVALUATION OF INTRUSION OF FOUR MAXILLARY INCISORS USING TWO DIFFERENT MECHANICS - A FEM STUDY***" is a bonafide work done by **Dr. Bivek Bijoy Senapati** under the supervision of **Dr. Tripti Tikku**, Professor, Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences, Babu Banarasi Das University, Lucknow, Uttar Pradesh.

Dr. Rohit Khanna
Professor & Head
Department of Orthodontics and Dentofacial Orthopaedics .
BBDCODS, BBDU
Lucknow

Dr. Puneet Ahuja
Principal
BBDCODS, BBDU
Lucknow

COPYRIGHT

Date: 20/3/2023

Place: Lucknow

Dr. Bivek Bijoy Senapati

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation entitled "***COMPARATIVE EVALUATION OF INTRUSION OF FOUR MAXILLARY INCISORS USING TWO DIFFERENT MECHANICS - A FEM STUDY***" is a bonafide and genuine research work carried out by me under the guidance of ***Dr. Tripti Tikku*** **,** Professor, Department of Orthodontics and Dentofacial Orthopaedics , Babu Banarasi Das College of Dental Sciences, Babu Banarasi Das University, Lucknow, Uttar Pradesh.

Date: 20/3/2023

Place: Lucknow

Dr. Bivek Bijoy Senapati

*I bow my head to the **Almighty God**, who blessed me with his blessings, bestowed me with his kind grace, provided me with strength, courage and good health to reach this stage and made it possible for me to bring out this manuscript. The satisfaction and euphoria that accompany the successful completion of a task could be incomplete without the mention of the people who made it possible.*

*It is my privilege and honor to express my most sincere and heartful thanks to my head, **Dr. Rohit Khanna,** MDS, Professor & Head, Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences, Lucknow whose brilliant foresight and practical approach have been the guiding force behind the present shape of my project. His inestimable calm and ineffable wisdom, continuous encouragement and earnest attention have always been a driving force throughout the project.*

*"I extend my sincere thanks to my advisor, mentor and guide, **Dr. Tripti Tikku, MDS, Professor**, Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences, Lucknow, for her constant support and guidance. Her insightful advice helped me navigate the challenges of this research project. I am deeply grateful for their patience, motivation, and expertise that she shared with me. Most importantly, I am thankful for her unwavering support, collaboration, and mentorship throughout the past three years."*

*I am also thankful to **Dr. Sneh Lata Verma**, MDS, Reader**, Dr. Rana Pratap Maurya,** MDS, Reader, **Dr. Kamna Srivastava,** MDS, Reader, all my Senior Lecturers **Dr.Srishti Aditi, Dr.Abhimanyu, Dr.Prateek, and Dr.Shweta** MDS, Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences, Lucknow, for their valuable suggestions, time to time guidance, encouragement and constant moral support during the period of my study. Without their support nothing would have been possible for me. It was their understanding, valuable suggestions, unstinted help and personal attention that have provided good and smooth basis for this work. I feel motivated and encouraged by their presence. It's honor to have to have such* *teachers and shall forever be indebted to them.*

Special thanks to ***Mr. Prateek Naik and Mr. Anupam Prasad*** *for doing FEM analysis and for his valuable suggestions, time to time guidance and constant support during the period of my study.*

I gratefully acknowledge my present standing to my dear parents ***Mr. Bijan Behari Senapati*** *and my mother* ***Late Mrs. Banani Senapati*** *for their love and constant support throughout my life. Thank you for giving me sincere encouragement and inspiration throughout my project and for giving me strength to reach for the star and chase my dreams. I owe you everything. Without your blessings it would never have been possible.*

I would also like to thank my dear wife ***Nipasha,*** *my daughter* ***Birajita,*** *my sister* ***Bijita,*** *my brother in law* ***Dipankar,*** *niece* ***Tiyasha,*** *and nephew* ***Bivan*** *and my dear mother in law* ***Bijoya*** *who has always cheered me up and has always been my strength at all times..*

I would like to pay high regards to all my loving seniors. Thank you my dear seniors ***Dr.Deepak Chandra, Dr. Rigzing O.Lepcha, Dr Deepa Soni, Dr.Tanjula Slair, Dr.Akansha Chowhan and Dr. Noor Zaman*** *. I would also like to thank my colleagues* ***Kamran Javied Khan, Haobam Minerva, Bhanu Pratap and Swagat Verma*** *for their help and encouragement throughout my work sailing together in the same boat.*

I would also like to thank my juniors ***Aliya Rehman, Sabrajit Saha, Jaya Shukla, Sweety Gupta, Monika Sharma, Shireen, Ashima, Sineen, Anupama, Nidhi, Ashim and Abhishek*** *for their constant support and help in all my work .*

Finally, I will be failing in my duty if I do not thank whose profound help, support and sincerity has helped me in completing my thesis. I deeply appreciate the undying support from my dear ***neighbour Deepak*** *for always being there for me and giving me moral support and for always staying like pillars through my ups and down. My lovely seniors and collegues whom I know since my under graduation time who have always been my side and supported me throughout my journey since BDS till now* ***Dr. Preeti Garg maam, Dr. Hirak Bhattacharya boss, Dr. Deepak Kumar boss, Dr. Navneet Agarwal boss, Dr. Sachin Gupta boss, Dr. Akhil Agarwal boss, Dr. Juhi Yadav, Dr. Pushpendra kr Verma***

and Dr. Vinod Upadhay*. My journey in this department would be incomplete without their encouragement and patience through the constant highs and lows.*

It is a pleasure at this point to thank my principal, ***Dr. Puneet Ahuja*** *for providing me with the opportunity to conduct the research and use the facilities of this college.*

I would like to express my heartfelt gratitude to the non-teaching personnel ***Mrs. Nirmala, Mr. Anurag, Narendra, Manjit and Amma*** *in the Department of Orthodontics and Dentofacial Orthopaedics for their compassion and assistance.*

Last, but not the least, I express my gratitude for all who directly or indirectly provided their esteemed cooperation that made me complete my library dissertation.

-Dr. Bivek Bijoy Senapati

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ANNEXURES

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.	BIA	Burstone intrusion arch
5.	FEM	Finite Element Analysis
6.	CR	Centre of resistance
7.	MPa	MegaPascal
8.	Mm	Millimetre
9.	N/mm^2	$Newton/millimetre^2$
10.	µm	Micrometre
11.	CTIA	Connecticut intrusion arch

Aim: To compare stress distribution and displacement of root apex of four normoinclined maxillary incisors using two different intrusive mechanics in presence of variable intrusive forces and variable bone loss using FEM.

Material and Method: A maxillary arch was modeled on the basis of CBCT images using MIMICS software. MBT bracket (0.022 slot), molar tube, titanium miniscrews of length (6mm X 1.2mm), stainless-steel stabilizing archwire of 0.019''X 0.025''inch and Burstone intrusion arch of 0.017" X 0.025"inch TMA fabricated on typhodont was scanned and CAD model was made. GEOMAGIC modeling software was used for construction of geometric model from CAD models and FEM models were made using ALTAIR HYPERMESH. FEM models were divided into two groups - Group I included FEM model where Burstone intrusion arch was used and Group II included FEM model for miniscrew assisted intrusion. Six FEM model was constructed at 0, 2 and 4mm bone loss and boundary conditions was applied. Variable forces were simulated by software for each group. Burstone intrusion arch was tied distal to lateral incisor bracket and force was simulated from mini-implant at same point. Stress and displacement in X, Y and Z axis was measured.

Result: On simulating intrusion by two different mechanics, it was found that stresses were concentrated at root apex. As 80gm force is optimum for intrusion of four maxillary incisors, amount of stress at 0, 2 and 4mm bone loss in Group I for central incisor was (0.45, 0.54 and 0.68 N/mm2) and for lateral incisor it was (0.11, 0.59 and 0.75 N/mm2) respectively and in Group II for central incisor was (0.45, 0.54 and 0.66 N/mm2) and for lateral incisor it was (0.11, 0.61 and 0.74 N/mm2). The comparable amount of intrusion as achieved at 80gm force at normal bone height could be achieved at lesser forces (60gm at 2mm bone loss and 40gm at 4mm bone loss).

Conclusion: Amount of intrusion, stress at apex and labial displacement increased with increase in amount of force applied as well as with increase in bone loss. To achieve optimum intrusion in presence of bone loss, a lesser forces without concentration of excessive stresses at apex should be considered.

Orthodontic treatment aims to correct malocclusion in all the three planes of space i.e. anteroposterior, transverse and vertical. Deep bite is one of the most common malocclusion seen in the vertical plane.

Deep bite could be skeletal or dental in origin. Skeletal deep bite is seen in horizontal growth pattern, and may be due to upward and forward rotation of mandible, downward and forward inclination of maxilla or combination of both. Also, it can be seen in subjects with vertical growth pattern with caudally tipped maxilla anteriorly along with downward and backward rotation of mandible. Dental deep bite is seen with supra erupted incisors or infra erupted molars. Correction of deep bite is an utmost requirement during orthodontic treatment as it has various detrimental effects on periodontium, temporomandibular joint and facial esthetics. It also acts as a limiting factor for anterior teeth retraction as emphasized by the principle "Bite before Jet", which states that overbite should be corrected before reduction of overjet is accomplished.[1] The treatment for patients with deep overbite could be achieved by extrusion of molars, intrusion of incisors, up righting of posterior teeth or flaring of anteriors or a combination of these.[2]

In growing children extrusion of molars can correct deep bite in children with horizontal growth pattern where there is compensatory increase in ramal height to retain the extrusion achieved. For growing children with vertical growth pattern, extrusion of molars leading to increase in ramal height will result in downward and backward rotation of mandible which is not desirable. For adult patients, extrusion of molars is not stable as extrusion of molars encroaches on the freeway space resulting in its relapse owing to action of masticatory muscles and due to no compensatory increase in ramal height. Hence for growing patients with vertical growth pattern or adult patients, intrusion of anterior teeth is the only option available for correction of deep bite.[3]

Burstone[4] defined intrusion as apical movement of geometric centre of root in respect to occlusal plane or a plane based on long axis of the tooth. As per **Marcotte**[5] intrusion is an axial type of translation with tooth movement in an axial (apical) direction and centre of rotation lies at infinity. Intrusion of single or group of teeth could be absolute or relative. A light continuous force can help to achieve true intrusion. In adult patients, true intrusion is desirable where teeth moves apically in cancellous bone in contrast to relative intrusion which includes flaring of incisors while intruding or extrusion of molars. Intrusion can be achieved in multiple ways using utility arches by Ricketts, intrusion arches by Burstone, use of Connecticut intrusion arch, Headgears, K- SIR (Simultaneous Intrusion and Retraction arch by Varun Kalra) or using micro implants / miniscrews.[6]

Prior to treatment of deep overbite patient with intrusion multiple factors have to be taken into consideration such as vertical dimension, smile line, incisor display and inclination of anterior teeth. In patients with increase incisor display during rest or smile with no skeletal discrepancy in vertical relation, intrusion of maxillary incisors will result in optimal position of incisors at rest and smile.[7] At rest or during smile if maxillary incisor exposure is just adequate then the intrusion of maxillary incisors is not possible as this will hamper facial esthetics. Intrusion of mandibular incisors is the alternative in such cases.

The extent and amount of intrusion depends on various factors like distance of applied force from centre of resistance (CR), inclination of teeth, alveolar bone loss and amount of force applied for intrusion. To understand this, it is important to know the biomechanics of intrusion.[8] The CR of single or group of teeth must be known before applying intrusive force. CR is the point at which tooth's resistance to movement is concentrated, in other words when vector of Orthodontic force passes through CR bodily movement or translation of teeth is seen.[9] According to "Proffit"[10] CR for single rooted tooth like maxillary incisor is approximately at midpoint of the embedded portion of root or at two third distance from the root apex as per "Nanda".[11] CR for four maxillary incisors is between lateral and canine at the level of one third from the apex.

In conventional mechanics, when intrusive force is applied on labial surface of anterior teeth, the teeth will rotate around CR instead of undergoing pure intrusive or translation movement. The undesirable effect of intrusion arch being inserted in the bracket slot, is creation of a two-couple system, resulting in generation of moment which will leads to flaring of the teeth along with intrusion. To achieve true intrusion, force should be applied either at CR or counterbalancing moment has to be added to prevent labial flaring of incisors in the two-couple system.[12] However, when intrusion arch is not inserted in the bracket slot a one couple system is created which avoids generation of anticlockwise moment **(one couple system).** Rickets utility arch works on two couple system as whereas Burstone intrusion arch and Connecticut intrusion arch etc works as one couple system. However, this effect is not seen with one couple system intrusion arch. Considering this, intrusion arch given by Burstone, which is not inserted in the slot, rather tied closer to the CR and provides one couple system for intrusion was used in this study.

Recently Temporary anchorage devices (TADs) or mini-implants have gained popularity and are being successfully used for intrusion, molar distalization, retraction etc. For intrusion of upper four incisors, mini-implants are commonly placed either at midline, between the roots of central incisors below the anterior nasal spine or bilaterally between lateral incisor and canine at a point closer to CR of four anterior teeth. "**Hernandez AV et al".**[13] observed that with bilateral placement of mini-implants, more overbite correction and intrusion can be achieved compared to single TAD placed at midline. During conventional mechanics when force is applied to achieve anterior intrusion an equal and opposite extrusive force is exerted on the molar teeth. As the force is exerted buccal to CR of molar tooth it results in lingual crown and buccal root tipping.[14] As there is no need of giving tip back bends in molars while attempting intrusion with mini-implants, hence there were less or clinically insignificant reactive forces on posterior segment, that could be managed by using heavy stainless-steel stabilizing archwire. Considering this, intrusion achieved using bilaterally placed mini-implants was selected for the present study.

Intrusive forces must be applied after correcting inclination of teeth, as more labial flaring will be seen when attempting intrusion of proclined teeth. The reason is, force application is further away from CR than in normoinclined tooth resulting in more labial flaring of incisors. If incisors are retroclined then CR will be lingual to point of application of force at brackets which is labially and lingual tipping will be obscured further deepening the bite. Hence correction of inclination prior to attempting intrusion or use of simultaneous intrusion and retraction arches should be used so that intrusive forces will be applied on four incisors with normal inclination.[11] Considering this, intrusion of normoclined incisors was attempted in the present study.

The role of alveolar bone height around incisors will also have the effect of amount of intrusive forces applied and moments generated due to this intrusive force. CR shifts apically with alveolar bone loss, thereby increasing the distance of the bracket to CR, hence moment generated will be more with same amount of intrusive force. Thus, the effect of alveolar bone loss on intrusion was evaluated in this study.

Among the different types of tooth movement, intrusion requires minimum amount of force as excessive forces can result in devitalisation of tooth, external root resorption etc. "**Steenbergen"** concluded that there was no statistically significant difference between the application of intrusive forces of 40g and 80g on four maxillary incisors in terms of the rate of incisor intrusion, or the amount of axial inclination change and extrusion. He advised the use of light forces for intrusion.[15] As intrusive force should be reduced with alveolar bone loss, hence it is decided to evaluate stress distribution at root apex on application of variable forces of 20, 40, 60 and 80gms for four maxillary incisors.

As clinical quantification of stress is not possible hence the finite element method (FEM), which calculates stress and displacement mathematically, was used in this study. Considering this the aim of the study was to evaluate stress distribution and displacement at root apex of normoinclined four maxillary incisors by two different mechanics (Burstone intrusion arch and miniscrew assisted intrusion) in presence of varying bone loss (0, 2 and 4mm) on application of variable intrusive forces (20, 40 60 and 80gms) using FEM.

AIM

Comparative evaluation of stress distribution and displacement of root apex of four normoinclined maxillary incisors using two different mechanics (Burstone intrusion arch and Mini-implants assisted intrusion) in presence of variable intrusive forces and variable bone loss using FEM.

OBJECTIVES

I. To calculate stress and displacement at apex of four normoinclined incisors by FEM on application of different magnitude of force i.e 20, 40, 60 and 80 gms at varying bone loss of 0, 2 and 4 mm using Burstone intrusion arch.

II. To calculate stress and displacement at apex of four normoinclined incisors by FEM on application of different magnitude of force i.e 20, 40 and 60 and 80 gms at varying bone loss of 0, 2 and 4 mm using Miniscrew placed at centre of resistance of four maxillary incisors.

III. To make intra group comparison of stress and displacement at apex of four maxillary incisors using Burstone intrusion arch at different forces and varying bone loss.

IV. To make intra group comparison of stress and displacement at apex of four maxillary incisors using Miniscrew at different forces and varying bone loss.

V. To make inter group comparison of stress and displacement at apex of four maxillary incisors on using two different mechanics at different forces and varying bone loss.

For a definitive stable result in correction of deep bite in adult and non-growing subjects, intrusion of upper anteriors is one of the options. Whenever forces are applied on teeth for various orthodontic movement there is stress build up on the teeth, surrounding periodontal ligaments and bone. And the stress distribution depends on the size and shape of tooth and amount of bone present around the tooth and its root surface. For the purpose of study the review of literature of the related articles are covered under following headings:

- Intrusion Biomechanics
- FEM studies on reaction of Intrusive forces and other Orthodontic forces on teeth and periodontium.

Intrusion Biomechanics

Burstone CJ (1977)[16] described about the necessity and differences in treatment mechanics for intrusion as not all patients can be treated using the same modality. He proposed six principles must be considered in incisor or canine intrusion: Use of optimal magnitude and constant of force delivery force with low load-deflection springs, use of a single point contact in the anterior region, point of force application with respect to the centre of resistance of the teeth to be intruded, inhibition of eruption of the posterior teeth and avoidance of undesirable eruptive mechanics.

Smith RJ, Burstone CJ (1984)[4] stated that Orthodontic forces can be treated mathematically as vectors. When more than one force is applied to a tooth, the forces can be combined to determine a single overall resultant. Forces produce either translation (bodily movement), rotation, or a combination of translation and rotation, depending upon the relationship of the line of action of the force to the centre of resistance of the tooth. The tendency to rotate is due to the moment of the force, which is equal to force magnitude multiplied by the perpendicular distance of the line of action to the centre of resistance. The only force system that can produce pure rotation (a moment with no net force) is a couple, which is two equal and opposite, noncolinear but parallel forces. The movement of a tooth (or a set of teeth) can be described through the use of a centre of rotation. The ratio between the net moment and net force on a tooth (M/F ratio) with reference to the centre of resistance determines the centre of rotation. Since most forces are applied at the bracket, it is necessary to compute equivalent force systems at the centre of resistance in order to predict tooth movement.

Vandenbulcke, Mark M, Dermmaut LR, Sachdeva RCL (1986)[17] did a study on twelve different systems of intrusion, based on the principle of the "segmented arch," on a macerated human skull. The number of teeth involved in the anterior unit and the location of the application points of intrusive force were considered to be variables. Initial displacements of the anterior teeth after loading were registered by means of the laser reflection technique and double exposure holographic recordings. An attempt was made to define "this" intrusive system, achieving the most genuine intrusion without flaring of the teeth. When two central incisors were incorporated in the sectional wire, strong torque forces appeared, especially when the intrusive forces seized more distally. When four or six anterior teeth were pinned in the sectional wire, tooth movement seemed to be under better control. When the six front teeth were incorporated in the sectional wire, the centre of resistance was located more to the distal side of the canines. It seemed more difficult, however, to define the centre of resistance of the four incisors; it was situated approximately distal to the lateral incisors. In some of the intrusive systems, the teeth underwent independent mesial or distal rotations. This was easily observed with the laser measuring techniques used.

Dermaut R. Munk AD (1986)[18] investigated whether root resorption of the upper incisors occurs during intrusion of maxillary incisors. It examines the possibility of a relationship between the amount of root shortening and duration of the intrusive force. The ratio of root length before and after intrusion was compared in 20 patients. In 66 incisors with an intrusion period of 29 weeks, an intrusion of 3.6 mm was performed. The control group consisted of 15 patients who underwent no orthodontic treatment. Consequently, 58 incisors had no intrusion. The follow-up time between 2 measurements was ±28 weeks. The findings clearly showed root shortening after intrusion. A mean resorption of 18% of the original root length was found. In comparison, none of the control patients showed root shortening. No correlation has been found between the amount of resorption and the amount and duration of intrusion. In combination with the apical deflection of the root, the nasal floor was occasionally a limiting factor for intrusion and this may have caused root resorption.

Melsen B, Agenbaek N, Markenstam G (1989)[19] found that elongated and spaced incisors are common problems in patients suffering from severe periodontal disease. Thirty patients characterized by marginal bone loss and deep overbite were treated by intrusion of incisors. Three different methods for intrusion were applied: (1) J hooks and extraoral high-pull headgear, (2) utility arches, (3) intrusion bent into a loop in a 0.17 x 0.25-inch wire, and (4) base arch as described by Burstone. The intrusion was evaluated from the displacement of the apex, incision, and the centre of resistance of the most prominent or elongated central incisor. Change in the marginal bone level and the amount of root resorption were evaluated on standardized intraoral radiographs. The pockets were assessed by standardized probing and the clinical crown length was measured on study casts. The results showed that the true intrusion of the centre of resistance varied from 0 to 3.5 mm and was most pronounced when intrusion was performed with a base arch. The clinical crown length was generally reduced by 0.5 to 1.0 mm. The marginal bone level approached the cementoenamel junction in all but six cases. All cases demonstrated root resorption varying from 1 to 3 mm. The total amount of alveolar support--that is, the calculated area of the alveolar wall--was unaltered or increased in 19 of the 30 cases. The dependency of the results on the oral hygiene, the force distribution, and the perioral function was evaluated in relation to the individual cases. It was obvious that intrusion was best performed when (1) forces were low (5 to 15 gm per tooth) with the line of action of the force passing through or close to the centre of resistance, (2) the gingiva status was healthy, and (3) no interference with perioral function was present.

McFadden WM, Engstrom C, Engstrom H, Anholrn JM (1989)[20] stated that apical root shortening is one of the most common complications of orthodontic treatment. Force magnitude has been suggested as an important factor. Studies on the occurrence of root resorption show equivocal results. The aim of the present study was to evaluate the relationship between intrusion with low forces (25 gm) using utility arches in the bioprogressive technique and root shortening. Age, sex, facial type, treatment time, extraction versus nonextraction therapy, width of the symphysis, and the angle of the incisors to skeletal reference planes also were studied for their relationship to intrusion and root shortening. Root shortening was found to average 1.84 mm for maxillary incisors and 0.61 mm for mandibular incisors subjected to intrusive force. Intrusion of incisors in a population exhibiting growth was found to be one of "holding against growth" and in the upper arch to a change in angulation of the maxillary incisors. Furthermore, when extraction was a part of the orthodontic treatment, it was related to intrusion of maxillary incisors but not to intrusion of mandibular incisors. No relationship was found between the amount of root shortening and degree of intrusion achieved. However, a long treatment time was significantly correlated to root shortening. None of the other characteristics studied were related to either intrusion or root shortening. In the present study, it was found that intrusion with the utility arch type of technique is not related to amount of root shortening. The degree of root shortening was markedly higher in the maxilla than the mandible.

Bennet JC, Mclaughlin RP (1990)[2] evaluated the correction of deep overbite by combination of various tooth movements such as – extrusion or uprighting of posterior teeth, increasing the inclination of anterior teeth or intrusion of anterior teeth are seen. It can be concluded from the study that deep overbites can effectively controlled with preadjusted appliances if we avoid extractions in low angle cases, using .022” slot bracket with .019x.025” inch working archwire, use of anterior bite plates at the beginning of the treatment in moderate to low angle cases, using light initial forces to avoid deeping of bite, avoid elastic retraction of cuspid, use of class II elastics selectively. For high angle cases, authors contraindicated the bite plates, class II elastics and stressed on anterior intrusion. They also advised avoiding banding of 2nd molar to avoid their extrusion and if required archwire should be stepped up behind the 1st molar.

Shroff B, Yoon WN, Lindaurer SJ, Burstone CJ (1995)[1] described the use of a three-piece base arch and Class I elastics to correct deep overbite while simultaneously closing spaces. An analysis of the biomechanics and a discussion of the appliance design are presented to help understand how the incisor axial inclination can be corrected and controlled during orthodontic therapy, so that incisors will be in cancellous bone during intrusion. It can be concluded that three-piece base arch assures the attainment of a predictable, reproducible and statistically determine force system with good control over the vertical dimension. The design of the appliance also allows the clinician to deliver a well-controlled force system with minimal chairside adjustment of the appliance.

Isaacson RJ, Rebellato J (1995)[21] in their study described that twists placed in an arch wire between incisor brackets are often used in an attempt to obtain root torque. This is only partially effective because of the equal and opposite reciprocals acting on the adjacent teeth. Alternatively, a V-bend in a torquing arch, inserted at only the molar and incisor brackets, may use the bending properties of the arch wire to create dissimilar moments in a two-bracket system. If the greater moment is present at the incisors, all of the incisors are rotated en masse in the same direction, with the associated equal and opposite vertical equilibrium forces directed at the incisors and molars. The lesser moment at the molar also usually has equilibrium forces that may reduce or supplement vertical forces at the molar and incisor depending on the magnitude and direction of the moment present. If the arch wire is unrestrained the resulting tooth movement shows rotation of the incisors around the C_{Res} and movement of the C_{Res} in the direction of the vertical equilibrium force present. The alternative use of a single force to rotate incisor crowns facially results in a reciprocal distal force at the posterior teeth and rotation of incisors with a centre of rotation apical to the C_{Res}.

Weiland FJ, Bantleon HP, Droschl (1996)[22] compared the efficacy of overbite correction achieved by a conventional continuous arch wire technique and the segmented arch technique as recommended by Burstone. The sample comprised 50 adult patients (age 18 to 40 years) with deep bites. Twenty-five patients were treated with a continuous arch wire technique (CAW); in the second half of the sample, the segmented arch technique (Burstone) was used for correction of the vertical malocclusion. Lateral cephalograms and plaster cast models taken before and immediately after treatment were evaluated. Statistical analysis was performed on the collected data. The results showed that both techniques produced a highly significant overbite reduction (CAW: -3.17 mm, $p < 0.001$; Burstone: -3.56 mm, $p < 0.001$). The CAW group showed an extrusion in the molar area with subsequent posterior rotation of the mandible. The Burstone group, however, showed overbite reduction by incisor intrusion without any substantial extrusion of posterior teeth. As a consequence, no significant posterior rotation of the mandible took place. It is concluded that in adult patients the segmented arch technique (Burstone) can be considered as being superior to a conventional continuous arch wire technique if arch leveling by incisor intrusion is indicated.

Costopoulos G, Ravindra Nanda (1996)[23] developed a new radiographic method to measure root length changes in orthodontic intrusion. Potential cause of apical root resorption of maxillary incisors due to orthodontic forces are investigated. An experimental group consisted of 17 patients was selected who were treated with a Burstone-type intrusion arch for excessive overbite, which delivered a low level of force (about 15 gm per tooth). A control group was made of 17 patients who were randomly selected with full-arch fixed appliances. After a period of approximately 4 months, the intrusion group had only slightly more root resorption than the controls, 0.6 mm versus 0.2 mm (statistically significant difference). Intrusion measured at the centre of resistance of the central incisor averaged 1.9 mm. The amount of resorption was not correlated with the amount of intrusion. A weak correlation, $r = 0.45$, was found between resorption and movement of the apex (i.e., in addition to intrusion, there was often palatal root movement). Results indicated that intrusion with low forces can be effective in reducing overbite while a negligible amount of apical root resorption takes place.

Ramsay DS, Barwick PJ (1996)[24] evaluated the effect of a 4-minute application of intrusive orthodontic force on human pulpal blood flow (PBF) with laser-Doppler flowmetry. Eight subjects had an intrusive force applied to a maxillary central incisor through a lever system. A cast chrome-cobalt coping was fabricated to fit over the incisor of each subject, and thus provided a reproducible point of force application as well as stabilization for the laser-Doppler flowmetry probe. Each subject participated in five testing sessions. During each session, PBF was measured during a 4-minute baseline period, then during the 4-minute force application, and then for a 12-minute period after removal of the force. Weights of 0, 5, 50, or 500 gm were attached to the end of the lever to produce intrusive forces ranging from 75 to 4498 gm. During the fifth testing session, local anesthetic with vasoconstrictor (epinephrine 1:100,000) was administered in place of the force application to determine the ability of this experimental paradigm to detect reductions in PBF. Baseline PBF values did not differ among sessions. Force levels had no statistically significant effect on PBF. However, PBF did drop significantly after administration of the vasoconstrictor. These results suggest that PBF is not altered during the application of a brief intrusive orthodontic force.

Nanda R, Marzban R, Kuhlberg A (1998)[25] described the Connecticut Intrusion Arch (CIA) is a multifunctional wire, preformed from nickel titanium and light continuous force distribution is used for incisor intrusion and performing other functions with minor modifications. The CIA remains active at a constant force level for a long period of time, allowing long interval between appointments and virtually eliminates the need of adjustments. Basic mechanism for force delivery is the V-bend to deliver 40-60gms of force, thereby achieving intrusion in every 6 weeks. The basic principles of intrusion is followed with this arch wire. Its simple design and minimal auxiliary requirement makes it a choice for busy clinician.

Parker RJ, Harris EF (1998)[26] found that external apical root resorption is a multifactorial problem encountered in all disciplines of dentistry, but it is most commonly seen in cases treated orthodontically. Specific tooth movements that are most likely to exacerbate external apical root resorption are poorly understood. Purpose of the present investigation was to quantify apical and incisal movements of the maxillary central incisor in the sagittal and vertical planes from cephalograms and to use stepwise multivariate linear regression analyses to see which tooth movements and skeleton-dental relationships are most predictive of external apical root resorption. On sample of 110 subjects treated with different appliance system there was no statistical difference in average external apical root resorption between sexes or among techniques. Measures of tooth movement were highly predictive, explaining up to 90% of the variation in root resorption. Apical and incisal vertical movements and increase in incisor proclination were the strong predictors of external apical root resorption for each regression model. Incisor intrusion with increase in lingual root torque together were the strongest predictors of external apical root resorption. In contrast, distal bodily retraction, extrusion, or lingual crown tipping had no significant effect.

Cobo J, Arguelles J (1998)[27] determined the stress that appears in the tooth, the periodontal ligament, and the alveolar bone, when a couple and horizontal forces were applied to obtain the bodily movement of a lower digitalized canine and its changes depending on the degree of loss of the supporting bone. The analysis of tensions was carried out by means of the finite element method (FEM) with no bone loss and after reducing the support bone 2, 4, 6, and 8 mm. False color three-dimensional images indicating intensity of stress (tensile and compressive) and extension are generated. After the application of the forces in the model without bone loss, a rather uniform distribution of stress is observed. When the bone loss is 2 mm, an increased stress in the levels next to the alveolar crest is already apparent. After 4, 6, and 8 mm of bone support reduction, a change of the sign and an increment of the magnitude of stress in the lowest levels occurs.

Tanne K, Sakuda M (1998)[28] investigated the stress levels induced in the periodontal tissue by orthodontic forces using the three-dimensional finite element method. The three-dimensional finite element model of the lower first premolar was constructed on the basis of average anatomic morphology and consisted of 240 isoparametric elements. Principal stresses were determined at the root, alveolar bone, and periodontal ligament (PDL). In all loading cases for the buccolingually directed forces, three principal stresses in the PDL were very similar. At the surface of the root and the alveolar bone, large bending stresses acting almost in parallel to the root were generally observed. During tipping movement, stresses nonuniformly varied with a large difference from the cervix to the apex of the root. On the other hand, in case of movement approaching translation, the stresses induced were either tensile or compressive at all occlusogingival levels with some difference of the stress from the cervix to the apex. The pattern and magnitude of stresses in the periodontium from a given magnitude of force were markedly different, depending on the centre of rotation of the tooth.

Parker RJ, Harris EF (1998)[29] conducted an investigation to quantify apical and incisal movements of the maxillary central incisor in the sagittal and vertical planes from cephalograms and to use stepwise multivariate linear regression analyses to see which tooth movements and skeletodental relationships are most predictive of external apical root resorption. The sample consisted of 110 adolescents with similar pre-treatment malocclusions (Class I crowded or bimaxillary protrusive) and treatment planned similarly (extraction of four first premolars) by experienced private practitioners. Each of three practitioners used a different orthodontic appliance; the sample was divided proportionately into cases treated with Tweed standard edgewise technique, Begg lightwire technique, and Roth-prescription straightwire technique. Lateral cephalograms were analyzed at the start, middle, and end of treatment. There was no statistical difference in average external apical root resorption between sexes or among techniques. Measures of tooth movement were highly predictive, explaining up to 90% of the variation in root resorption. Apical and incisal vertical movements and increase in incisor proclination were the strong predictors of external apical root resorption for each regression model. Incisor intrusion with increase in lingual root torque together were the strongest predictors of external apical root resorption. In contrast, distal bodily retraction, extrusion, or lingual crown tipping had no discernible effect.

Pearson LE, Pearson BL (1999)[30] conducted a prospective study of 20 consecutively treated patients (12 females and 8 males of average age 11.2 years) needing maxillary expansion and incisor intrusion. The patients were treated with a bonded maxillary expansion appliance, intrusion of the incisors with either a one-piece or three-piece base arch and anchorage augmented by the use of vertical pull chin cup therapy.

Because rapid palatal expansion and intrusion of maxillary incisors both produce extrusion of posterior teeth, this study was undertaken to determine if a combination of controlled forces could prevent undesirable increases in vertical dimension. The maxillae were widened approximately 8 mm, the incisors were intruded 3 mm, the maxillary molars stayed the same or were intruded slightly, and the mandibular plane angle stayed essentially the same. In addition, A-point was retracted slightly and the occlusal plane was rotated in a counter-clockwise direction.

Steenbergen EV, Burstone CJ, Anderson BP (2004)[15] determined whether the magnitude of intrusive force to the maxillary incisors influences the rate of incisor intrusion or the axial inclination, extrusion, and narrowing of the buccal segments. Twenty patients between the ages of 9 and 14 years who needed at least two mm of maxillary incisor intrusion were assigned to one of two equal groups. In group 1 patients, the teeth in the maxillary anterior segment were intruded using 40 g, whereas in group 2 patients, 80 g was used. Records were taken from each patient at the beginning and end of intrusion. There was no statistically significant difference between the 40 and 80 gm groups in the rate of incisor intrusion, or the amount of axial inclination change, extrusion, and narrowing of the buccal segments. Therefore 80 gm intrusive force compared to 40 gm force does not increase the rate of intrusion.

Geron S, Romano R, Brosh T (2004)[31] applied basic biomechanical considerations in understanding the influence of maxillary incisor inclination and to compare the effect of labial vs lingual intrusive/extrusive forces on tooth movement. Basic anatomic and geometric hypotheses were assumed, ie, tooth length (crown and root), location of the centre of resistance, and crown thickness. Incisor inclination as related to a perpendicular line to the occlusal plane (OP) varied between -35 degrees (retroclination) and 45 degrees (proclination). A 0 degrees inclination was defined as a tooth position with its long axis perpendicular to the OP. The buccolingual moment for characterizing root movement was calculated for an applied force perpendicular to the OP. The results showed that when using LaO, an extrusion force resulted in labial root movement from a retroclination of 20 degrees up to a proclination of 45 degrees. In LiO, labial root movement occurred only when the tooth was proclined more than

20 degrees. In all other tooth inclinations, lingual root movement occurred. The opposite tooth movement occurred when an intrusive force was applied. Application of a vertical force has different clinical effects on tooth movement with labial and lingual appliances. Application of a lingual force is more complicated, and its effect on tooth movement depends on bracket position and initial tooth inclination.

Papagegeorgiou IS (2005)[9] the aim of this study was to review the centre of resistance of one tooth or a group of teeth. The main methods used for determining the centre of resistance; relevant studies and their results are also reported. The centre of resistance of single-rooted teeth is found at a point located at a distance of 33-42% of the root length, when measured from the alveolar crest. Its location may change depending on root length, direction of applied forces, quantity of surrounding bone and age; there are indications that its location is also affected by tooth morphology, type of periodontal ligament, quality of surrounding bone, tissue response to forces applied, degree of humidity of neighbouring osseous structures and tooth axial inclination. The centre of resistance of a group of teeth differs depending on the number of teeth. Most research studies concern upper incisors and upper anterior teeth. However, there are conflicting views about the centre of resistance location during palatal movement and intrusion. Furthermore, our knowledge concerning the factors affecting the centre of resistance of a group of teeth is limited; this may be due to the fact that these factors cannot be easily measured when a tooth group is involved.

Amasyali M, Sagdic D, Olmez H, Akin E, Karacay S (2005)[32] examined and compared the effects of two different arches, the Connecticut Intrusion Arch (CIA) and the Utility Intrusion Arch (UIA). A total of 20 patients (15 girls and 5 boys) having Class I or Class II malocclusions with deep bite were divided into two groups. Lateral cephalograms were obtained before treatment and after intrusion of upper incisors. Statistical evaluation of lateral cephalograms revealed that upper incisors were intruded and protruded, upper first molars were extruded, and lower incisors were protruded in both groups. Due to the extrusion of the molars, anterior and posterior facial heights increased. It was determined that both of the mechanics were effective on intrusion of anterior teeth.

Kim TW, Kim H, Lee SJ (2006)[33] did a dental study where a boy of 10.5 years with Class II molar relationship and deep overbite, complaining of a gummy smile and anterior crowding, he was treated non extraction with a mini-implant and Twin-block and edgewise fixed appliances. Severely extruded and retroclined maxillary incisors were intruded and proclined with a nickel-titanium closed-coil spring anchored to a mini-implant and segmented wires; this resolved the gummy smile and deep overbite efficiently without extruding the maxillary molars or opening the mandible. The mandibular incisors were proclined without direct orthodontic force during intrusion of the maxillary incisors; this helped the non-extraction treatment of mandibular incisor crowding. The Twin-block appliance with high-pull headgear promoted mandibular growth, restrained maxillary growth, and changed the canine and molar relationship from Class II to Class I. The patient's overbite and overjet were overtreated, and, 1year post retention, the patient maintained a good overbite and overjet.

Steenbergen EV, Burstone CJ, Anderson BP, Aartman IHA (2006)[34] determined whether the size of the maxillary buccal segment influences the amount of steepening, extrusion, or narrowing of the buccal segments, or the rate of intrusion that occurs with maxillary incisor intrusion. Twenty patients, 9 to 14 years of age, seeking treatment at a private practice, were divided into 2 groups. Patients in the long buccal-segment group had maxillary buccal segments that included the canines, both premolars, and the first molars. In the short buccal-segment group, the buccal segments consisted of only the maxillary first molars. Patient records were taken at the beginning and end of maxillary incisor intrusion. Intermolar width increased slightly in the short buccal-segment group and decreased slightly in the long buccal-segment group. More steepening of the buccal segment occurred in the short buccal-segment group, and more proclination of the anterior segment in the long buccal-segment group. The size of the buccal segment had no influence on the rate of incisor intrusion or on the amount of buccal-segment extrusion. In both groups, the mean amount of incisor intrusion exceeded 2 mm. A buccal segment that extends from canine to first molar will help minimize the side effects of incisor intrusion.

Upadhayay M, Nagaraj K, Yadav S, Saxena R (2008)[35] described the treatment of a 16-year-old post pubertal male patient with a severe Class II division 2 malocclusion and 100% deep bite. In the first phase of treatment, a 'Jones-Jig' molar distalization appliance was used to distalize the maxillary molars by more than 6 mm, to achieve a Class I molar relation. In the second phase of treatment, mini-implants were inserted between the roots of the maxillary lateral incisor and canine to intrude all the maxillary anterior teeth en masse in a single step. Four millimetres of intrusion was achieved. The implants remained stable throughout treatment. In the mandibular arch the incisors were proclined to alleviate the severe crowding. Good overjet and overbite was achieved and has been maintained one year after completion of active orthodontic treatment.

Sifakakis I, Pandis N, Makou M, Elides T, Bourauel C (2009)[36] conducted a study to evaluate the comparative intrusive forces and torquing moments in the sagittal plane generated during anterior intrusion using different incisor intrusion mechanics in the maxillary and mandibular anterior teeth. Five wire specimens were used for each of the following intrusive arches: non-heat-treated, 0.016 x 0.016-inch blue Elgiloy utility arch, 0.017 x 0.025-inch TMA utility arch, and 0.017 x 0.025-inch TMA Burstone intrusion arch. The wires were inserted on bracketed dental arches on Frasaco models, segmented mesial to the canines. Simulated intrusion from 0.0-1.5 mm was performed on the Orthodontic Measurement and Simulation System (OMSS), and forces and moments were recorded at 0.1 mm vertical displacement increments. The 0.017 x 0.025-inch TMA Burstone intrusion arch exerted the lowest intrusive forces, followed by the 0.017 x 0.025-inch TMA utility and the 0.016 x 0.016-inch blue Elgiloy utility arch. The lowest anterior moment in the sagittal plane in this experiment was generated from the 0.017 x 0.025-inch TMA Burstone intrusion arch. The intrusive forces, as well as the generated moments, were always higher in the mandible, where significant differences were observed among these configurations tested.

Ramanathan C and Hofman Z (2009)[37] compared the extent of maxillary incisor root resorption during different orthodontic tooth movements using three different techniques, namely the basal intrusion arch, the three-component arch, and levelling of the upper dental arch with the straightwire appliance. The radiographs of 49 subjects (20 males and 29 females) with a mean age of 14.5 years were taken at two time points: in groups 1 and 2 after the levelling phase and in group 3 immediately after placement of the archwire (T1) and in all groups after a period of 6 months (T2). The amount of root resorption of the central incisors was determined at T2. The average incisor resorption was different in the three groups, with group 2 (three component arch) showing greater resorption (0.46 mm) than groups 1 (basal arch) and 3 (straightwire) of 0.26 and 0.25 mm, respectively. Analysis of variance (ANOVA) demonstrated that differences in root resorption in the three groups were not significant. Wilcoxon paired test showed that the root resorption occurring between T1 and T2 in the three groups was not significant. There was also no significant difference among the rates of resorption in the three groups. Grouping the subjects on the basis of the extent of root resorption and the biomechanics used showed differences in the percentage of subjects with the least (<0.5 mm) and greatest (0.5-0.9 mm) amounts of root resorption between the three groups. This again showed that the technique of three component intrusion arch resulted in the greatest increase in root resorption.

Amarnath BC, Prashnath CS, Dharma RM (2010)[38] suggested that the excessive overbite is a complex orthodontic problem that may involve a particular group of teeth or the whole dentition, or the maxilla and mandible. The correction of deep bite is one of the primary objectives of orthodontic treatment and one of the most difficult to treat successfully. Innumerable methods have been developed to treat deep bite but no single approach is best. Each approach has its own advantages and disadvantages and optimal correction of deep overbite requires accurate diagnosis, individualized treatment planning and efficient execution of treatment mechanics. The authors suggested the use of various treatment modalities such as utility arches, three piece intrusion arch, K-SIR arch, implants, J-hook and headgear for deep bite correction presently available to the clinician and also gives a brief inside into the diagnostic and selection criteria to be applied for successful and stable deep bite correction.

Belludi A, Bhardwaj A, Gupta A, Karandikar A (2011)[6] stated Orthodontic anterior intrusion for correcting deep bites often constitutes an integral part of orthodontic treatment in order to improve sagittal and vertical incisor relationships, in cases of pseudo-deep overbite, where the anteriors are supra erupted true intrusion of the incisors is indicated and also in patients with gummy smiles and periodontal compromised teeth to correct the gingival line and restore the esthetics of smile. There are various treatment modalities for most of these clinical situations with conventional mechanics like the technique advocated by Rickets or Burstone. However, the use of mini-implants for intrusion has revolutionized orthodontic anchorage and biomechanics by making anchorage perfectly stable. Bilateral Mini implants (TAD's) placed between lateral incisor and canine serve as an efficient source of anchorage for achieving true incisor intrusion for correcting deep overbite. Single mini-implant placed below anterior nasal spine is also an effective method to achieve true intrusion. And TAD's has no deleterious side effects on posterior segment as here skeletal anchorage is used rather that posterior teeth as anchor unit or reciprocal unit.

Polat Ozsoy, Arman Ozcirpici, Veziroglu F, Cetinsahin A (2011)[7] compared the effects of incisor intrusion obtained with the aid of miniscrews and utility arches. Twenty-four patients (10 male, 14 female) with a deep bite of at least 4 mm were divided to 2 groups. In group 1, 13 patients (3 male, 10 female) in the post pubertal growth period were treated by using miniscrews; in group 2, 11 patients (7 male, 4 female) were treated with utility arches. Lateral cephalometric head films were taken at the beginning of treatment and after intrusion for the evaluation of the treatment changes. Statistical analyses of the data were performed with a significance level of $P < 0.05$. It was observed that Intrusion lasted 6.61 ± 2.95 months for group 1 and 6.61 ± 2.46 months for group 2. The changes in the centre of resistance of the incisors were 1.75 ± 0.4 mm for group 1 and 0.86 ± 0.5 mm for group 2. The difference between the groups was significant. In the miniscrew group, the incisors were protruded 0.79 ± 1.4 mm relative to pterygoid vertical and $3.85° \pm 2.4°$ relative to the palatal plane. In group 2, the incisors showed 3.91 ± 0.7 mm of protrusion relative to pterygoid vertical and $13.55° \pm 2.4°$ relative to the palatal plane. The maxillary first molars showed significant distal tipping in group 2. And it is concluded from the study that with true maxillary incisor intrusion can be achieved by application of intrusive forces close to the centre of resistance by using miniscrews with no counteractive movements in the molars.

Senisik NE, Turkkahraman H (2012)[39] compared the skeletal and dental effects of 2 intrusion systems involving mini-implants and the Connecticut intrusion arch in patients with deep bite. The study sample consisted of 45 adults (26 women, 19 men) with deep bite. They were divided into 3 groups: 2 treatment groups and 1 untreated control group (15 subjects in each group). The Connecticut intrusion arch and the implant groups underwent maxillary incisor intrusion with Connecticut intrusion arches and a mini-implant system, respectively. During the 7-month study period, no other treatment was performed with the exception of maxillary incisor intrusion. It is observed that mean amounts of genuine intrusion were 2.20 mm (0.31 mm per month) in the Connecticut intrusion arch group and 2.47 mm (0.34 mm per month) in the implant group. No statistically significant differences were found in the extent of maxillary incisor intrusion between the 2 intrusion systems. Both systems led to protrusion and intrusion of the maxillary incisors and protrusion and extrusion of the mandibular incisors. In the Connecticut intrusion arch group, the maxillary molars were extruded by moving the crown distally and the root mesially. The 2 intrusion systems were statistically different in the extent of axial inclinations of the maxillary molars. The authors concluded that Connecticut intrusion arch and the mini-implant intrusion systems successfully intruded the 4 maxillary incisors. Although the movement of the maxillary molars led to the loss of sagittal and vertical anchorages during intrusion of the incisors in the Connecticut intrusion arch group, these anchorages were maintained in the implant and control groups.

Sana S, Bansal A, Sami L, Tapashetti R, Gaikwad S (2014)[40] found that most Class II division 2 malocclusion manifest a severe deep bite, the orthodontic correction of deep overbite can be achieved with several mechanisms one such mechanics is true intrusion of anterior teeth. Deep overbite correction by intrusion of anterior teeth affords a number of advantages which includes simplifying control of the vertical dimension and allowing forward rotation of mandible to aid in Class II correction. It also aids in correction of a high gingival smile line. This case report presents the patient of a 14 year old boy with Class II division 2 subdivision malocclusion treated with Connecticut intrusion arch and also highlights the biomechanical aspect of this appliance. Intrusion of anterior teeth is difficult. An appropriate, effective and clinically manageable biomechanical system is required. The treatment approach shown in this case can treat the deep overbite precisely with incisor intrusion. The article shows the versatility of Connecticut Intrusion Arch and by applying the sound biomechanical principles we can execute the planned mechanics with minimal side effects.

Atik E, Coskuner HG, Guven BA and Taner T (2018)[41] investigated the changes in alveolar bone after maxillary incisor intrusion and to determine the related factors in deep-bite patients. Fifty maxillary central incisors of 25 patients were evaluated retrospectively. The maxillary incisors in Group I (12 patients; mean age, 16.51± 1.32 years) were intruded with a base-arch, while those in Group II (13 patients; mean age, 17.47 ± 2.71 years) were intruded with miniscrews. Changes in the alveolar envelope were assessed using pre-intrusion and post-intrusion conebeam computed tomography images. Labial, palatal, and total bone thicknesses were evaluated at the crestal (3 mm), mid root (6 mm), and apical (9 mm) levels. Buccal and palatal alveolar crestal height, buccal bone height, and the prevalence of dehiscence were evaluated. Two-way repeated measure ANOVA was used to determine the significance of the changes. Pearson's correlation coefficient analysis was performed to assess the relationship between dental and alveolar bone measurement changes. It is observed that upper incisor inclination and intrusion changes were significantly greater in Group II than in Group I. With treatment, the alveolar bone thickness at the labial bone thickness (LBT, 3 and 6 mm) decreased significantly in Group II as compared to Group I. The LBT change at 3 mm was strongly and positively correlated with the amount of upper incisor intrusion. Hence, it is concluded from the study that change in the labial inclination and the amount of intrusion should be considered during upper incisor intrusion, as these factors increase the risk of alveolar bone loss.

Hernández AV, Zubeldia LG, García RL, Sanz VG, Gallardo VP (2020)[13] found miniscrews are effective devices for performing upper incisor intrusion. Different mechanics can be applied depending on the treatment objectives. This study aimed to evaluate the efficacy of one or two anterior miniscrews for upper incisor correction in cases of overbite and angulation in adult patients. Forty-four adults with deep overbite were divided into two groups. Group 1 was treated with one miniscrew between upper central incisors and Group 2 with two miniscrews between upper lateral incisors and canines. Incisor intrusion and length were measured from lateral cephalograms before treatment, after treatment and at least 12 months into retention. Forces were applied 90 gms from the miniscrews to the archwire using elastomeric chains. ANOVA analysis was used to determine whether differences between evaluation times were statistically significant. The mean root resorption was 2.15 ± 0.85 mm, which ceased after active treatment. Overbite mean correction was − 3.23 ± 1.73 mm with no statistically significant relapse. Overbite correction and incisor intrusion were significantly greater in group 2 (− 3.80 ± 1.43 versus − 2.75 ± 1.63) for overbite and for intrusion (8.19 ± 3.66 versus 5.69 ± 2.66). Resorption and overbite correction were positively related. No counter clockwise rotation of the mandibular plane was observed.

FEM studies on reaction of Intrusive forces and other Orthodontic forces on teeth and periodontium.

Tanne K, Koenig AH, Burstone CJ, Sakuda M (1989)[42] investigated the effect of moment to force (M/F) ratios on stress distributions in the PDL. Three-dimensional finite element method (FEM) was applied to stress analysis, using a three-dimensional model of the upper central incisor. Five force systems were established to produce different M/F ratios with a constant 100 g lingual force and/or varying labial crown couples, applied at a point on the labial crown surface, 4 mm gingival to the incisal edge. Stresses were determined in the centre of the PDL for eight apico-gingival levels and at sixteen points around the root. Stress patterns and levels in the PDL changed in response to varying M/F ratios, however, stress values were invariable at the level of the centre of resistance. M/F ratio for translation of a tooth produced the most uniform pattern of stress distributions and the minimum stress levels. It is found that the stress level induced in tooth translation is approximately 0.29 times as that in simple tipping of a tooth. Thus, it is shown that the M/F ratio is an important determinant for controlling the stress patterns and levels in the PDL and for achieving optimal tooth movement.

McGuinness N, Wilson AN, Jones M (1992)[43] used finite element technique to determine the stress induced in the periodontal ligament in three dimensions when a maxillary canine tooth is subjected to an orthodontic force similar to that produced by an edgewise appliance. The maximum stress induced at the cervical margin of the periodontal ligament was 0.072 N/mm2, while the maximum stress induced at the level of the apical foramen was 0.0038 N/mm2. These results are discussed in the light of known clinical experience and compared with the stresses produced in the periodontal ligament by other orthodontic forces. The findings would suggest that even with 'perfect' edgewise mechanics it would be difficult to obtain canine movement by pure translation or bodily movement.

Geramy A (2000)[44] studied the behaviour of initial tooth displacements associated with alveolar bone loss situations when loaded by a force of 1 N. The analysis of displacements was carried out by the finite element method. Six 3-dimensional models of an upper central incisor with 1 to 8 mm of alveolar bone loss were formulated and used by the authors. Centre of rotation and centre of resistance were located for the various stages of alveolar bone loss. The results revealed that the moment/force ratio at the bracket level required to produce bodily movement increases in association with alveolar bone loss. Bone loss causes centre of resistance movement toward the apex, but its relative distance to the alveolar crest decreases at the same time. Greater amounts of displacements of incisal edge and apex were observed with increased alveolar bone loss for a constant applied force. Centre of rotation of the tipping movement also shifted toward the cervical line. Among the many differences between orthodontic treatment of an adolescent and an adult patient is the presence of alveolar bone loss in the adult cases. Alveolar bone loss causes centre of resistance changes as a result of the alterations in bone support. This necessitates modifications in the applied force system to produce the same movement as in a tooth with a healthy supporting structure.

Rudolph D J, Willes M G, Sameshima G T (2001)[45] determined the types of orthodontic forces that cause high stress at the root apex. A 3-dimensional finite element model of a maxillary central incisor, its periodontal ligament (PDL), and alveolar bone was constructed on the basis of average anatomic morphology. The maxillary central incisor was chosen for study because it is one of the teeth at greatest risk for apical root resorption. The material properties of enamel, dentin, PDL, and bone and 5 different load systems (tipping, intrusion, extrusion, bodily movement, and rotational force) were tested. The finite element analysis showed that purely intrusive, extrusive, and rotational forces had stresses concentrated at the apex of the root. The principal stress from a tipping force was located at the alveolar crest. For bodily movement, stress was distributed throughout the PDL; however, it was concentrated more at the alveolar crest. We conclude that intrusive, extrusive, and rotational forces produce more stress at the apex. Bodily movement and tipping forces concentrate forces at the alveolar crest, not at the apex.

Geramy A (2002)[46] investigated the stress components (S1 and S3) that appear in the periodontal membrane (PDM), when subjected to transverse and vertical loads equal to 1 N. A further aim was to quantify the alteration in stress that occurs as alveolar bone is reduced in height by 1, 2.5, 5, 6.5, and 8 mm, respectively. Six three-dimensional (3D) finite element models (FEM) of a human maxillary central incisor were designed. The models were of the same configuration except for the alveolar bone height. Special attention was paid to changes of the stress components produced at the cervical, apical, and sub-apical levels. In the absence of alveolar bone loss, a tipping force of 1 N produced stresses, which reached 0.072 N/mm2 at the cervical margin, up to 0.0395 N/mm2 at the apex and up to 0.026 N/mm2 sub-apically. In the presence of 8 mm of alveolar bone loss, the findings were -0.288, 0.472, and 0.722 N/mm2, respectively. Without bone loss, an intruding force of the same magnitude produced stresses of -0.0043, -0.0263, and 0.115 N/mm2, respectively, for the same areas and sampling points. In the presence of 8 mm of alveolar bone loss the findings were -0.019, -0.043, and 0.185 N/mm2 for intrusive movement. The results showed that alveolar bone loss caused increased stress production under the same load compared with healthy bone support (without alveolar bone resorption). Tipping movements resulted in an increased level of stress at the cervical margin of the PDM in all sampling points and at all stages of alveolar bone loss. These increased stress components were found to be at the sub-apical and apical levels for intrusive movement.

Choy K, Pae E K, Park Y, Kim K H, Burstone C J (2004)[47] conducted a study to achieve predictable and physiologic orthodontic tooth movement, estimating the axis of rotation of a tooth and the level and location of maximum stress distributed in the periodontal ligament. An extracted upper canine was scanned into a computer 2-dimensionally and divided into 80 nodes along the long axis of the tooth. A mathematical formula was derived, and stress was calculated on each node. The purpose of this study was to reveal the centre of resistance, axis of rotation, and an ideal force magnitude associated with various periodontal conditions, such as potential root resorption, alveolar bone loss, and varying anatomic root shape by analysing the stress distribution in the periodontal ligament. The study demonstrates that the location of centre of resistance changes significantly with variation of shape and length of the root embedded in alveolar bone. In contrast, in response to alveolar bone loss, the relative location of the centre of resistance to total root length remains constant. Analysis of the stress distribution pattern in our 2-dimensional model reveals that the relationship between location of force and axis of rotation is determined by "*s2*" that is a constant depends on shape and length of a root in alveolar bone. Tapered and short roots that result from alveolar bone loss or apical root resorption are prone to tipping. The optimal orthodontic force may vary depending on the maximum stress in the periodontal ligament.

Brezeanu L, Bica C, Pacurar M, Sita D (2007)[48] focused on analysis of the biomechanical reactions within teeth displacements during the action of orthodontic forces and it uses the FEM in order to anticipate the tissue phenomena into the dental-periodontal structures. The orthodontic forces are exerted on the tooth crowns by different directions. The most important types of orthodontic forces are the vertical and horizontal forces which produces intrusion and tipping orthodontic tooth displacements. Optimal intensities of orthodontic forces are IN and 3N but excessive values of 7N and 10N have been used in this study, in order to obtain a complex study and a correct comparison of the effect of orthodontic force when its intensity is increased. When a tooth is intruded, the force is concentrated over a small area at the apex. According to the geometry, dimensions and morphology of the central incisor (CI), a general three-dimensional model was created, which includes three components: tooth, periodontal ligament (PDL) and alveolar bone. Horizontal and vertical orthodontic force were applied. Result showed that displacements and stress (tensions) depending on the force direction on oral (O) and labial (L) sides and in dental axis. It concluded that stress concentration at the apex during orthodontic intrusions is confirmed and it could lead to undesirable reactions like pulpal alterations, root resorbtions or alveolar bone loss. When intensities of force passes 4N, it act as iatrogenic factors for dental Periodontal structures. Stress more than 60gm/cm² causes haemorrhages, diapedesis, partial or complete pulpal degeneration. The most affected tissue is periodontal ligament (PDL) which reacts strangely when orthodontic forces with high values intensities are applied.

Szuhanek C (2007)[49] Studied the stress distribution in the PDL by lingual orthodontics after application of forces, in cases with varying bone height was evaluated by 3D FEM models. In case of periodontal disease and of alveolar bone loss, the centre of resistance will be modified and the application point of orthodontic forces will vary. Based on the normal teeth morphology, 3D models of an upper central incisor with normal bone level, 3mm bone loss and 6mm bone loss were constructed. After the construction of the geometrical models, material characteristics were introduced and the resulted numerical models were subjected to orthodontic forces. Tipping forces were applied lingually with an intensity of 25g. The application points varied on mesiodistal direction and on different heights from the incisal area. The stress values were concentrated on apical area and on alveolar crest and were higher with the degree of the alveolar bone loss. The statistical analysis showed that for the same alveolar bone loss degree, the stress are decreasing with the increasing of H and they are less dependent of M-D values. The accuracy of bracket placement is very important in achieving the desired result. The intensity of orthodontic forces should be kept at minimal levels especially in cases with alveolar bone loss, in order to allow bone remodeling and to reduce iatrogenic effects.

Holberg C, Steinhauser S, Rudzki-Janson I (2007)[50] examined the extent of stress reduction in the midface and the cranial base with various surgical procedures. Four finite element models of the skull were generated (one without and three with different surgical incisions), in which a virtual RME (5mm gap width) was simulated. In all four simulations, Von-Mises stresses were measured at 30 anatomical structures of the midface and cranial base (in MPa) and compared. The highest Von-Mises stresses were measured with the model that did not involve any osteotomies, A reduction of the observed stresses was found after isolated weakening of the zygomaticoalveolar crest on both sides. The model with a complete lateral osteotomy from the piriform aperture to the pterygopalatal junction clearly showed lower stresses than the model with isolated weakening of the zygomaticoalveolar crest. The lowest stress values, however were seen on the model with a complete osteotomy at the Le Fort I level. In order to prevent complications at the cranial base. surgical assistance is an important aspect of RME in adults. The extent of osteotomies can be varied. The older the patient and the less the bone elasticity, the more extensive should be the surgical weakening in order to minimize the stresses induced at the cranial base and the midface. In older patients, a complete lateral osteotomy from the piriform aperture to the pterygopalatal junction seems to reduce stresses at the cranial base more effectively than isolated weakening of the zygomaticoalveolar crest.

Jin S, Kim IT, Kook YA (2009)[51] investigated the changes in the centre of resistance of the maxillary teeth in relation to alveolar bone loss. A FEM model, which included the upper dentition and PDL was designed according to the amount of bone loss (0mm, 2mm and 4mm). The teeth in each group were fixed with buccal and lingual arch wires and splint wires. Retraction and intrusion forces of 200gm for 4 and 6 anterior teeth groups and 400gm for the full dentition group were applied. It was concluded that the centre of resistance shifted apically and posteriorly as alveolar bone loss increased in 4 and 6 anterior teeth groups. However, in the full dentition group, the centre of resistance shifted apically and anteriorly in the 4mm bone loss model.

Freitas AC, Rocha EP, Santos PHD, Chang KC, Martin M, De Almeida EO (2009)[52] aimed to evaluate the influence of loading on a maxillary central incisor with the periodontal ligament (PDL) represented by 2D elastic beam elements using a 2D finite element analysis. Two models (M) were built varying the PDL representation: Mh (homogeneous PDL) and Mht (heterogeneous PDL with beam3 elements). Stress and displacements were determined for three loading conditions (L): Ll, lingual face loading at 45° with the tooth long axis; Li, perpendicular to the incisal edge; and Lip, on the incisal edge, parallel to the tooth long axis. Evaluation was performed on ANSYS software. Lip provided lower stress variation on the tooth and support structures when compared to Ll and Li. PDL's influence on stress values was lower for Lip. Oblique loading showed stress and displacement not observed in parallel loading condition through PDL's heterogeneous representation and it is probably incompatible with the in vivo condition.

Liang W, Rong Q, Lin J, Xu B (2009)[53] conducted a study on torque control variance of the maxillary incisors in both labial Orthodontics (LaO) and lingual Orthodontics (LiO) with 3-D finite element methods. A 3-D finite element model of the maxilla and the maxillary incisors was made. Horizontal retraction force, vertical intrusive force and lingual root torque were applied to simulate LaO and Lio treatment. Load 1, Mo+ Fo+ Fz was applied to the midpoint of the labial surface of the crown of maxillary central and lateral incisor. Mo was -5 x 103 N with M couple applied in the lingual root direction, Fo was IN horizontal retraction force in the lingual direction and Fz was 0.64 N vertical intrusive force. The force application nodes on the central and lateral incisors were at the same horizontal level - 4.67 and 4.31mm respectively, vertical from the incisal edge. Load 2 was the same as load 1 to the midpoint of the lingual surface of the crown of the maxillary central and lateral incisor. Point of force application was at the same horizontal level that is 3.51 and 3.03mm respectively vertical from the incisal edge. Distribution of the stress-strain in the PDL, the total displacement and the vector graph of displacement of the nodes of the maxillary central incisor were analysed and compared between LaO and LiO. Result showed that loads of the same magnitude produce translation of the maxillary incisors in LaO but lingual crown tipping of the same tooth in LiO. This suggest that loss of torque control of the maxillary incisors during retraction in extraction patients is more likely in Lio treatment. Hence it can be concluded that LiO should not simply follow the clinical experience of the labial techniques but should increase lingual root torque, increase vertical intrusive force and decrease horizontal retraction force.

Vikram NR, Hashir YM, Karthikeyan MK (2010)[54] in their review article stated that finite element analysis is a commonly applied experimental research technique which enables us to study the effects of geometric and material variations under load and internal mechanical process. FEM originally used in structural analysis has revolutionised dental biomedical research. FEM can be applied in analysis of stresses produced in the periodontal ligament when subjected to orthodontic forces, to study stress distribution in tooth in relation to different designs, to optimize the design of dental restorations. to investigate stress distribution in tooth with cavity preparation, the type of predictive computer model described may be used to study the biomechanics of tooth movement. Concentrating on the advantages of FEM - it does not require extensive instrumentation, it's a non-invasive technique with close resemblance to natural conditions and enables us to perform static and dynamic analysis whereas disadvantage of FEM includes the tooth is treated as pinned to the supporting bone, which is considered to be rigid and the nodes connecting the tooth to the bone are considered fixed. This assumption will introduce some error however, maximum stresses are generally located in the cusp area of the tooth. The progress in the FEA will be limited until better defined physical properties for enamel, dentin, periodontal ligament, cancellous and cortical bone are available.

Mathur AK, Gupta V, Sarmah (2011)[55] calculated the stress pattern in periodontal ligament due to various orthodontic forces with emphasis on stress distribution at the root apex at maxillary central incisor using FEM. An in vitro FEM was used to construct a three dimensional FE model of a maxillary central incisor, its PDL and alveolar bone was constructed on the basis of average anatomic morphology. To this model, five types of orthodontic forces namely tipping, bodily movement, intrusion, extrusion and rotations were applied at various points on the crown of the tooth model. After the application of the forces (intrusive force of 10gm), initial stress and displacement of the PDL were evaluated. The principal stress obtained on the PDL due to various orthodontic loading on the maxillary central incisor was analysed using ANSYS 10 finite element software. Results showed that the greatest amount of relative stress at the apex of maxillary central incisor occurred with intrusion, extrusion and rotation. Bodily movement and tipping forces produce stress concentration at the alveolar crest and not at the root apex. Clinical implication of this study suggested that if the clinician is concerned about placing heavy stresses on the root apex, then vertical and rotational forces must be applied with caution.

Suzuki A., Masuda T, Takahashi 1, Deguchi T, Suzuki O, Takano- Yamamoto T (2011)[56] found miniscrews can be used to provide absolute anchorage during orthodontic treatment. If optimum design or shape of the miniscrew can be obtained, we might be able to reduce its size and lessen the chance of root contact. In addition, miniscrews are placed at several angles and orthodontic forces are applied in various directions for clinical requirements. In this study, finite element analysis was used to investigate changes in stress distribution at the supporting bone and miniscrew by changing the angle and the shape of the miniscrew and the direction of force. Three types of miniscrews (cylindrical pin, helical thread, and nonhelical thread) were designed and placed in 2 types of supporting bone (cancellous and cortical). The miniscrews were inclined at 30°, 40°, 45°, 50°, 60°, 70°, 80° and 90° to the surface of the supporting bone. A force of 2N was applied in 3 directions. Results showed significantly lower maximum stress was observed in the cancellous bone compared with the cortical bone. By changing the implantation angle, the ranges of the maximum stress distribution at the supporting bone were 9.46 to 14.8 MPa in the pin type and 17.8 to 75.2 MPa in the helical thread type. On the other hand, the ranges of the maximum stress distribution at the titanium element were 26.8 to 92.8 MPa in the pin type and 121 to 382 MPa in the helical thread type. According to the migration length of the threads in the non-helical type, the maximum stresses were 19.9 to 113 MPa at the bone and 151 to 313 MPa at the titanium element. By changing the angle of rotation in the helical thread type, the maximum stress distributions were 25.4 to

125 MPa at the bone and 149 to 426 MPa at the titanium element. Furthermore, the maximum stress varied at each angle according to the direction of the applied load.

Singh M, Mehrotra P (2011)[57] stated that certain clinical conditions often demand selective intrusion of anterior teeth like Class II div 1 or the Class II div 2 cases where only the incisors or anteriors are extruded especially in adult patients in which esthetics hold a major issue leading to the increased demand of lingual orthodontic appliance. Thus the amount of intrusive force ratio as compared to the retractive force required for true intrusion of maxillary central incisor with lingual bracket system was evaluated and compared those biomechanical responses with that of labial bracket system. A FE Model of maxillary central incisor was prepared using Solid Edge and HYPERMESH and analysis was carried out with ANSYS software. Three inclinations to occlusal plane were created i.e. normal inclination (61 deg), retroclination (79 deg) and proclination (39 deg). Various force magnitudes were applied to determine a distinctive ratio of intrusive (25gm for each inclination) and counterbalancing retractive forces (32.3gm for 61°, 13.8gm for 39º and 40.32gm for 79°) such that pure intrusion could occur in all the three clinical scenarios. Results showed that true intrusion can be achieved with lingual mechanics similar to that of labial mechanics when an accurate biomechanical principle is applied. It is concluded that significantly different force ratios were obtained for labial and lingual brackets so that pure intrusion could occur in all three clinical scenarios.

Kamble RH, Lohkare S, Hararey PV, Mundada RD (2012)[58] investigated stress distribution in the roots of maxillary central incisors bearing various types of root morphologies with regard to application of different types of orthodontic forces using the finite element model (FEM). FEMs of maxillary central incisors with different root morphologies (normal, short, blunt, dilacerated, and pipette) were constructed, and orthodontic forces in various directions (intrusion, extrusion, tipping, and rotational) were applied to the tooth axis at the bracket level. On application of various forces, significantly increased stress was seen at the apex of the root with dilacerated morphology and at the cervical one-third region of the tooth with the short root. Increased stress was observed at the middle one-third region in the tooth with the pipette-shaped root during intrusion and extrusion. Authors from this study concluded that the stress distribution pattern indicates that the maxillary central incisors with deviated root morphology are at higher risk of root resorption.

Padmawar SS, Belludi A, Bhardwaj A, Vadvadgi V, Saini R (2012)[59] evaluated and compared the stresses generated in maxillary anterior region during absolute en masse intrusion of six maxillary teeth using mini-implants at strategic locations. Finite element model was generated using FEM software and analysis was carried out to study the stress distribution in maxillary anterior region during true incisor intrusion. This model is the replica of adult human maxilla. The model consisted of periodontal ligament, alveolar bone and all the teeth except third molars. The bracket system simulated was MBT extraction series bracket system from 3M Unitek (0.22" Slot) and the archwire was of 0.021×0.025 inch stainless steel consisting of two attachments between central and lateral incisors bilaterally. Results showed that soft bone and hard bone showed significantly high stress distribution in maxillary anterior region. It was concluded that stresses on the teeth, soft bone and hard bone were concentrated more on and near the central incisors as compared to lateral incisors. This was probably because the point of force application was between the central incisors and away from the lateral incisors.

Vikram NR, KS Senthil Kumar, Nagachandran KS, Hashir YM (2012)[60] determined an apical stress incident on the maxillary central incisor during tooth movement with varying cemental and periodontal ligament thickness by Finite Element Method (FEM) modeling. Four parameters will influence the predictive accuracy of a mechanical FE model.

1) Geometric details of an object to be modelled

2) Choice of an element type

3) Material properties

4) Boundary conditions

Cemental thickness at the root apex was varied from 200um to 1000µm in increments of 200µm. PDL thickness was varied as 0.24mm and 0.15mm. Results indicated that an apical stress induced in the cementum remained the same or decreased with an increase in the PDL thickness. The study concluded that the clinical delivery of an orthodontic forces will cause stress in the cementum and PDL. Hence, it is necessary to limit the orthodontic force to prevent root resorption.

Kanjanaouthai A, Mahatumarat K, Techalertpaisam P. Versluis A (2012)[61] determined the effect of labiolingual inclination of a maxillary central incisor on the magnitude and distribution of stresses within the periodontal space. Five three-dimensional finite element models of a right maxillary central incisor were created with different inclination (0°, 10°, 20°, 30° and 40°) with lingual directed force of IN and 6-12 Nmm counter tipping moment on the labial surface. Results showed that with increased inclination, compressive stresses tended to increase whereas tensile stresses tended to decrease. The location where compressive stress was prevalent changed from the mid root area to the apical area on the lingual side, while the area where tensile stresses were predominant changed from the mid root area to the cervical area on the labial side. It was concluded that there are more compressive stresses concentrated at the apex of incisors with a high degree of inclination which makes it more prone for apical root resorption than in incisors that are more upright.

Lee HK et al (2012)[62] analysed stress distribution and displacement of the maxilla and teeth according to different designs of bone- borne palatal expanders using micro-implants. Four designs of rapid maxillary expanders: one with micro-implants placed lateral to mid-palatal suture (type 1), the second at the palatal slope (type 2), the third as in type 1 with additional conventional Hyrax arms (type 3) and the fourth surgically assisted tooth-bome expander (type 4) were added to the FE models. Expanders were activated transversely for 0.25mm Geometric nonlinear theory was applied to evaluate Von-Mises Stress distribution and displacement. All types exhibited downward and demonstrated more horizontal movement in the posterior area. Type 3 showed the most transverse displacement. The rotational movement of dentoalveolar unit was larger in types 1 and 3, whereas it was relatively parallel in types 2 and 4. The stresses were concentrated around the micro-implants in types 1 and 3 only. Type 2 had the least stress concentrations around the anchorage and showed alveolar expansion without buccal inclination. It is recommended to apply temporary anchorage devices to the palatal slopes to support expanders for efficient treatment of maxillary transverse deficiency.

Jagdev PS, Mehrotra P, Dattada H, Rastogi N (2012)[63] evaluated stress distribution on teeth with varying degree of bone support during orthodontic force application by using three dimensional finite element model. A three-dimensional finite element model of a tooth with different levels of bone height was constructed to estimate the magnitude of tooth displacement and stress pattern distribution. 100gm of orthodontic tipping force was applied at the centre of the crown in labiolingual direction perpendicular to the long axis of the tooth and initial stress in tooth, PDL and alveolar bone with normal vertical bone height and with bone loss that ranged from 2-8mm was evaluated. The results showed that the magnitude of tooth displacement and stresses increases with the decrease in vertical bone height. The magnitude of stresses showed a dramatic increase with 6.0 and 8.0mm of vertical bone height reduction. It was concluded that force control is the most important factor to achieve an optimal tooth movement.

Rex S, Balasubramanian, Ravi K, Krishna RP, Dilip S (2012)[64] determined the apical force distribution produced by tipping, intrusion, extrusion, bodily movement and rotational movement using FEM. A 3D FEM model of a maxillary central incisor, its PDL and alveolar bone was constructed on the basis of average anatomic morphology. The maxillary central incisor was chosen for study because it is one of the teeth at greatest risk for apical root resorption. The material properties of enamel, dentin, PDL and bone and 5 different load systems were tested. This study showed that for intrusion stress concentration was more in the root apex. For extrusion stress concentration was in the mid root and the apex. Stress was distributed over a wider area and was thus lesser in magnitude. For rotation maximum stress was towards the mid root. For tipping stress concentration was towards the alveolar crest and the apical third of the alveolar bone. For bodily movement maximum stress was on the alveolar crest and not at the root apex.

Heravi F, Salari S, Tanbakuchi B, Loh S, Amiri M (2013)[65] studied the effects of the different crown-root angles on stress distributions in the maxillary central incisor's periodontal ligament (PDL) during application of intrusive and retraction forces using a 3D finite element method. Two models of a maxillary central incisor were constructed using ANSYS software: the first one with an angle of 166.7° (as a sample of the maxillary central incisor in a class II, division 2 patient) and the other one with an angle of 173.4° (normal angulation). Each of the samples was loaded twice by an intrusive force (0.25N) and a retraction force (0.5N) through the ideal position of brackets. FEM results showed little difference between stress distributions in the two models during intrusion compared to retraction. Study concluded that to produce similar patterns of stress in the PDL, orthodontists can apply 1.18 times heavier retraction forces on the maxillary central incisors in class II division 2 patients compared to class 1 patients.

Mascarenhas R., Revankar AV, Mathew JM, Chatra L, Husain A, Shenoy S (2014)[66] analysed the effect of vertical and horizontal forces together on the tooth using FEM. An extracted right maxillary central incisor was radiographed and was used to create a solid model using ANSYS. The geometric model was converted into a finite element model with the help of ANSYS software. The model consists of 27,000 elements and 30,000 nodes. Two force vectors (vertical and horizontal forces of 100gm each) were applied labially and lingually at 3 different heights-4 mm, 5mm and 6mm from the incisal edge. Results showed that in the labial system, the net force vector passes through the centre of resistance (CR) and brings about intrusion. The net force vector in lingual orthodontics does not pass through the centre of resistance and produces lingual tipping of the incisors. It was concluded that intrusion and retraction forces bring about tipping of incisors in lingual orthodontics. The same amount of intrusion and retraction forces brings about intrusion of incisors in labial orthodontics. Therefore, direction and amount of forces should be carefully and applied after taking into consideration the resultant biomechanical differences.

Dabla N, Phull TS, Prasad PN, Rawat N (2014)[67] evaluated the effects of various intrusive forces on maxillary first molar using - finite element method. The loading condition was designed to mimic conventional orthodontic tooth movement which was subjected to three different intrusive force magnitudes via 150g, 180g and 210g and was put through finite element analysis. The results were suggested high stress concentration at furcation level of the tooth and compression was seen in apical third of root area of the periodontal ligament (PDL) except in palatal side of palatal root. It was concluded that the furcation area of the tooth is most prone to root resorption and compression was observed in apical third of all root area of PDL except in palatal side. Displacement at cervical region in palatal side of PDL, at central fossa of the tooth and at the cervico-palatal region of alveolar bone. Displacement at cervical region in palatal side of PDL, at central fossa of the tooth and at the cervico-palatal region of alveolar bone.

Salehi P, Gerami A, Najafi A, Torkan S[68] assessed the stress distribution in the periodontal ligament of maxillary incisors when addressed to different models of intrusion mechanics using miniscrews by employing finite element methods. The degree of relative and absolute intrusion of maxillary incisors in different conditions was also evaluated. A finite element model of maxillary central incisor to first premolar was generated by assembling images obtained from a three-dimensional model of maxillary dentition. Four different conditions of intrusion mechanics were simulated with different placement sites of miniscrews as well as different points of force application. In each model, 25-g force was applied to maxillary incisors via miniscrews. In all four models, increased stress values were identified in the apical region of lateral incisor. Proclination of maxillary incisors was also reported in all the four models. The minimum absolute intrusion was observed when the miniscrew was placed between the lateral incisor and canine and the force was applied at right angles to the archwire, which is very common in clinical practice. They concluded from the results yield by this study, it seems that the apical region of lateral incisor is the most susceptible region to root resorption during anterior intrusion. When the minimum flaring of maxillary incisors is required in clinical situations, it is suggested to place the miniscrew halfway between the roots of lateral incisor and canine with the force applied to the archwire between central and lateral incisor. In order to achieve maximum absolute intrusion, it is advised to place miniscrew between the roots of central and lateral incisors with the force applied at a right angle to the archwire between these two teeth.

Gupta, R K Tikku T, Khanna R, Verma SL, Srivastava K (2016)[8] calculated the stress and displacement generated at apex of maxillary central incisor for three different magnitude of intrusive forces (5, 10 and 15gms) at varying bone loss (0, 3 and 6mm) and at three different inclination (51°, 56° and 61°) and it is observed that maximum amount of stress and displacement was observed at apex for 15gms of forces in all the groups and it was concluded from the study that stresses are concentrated at a smaller area apically, it is always better to use lighter forces for intrusion and making it comfortable for the patient and reduce the chances of external resorption of the tooth.

Saga AY, Maruo H, Argenta MA, Maruo IT, Tanaka OM (2016)[69] evaluated the initial distribution patterns and magnitude of compressive stress in the periodontal ligament (PDL) in a simulation of orthodontic intrusion of maxillary incisors, considering the points of force application. Maxillary incisors models were constructed from cone-beam computed tomography scans were simulated intrusion loading. The points of force application selected were cantered between central incisors brackets (LOAD 1), bilaterally between the brackets of central and lateral incisors (LOAD 2), bilaterally distal to the brackets of lateral incisors (LOAD 3) and bilaterally 7 mm distal to the center of brackets of lateral incisors (LOAD 4). Stress concentrated at the PDL apex region, irrespective of the point of orthodontic force application. The four load models showed distinct contour plots and compressive stress values over the midsagittal reference line. The contour plots of central and lateral incisors were not similar in the same load model. LOAD 3 resulted in more balanced compressive stress distribution.

Cho SM, Choi SH, Sung SJ, Yu HS, Hwang CJ (2016)[70] determined the optimal loading conditions for pure intrusion of the six maxillary anterior teeth with miniscrews according to alveolar bone loss. A three-dimensional finite element model was created for a segment of the six anterior teeth, and the positions of the miniscrews and hooks were varied after setting the alveolar bone loss to 0, 2, or 4 mm. Under 100 g of intrusive force, initial displacement of the individual teeth in three directions and the degree of labial tilting were measured. The degree of labial tilting increased with reduced alveolar bone height under the same load. When a miniscrew was inserted between the two central incisors, the amounts of medial-lateral and anterior-posterior displacement of the central incisor were significantly greater than in the other conditions. When the miniscrews were inserted distally to the canines and an intrusion force was applied distal to the lateral incisors, the degree of labial tilting and the amounts of displacement of the six anterior teeth were the lowest, and the maximum von Mises stress was distributed evenly across all the teeth, regardless of the bone loss.

Sakdakornkul S, Patanaporn V, Rungsiyakull C (2019)[71] evaluated the von Mises stress distribution and displacement of the six maxillary anterior teeth intruded with two patterns of mini-screw anchorage, analyzed by the finite element method. A finite element model of six maxillary anterior teeth with periodontal ligament and alveolar bone was constructed. In anchorage pattern 1, one mini-screw was placed between the central incisors with a net force of 60 g applied to the arch wire between the central incisors towards the mini-screw. In anchorage pattern 2, two mini-screws were placed between the lateral incisors and canines, left and right, with force applied to the arch wire between the central and lateral incisors in an oblique direction towards the mini-screws. The stress distribution and the displacement of the teeth were analysed. They observed that in anchorage pattern 1, the von Mises stress on the central incisors was greater than that on the lateral incisors or canines. In anchorage pattern 2, the von Mises stress distribution was greater on the central and lateral incisors than on the canines. In anchorage pattern 1, all teeth were intruded with proclination. In anchorage pattern 2, the central incisors were intruded along their long axes, whereas the lateral incisors and canines were slightly proclined. They concluded that two mini-screw pattern distributes stress in four incisors and displaces teeth closer to pure intrusion than the one-mini-screw pattern.

Thakkar U, Patil NS, Thakkar AP, Chitko SS, Jaltare P (2020)[72] evaluated the stress distribution around the mini-implant during maxillary anterior intrusion under different conditions of different angulations and different positions of implant. Finite element analysis was carried out. Stress under the following 4 conditions was analysed: (a) single central implant placed at 90°, (b) single central implant placed at 120°, (c) bilaterally placed implant at 90°, and (d) bilaterally placed implant at 120°. They found displacement seen with 90° angulation in the single implant case is less compared with the 120° angulation case for all the 6 maxillary anterior teeth. Also, in the bilateral implant case, the Von Mises stress is less when the 90° angulation case is compared to 120° angulation case. But in bilaterally placed implant, the stress gets distributed evenly in the anterior region. The stress in 90° angulation cases seems to be concentrated at the centre. They concluded that stresses measured on the teeth are less and distributed more evenly when the point of force application is bilateral. It was also observed that the stress increases with increase in the angulation of the implant. As the contact between the implant and the bone increases, the stability increases. Hence, the implant should be obliquely inserted into the bone. Concentrated stresses are not favourable as they can increase the risk of bone and root resorption.

This comparative in-vitro study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences. Lucknow in collaboration with FEA Solution Mumbai, with an aim to evaluate stress distribution and displacement of root apex of four normoinclined maxillary incisors using two different mechanics in presence of variable intrusive forces and variable bone loss using FEM.

Materials:

I. For construction of FEM model

A. A Cone Beam Computed Tomography (CBCT) of a fully developed adult skull with maxillary and mandibular jaw was taken. **(FIGURE 1)**

B. Bracket and buccal tubes

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

C. Archwire

a) 0.019’’X 0.025’’ Rectangular Stainless steel (SS) arch of ovoid arch form. (Gemini:3M, St Paul, Minnesota, USA).
b) .017” X .025” TMA (Titanium Molybdenum Alloy) straight length wire.
c) .009” stainless steel ligature wire was used for ligating the Burstone intrusion arch with the anterior incisor segment arch wire for intrusion.

D. Miniscrew

Two Titanium miniscrew miniscrews of length 6mm and diameter 1.2mm.

II. Laser scanner

III. Softwares used in the study:

a) MIMICS software.
b) GEOMAGIC modeling software.

c) ALTAIR HYPERMESH by Altair Engineering Inc. (Troy, Michigan, United States).

d) ALTAIR HYPERMESH by Altair Engineering Inc. (Troy, Michigan, United States).

e) ALTAIR OPTISTRUCT by Altair Engineering Inc. (Troy, Michigan, United States).

f) ALTAIR HYPERVIEW by Altair Engineering Inc. (Troy, Michigan, United States).

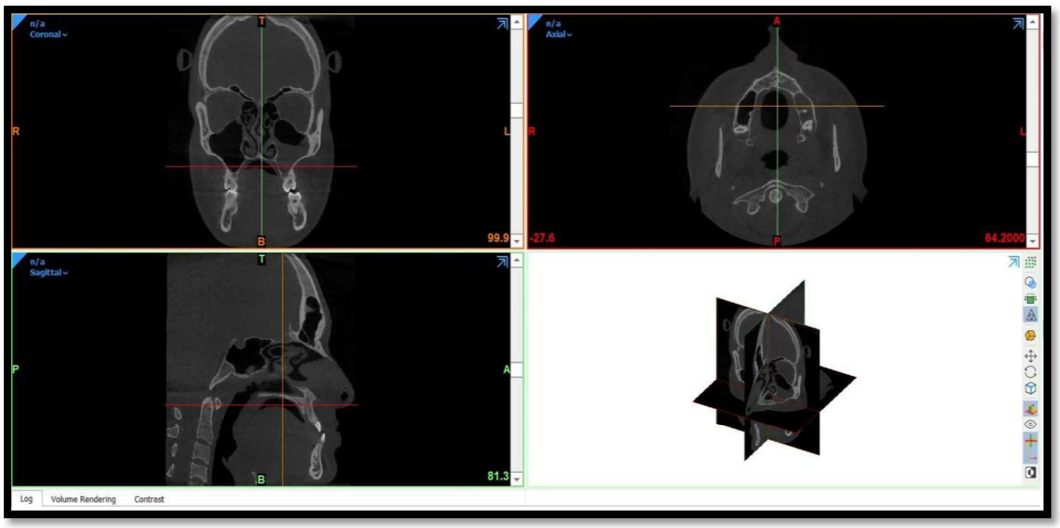

FIGURE 1: CBCT images of the maxilla used for the study.

METHODOLOGY:

Construction of Finite Element Model generally involved the following steps **(FIGURE 2)**

1. Pre-Processing: As the name says, this is the process before FEA calculations are run. At this step the model was constructed. Mesh was generated. Finally, boundary conditions were applied. Software used at pre-processing stage was **Altair Hypermesh**
2. FEA Solver: This is the software which processes the input and calculates results for the FEM. Software used at solver stage was **Altair Optistruct**

3. Post-Processing: This is the stage where results were seen, extracted, reviewed and stored.

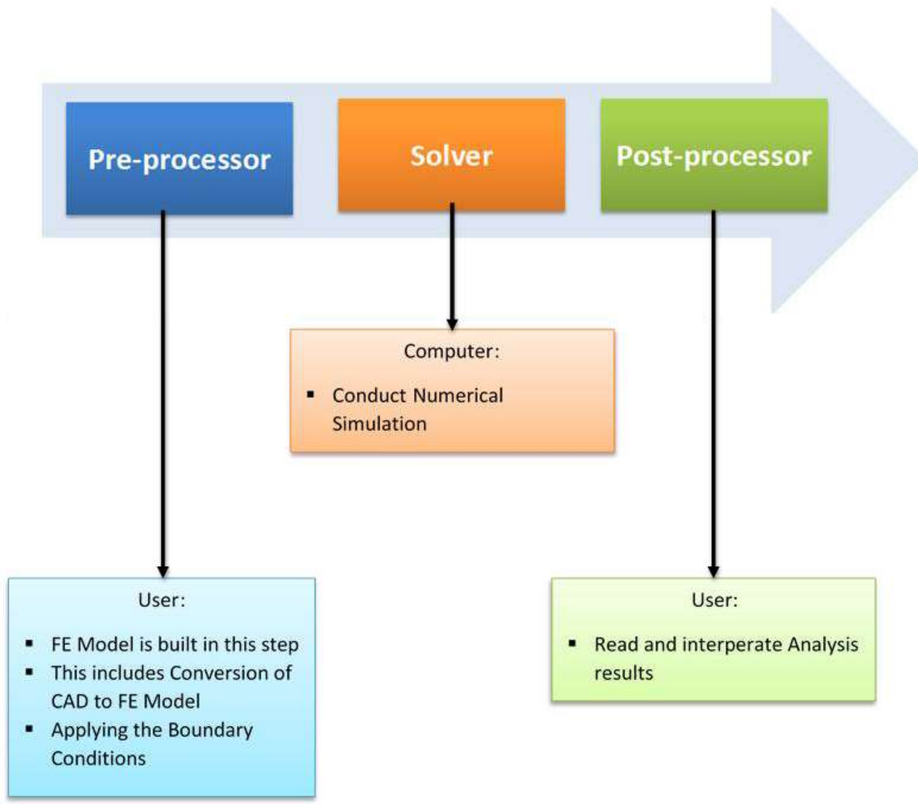

FIGURE 2: Flow chart showing processing of results.

In the present study, the following steps was involved for the finite element study **(FIGURE 3)**:

- Generation of the CAD (Computer Aided Design) Model.
- Construction of the geometric model of the maxillary bone around the TAD and construction of geometric model of bracket, molar tubes, Burstone intrusion arch, stabilizing wire.
- Conversion of the geometric models to a finite element model.
- Incorporation of material properties of tooth structure and periodontium
- Defining boundary condition
- Loading configuration
- Translation of results and interpretation

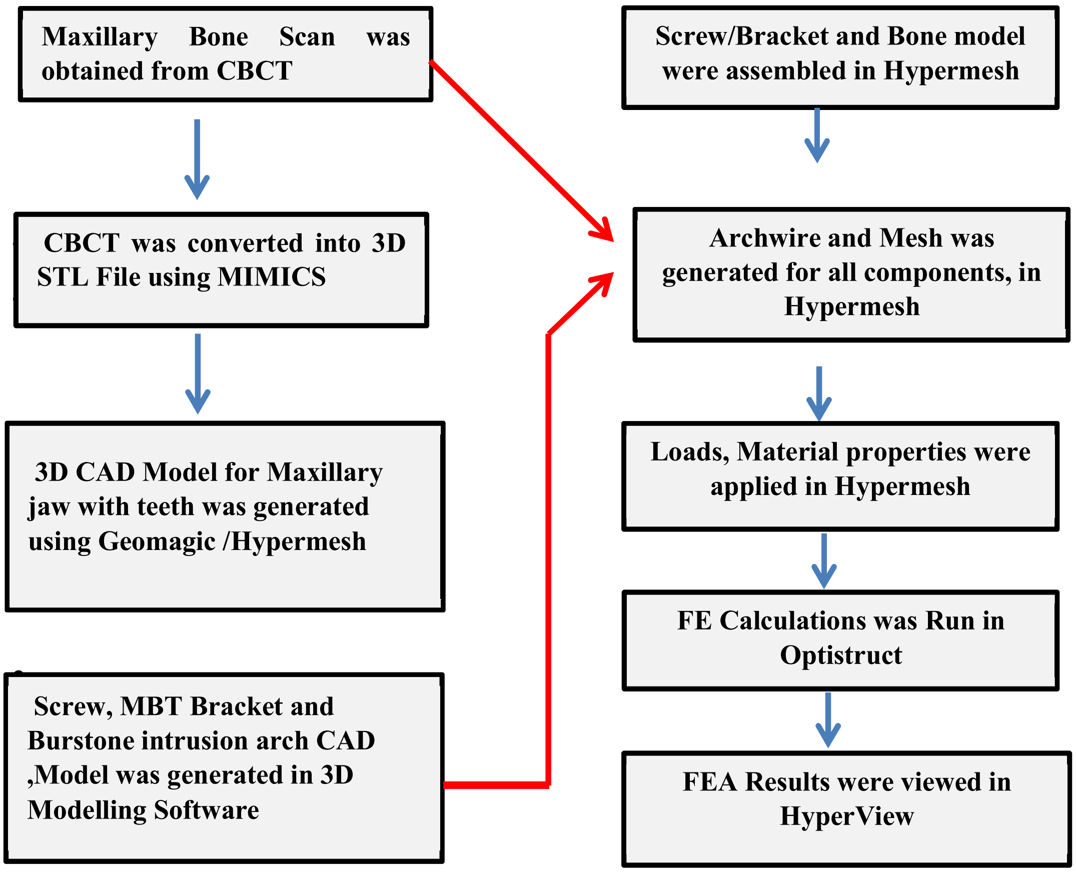

FIGURE 3: Schematic flowchart showing the steps involved in the study.

1. Generation of CAD Model of maxilla

CBCT scan of normal adolescent skull without any skeletal defects, trauma, lesions etc. and with full complement of teeth up to 2nd molar were obtained from the archives of a reputed CBCT scan centre. Sequential CT images were acquired at 0.5-mm intervals in the axial direction, parallel to the Frankfort plane. DICOM files were the output of the scan. These DICOM files were at each scan interval. All DICOM files were then imported into MIMICS Software to develop a 3D model. Mimics software assists in transporting the data, envisions and aids in 3D interpretation and calculating the CT scan details. Different parts like teeth, jawbone etc. were then extracted from MIMICS by separating then based on bone density in MIMICS. Stereo-lithography (STL) file was exported from MIMICS. This file was a constructed 3D representation of all DICOM slices. Files in stereo-lithography (STL) format were converted into CAD model as shown in (**FIGURE 4)** after importing into Geomagic software where STL was converted into Surface CAD model. In Geomagic software complete assembly of the model was generated.

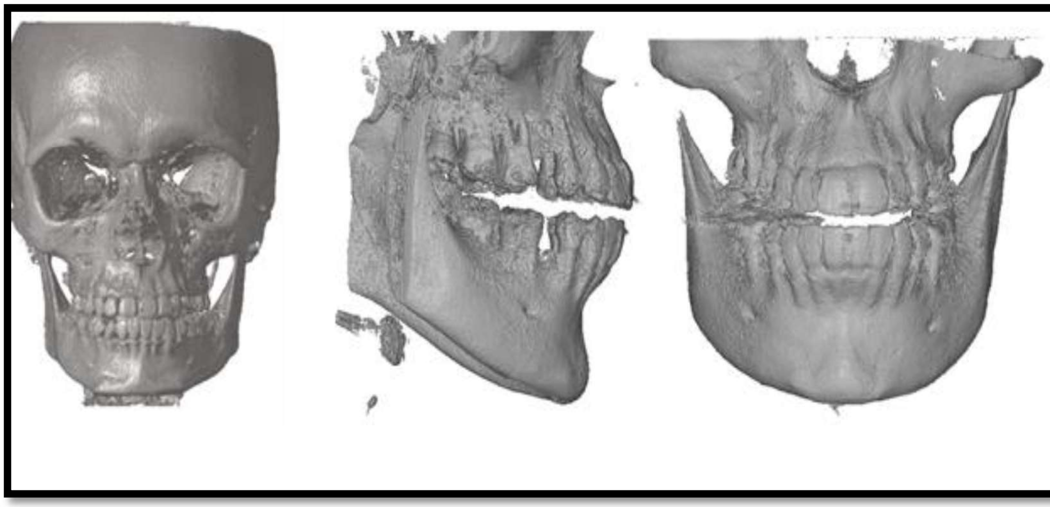

FIGURE 4: Raw STL File output of the human skull from the CAD model for the study.

2. Construction of the geometric model of the maxillary bone

CAD model was exported to 3D image processing and editing software- 3D-Doctor (Able Software Corp., Lexington, Massachusetts, USA), and image obtained as stereolithographic (STL format). This bone model was imported in Altair HyperMesh (Troy, Michigan, United States) and complete model was assembled in Altair HyperMesh software. **(FIGURE 5).**

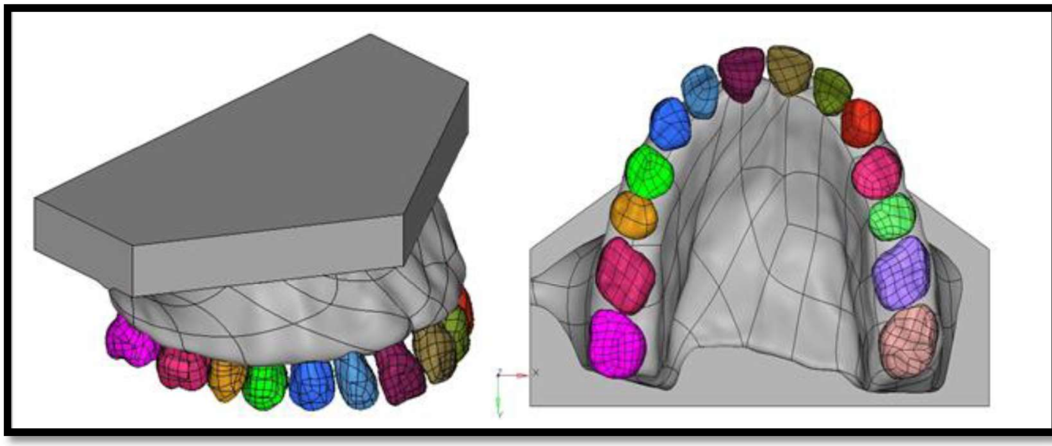

FIGURE 5: Final finite element model of the maxillary arch.

3. **Construction of geometric model of components**

   i. Burstone intrusion arch was fabricated on typhodont of maxillary arch. A straight length 0.017X0.025inch TMA (Titanium Molybdenum Alloy) wire was given an arch form using Dela Rosa plier. From a straight portion in buccal tube wire was stepped up by 3mm, followed a curvature with a step down of 2mm distal to lateral incisor and continued similarly to other side. Tip back bend was given at molar region to apply desired force. **(FIGURE 6a-c)**

   ii. Along with Burstone intrusion arch, stabilizing arch wire of 0.019X0.025 inch stainless steel was segmented into two posterior and one anterior segment. Posterior segment extending from canine to 1st molar and the anterior segment extended from lateral incisor of one side to the lateral incisor of other side. **(FIGURE 6d)**

   iii. For intrusion by mini-implants, similar segmental stabilizing arch wire was used in one FEM model and continuous stabilizing arch wire of 0.019X0.025 inch stainless steel extending from 1st molar on one side to the 1st molar of other side was used in other model. **(FIGURE 7)**

   iv. Burstone intrusion arch, Brackets, molar tubes, stabilizing arch wires, TAD with 6mm length and diameter of 1.2mm were scanned using laser scanning system and CAD model were obtained for these components. **(FIGURE 8 - 11).**

v. On FEM model TAD was simulated to be placed at CR of four maxillary incisors which is distal and apical to lateral incisor. Based on study of **"Burstone CJ"**[17], CR for four maxillary incisors at normal alveolar bone height, was taken as 8 mm apical and 7mm distal to lateral incisor root in the present study.

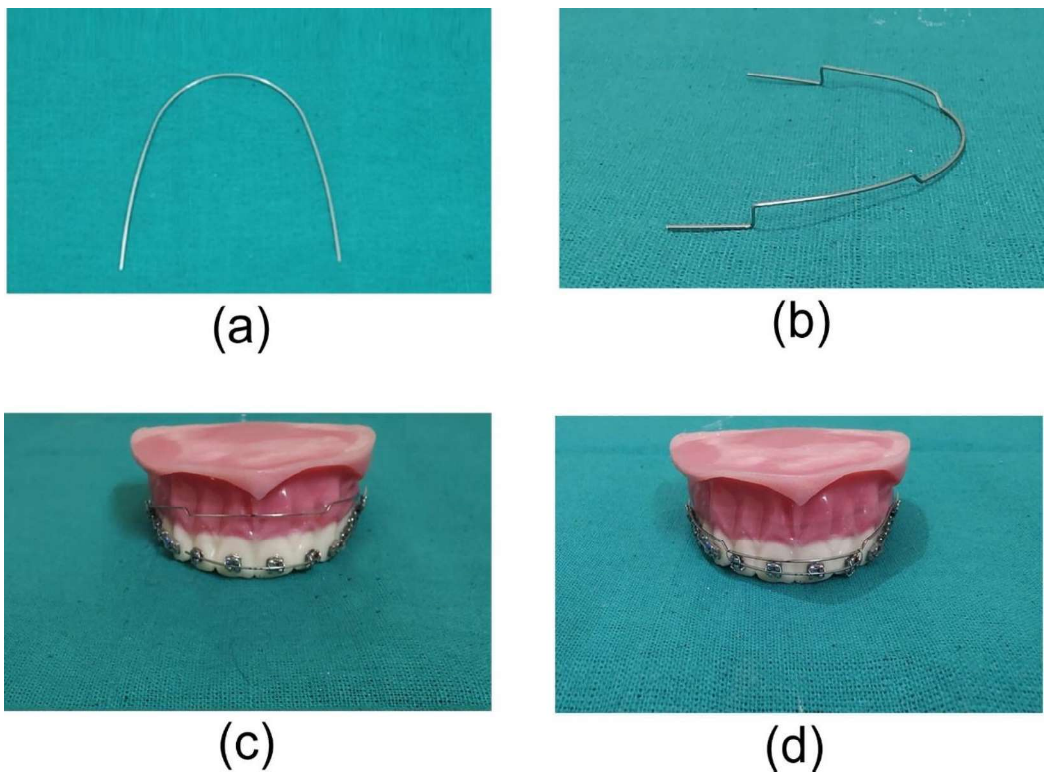

FIGURE 6: Fabrication of Burstone Intrusion arch on typhodont

(a) Arch form of 0.017X0.025inch TMA, (b) Required bends in arch wire incorporated, (c) Burstone Intrusion arch on giving tip back bend at molars and (d) Tying of Burstone Intrusion arch distal to lateral incisor

FIGURE 7: Placement of mini-implants on typhodont

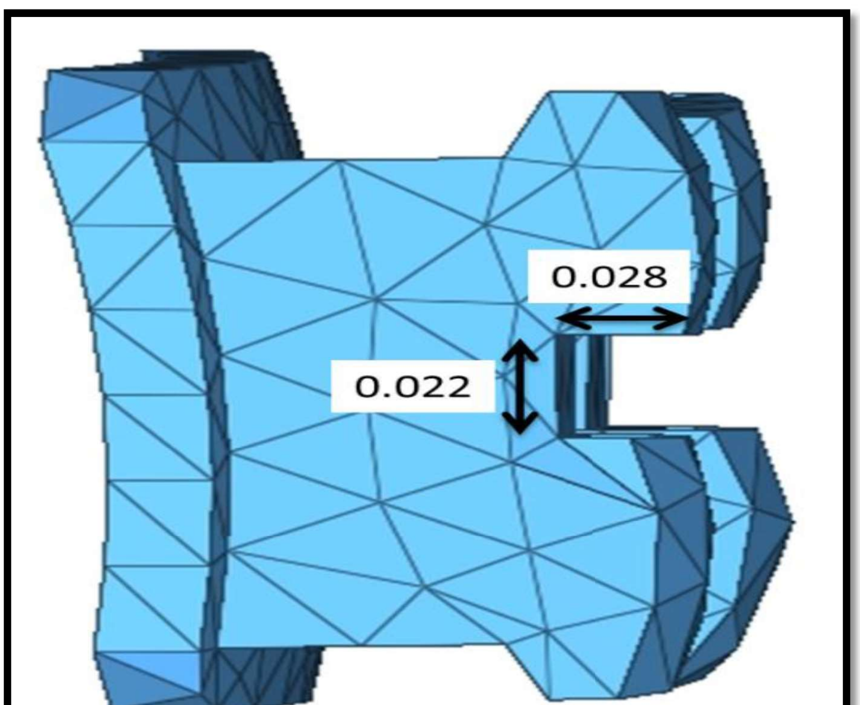

FIGURE 8: Mesh model of bracket (slot size 0.022'X 0.028'')

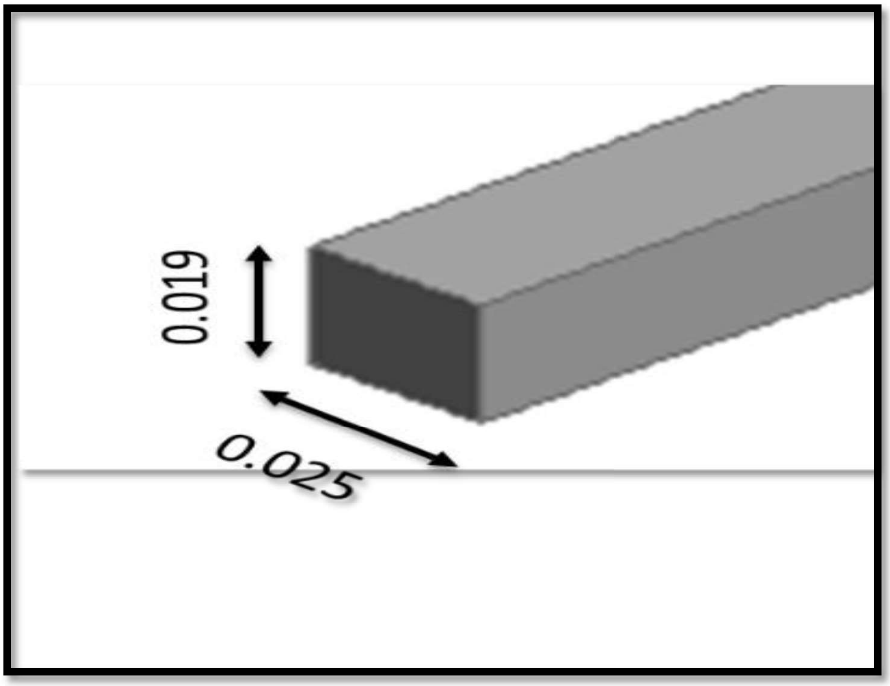

FIGURE 9: Mesh model of 0.019’’X0.025’’ SS archwire.

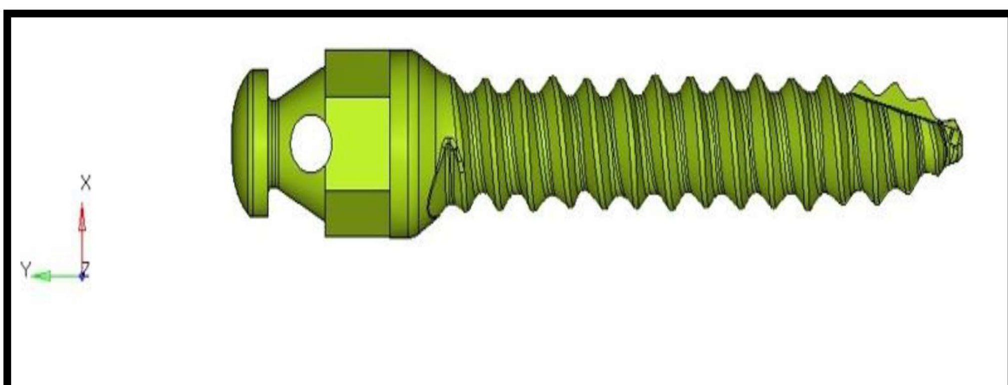

FIGURE 10: Mesh model of Mini-implant used for the study.

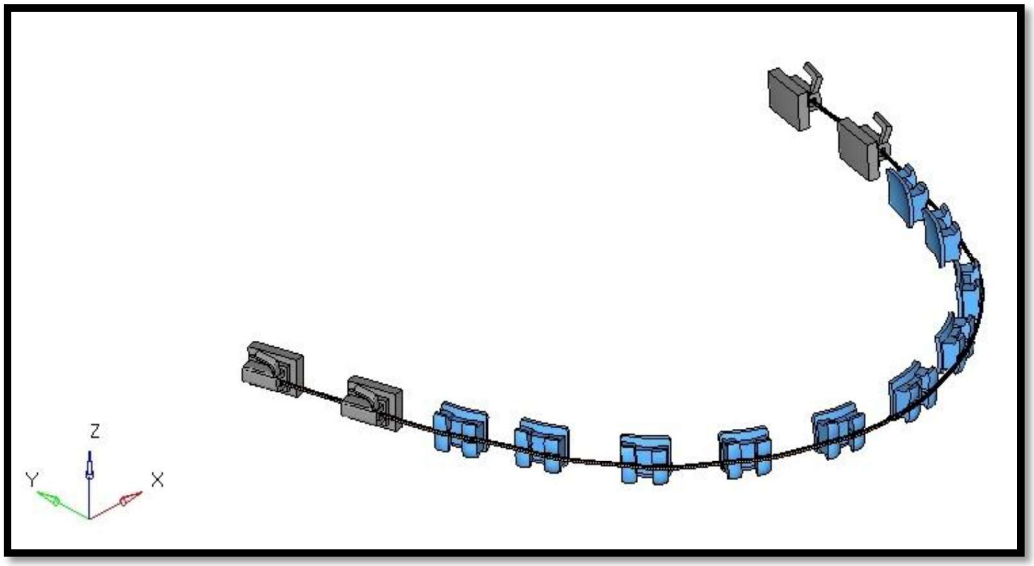

FIGURE 11: Bracket & Archwire assembled in a single curve

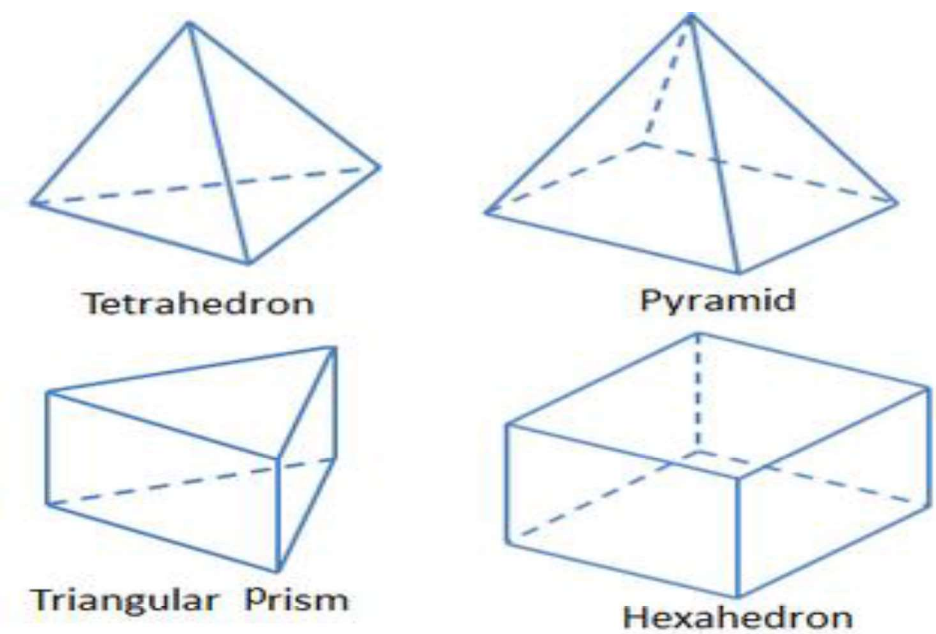

FIGURE 12: Different geometric shapes that can be used for generation of a model.

4. Conversion of the geometric models to a finite element model

The FEM is composed of an aggregate of small elements that are sufficient to describe the geometry of the subjects. This is called ‘creating the mesh or meshing’. With the help of Altair HyperMesh Software, the geometric models were converted into finite element models and this process is called meshing or mesh generation. The finite element model represents geometry in terms of finite elements and the nodes that could be tetrahedron, pyramid, triangular Prism and Hexahedron. This process is called “discretization.” In this study, to model the irregular geometry of the teeth, maxilla, wire, bracket, Burstone intrusion arch and TAD, 4-noded tetrahedral shape was selected as the finite element and for modeling a 3-D Quad mesh was used. **(FIGURE 12 and 13)**

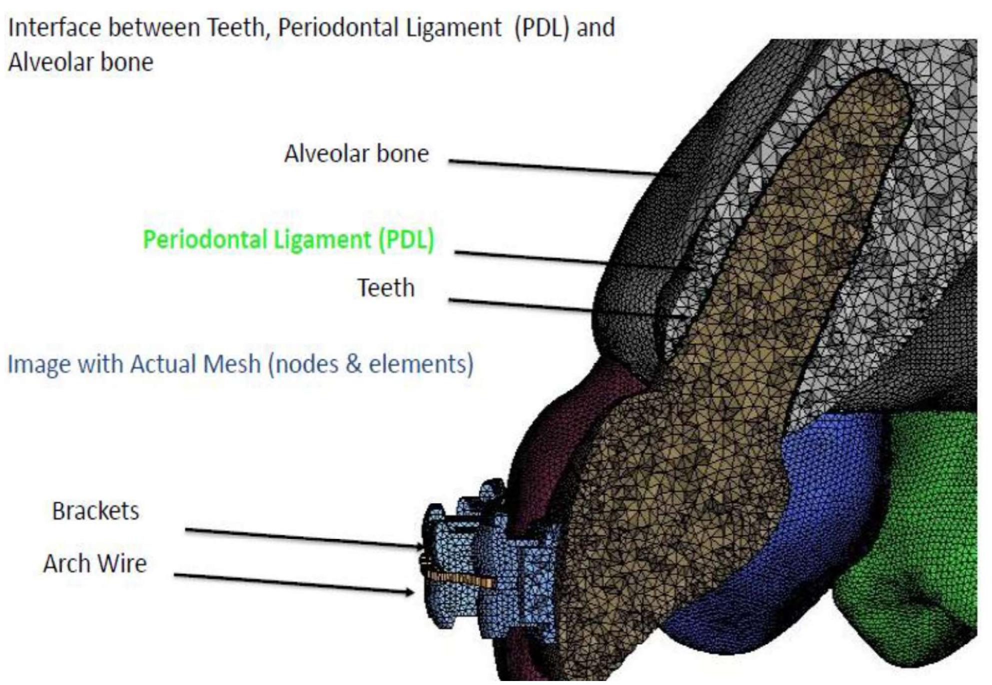

FIGURE 13: Final finite element model of maxillary arch with mini-implant and stabilizing arch wire.

Once the basic FEM model was constructed at 0mm bone loss for both the groups, **(Figure 14 and 15)** two more FEM models were constructed at 2mm and 4mm of alveolar bone loss.

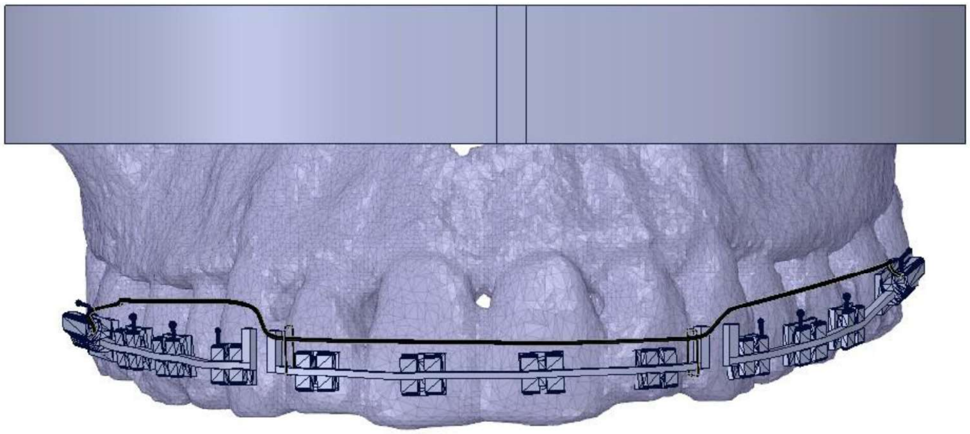

FIGURE 14: FEM model of Group I (Burstone intrusion arch)

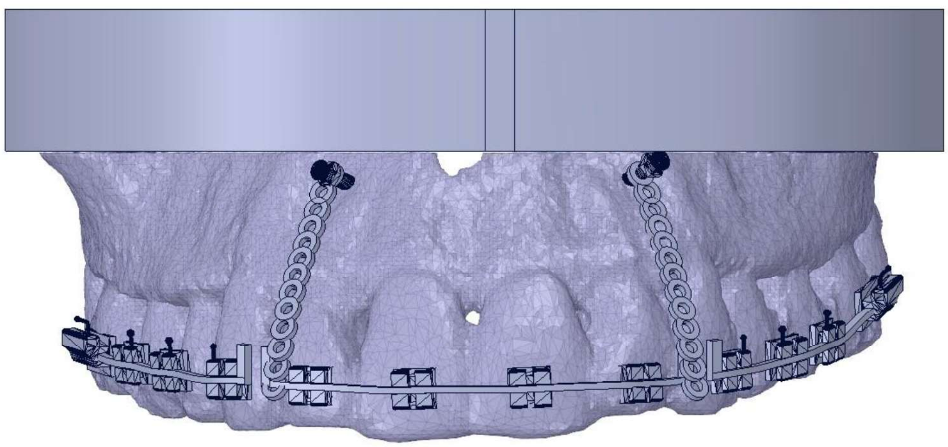

FIGURE 15: FEM Model of Group II (Mini-implant assisted intrusion)

5. Meshing Details

Meshing is nothing but to Subdivide i.e discretize the complex geometry into suitable set of smaller "elements" of finite dimensions (2D or 3D). The points connecting two or more discrete elements are called as nodes or nodal points. The corner nodes are called primary external nodes. The additional nodes which occur on the sides of the elements are called secondary external nodes. The secondary nodes have fewer displacement than corner nodes. Collection of nodes and element result in formation of element mesh that could be in shape of tetrahedron prism and hexahedron**.** Number, size and type of element are decided. Practical knowledge and judgement are needed to limit the number of elements to minimum amount conductive to acceptable results. **(TABLE 1)** represent the number of nodes and elements of the present FEM study.

Component	No. of Nodes	No. of elements
Teeth	105714	522566
Periodontal Ligament (PDL)	111782	183943
Jaw bone	148986	749379
Brackets	8500	30990
TAD	2801	10821
Arch Wire	2223	980
Burstone Intrusion Arch	3546	1956

TABLE 1: Number of nodes and elements of present study

6. Incorporation of material properties of tooth structure and periodontium

The material properties of teeth, cortical bone, cancellous bone, mini-implants, brackets, molar tube, arch wire and titanium molybdenum wire (used in Burstone intrusion arch) were incorporated based on 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**
Titanium mini-implant	**1,10,000**	**0.35**
Cortical bone	**13,700**	**0.30**
Cancellous bone	**1,600**	**0.30**
Stainless steel bracket / arch wire / molar tube	**2,00,000**	**0.30**
Burstone intrusion arch (YMA wire)	**42,840**	**0.31**

TABLE 2: Material properties as used in present study

7. **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 was a stage for trial RUN of FEA. It was a stage for element quality check. Element qualities like Warpage, Aspect Ratio, tet Collapse were checked & required modification were done in the model to improve the element quality. Local re-meshing in some areas was considered to improve the overall mesh quality of the Finite Element Model. All this was done to ensure generated mesh/element quality is within acceptable limit for FEA Solver. This process was performed for both Maxilla model.

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 on red areas and reference point of displacement at root apex and incisal edge are marked as shown below. **(FIGURE 16 AND 17)**

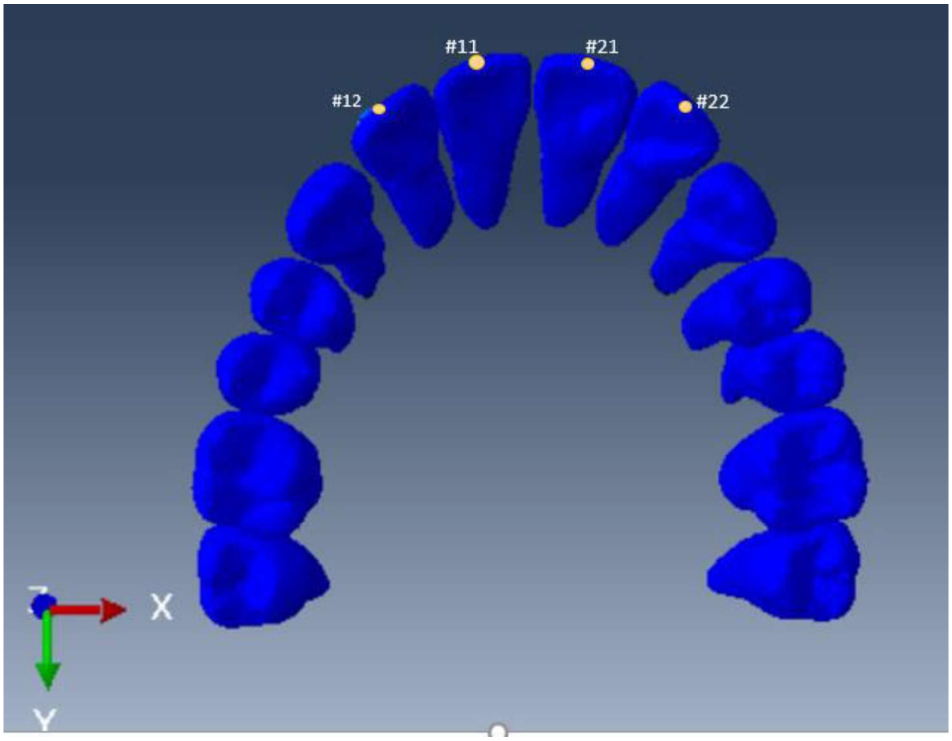

FIGURE 16: Reference points marked at the incisal edges (IE)

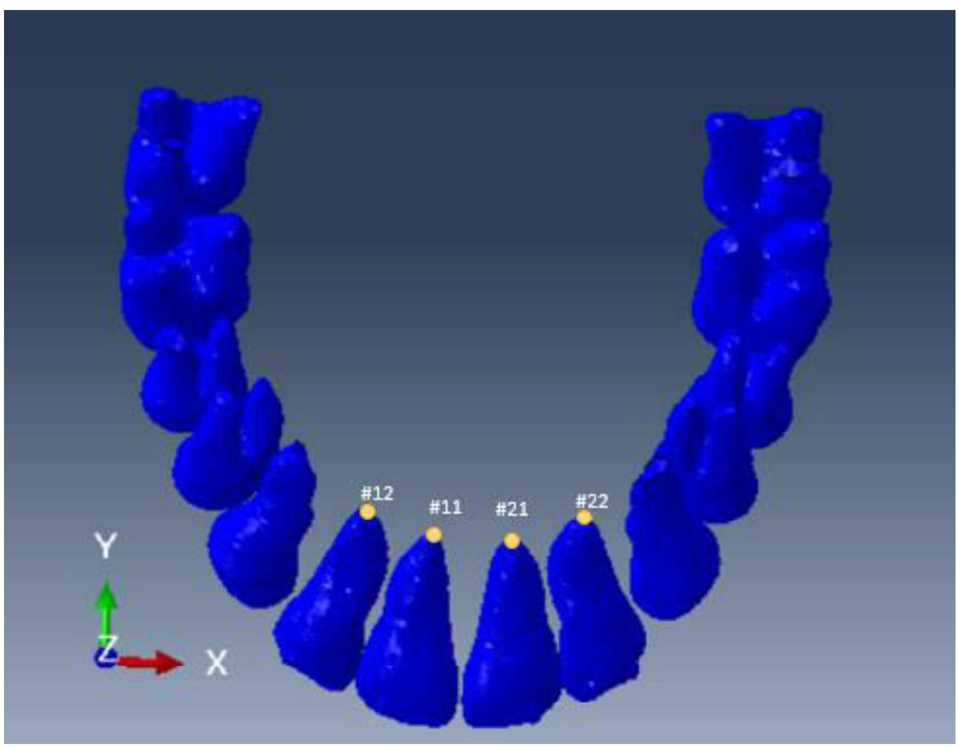

FIGURE 17: Reference points marked at the root apex (AP)

Force Application:

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

8. Loading Configuration

In this step all the types of forces experienced by the model are understood, converted into numerical values with force direction and magnitude. This force is then applied on the model. Before application of force, FEM models were divided in groups based on intrusive mechanics applied.

- Group I – FEM models where intrusion was attempted using Burstone Intrusion arch and stainless steel 0.019X0.025inch segmental stabilizing arch wire was used.
- Group II – FEM models where intrusion was attempted using mini-implants and segmental stainless steel 0.019X0.025inch stabilizing arch wire was used.

For each group, three FEM models were made according to alveolar bone loss of 0mm, 2mm and 4mm were used.

Force application:

- Group I – Burstone intrusion arch was tied at a point distal to lateral incisor bracket on anterior component of segmental stabilizing arch wire. Tying of Burstone intrusion arch was simulated with variable forces of 20, 40, 60 and 80 grams on each FEM model with 0, 2 and 4mm of alveolar bone loss.

- Group II – Variable intrusive forces were simulated from mini-implants placed at CR to a point distal of lateral incisor bracket on anterior component of segmental stabilizing arch wire with variable forces of 20, 40, 60 and 80 grams on each FEM model with 0, 2 and 4mm of alveolar bone loss.

A total of 6 finite element model will be generated and boundary conditions will be applied. The FE model will be then submitted to Altair Optistruct Software for the Finite Element Calculation.

9. 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.

This study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences in collaboration with FEA Solutions, Mumbai with an aim to evaluate stress distribution and displacement of root apex of four normoinclined maxillary incisors using two different mechanics in presence of variable intrusive forces and variable bone loss using FEM.

In this study the FEM models were divided in groups based on intrusive mechanics as follows.

- Group I – FEM models where intrusion was attempted using Burstone Intrusion arch and 0.019X0.025inch stainless steel segmental stabilizing arch wire was used.
- Group II – FEM models where intrusion was attempted using mini-implants and 0.019X0.025 inch stainless steel segmental stabilizing arch wire was used.

After application of variable forces of 20, 40, 60 and 80 gm at different bone loss of 0, 2 and 4 mm in two different groups, FEM analysis results were obtained as Von Mises stress at apex of central and lateral incisor in Newton/mm^2 (N/mm^2) **(TABLE 3)** and displacement in all the three planes (X-Axis for mesio-distal movement, Y-Axis for labio-lingual movement and Z-Axis for occluso-gingival movement / or amount of intrusion) both for central and lateral incisor **(TABLE 4).**

The stress and displacement in all the three axis for central incisor and lateral incisor were calculated for right and left side separately after application of force on each side. The mean values of right and left side were taken for each tooth (Central incisor and lateral incisor) for stress at apex and displacement in all the three axis. As displacement in X-axis denotes tipping, which is not considered in intrusive mechanics, hence these values were not described.

Table 3 shows Von Mises stresses at root apex of central and lateral incisor for Group I and Group II

GROUPS	INTRUSION APPLIANCE USED	ALVEOLAR BONE LOSS		FORCE APPLIED	VON MISES STRESS AT APEX OF CENTRAL INCISOR (N/mm2)	VON MISES STRESS AT APEX OF LATERAL INCISOR (N/mm2)
I	BURSTONE INTRUSION ARCH	Ia	0mm	20gm	0.11	0.03
				40gm	0.23	0.06
				60gm	0.34	0.08
				80gm	0.45	0.11
		Ib	2mm	20gm	0.14	0.15
				40gm	0.27	0.30
				60gm	0.41	0.45
				80gm	0.54	0.59
		Ic	4mm	20gm	0.17	0.19
				40gm	0.34	0.37
				60gm	0.51	0.57
				80gm	0.68	0.75
II	INTRUSION USING MINI IMPLANT (Segmental arch wire)	IIa	0mm	20gm	0.11	0.03
				40gm	0.24	0.06
				60gm	0.33	0.08
				80gm	0.45	0.11
		IIb	2mm	20gm	0.13	0.15
				40gm	0.27	0.30
				60gm	0.40	0.44
				80gm	0.54	0.61
		IIc	4mm	20gm	0.16	0.18
				40gm	0.33	0.37
				60gm	0.49	0.55
				80gm	0.66	0.74

TABLE 3: Von Mises stresses at root apex of central incisor and lateral incisor for Group I and Group II.

For Group I:

The mean value of Von Mises stress at root apex of central incisor was **0.11 N/mm^2** at 20 gm **< 0.23 N/mm^2** at 40 gm **< 0.34 N/mm^2** at 60 gm **< 0.45 N/mm^2** at 80gm for **<u>0mm bone loss</u>**; **0.14 N/mm^2** at 20gm **< 0.27 N/mm^2** at 40gm **< 0.41 N/mm^2** at 60gm **< 0.54 N/mm^2** at 80gm for **<u>2mm bone loss</u>**; **0.17 N/mm^2** at 20gm **< 0.34 N/mm^2** at 40gm **< 0.51 N/mm^2** at 60gm **< 0.68 N/mm^2** at 80gm for **<u>4mm bone loss</u>** respectively.

Similarly, the mean value of Von Mises stress at root apex of lateral incisor was **0.03 N/mm^2** at 20gm **< 0.06 N/mm^2** at 40gm **< 0.08 N/mm^2** at 60gm **< 0.11 N/mm^2** at 80gm at **<u>0mm bone loss</u>**; **0.15 N/mm^2** at 20gm **< 0.30 N/mm^2** at 40gm**< 0.45 N/mm^2** at 60gm **< 0.59 N/mm^2** at 80gm for **<u>2mm bone loss</u>**; **0.19 N/mm^2** at 20gm **< 0.37 N/mm^2** at 40gm **< 0.57 N/mm^2** at 60gm **< 0.75 N/mm^2** at 80gm for **<u>4 mm bone loss</u>** respectively. **(TABLE: 3)**

For Group II

The mean value of Von Mises stress at root apex of central incisor on applying **0.11 N/mm^2** at 20gm **< 0.24 N/mm^2** at 40gm**< 0.33 N/mm^2** at 60gm **< 0.45 N/mm^2** at 80gm for **<u>0mm bone loss</u>**; **0.13 N/mm^2** at 20gm **< 0.27 N/mm^2** at 40gm **< 0.40 N/mm^2** at 60gm**< 0.54 N/mm^2** at 80gm for **<u>2mm bone loss</u>**; **0.16 N/mm^2** at 20gm < **0.33 N/mm^2** at 40gm **< 0.49 N/mm^2** at 60gm < **0.66 N/mm^2** at 80gm for **<u>4mm bone loss</u>** respectively.

Similarly, the mean value of Von Mises stress at root apex of lateral incisor was **0.03 N/mm^2** at 20gm **< 0.06 N/mm^2** at 40gm**< 0.08 N/mm^2** at 60gm**< 0.11 N/mm^2** at 80gm for **<u>0mm bone loss</u>**; **0.15 N/mm^2** at 20gm **< 0.30 N/mm^2** at 40gm **< 0.44 N/mm^2** at 60gm **< 0.61 N/mm^2** at 80gm for **<u>2mm bone loss</u>**; **0.18 N/mm^2** at 20gm < **0.37 N/mm^2** at 40gm **< 0.55 N/mm^2** at 60gm < **0.74 N/mm^2** at 80gm for **<u>4mm bone loss</u>** respectively. **(TABLE 3).**

GROUPS	INTRUSION APPLIANCE USED	ALVEOLAR BONE LOSS		FORCE APPLIED	DISPLACEMENT OF APEX OF CI (IN THREE PANES) µm			DISPLACEMENT OF APEC OF LI (IN THREE PLANES) µm		
					X -AXIS	Y – AXIS	Z – AXIS	X -AXIS	Y – AXIS	Z – AXIS
I	BURSTONE INTRUSION ARCH	Ia	0mm	20gm	0.0229	0.5851	1.5599	0.0237	0.5847	1.5595
				40gm	0.0460	1.1693	3.1089	0.0476	1.1674	3.1091
				60gm	0.0684	1.7435	4.6322	0.0707	1.7408	4.6325
				80gm	0.0907	1.2035	4.2329	0.0937	2.3136	6.1485
		Ib	2mm	20gm	0.0361	0.7135	1.8702	0.0370	0.7125	1.8703
				40gm	0.0722	1.4231	3.7311	0.0739	1.4211	3.7313
				60gm	0.1087	2.1363	5.6017	0.1113	2.1334	5.6019
				80gm	0.1430	2.8093	7.3872	0.1464	2.8055	7.3875
		Ic	4mm	20gm	0.0345	0.8961	2.3337	0.0354	0.8954	2.3336
				40gm	0.0678	1.7743	4.6039	0.0695	1.7730	4.6039
				60gm	0.1044	2.7018	7.0347	0.1071	2.6997	7.0347
				80gm	0.1368	3.5662	9.2790	0.1404	3.5636	9.2789
II	INTRUSION USING MINI IMPLANT (Segmental arch wire)	IIa	0mm	20gm	-0.0004	0.5860	1.5449	0.0005	0.5851	1.5450
				40gm	-0.0009	1.1718	3.0946	-0.0031	1.1689	3.0961
				60gm	-0.0011	1.7639	4.6468	0.0015	1.7611	4.6470
				80gm	-0.0007	2.3662	6.2242	0.0028	2.3624	6.2245
		IIb	2mm	20gm	0.0050	0.7126	1.8507	0.0060	0.7116	1.8508
				40gm	0.0101	1.4261	3.7060	0.0121	1.4241	3.7061
				60gm	0.0152	2.1251	5.5185	0.0181	2.1221	5.5188
				80gm	0.0238	2.9182	7.5617	0.0278	2.9140	7.5621
		IIc	4mm	20gm	-0.0085	0.8916	2.2916	-0.0075	0.8909	2.2916
				40gm	-0.0169	1.7978	4.6140	-0.0149	1.7964	4.6141
				60gm	-0.0270	2.6760	6.8746	-0.0240	2.6739	6.8746
				80gm	-0.0334	3.5745	9.1810	-0.0294	3.5717	9.1810

TABLE 4: Displacement of root apex of central incisor and lateral incisor in all three planes for Group I and Group II.

TABLE 4 shows Displacement of apex of central incisor and lateral incisor in all three planes for Group I and Group II.

Apical displacement in Z-Axis (Intrusion)

<u>For Group I</u>

Amount of intrusion achieved as seen by displacement of central incisor in Z-axis was **1.5599 µm** at 20gm **< 3.1089 µm** at 40gm **< 4.6322 µm** at 60gm **< 4.2329 µm** at 80gm for **<u>0mm bone loss</u>**; 1**.8702 µm** at 20gm **< 3.7311 µm** at 40gm**< 5.6017 µm** at 60gm **< 7.3872 µm** at 80gm for **<u>2mm bone loss</u>**; **2.3337 µm** at 20gm **< 4.6039 µm** at 40gm **< 7.0347 µm** at 60gm**< 9.2790 µm** at 80gm for **<u>4 mm bone loss</u>** respectively.

Similarly amount of intrusion achieved as seen by displacement of lateral incisor in Z-axis was **1.5595 µm** at 20gm**< 3.1091 µm** at 40gm**< 4.6325 µm** at 60gm **< 6.1485 µm** at 80gm for **<u>0mm bone loss</u>**; **1.8703 µm** at 20gm **< 3.7313 µm** at 40gm **< 5.6019 µm** at 60gm **< 7.3875 µm** at 80gm for **<u>2mm bone loss</u>**; **2.3336 µm** at 20gm **< 4.6039 µm** at 40gm **< 7.0347 µm** at 60gm **< 9.2789 µm at 80gm** for **<u>4mm bone loss</u>** respectively. **(TABLE 4)**

<u>For Group II</u>

Amount of intrusion achieved as seen by displacement of central incisor in Z-axis was **1.5449 µm** at 20gm **< 3.0946 µm** at 40gm **< 4.6468 µm** at 60gm **< 6.2242 µm at 80gm** for **<u>0mm bone loss</u>**; **1.8507 µm** at 20gm **< 3.7060 µm** at 40gm **< 5.5185 µm** at 60gm **< 7.5617 µm** at 80gm for **<u>2mm bone loss</u>**; **2.2916 µm** at 20gm **< 4.6140 µm** at 40gm **< 6.8746 µm** at 60gm **< 9.1810 µm** at 80gm for **<u>4mm bone loss</u>** respectively.

Similarly amount of intrusion achieved as seen by displacement of lateral incisor in Z-axis was **1.5450 µm** at 20gm **< 3.0961 µm** at 40gm **< 4.6470 µm** at 60gm **< 6.2245 µm** at 80gm for **<u>0mm bone loss</u>**; **1.8508 µm** at 20gm **< 3.7061 µm** at 40gm **< 5.5188 µm** at 60gm **< 7.5621 µm** at 80gm for **<u>2mm bone loss</u>**; **2.2916 µm** at 20gm **< 4.6141 µm** at 40gm **< 6.8746 µm** at 60gm**< 9.1810 µm** at 80gm for **<u>4mm bone loss</u>** respectively. **(TABLE 4)**

Labiolingual displacement in Y-axis

<u>For Group I</u>

For central incisor labiolingual displacement was **0.5856 µm** at 20gm **< 1.1693 µm** at 40gm **< 1.7435 µm** at 60gm **< 1.2035 µm** at 80gm for **<u>0mm bone loss</u>**; **0.7135 µm** at 20gm **< 1.4231 µm** at 40gm **< 2.1363 µm** at 60gm **< 2.8093 µm** at 80gm for **<u>2mm bone loss</u>**; **0.8961 µm** at 20gm **< 1.7743 µm** at 40gm **< 2.7018 µm** at 60gm **< 3.5662 µm** at 80gm at **<u>4mm bone loss</u>** respectively.

Similarly for lateral incisor it was **0.5847 µm** at 20gm **< 1.1674 µm** at 40gm **< 1.7408 µm** at 60gm **< 2.3136 µm** at 80gm for **<u>0mm bone loss</u>**; **0.7125 µm** at 20gm **< 1.4211 µm** at 40gm **< 2.1334 µm** at 60gm **< 2.8055 µm** at 80gm for **<u>2mm bone</u>** loss; **0.8954 µm** at 20gm **< 1.7730 µm** at 40gm **< 2.6997 µm** at 60gm **< 3.5636 µm** at 80gm for **<u>4mm bone loss</u>** respectively. **(TABLE 4).**

<u>For Group II</u>

For central incisor labiolingual was **0.5860 µm** at 20 gm **< 1.1718 µm** at 40gm **< 1.7639 µm** at 60gm **< 2.3662 µm** at 80gm for **<u>0mm bone loss</u>**; **0.7126 µm** at 20gm **< 1.4261 µm** at 40gm **< 2.1251 µm** at 60gm **< 2.9182 µm** at 80gm for **<u>2mm bone loss</u>**; **0.8916 µm** at 20gm **< 1.7978 µm** at 40gm **< 2.6760 µm** at 60gm **< 3.5745 µm** at 80gm for **<u>4mm bone loss</u>** respectively.

Similarly for lateral incisor it was **0.5851 µm** at 20gm **< 1.1689 µm** at 40gm **< 1.7611 µm** at 60gm **< 2.3624 µm** at 80gm for **<u>0mm bone loss</u>**; **0.7116 µm** at 20gm **< 1.4241 µm** at 40gm **< 2.1221 µm** at 60gm **< 2.9140 µm** at 80gm for **<u>2mm bone</u>** loss; **0.8909 µm** at 20gm **< 1.7964 µm** at 40gm **< 2.6739 µm** at 60gm **< 3.5717 µm** at 80gm for **<u>4mm bone loss</u>** respectively. **(TABLE 4).**

FIGURE 18 - 23 shows contour plots for Von Mises stress for Group I at 0, 2 and 4mm of bone loss and for Group II at 0, 2 and 4mm of bone loss respectively.

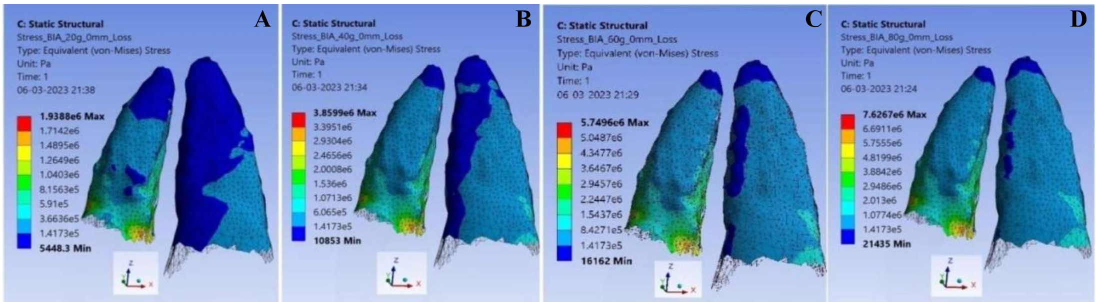

FIGURE 18: Von Mises stress seen for Group I at 0mm bone loss for different intrusive forces. (A)At 20gm, (B) At 40gm, (C) At 60gm, (D) At 80gm

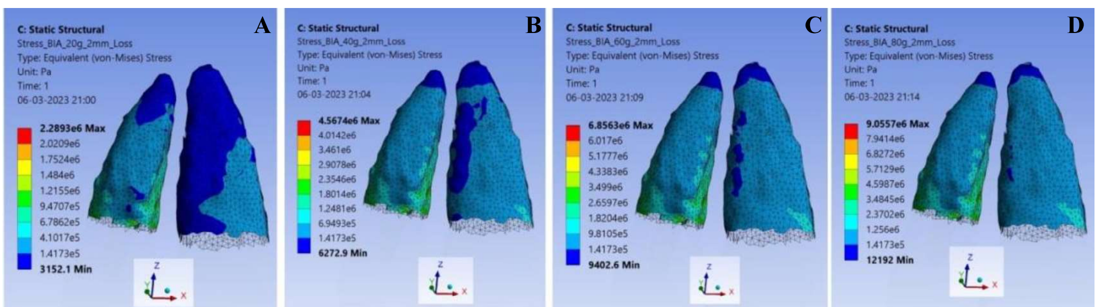

FIGURE 19: Von Mises stress seen for Group I at 2mm bone loss for different intrusive forces. (A)At 20gm, (B) At 40gm, (C) At 60gm, (D) At 80gm

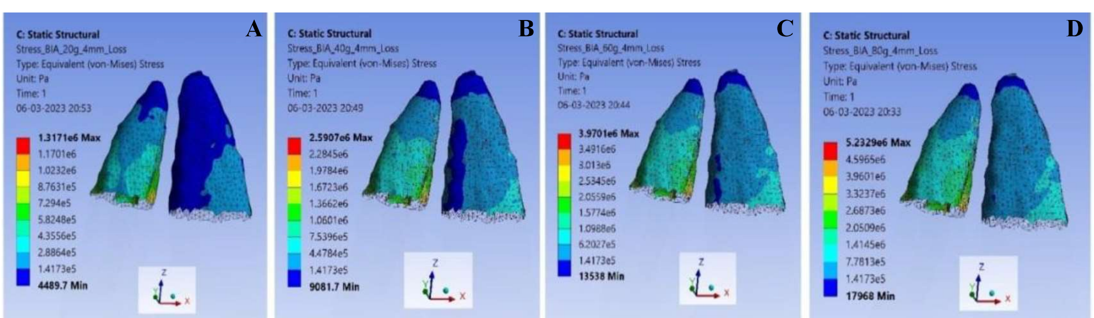

FIGURE 20: Von Mises stress seen for Group I at 4mm bone loss for different intrusive forces. (A)At 20gm, (B) At 40gm, (C) At 60gm, (D) At 80gm

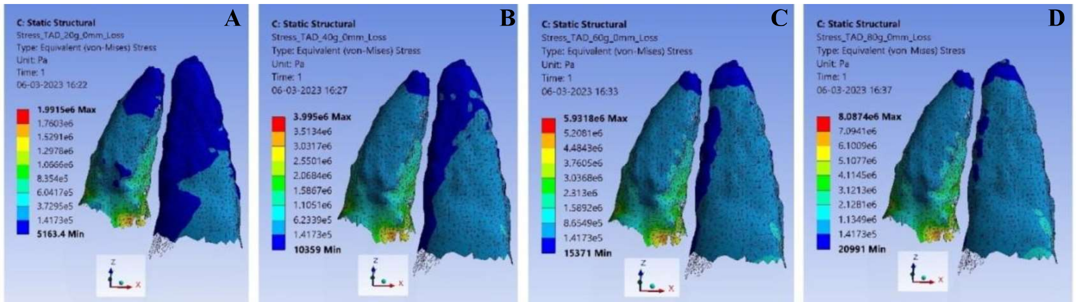

FIGURE 21: Von Mises stress seen for Group II at 0mm bone loss for different intrusive forces. (A) At 20gm, (B) At 40gm, (C) At 60gm, (D) At 80gm

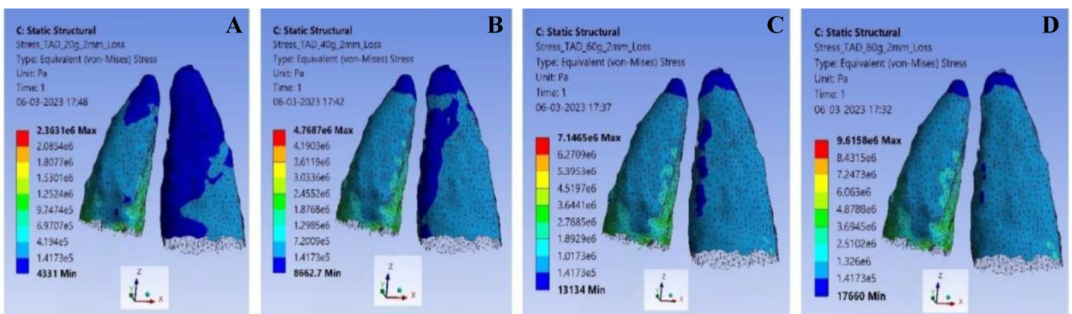

FIGURE 22: Von Mises stress seen for Group II at 2mm bone loss for different intrusive forces. (A) At 20gm, (B) At 40gm, (C) At 60gm, (D) At 80gm

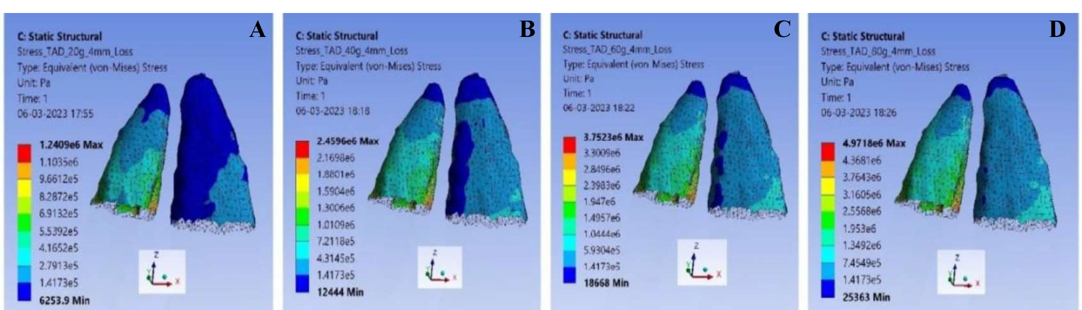

FIGURE 23: Von Mises stress seen for Group II at 4mm bone loss for different intrusive forces. (A) At 20gm, (B) At 40gm, (C) At 60gm, (D) At 80gm

Highest Von mises stress was seen at apex of central incisor and lateral incisor during intrusion in both the groups. As force was increased or bone loss was increased, stress was more concentrated at the apex as seen by dark blue color, for both the groups at 0, 2 and 4mm of bone loss.

Deep bite is one of the most common malocclusion seen in the vertical plane, that could be skeletal or dental in origin. Correction of deep bite is an utmost requirement during orthodontic treatment as it has various detrimental effects on periodontium, temporomandibular joint and facial esthetics. The treatment for patients with deep overbite could be achieved by extrusion of molars, intrusion of incisors, up righting of posterior teeth or flaring of anteriors or a combination of these. **Burstone** defined intrusion as apical movement of geometric centre of root in respect to occlusal plane or a plane based on long axis of the tooth.[17] For adult patients, extrusion of molars is not stable hence for growing patients with vertical growth pattern or adult patients, intrusion of anterior teeth is the only option available for correction of deep bite.[3]

Intrusion can be achieved in multiple ways using utility arches by Ricketts, intrusion arches by Burstone, use of Connecticut intrusion arch, Headgears, K- SIR (Simultaneous Intrusion and Retraction arch by Varun Kalra), removable myofunctional appliances or using micro implants / miniscrews.[4]The extent and amount of intrusion depends on various factors like distance of applied force from centre of resistance (CR), inclination of teeth, alveolar bone loss and amount of force applied for intrusion. To understand this, it is important to know the biomechanics of intrusion.[8] CR for four maxillary incisors is between lateral and canine at the level of one third from the apex of lateral incisor,[17] however force is applied at the level of bracket i.e. away from the CR, resulting in labial flaring of incisors. To overcome this, force should be applied either at CR, which is not feasible clinically or should be applied closer to CR so as to minimise unwanted moment created as a result of being away from CR. Intrusion arch when inserted in bracket slot (like Ricketts utility arch) results in two couple system, which generates a counter clockwise moment resulting in flaring of incisors. However, when intrusion arch is not inserted in the bracket slot (like Burstone intrusion arch), a one couple system is created as there is a point contact which avoids generation of counter clockwise moment due to placement of intrusion arch in bracket slot. Considering this, intrusion arch given by Burstone, which is not inserted in the slot, rather tied closer to the CR and provides one couple system for intrusion was used in this study.

Mini-implants or TAD's placed at CR or just below anterior nasal spine (ANS) are used nowadays for attempting intrusion in adults. It has been observed that with bilateral placement of mini-implants, overbite correction and intrusion can be achieved more efficiently in comparison to single implant placed in midline.[13] Considering this, intrusion achieved using bilaterally placed mini-implants was another method selected for intrusion in this study. Intrusive forces must be applied after correcting inclination of teeth, as more labial flaring will be seen when attempting intrusion of proclined teeth. Hence, intrusion of normoclined incisors was attempted in the present study.

Alveolar bone height around incisors also effects the amount of intrusive forces applied and moments generated due to intrusive force. CR for four anterior teeth is taken as 8-10 mm apical and 5-7 mm distal to lateral incisor root. As CR shifts more apically with alveolar bone loss, moment generated will be more with same amount of intrusive force.

Among various Orthodontic tooth movement, intrusion requires minimum amount of force as excessive forces can result in devitalisation of tooth, external root resorption etc. "**Steenbergen"** concluded that there was no statistically significant difference between intrusive forces of 40g or 80g for upper four incisors in terms of rate of incisor intrusion, or the amount of axial inclination change and extrusion.[15] As intrusive force should be reduced with alveolar bone loss, hence was decided to evaluate stress distribution at root apex on application of variable forces of 20, 40, 60 and 80gms for four maxillary incisors.[13] As clinical quantification of stress is not possible hence the finite element method (FEM), which calculates stress and displacement mathematically, was used in this study.

Considering this aim of the present study was comparative evaluation of stress distribution and displacement of root apex of four normoinclined maxillary incisors using two different mechanics (Burstone intrusion arch and Mini-implant assisted intrusion) in presence of variable intrusive forces and variable bone loss using FEM.

This comparative in-vitro study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences. Lucknow in collaboration with FEA Solution Mumbai.

A maxillary arch was modeled on the basis of CBCT images. MIMICS software was used to convert CBCT into STL format. MBT bracket prescription with 0.022’’ X 0.028’’inch bracket slot, molar tube, titanium miniscrews of length 6mm and diameter 1.2mm and rectangular stainless-steel stabilizing archwire of 0.019’’X 0.025’’inch was scanned using laser scanner and CAD model was made. Clinically stabilizing arch wire is segmental for Burstone intrusion arch, hence to have uniformity segmental stabilizing arch wire was used for mini-implant assisted intrusion as well. Burstone intrusion arch was fabricated using rectangular 0.017” X 0.025”inch TMA (Titanium Molybdenum Alloy) wire on typhodont, then was laser scanned and CAD model were obtained. GEOMAGIC modeling software was used for the construction of geometric model from CAD models. ALTAIR HYPERMESH software was used to create mesh models and also was used to fuse the model of maxilla with PDL, bone and complete assembly of brackets, molar tube, arch wire, mini-implants etc. to make FEM models. Material properties were incorporated for teeth, PDL, bone, stainless steel and TMA. FEM models were divided into two groups (Group I and Group II) based on intrusive mechanics. Group I included FEM model where Burstone intrusion arch was used for intrusion and Group II included FEM model for miniscrew assisted intrusion. Once the basic FEM model was constructed at 0mm bone loss, two more FEM models were constructed at 2mm and 4mm of alveolar bone loss for each group.

For force application Burstone intrusion arch (Group I) was tied at a point distal to lateral incisor bracket in line with CR on anterior component of segmental stabilizing arch wire. This tying of Burstone intrusion arch was simulated with variable forces of 20, 40, 60 and 80 grams on each FEM model using ANSYS software (with 0, 2 and 4mm of alveolar bone loss).

For Group II variable intrusive forces were simulated from mini-implants placed at CR (8mm apical and 7mm distal to lateral incisor), at an angulation of 90˚ to a point (same as Group I) distal of lateral incisor bracket on anterior component of segmental stabilizing arch wire with variable forces of 20, 40, 60 and 80 grams on each FEM model (with 0, 2 and 4mm of alveolar bone loss). A total of 6 finite element model were generated and boundary conditions was applied. The finite element model was submitted to ALTAIR OPTISTRUCT Finite Element (FE) solver to perform the simulation. Finally, ALTAIR HYPERVIEW software was used to read finite element results, generate result images and extract stress data from simulation. Von Mises stress at apex and displacement in three axis (X-Axis for mesio-distal movement, Y-Axis for labio-lingual movement and Z-Axis for occluso-gingival movement / or amount of intrusion) was measured.

The result of the present study stated that stresses were concentrated at root apex while attempting intrusion and Von Mises stress at apex and amount of intrusion increased as force was increased or as amount of bone loss was increased for both the groups.

For Group I:

The mean value of Von Mises stress at root apex of central incisor was **0.11 N/mm^2** at 20 gm **< 0.23 N/mm^2** at 40 gm **< 0.34 N/mm^2** at 60 gm **< 0.45 N/mm^2** at 80gm for **0mm bone loss**; **0.14 N/mm^2** at 20gm **< 0.27 N/mm^2** at 40gm **< 0.41 N/mm^2** at 60gm **< 0.54 N/mm^2** at 80gm for **2mm bone loss**; **0.17 N/mm^2** at 20gm **< 0.34 N/mm^2** at 40gm **< 0.51 N/mm^2** at 60gm **< 0.68 N/mm^2** at 80gm for **4mm bone loss** respectively.

Similarly, the mean value of Von Mises stress at root apex of lateral incisor was **0.03 N/mm^2** at 20gm **< 0.06 N/mm^2** at 40gm **< 0.08 N/mm^2** at 60gm **< 0.11 N/mm^2** at 80gm at **0mm bone loss**; **0.15 N/mm^2** at 20gm **< 0.30 N/mm^2** at 40gm**< 0.45 N/mm^2** at 60gm **< 0.59 N/mm^2** at 80gm for **2mm bone loss**; **0.19 N/mm^2** at 20gm **< 0.37 N/mm^2** at 40gm **< 0.57 N/mm^2** at 60gm **< 0.75 N/mm^2** at 80gm for **4 mm bone loss** respectively. **(TABLE 3)**

For Group II

The mean value of Von Mises stress at root apex of central incisor on applying **0.11 N/mm^2** at 20gm **< 0.24 N/mm^2** at 40gm**< 0.33 N/mm^2** at 60gm **< 0.45 N/mm^2** at 80gm for **0mm bone loss**; **0.13 N/mm^2** at 20gm **< 0.27 N/mm^2** at 40gm **< 0.40**

N/mm^2 at 60gm< **0.54 N/mm^2** at 80gm for **2mm bone loss**; **0.16 N/mm^2** at 20gm < **0.33 N/mm^2** at 40gm **< 0.49 N/mm^2** at 60gm **< 0.66 N/mm^2** at 80gm for **4mm bone loss**.

Similarly, the mean value of Von Mises stress at root apex of lateral incisor was **0.03 N/mm^2** at 20gm **< 0.06 N/mm^2** at 40gm**< 0.08 N/mm^2** at 60gm**< 0.11 N/mm^2** at 80gm for **0mm bone loss**; **0.15 N/mm^2** at 20gm **< 0.30 N/mm^2** at 40gm **< 0.44 N/mm^2** at 60gm **< 0.61 N/mm^2** at 80gm for **2mm bone loss**; **0.18 N/mm^2** at 20gm < **0.37 N/mm^2** at 40gm < **0.55 N/mm^2** at 60gm **< 0.74 N/mm^2** at 80gm for **4mm bone loss** respectively. **(TABLE 3)**

Apical displacement in Z-Axis (Intrusion) **(TABLE 4)**

<u>For Group I</u>

Amount of intrusion achieved as seen by displacement of central incisor in Z-axis was **1.5599 µm** at 20gm **< 3.1089 µm** at 40gm **< 4.6322 µm** at 60gm **< 4.2329 µm** at 80gm for **0mm bone loss**; 1**.8702 µm** at 20gm **< 3.7311 µm** at 40gm**< 5.6017 µm** at 60gm < **7.3872 µm** at 80gm for **2mm bone loss**; **2.3337 µm** at 20gm **< 4.6039 µm** at 40gm < **7.0347 µm** at 60gm**< 9.2790 µm** at 80gm for **4 mm bone loss** respectively.

Similarly amount of intrusion achieved as seen by displacement of lateral incisor in Z-axis was **1.5595 µm** at 20gm**< 3.1091 µm** at 40gm**< 4.6325 µm** at 60gm **< 6.1485 µm** at 80gm for **0mm bone loss**; **1.8703 µm** at 20gm **< 3.7313 µm** at 40gm **< 5.6019 µm** at 60gm **< 7.3875 µm** at 80gm for **2mm bone loss**; **2.3336 µm** at 20gm **< 4.6039 µm** at 40gm **< 7.0347 µm** at 60gm **< 9.2789 µm at 80gm** for **4mm bone loss** respectively. **(TABLE 4)**

<u>For Group II</u>

Amount of intrusion achieved as seen by displacement of central incisor in Z-axis was **1.5449 µm** at 20gm **< 3.0946 µm** at 40gm **< 4.6468 µm** at 60gm **< 6.2242 µm at 80gm** for **0mm bone loss**; **1.8507 µm** at 20gm **< 3.7060 µm** at 40gm **< 5.5185 µm** at 60gm < **7.5617 µm** at 80gm for **2mm bone loss**; **2.2916 µm** at 20gm **< 4.6140 µm** at 40gm **< 6.8746 µm** at 60gm **< 9.1810 µm** at 80gm for **4mm bone loss** respectively.

Similarly amount of intrusion achieved as seen by displacement of lateral incisor in Z-axis was **1.5450 µm** at 20gm **< 3.0961 µm** at 40gm **< 4.6470 µm** at 60gm **< 6.2245 µm** at 80gm for **0mm bone loss**; **1.8508 µm** at 20gm **< 3.7061 µm** at 40gm **< 5.5188 µm** at 60gm **< 7.5621 µm** at 80gm for **2mm bone loss**; **2.2916 µm** at 20gm **< 4.6141 µm** at 40gm **< 6.8746 µm** at 60gm**< 9.1810 µm** at 80gm for **4mm bone loss** respectively. **(TABLE 4)**

As 80gm force for is considered optimum for causing intrusion of four maxillary incisors,[13] the amount of displacement in Z-axis (intrusion) at 0mm bone loss was **4.2329 µm and 6.1485 µm** for Group I and **6.2242 µm and 6.2245 µm** for Group II for central and lateral incisor respectively. This amount of intrusion achieved was more than that achieved using 20, 40 and 60gm of force. In presence of bone loss, it could be seen that similar displacement occurred at lesser forces.

For Group I, amount of intrusion achieved with 80gm at 0mm bone loss was comparable to intrusion achieved at 60gm **(5.6017 µm and 5.6019 µm)** for 2mm bone loss and at 40gm (**4.6039 µm and 4.6039 µm)** for 4mm bone loss for central incisor and lateral incisor respectively**.**

For Group II, amount of intrusion achieved with 80gm at 0mm bone loss was comparable to intrusion achieved at 60gm **(5.5185 µm and 5.5188 µm)** for 2mm bone loss and at 40gm (**4.6140 µm and 4.6141 µm)** for 4mm bone loss for central incisor and lateral incisor respectively**.**

The results of the present study were compared to previous studies that evaluated intrusion of four anterior teeth using variable forces, variable amount of bone loss or varying points of force application in FEM studies **(Salehi P et al[68], Saga A Y et al[69], Cho S M et al[70], Thakkar U et al[72], Sakdakornkul S et al[71], Gupta R K et al[8], Geramy A et al[44], Rudolph D J et al[45] and Mathur A K et al[55])** and clinical studies **(Polat-Ozsoy et al[7] and Senisik N E et al[39] and Vela-Hernández A et al[13]).**

Salehi P et al[68] in their FEM study used mini-implants at different position along with varying point of force application. Four FEM models were constructed - First model had mini-implants placed halfway between the roots of central and lateral incisors and applied force was at right angle to the archwire between central and lateral incisor, second model had mini-implants placed halfway between the roots of lateral incisor and canine and the force was applied bilaterally between central and lateral incisor, third model mini-implants placed halfway between the roots of lateral incisor and canine and the force was applied between lateral incisor and canine at right angle to archwire (similar to the model used in present study) and fourth model had mini-implants placed at halfway between the roots of central and lateral incisors and the force was applied to a point on the archwire between lateral incisor and canine. A total force of 25gm was applied to each model through mini-implants. They found that absolute intrusion (apical displacement of root apex in Y plane) was lesser in lateral incisor **(0.008 µm)** than in central incisor **(0.029 µm)**. Contrary to this, in the present study absolute intrusion of for central incisor **(1.5449 µm)** was lesser than lateral incisor **(1.5450 µm)** in the present study for Group II at 0mm bone loss and 20gm of force. However, in Group I where Burstone intrusion arch was used, intrusion was less in lateral incisor **(1.5594 µm)** than in central incisor **(1.5599 µm).** They found labial displacement of central incisor **(0.161 µm)** was less than that of lateral incisor **(0.20 µm)** for third model whereas in our present study labial displacement of central incisor **(0.5860 µm)** was more than in lateral incisor **(0.5851µm)** at 20gm force for 0mm bone loss for Group II**.** Similar to present study, stresses were concentrated near apex in their study. Von Mises stress for lateral incisor **(0.03 N/mm^2)** was less than in central incisor **(0.11 N/mm^2)** in the present study for Group II at 0mm bone loss at 20gm force, however they found highest stress near apex of lateral incisor for third model but did not give values. The variation in values from present study could be due to the fact that they took CR as halfway between roots of lateral incisor and canine whereas we took it as 8mm apical and 7mm distal to lateral incisor and continuous stabilizing archwire was used in their study whereas segmental archwire was used in the present study. According to authors, the values of absolute intrusion was more and labial displacement was lesser in third model compared to others, hence they recommended this for use in clinical practice to achieve intrusion with minimal amount of labial flaring.

Saga A Y et al[69] evaluated stress distribution predominantly in the apical region irrespective of point of force application for intrusion of four maxillary incisors stabilized by 0.021X0.025inch stainless steel wire, using force of 15gm per tooth. Four FEM models were made - First model had point of force application centred between central incisor brackets (LOAD 1), second model had point of force located bilaterally between central and lateral incisor brackets (LOAD 2), third model had point force is application distal to lateral incisor brackets bilaterally (LOAD 3) and fourth model had point of force application located bilaterally 7 mm distal to the centre of lateral incisors brackets (LOAD 4). The situation of LOAD 3 could be corroborated with FEM model of present study. According to authors, stress concentration was predominantly in the apical region irrespective of point of force application as also seen in present study. In LOAD 3 compressive stresses as seen at the apex of lateral incisor was **1.26Mpa** and at central incisor was **0.69Mpa**. LOAD 3 and 4 had lesser compressive stress than other two loads with lesser labial displacement of incisors. They found lesser compressive stresses on labial side in LOAD 3, but they didn't gave values for labial displacement in their study. When values for LOAD 3 was compared to values of present study at 0mm bone loss for 60gm (15gm per tooth) stress at central incisor was **(0.34 N/mm^2)** for Group I and **(0.33 N/mm^2)** for Group II and for lateral incisor, stress was similar for Group I and II was **(0.08 N/mm^2).** The variation between values could be due to the fact that they applied intrusive force irrespective of any mechanics like Burstone intrusion arch or mini-implant as used in present study and they applied boundary conditions for zero rotation and displacement

Cho S M et al[70] evaluated stress distribution and displacement in three axis, during intrusion of six maxillary anterior teeth by placing mini-implants at various positions with variable point of force application. Amongst different combinations, the bilaterally placed mini-implants between lateral incisor and canine was similar to present study, however they varied point of force application i.e. between central incisor and lateral incisor and distal to lateral incisor bracket. We used single point of force application distal to lateral incisor bracket in present study. The model that had same placement of mini-implants and point of force application for intrusion with force of 100gm was compared to results for 80gm force for group II of present study, as other force levels used in present study were comparatively lesser (20, 40 and 60gm). They found that amount of intrusion in Z-axis was **1.9, 2.3 and 2.9 µm** for central incisor at 0, 2 and 4mm bone loss respectively and **2.1, 2.5 and 3.1 µm** at 0, 2 and 4mm bone loss respectively for lateral incisor in their study. In present study displacement of root apex in Z-axis for central and lateral incisor was same for Group II at 0, 2 and 4 mm bone loss were **(6.22, 7.56 and 9.18 µm)** at 80gm force. Similar to present study Von Mises stress were concentrated more in apex than in cervical area of the periodontal ligaments (PDL) for all models. In their study for model similar to present study, Von Mises stress at apex of Central incisors with 0, 2 and 4mm bone loss were **0.8, 1.0 and 1.3 g/mm^2** respectively, similarly for lateral incisors with 0, 2 and 4mm bone loss were **0.9, 1.1 and 1.4 g/mm^2.** In present study stress at root apex for 0, 2 and 4mm bone loss at 80gm of force were **0.45, 0.54 and 0.66 N/mm^2** respectively for central incisor and were **0.11, 0.61 and 0.74 N/mm^2** respectively for lateral incisor. Similar to this study, stresses were more in lateral incisor in comparison to central incisor for 2 and 4mm bone loss only in present study, however it was other way round for 0mm bone loss. They found uncontrolled tipping of incisors in their study that was measured in degrees and displacement in Y-axis was measured in µm and these values were lesser in the model similar to present study in comparison to the model where point of force application was between central and lateral incisor. Labial tilting of central incisor at 0, 2 and 4mm bone loss in degree were **9.1, 13.4 and 21.0 millidegrees** and labial displacement in Y-axis in micrometer were **1.1, 1.4 and 2.0 µm.** Similarly for lateral incisor labial tilting were **9.9, 14.1 and 21.5 millidegrees** and for labial displacement in Y-axis was **1.5, 1.8 and 2.4 µm** respectively at 0, 2 and 4mm bone loss. In present study labial displacement of central incisor at 80gm force for 0, 2 and 4mm bone loss were **2.37, 2.92 and 3.57 µm** and for lateral incisor were **2.36, 2.91 and 3.57 µm** respectively. Similar to present study they found that amount of intrusion as well as labial displacement increased as amount of bone loss increased. Variation in values could be due to different in placement of mini-implants, it was 12mm gingival to archwire whereas it was 8mm apical 7mm distal to lateral incisor in our present study.

Thakkar U et al[72] in their FEM study, evaluated stress distribution during mini-implants assisted intrusion of maxillary anterior with variation in mini-implant placement and angulation of the mini-implants constructed four FEM models. 1st and 2nd model had single implants placed between central incisors at 90° and 120°

respectively, and 3rd and 4th model had bilateral mini-implants were placed between lateral incisor and canine at 90˚and 120˚respectively and used a force of 100gm. The result of present study for intrusion at 80gm force for 0mm bone loss in Group II could be discussed with respect to third model of their study. Von Mises stresses of 3rd model exhibited stress **(0.005 N/mm^2)** in PDL. When amount of displacement was evaluated, 3rd model exhibited the least gingival displacement of central incisor **(0.042 mm)** followed by and lateral incisor **(0.056 mm)**. In present study displacement of central and lateral incisor in Z-axis was **(6.2242 µm and 6.2245 µm respectively)** at 80gm force and 0mm bone loss for Group II. According to authors, stress on teeth were less and distributed evenly when point of force application is bilateral, however stress increased on increasing angulation to 120˚ with more intrusion as well. However, we calculated stress for mini-implant placed at 90˚angulation only.

Sakdakornkul S et al[71] evaluated Von Mises stress on six maxillary anterior teeth during intrusion using two different location of mini-implant placement i.e. unilateral and bilateral. The later model was similar to present study where bilateral mini-implants were placed between lateral incisors and canine and the point of force application was between lateral incisor and canine bilaterally and force of 60gm divided by two was applied on each side. The results were compared with Group II of present study at 0mm bone loss and 60gm force. They observed stress of **(0.0011 Mpa)** for central incisor that was more than that of stress at lateral incisor apex **(0.00013 Mpa)** similar to present study, where stress at the apex of Central incisor **(0.33 N/mm^2)** was more than that of lateral incisor **(0.08 N/mm^2)** for Group II at 0mm bone loss for 60gm force. Amount of mean intrusion at apex of central incisor was **(1.53 µm)** and for lateral incisor was **(1.07 µm)** in their study, whereas in present study amount of intrusion seen in Z-axis for central incisor and lateral incisor was same **(4.65 µm).** The amount of mean labial displacement seen in their study for central incisor **(1.18 µm)** was more than that for lateral incisor **(1.07 µm),** similarly in present study labial displacement seen in Y-axis for central incisor **(1.7639 µm)** was more than that for lateral incisor **(1.7611 µm).**

Other studies that evaluated stress distribution on intrusion of single incisors , it was seen that amount of stress and displacement increased as force was increased or amount of bone loss was increased. **(Gupta R K[8] et al, Geramy A et al[44], Rudolph D J et al[45] and Mathur A K et al[55]).**

Gupta R k et al[8] studied the effect of intrusive forces on maxillary central incisor at different inclination in presence of varying bone loss **(0, 3 and 6mm)** with variable force of **5, 10 and 15gm**. For normoclined incisor, force of 5gm at 0, 3 and 6mm bone loss gave apical displacement as **(232.3, 234.7 and 238.5 µm)** and stress as **(0.000353**, **0.000325 and 0.000316 N/mm^2)** respectively, for force of 10gm displacement was **(251.5, 252.3 and 253.9 µm)** and stress was **(0.00126**, **0.001064 and 0.00879 N/mm^2)** respectively and for force of 15gm displacement was **(258.9, 261.1 and 7.93 µm)** and stress was **(0.00832**, **0.00811 and 0.00793 N/mm^2)** respectively. In the present study as the FEM models was constructed with normoclined anterior teeth the apical displacement seen in **Group I** at **0, 2 and 4mm** bone loss with **20gm** force were **(1.56, 1.87and 2.33 µm)** and in **Group II** were **(1.54, 1.85 and 2.29 µm)** respectively, similarly stress at apex for **Group I** were **(0.11, 0.14 and 0.17 N/mm^2)** and for **Group II** were **(0.11, 0.13 and 0.16 N/mm^2)** respectively. The trend of increase in displacement and stress with force and bone loss for central incisor was same as present study. However, values were much more for single tooth as it was not constrained by presence of adjacent teeth and stabilizing archwire as used in present study.

Geramy A et al[44] in their study constructed 6 FEM models of maxillary central incisor with **0, 1, 2, 2.5, 5, 6.5 and 8 mm** bone loss assuming normal alveolar bone height as13mm and applied **98.1gmforce or 1N** force (intrusive force and tipping force) on each model to calculate the apical stress and displacement. They found stress increased with increase in bone loss **(**at **0, 1, 2.5, 5, 6.5 and 8mm** bone loss maximum stress at apex was **0.031 N/mm^2**, **0.033 N/mm^2**, **0.036 N/mm^2, 0.041 N/mm^2, 0.045 N/mm^2 and 0.050 N/mm^2** respectively**)**. This trend was similar to present study where stress increased with increase in bone loss for both types of intrusive mechanics.

Rudolph D J et al[45] evaluated and compared the stress generated at root apex of single maxillary central incisor during various orthodontic tooth movement. For intrusion in their study they applied 25gm force, parallel to the long axis of the tooth and stress generated at root apex was **0.0017 N/mm^2** which is much less than that observed for central incisor **(0.11 N/mm^2)** in present study at 20gm force for Group I at 0mm bone loss. The variation could be due to the fact that point of force application was parallel to the long axis of central incisor, whereas in present study point of force application was between lateral incisor and canine.

Mathur A K et al[55] analysed stress generated due to various orthodontic tooth movement for maxillary central incisor. For intrusion force applied was parallel to the long axis and at centre of the tooth. At force of 10gm stress generated at root apex was **0.004497 N/mm^2,** however this force level was not considered in present study.

The results of present FEM study will also be compared to values of clinical studies **(Polat-Ozsoy[7] et al and Senisik N E[39] et al and Vela-Hernández A et al[13]).**

Polat-Ozsoy O et al[7] compared the intrusive effects of mini-implants and conventional utility arches. Group 1 consisted of 13 patients had 0.016X0.022inch stabilizing arch wire in upper four incisors and bilateral mini-implants of 1.2mm diameter and 6mm length were placed distal to lateral incisor and force of 80gm was applied and in Group 2 consisted of 11 patients where custom made utility arch were placed in four anterior teeth along with 45° tip back bend at molars. The reduction in overbite **(2.18 ± 0.6 mm)** for Group I and **(2.32 ± 0.4 mm)** for Group II and did not differ significantly between groups and suggestive of fact that amount of intrusion was similar in both the groups. However, both the groups showed significant intrusion from pre to post intrusion as seen on lateral cephalograms. When centroid marked for central incisor was measured with respect to palatal plane, changes were significantly different between pre and post intrusion for mini-implant group and statistically non-significant for utility arch group. The changes in CR – PP distance were **1.75 ± 0.4 mm** for mini-implant group and **0.86 ± 0.5 mm** for utility arch group but differences was statistically significant. The decrease in the vertical position of the maxillary incisors relative to the PP were **2.97 ± 0.4 mm** for Group I and **1.81 ± 0.5 mm** for Group II but differences was statistically significant. The sagittal movement of maxillary incisor and labial tipping of maxillary incisor happened in both the groups, however difference was statistically significant from pre to post intrusion only in group where utility arch was used and on intergroup comparison differences was statistically significant. In their study it was observed that with mini-implants intrusion was more when measured from centroid and labial flaring of the incisors was significantly less compared to the utility arch group. As ours was a FEM study, where forces were applied for 10 seconds and displacements were measured unlike clinical studies where amount of intrusion over a period of 4 -8 months is assessed, hence variation was observed. Though amount of intrusion was slightly different in Group II than Group I in present study, this could be due to the fact that Burstone intrusion arch is a one couple system where intrusion arches is not inserted in the slot unlike utility arch of the clinical study which is a two couple system.

Senisik N E et al[39] compared intrusion with Connecticut intrusion arch (CTIA) and mini-implant (1.3 mm diameter and 5mm length) placed between lateral incisor and canine using lateral cephalograms taken at gap of seven months. For CTIA group force applied was 60gm whereas in mini-implant group force was 90gm, they found that intrusion achieved in mini-implant group was more (**2.47 mm)** compared to CTIA **(2.20 mm)** but difference was statistically insignificant. For Group I, at 0mm bone loss and 60gm of force, amount of intrusion for central and lateral incisor was **(4.6322 and 4.6325 µm)** respectively and for Group II it was **(4.6468 and 4.6470 µm)** respectively at 60gm force and at 80gm of force **(6.2242 and 6.2245 µm)** respectively. Thus, amount of intrusion for Group II was more than Group I, similar to results of above clinical study. As CTIA was cinched back behind the molars, labial flaring (both angular and linear) was less in this group **(2.33mm and 4.87°)** compared to mini-implant group where it was **(2.80mm and 8.10°)**. Labial displacement at 60gm force (0mm bone loss) for Group I was **(1.74 µm)** and less than Group II**(1.76 µm)**. Thus, trend is similar for both the studies.

Vela-Hernández A et al[13] evaluated the efficacy of single (Group 1) or bilaterally placed (Group 2) mini-implants. They found statistically significant intrusion in Group 2 **(3.80±1.43mm)** than in Group 1 **(2.75±1.63mm)** and statistically significant less labial flaring seen in Group 2 **(11.58±8.03)** than in Group 1 **(2.75±1.63mm)**.

Overall conclusion from above mentioned FEM studies is that amount of intrusion and stresses increased as force was increased or amount of bone loss increased. It can be suggested, based on clinical studies that mini-implant assisted intrusion was more effective with less undesirable effects than one couple or two couple intrusion arches. Also, bilateral placement of mini-implant resulted in more effective intrusion with lesser labial flaring in comparison to single mini-implant used for intrusion.

As 80gm of force is considered optimum for intrusion at normal bone height, it was seen that comparable intrusion was achieved at 60gm at 2mm bone loss and 40gm at 4mm bone loss for both the groups. Within limitation of the present study, it can be suggested that on simulating intrusion by two different mechanics, stress were concentrated at apex and in the presence of bone loss to achieve optimum intrusion lesser forces without excessive concentration of stresses at apex should be considered.

The main clinical implication of the study would be that, type of intrusive mechanics should be selected based on requirement of individual case. If labial flaring is desirable as in retroclined teeth, Burstone intrusion arch could be a better choice and mini-implant assisted intrusion is more effective in achieving absolute intrusion. Also force levels should be decreased, whenever bone loss is evident for achieving similar amount of intrusion.

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

Major limitation of the finite element analysis technique is that it is based on several assumptions. The structures in the model were all assumed to be homogenous and isotropic with linear elasticity whereas the properties of the materials, particularly the living tissues were different. For instance, it is well documented that the alveolar bone of the maxilla and mandible is non-homogenous, the mechanical properties of the materials are nonlinear and complicated, and it might be impossible to include ideal properties in the model. This makes the problem even more complex. The stress distribution patterns simulated also might be different, depending on the materials and properties assigned to each layer of the model used in the experiments. Also, force is applied for limited time i.e. around 10 sec in FEM studies, whereas clinically force is applied over a longer period. These are inherent limitations of this study.

Further studies with Finite element method could analyze a variety of factors related to stress generation such as variable combination of mini-implant length, diameter, design, placement, variable point of force application while attempting intrusion. Additionally, stress distribution with other intrusion mechanics in labial as well as lingual appliances can be studied. Results of the FEM studies can be corroborated with clinical measurements related to intrusion, to reach up to the definitive conclusion.

Following conclusion are drawn from the present study conducted with an aim to compare and evaluate stress distribution and displacement of root apex of four normoinclined maxillary incisors using two different intrusive mechanics (Burstone intrusion arch mini-implant assisted intrusion) in presence of variable intrusive forces and variable bone loss:-

- On simulating intrusion by two different mechanics (Burstone intrusion arch and Mini-implant assisted intrusion) at variable bone loss (0, 2 and 4mm) and different forces (20, 40, 60 and 80gm), it was found that stresses were concentrated at root apex.
- Von Mises stress at root apex and amount of intrusion were increased with increasing force levels as well as with increase in amount of bone loss, for both the groups.
- Amount of labial displacement of incisors was found to be increased with increase in force level as well as with increase in amount of bone loss for both the groups.
- As 80gm of force is considered as optimum intrusive force for four maxillary incisors at normal bone height hence, the comparable amount of intrusion can be achieved with lesser forces in presence of bone loss. The amount of intrusion achieved by 80gm of at 0mm bone loss was comparable to intrusion achieved at 60gm of force at 2mm bone loss and at 40gm of force at 4mm bone loss for both the group.
- The trend of stresses, intrusion and labial displacement was comparable in both the groups.

Within the limitation of the present study, it can be suggested that in the presence of bone loss to achieve optimum intrusion lesser forces without excessive concentration of stresses at apex should be considered.

Further studies with Finite element method could analyse a variety of factors related to stress generation such as variable combination of mini-implant length, diameter, design, placement, variable point of force application while attempting intrusion. Results of the FEM studies can be corroborated with clinical measurements related to intrusion to reach up to the definitive conclusion.

Deep bite is one of the most common malocclusion seen in the vertical plane, that could be skeletal or dental in origin. Deep overbite can be corrected by extrusion of molars, intrusion of incisors, up righting of posterior teeth or flaring of anteriors or a combination of these. **Burstone** defined intrusion as apical movement of geometric centre of root in respect to occlusal plane or a plane based on long axis of the tooth. Intrusion can be achieved in multiple ways using utility arches by Ricketts, intrusion arches by Burstone, use of Connecticut intrusion arch, Headgears, K- SIR (Simultaneous Intrusion and Retraction arch by Varun Kalra), removable myofunctional appliances or using micro implants / miniscrews.

Burstone intrusion arch, a one couple system where arches are not placed in the bracket slot was selected in the present study. It has been observed that with bilateral placement of mini-implants, overbite correction and intrusion can be achieved more efficiently in comparison to single implant placed in midline. Considering this, intrusion achieved using bilaterally placed mini-implants was another method selected for intrusion in this study.

Previous studies suggested that 40gm to 80gm force for intrusion of four maxillary incisors can be used. Alveolar bone height also effects the amount of intrusion achieved. As CR shifts apically with alveolar bone loss and moment generated is also more, hence reduction of force levels had been recommended. Considering this force levels were varied in present study as 20, 40, 60 and 80gm.

As clinical quantification of stresses is difficult, hence Finite element method was used for evaluating stresses. Considering this aim of the present study was comparative evaluation of stress distribution and displacement of root apex of four normoinclined maxillary incisors using two different mechanics (Burstone intrusion arch and Mini-implant assisted intrusion) in presence of variable intrusive forces and variable bone loss using FEM.

This comparative in-vitro study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences. Lucknow in collaboration with FEA Solution Mumbai.

A maxillary arch was modeled on the basis of CBCT images. MIMICS software was used to convert CBCT into STL format. MBT bracket with 0.022'' X 0.028''inch slot, molar tube, titanium miniscrews of length 6mm and diameter 1.2mm, stainless-steel stabilizing archwire of 0.019''X 0.025''inch and Burstone intrusion arch of 0.017" X 0.025"inch TMA (Titanium Molybdenum Alloy) fabricated on typhodont was scanned and CAD model was made. To have uniformity segmental stabilizing arch wire was used for Burstone intrusion arch and for mini-implant assisted intrusion as well. GEOMAGIC modeling software was used for construction of geometric model from CAD models. ALTAIR HYPERMESH software was used to create mesh model of maxilla with complete assembly. Material properties were incorporated for teeth, PDL, bone, stainless steel and TMA. FEM models were divided into two groups (Group I and Group II) based on intrusive mechanics. Group I included FEM model where Burstone intrusion arch was used and Group II included FEM model for miniscrew assisted intrusion. Once the basic FEM model was constructed at 0mm bone loss, two more FEM models were constructed at 2mm and 4mm of alveolar bone loss for each group. A total of 6 finite element model were generated and boundary conditions was applied.

For force application, Burstone intrusion arch (Group I) was tied at a point distal to lateral incisor bracket in line with CR on anterior component of segmental stabilizing arch wire and variable forces (20, 40, 60 and 80gm) were simulated using ANSYS software on each FEM model (0, 2 and 4mm bone loss). Similarly for mini-implant assisted intrusion (Group II) variable intrusive forces (20, 40, 60 and 80gm) were simulated from mini-implants placed at CR to a point (same as Group I) distal of lateral incisor bracket on anterior component of segmental stabilizing arch wire with variable forces of 20, 40, 60 and 80 grams on each FEM model (with 0, 2 and 4mm of alveolar bone loss). The finite element model was submitted to ALTAIR OPTISTRUCT Finite Element (FE) solver to perform the simulation. Finally, ALTAIR HYPERVIEW software was used to read finite element results, generate result images and extract stress data from simulation. Von Mises stress at apex and displacement in three axis (X axis: Mesio-dital, Y axis: Labio-lingual and Z axis: Occluso-gingival) was measured.

Following conclusion were drawn from present study

- On simulating intrusion by two different mechanics (Burstone intrusion arch and Mini-implant assisted intrusion) at variable bone loss (0, 2 and 4mm) and different forces (20, 40, 60 and 80gm), it was found that stresses were concentrated at root apex.
- Von Mises stress at root apex and amount of intrusion were increased with increasing force levels as well as with increase in amount of bone loss, for both the groups.
- Amount of labial displacement of incisors was found to be increased with increase in force level as well as with increase in amount of bone loss for both the groups.
- As 80gm of force is considered as optimum intrusive force for four maxillary incisors at normal bone height hence the comparable amount of intrusion can be achieved with lesser forces in presence of bone loss. The amount of intrusion achieved by 80gm of at 0mm bone loss was comparable to intrusion achieved at 60gm of force at 2mm bone loss and at 40gm of force at 4mm bone loss for both the group.
- The trend of stresses, intrusion and labial displacement was comparable in both the groups.

Within the limitation of the present study, it can be suggested that in the presence of bone loss to achieve optimum intrusion lesser forces without excessive concentration of excessive stresses at apex should be considered.

Further studies with Finite element method could analyse a variety of factors related to stress generation such as variable combination of mini-implant length, diameter, design, placement, variable point of force application while attempting intrusion. Additionally, stress distribution with other intrusion mechanics in labial as well as lingual appliances can be studied. Results of the FEM studies can be corroborated with clinical measurements related to intrusion to reach up to the definitive conclusion.

1. Shroff B, Yoon WN, Lindaurer SI, Burstone CJ. Simultaneous intrusion and retraction using three piece base arch. Angle Orthod 1997:6:455-461.

2. Bennet IC, Mclaughlin RP. Management of deep overbite with a readjusted appliance system. J Clin Orthod 1990;684-696.

3. Graber TM, Rakosi T, Petrovic AG. Dentofacial orthopedics with functional appliances. 2nd ed. St Louis: C. V. Mosby; 1997:452-60.

4. Smith RJ, Burstone CJ. Mechanics of tooth movement. Am J Orthod. 1984; 85(4): 294-307.

5. Marcotte MR, Decker BC. Biomechanics in orthodontics. 1st ed. united state: cbs publishers; 1990

6. Belludi A, Bhardwaj A, Gupta A, Karandikar A. Orthodontic intrusion: Conventional and mini implant assisted intrusion mechanics. J Asian Pacific Orthod Soc 2011;II(4).

7. Polat Ozsoy O, Arman Ozirpic A., Veziroglu F, Cetinsahin A. Comparison of the intrusive effects of miniscrews and utility arches. Am J Orthod Dentofacial Orthop 2011;139(4):526-32.

8. Tikku T, Khanna R, Verma S, Srivastava K, Gupta R. Effect of intrusive forces on maxillary central incisor at different inclinations at normal bone height is – A FEM Study. International Journal of IT, Engineering and Applied Sciences Research (IJIEASR) ISSN: 2319-4413 Volume 5, No. 7, July 2016:08-14.

9. Papageorgiou IS. The centre of resistance of teeth in Orthodontics. Hellenic Orthod Rev 2005;8(1):41-55.

10. Proffit WR, Fields HW, Ackerman JL, Bailey LJ, Tulloch JEC. Contemporary orthodontics. 3rd ed. St Louis: C. V. Mosby;2000

11. Nanda R, Kuhlberg A. Principles of biomechanics. Biomechanics in Clinical Orthodontics. Philadelphia, Penn: WB Saunders Co; 1997:1-22.

12. Polat Ozsoy O, Arman Ozcirpici A, Veziroglu F. Miniscrews for upper incisor intrusion. Eur J Orthod 2009;31:412-6.

13. Vela-Hernández A, Gutiérrez-Zubeldia L, López-García R, García-Sanz V, Paredes-Gallardo V, Gandía-Franco JL, Lasagabaster-Latorre F. One versus two anterior miniscrews for correcting upper incisor overbite and angulation: a retrospective comparative study. Prog Orthod. 2020 Sep 7;21(1):34. doi: 10.1186/s40510-020-00336-2. PMID: 32893322; PMCID: PMC7475152.

14. Dr. HarishAtram; Dr.Kalyani Chaudhari; Dr.DamyantiAtram .; Dr. Shantanu Kalokhe; Dr.Nandini Jaiswal; Dr.MohiniDharmadhikari .. "INTRUSION MECHANICS IN ORTHODONTICS: A REVIEW". European Journal of Molecular & Clinical Medicine, 8, 3, 2021, 624-632.

15. Steenbergen EV, Burstone CJ, Andersen BP. The influence of force magnitude on intrusion of the maxillary segment. Angle Orthod 2004;75(5):608-614.

16. Burstone CJ. Deep overbite correction by intrusion. Am J Orthod 1971;72(1):1-22.

17. Vanden Bulcke MM, Dermaut LR, Sachdeva RCL, Burstone CJ. The center of resistance of anterior teeth during intrusion using the laser reflection technique and holographic interferometry. Am J Orthod Dentofacial Orthop 1986;90(3):211-220.

18. Dermaut LR, Munk AD. Apical root resorption of upper incisors caused by intrusive tooth movement: a radio graphic study. Am J Orthod 1986;90(4):321-326.

19. Melsen B, Agenback N, Markenstam G. Intrusion of incisors in adult patients with marginal bone loss. Am J Orthod Dentofacial Orthop 1989;96(3):232-41.

20. McFadden WM, Engstrom C, Engstrom H, Anholm JM. A study of the relationship between incisor intrusion and root shortening. Am J Orthod Dentofac Orthop 1989;96:390-6.

21. Isaacson RJ, Rebellato J. Two-couple orthodontic appliance systems: torquing arches. Semin Orthod 1995;1(1):31-6.

22. Weiland FJ, Bantleon HP, Droschl H. Evaluation of continuous arch and segmented arch leveling techniques in adult patients A clinical study. Am J Orthod Dentofacial Orthop 1996; 110(6):647-52.

23. Costopoulos G, Nanda R. An evaluation of root resorption incident to orthodontic intrusion. Am J Orthod Dentofacial Orthop 1996;109(5):543-8.

24. Ramsay DS, Barwick PJ. Effect of brief intrusive force blood flow on human pulpal blood flow. Am J Orthod Dentofacial Orthop 1996;Vol 109, No.3:543-548.

25. Nanda R, Marzban R, Kuhlberg A. The Connecticut intrusion arch. J Clin Orthod 1998;32(12):708-715.

26. Parker RJ, Harris EF. Directions of orthodontic tooth movements associated with external apical root resorption of the maxillary central incisor. Am J Orthod Dentofacial Orthop 1998;114(6):677-83.

27. Cobo J, Arguelles J. Dentoalveolar stress from bodily tooth movement at different levels of bone loss. Am J Orthod Dentofacial Orthop 1996;110:256 - 262.

28. Tanne K, Sakuda M. Three dimensional finite element analysis for stress in the periodontal tissue by orthodontic forces. Am J Orthod Dentofacial Orthop 1998:92:499-505.

29. Parker RJ, Harris EF. Directions of orthodontic tooth movements associated with external apical root resorption of the maxillary central incisor. Am J Orthod Dentofacial Orthop 1998; 114(6):677-83.

30. Pearson LE, Pearson BL. Rapid maxillary expansion with incisor intrusion: A study of vertical control. Am J Orthod Dentofacial Orthop 1999;115(5):576-82.

31. Geron S, Romano R, Brosh T. Vertical Forces in Labial and Lingual Orthodontics Applied on Maxillary Incisors- A Theoretical Approach. Angle Orthod 2004;74(2):195-201.

32. Amasyali M, Sagdic D, Olmez H, Akin E, Karacay S. Intrusive Effects of the Connecticut Intrusion Arch and the Utility Intrusion Arch. Turk J Med Sci 2005;35:407-415.

33. Kim TW, Kim H, Lee SJ. Correction of deep overbite and gummy smile by using a mini-implant with a segmented wire in a growing Class II Division 2 patient. Am J Orthod Dentofacial Orthop 2006;130(5):676-85.

34. Steenbergen EV, Burstone CJ, Andersen BP, Aartman IHA. Influence of buccal segment size on prevention of side effects from incisor intrusion. Am J Orthod Dentofacial Orthop 2006;129(5):658-65.

35. Upadhyay M, Nagaraj K, Yadav S, Saxena R. Mini-implants for en masse intrusion of maxillary anterior teeth in a severe Class II division 2 malocclusion. J Orthod 2008;35(2): 79-89.

36. Sifakakis I, Pandis N, Makou M, Eliades T, Bourauel C. Forces and moments generated with various incisor intrusion systems on maxillary and mandibular anterior teeth. Angle Orthod 2009;79(5):928-933.

37. Ramanathan C and Hofman Z. Root resorption during orthodontic tooth movements. Eur J Orthod 2009;31:578-583.

38. Amarnath BC, Prashanth CS, Dharma RM. Clinical Overview of Deep Bite Management. Int J Contemporary Dentistry 2010; 1(2):30-33.

39. Senışık NE, Türkkahraman H. Treatment effects of intrusion arches and mini-implant systems in deepbite patients. Am J Orthod Dentofacial Orthop. 2012 Jun;141(6):723-33.

40. Sana S, Bansal A, Sami L, Tapashetti R, Gaikwad S. Anterior deep bite malocclusion treated with connecticut intrusion arch: biomechanical consideration. J Clin Diagn Res. 2014 May;8(5):ZD30-2.

41. Atik E, Gorucu-Coskuner H, Akarsu-Guven B, Taner T. Evaluation of changes in the maxillary alveolar bone after incisor intrusion. Korean J Orthod. 2018;48(6):367-376.

42. Tanne K, Koenig HA, Burstone CJ, Sakuda M. Effect of moment to force ratios on stress patterns and levels in the PDL. J Osaka Univ Dent Sch. 1989; 29:9-16.

43. McGuinness N, Wilson AN, Jones M. Stresses induced by edgewise appliances in the periodontal ligament-a FEM study. Angle Orthod 1992;62(1):15-22.

44. Geramy A. Alveolar bone resorption and the center of resistance modification 3-D analysis by means of the finite element method. Am J Orthod Dentofacial Orthop. 2000;117(4):399-405.

45. Rudolph DJ, Willes MG, Sameshima GT. A finite element model of apical force distribution from orthodontic tooth movement. Angle Orthod 2001;71(2):127-131.

46. Geramy A. Initial stress produced in the periodontal membrane by orthodontic loads in the presence of varying loss of alveolar bone-a three dimensional finite element analysis. Eur J Orthod 2002;24:21-23.

47. Choy K, Pae EK, Park Y, Kim KH, Burstone CJ. Effect of root and bone morphology on the stress distribution in the periodontal ligament. Am J Orthod Dentofacial Orthop. 2000;117 (1):98-105.

48. Brezeanu L, Bica C, Pacurar M, Sita D. FEM simulation of biomechanical phenomena during Orthodontic tooth displacements. Inter-Ing 2007;15:1-5.

49. Szuhanek C. Finite element analysis of lingual forces effect in alveolar bone loss cases. Lingual Orthod 2007;5(1)1-6.

50. Holberg C, Steinhauser S, Rudzki-Janson I. Rapid maxillary expansion in adults: Cranial stress reduction depending on the extent of surgery. Eur J Orthod 2007;29:31-36.

51. Jin S, Kim IT, Kook YA. Finite element analysis of the shift in center of resistance of the maxillary dentition in relation to alveolar bone loss. Korea College of Medicine 2009.

52. Freitas AC, Rocha EP, Santos PHD, Ko Chang C, Martin M, De Almeida EO. Mechanics of the maxillary central incisor. Influence of the periodontal ligament represented by beam elements. Computer Methods in Biomechanics and Biomedical Engineering 2010;13(5):515-521.

53. Liang W, Rong Q, Lin J, Xu B. Torque control of the maxillary incisors in lingual and labial orthodontics: A 3-dimensional finite element analysis. Am J Orthod Dentofacial Orthop 2009;135(3):316-22.

54. Vikram NR, Hashir YM, Karthikeyan MK. Finite element method in orthodontics. Ind J Multidisciplinary Dent 2010;1(1):40-46.

55. Mathur AK, Gupta V, Sarmah A. Apical force distribution due to orthodontic forces: A Finite Element Study. J Contemporary Dent Pract 2011;12(2):104-108.

56. Suzuki A, Masuda T, Takahashi I, Deguchi T, Suzuki O, Takano-Yamamoto T. Changes in stress distribution of orthodontic miniscrews and surrounding bone evaluated by 3-dimensional finite element analysis. Am J Orthod Dentofacial Orthop 2011;140(6):273-280.

57. Singh M, Mehrotra P. Biomechanical aspects for true intrusion with lingual mechanics- An FEM study. Lingual Biomechanics: 2009;1(1):55-65.

58. Kamble RH, Lohkare S, Hararey PV, Mundada RD. Stress distribution pattern in a root of maxillary central incisor having various root morphologies- A finite element study. Angle Orthod 2012;82(5) :799-805.

59. Padmawar SS, Belludi A, Bhardwaj A, Vadvadgi V, Saini R. Study of Stress Distribution in Maxillary Anterior Region during True Intrusion of Maxillary Incisors using Finite Element Methodology. Int J Experiment Dent Sc 2012;1 (2):89-92.

60. Vikram NR, KS Senthil Kumar, Nagachandran KS, Hashir YM. Apical stress distribution on maxillary central incisor during various orthodontic tooth movements by varying cemental and two different periodontal ligament thicknesses: A FEM study. Ind J Dent Res 2012:23 (2):213-220.

61. Kanjanaouthai A, Mahatumarat K, Techalertpaisam P, Versluis A. Effect of the inclination of maxillary central incisor on periodontal stress. Angle Orthod 2012;82(5):812-819.

62. Lee HK et al. Stress distribution and displacement by different bone-borne palatal expanders with micro-implants: A three-dimensional finite-element analysis. Eur J Orthod 2012;11:1-10.

63. Jagdev PS, Mehrotra P, Dattada H, Rastogi N. Evaluation of stresses on tooth and periodontium with varying degree of bone support on orthodontic force application - A 3D Finite Element Analysis. J Ind Dent Sci 2012:3-14.

64. Rex S, Balasubramanian, Ravi K, Krishna RP, Dilip S. Evaluation of apical force distribution for orthodontic tooth movements - A FEM Analysis. J Ind Dent Sci 2012:38-42.

65. Heravi F, Salari S, Tanbakuchi B, Loh S, Amiri M. Effects of crown-root angle on stress distribution in the maxillary central incisors' PDL during application of intrusive and retraction forces: a three-dimensional finite element analysis. Progress in Orthod 2013:14:1-10.

66. Mascarenhas R, Revankar AV, Mathew IM, Chatra L, Husain A, Shenoy S. Effect of intrusive and retraction forces in labial and lingual orthodontics: A finite element study. Asian Pacific Ortho sci 2014;4(2):36-39.

67. Dabla N, Phull TS, Prasad PN, Rawat N. Stress appraisal in periodontium of maxillary first molar using various intrusive forces: A finite element analysis study. J Orthod Research 2014;2(2):90-96.

68. Salehi P, Gerami A, Najafi A, Torkan S. Evaluating Stress Distribution Pattern in Periodontal Ligament of Maxillary Incisors during Intrusion Assessed by the Finite Element Method. J Dent (Shiraz). 2015 Dec;16(4):314-22.

69. Saga AY, Maruo H, Argenta MA, Maruo IT, Tanaka OM. Orthodontic intrusion of maxillary incisors: a 3D finite element method study. Dental Press J Orthod. 2016. Jan-Feb;21(1):75-82.

70. Cho SM, Choi SH, Sung SJ, Yu HS, Hwang CJ. The effects of alveolar bone loss and miniscrew position on initial tooth displacement during intrusion of the maxillary anterior teeth: Finite element analysis. Korean J Orthod. 2016 Sep;46(5):310-22.

71. Sakdakornkul S, Patanaporn V, Rungsiyakull C. Intrusion of Six Maxillary Anterior Teeth Using Mini-screw Anchorage: A Finite Element Study: Original articles. CM Dent J. 2019. May 01;40(2):51-63.

72. Thakkar U, Patil NS, Thakkar AP, Chitko SS, Jaltare P. Study of the Stress Distribution Around the Mini-implant During Maxillary Anterior Intrusion Under Different Conditions: A 3-Dimensional Finite Element Analysis. Journal of Indian Orthodontic Society. 2020;54(2):106-114.

ANNEXURE-I

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

INSTITUTIONAL RESEARCH COMMITTEE APPROVAL

The project titled **"Comparative Evaluation of Intrusion of Four Maxillary Incisors using Two Different Mechanics- A Fem Study"** submitted by **Dr Bivek Bijoy Senapati** Post graduate student from the **Department of Orthodontics and Dentofacial Orthopaedics** as part of MDS Curriculum for the academic year 2020-2023 with the accompanying proforma was reviewed by the Institutional Research Committee present on **12th October 2021** at BBDCODS.

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

Prof. Vandana A Pant
Co-Chairperson

Prof. B. Rajkumar
Chairperson

ANNEXURE-II

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

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

Communication of the Decision of the IXth Institutional Ethics Sub-Committee

IEC Code: 03 **BBDCODS/04/2022**

Title of the Project: Comparative Evaluation of Intrusion of Four Maxillary Incisors using Two Different Mechanics- A Fem Study.

Principal Investigator: Dr Bivek Bijoy Senapati **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 Bivek Bijoy Senapati,

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

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

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

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

Forwarded by:

Lakshmi Bala

(Dr. Lakshmi Bala)
Member-Secretary
IEC

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

Received
BBingh
28/4/2022

(Dr. Puneet Ahuja)
Principal
PRINCIPAL BBDCODS
Babu Banarasi Das College of Dental Sciences
(Babu Banarasi Das University)
BBD City, 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 InformationDocument (PID) in English

1. **Study Title**

Comparative evaluation of intrusion of four maxillary incisors using two different mechanics - A FEM STUDY

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

3. **What is the purpose of the study?**
   the purpose of the study is to compare and evaluate of intrusion of four maxillary incisors using two different mechanics - a fem study

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 intrusion of four

maxillary incisors using two different mechanics - a fem study

9. What are the interventions for the study?

- To calculate stress and displacement at apex of four normoinclined incisors by FEM on application of different magnitude of force i.e 20, 40, 60 and 80 gms at varying bone loss of 0, 2 and 4 mm using Burstone intrusion arch.
- To calculate stress and displacement at apex of four normoinclined incisors by FEM on application of different magnitude of force i.e 20, 40 and 60 and 80 gms at varying bone loss of 0, 2 and 4 mm using Miniscrew placed at centre of resistance of four maxillary incisors.
- To make intra group comparison of stress and displacement at apex of four maxillary incisors using Burstone intrusion arch at different forces and varying bone loss.
- To make intra group comparison of stress and displacement at apex of four maxillary incisors using Miniscrew at different forces and varying bone loss.

10. What are the side effects of taking part?

Not applicable

11. What are the possible disadvantages and risks of taking part?

Not applicable

12. What are the possible benefits of taking part?

Not applicable

13. What if new information becomes available?

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

14. What happens when the research study stops?

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

15. What if something goes wrong?

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

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

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

Not applicable as it is an in vitro study.

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

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

18. Who is organizing the research?

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

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

Yes

20. Who has reviewed the study?

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

21. Contact for further information

Dr. Bivek Bijoy Senapati
Department of Orthodontics and Dentofacial Orthopaedics
Babu Banarasi College of Dental Sciences.
Lucknow-227105
Mob- 9436124448

Dr. Tripti Tikku (Professor)
Department of Orthodontics and Dentofacial Orthopaedics
Babu Banarasi College of Dental Sciences.
Lucknow-227105
Mob-9554832799

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

Signature of PI………………………………

Name………………………………………..

Date…………………………………………

ANNEXURE -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?

दो अलग-अलग यांत्रिकी का उपयोग करते हुए चार मैक्सिलरी सामने के दांतों को अंदर ले जाने का तुलनात्मक मूल्यांकन - एक परिमित तत्व अध्ययन।

2. निमंत्रण अनुच्छेद?

मान्य नहीं।

3. अध्ययन का उद्देश्य क्या है?

दो अलग-अलग यांत्रिकी का उपयोग करते हुए चार मैक्सिलरी सामने के दांतों को अंदर ले जाने का तुलनात्मक मूल्यांकन - एक परिमित तत्व अध्ययन।

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

किसी रोगी की आवश्यकता नहीं है।

5. क्या इसमें मुझे भाग लेना चाहिए?

मान्य नहीं।

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

मान्य नहीं।

7. मुझे क्या करना है?

मान्य नहीं।

8. किस प्रक्रिया का अध्ययन किया जा रहा है?

- बर्स्टोन इंट्रूज़न आर्च का उपयोग करके 0, अलग हड्डी-मिमी की अलग 4 और 2नुकसान पर बल के विभिन्न परिमाण यानी 20, 40, ग्राम के आवेदन पर 80 और 60FEM द्वारा चार नॉर्मोइनक्लाइन्ड इंसुसर के शीर्ष पर तनाव और विस्थापन की गणना

करना।

- FEM द्वारा चार मैक्सिलरी के प्रतिरोध के केंद्र में रखे मिनीस्क्रू का उपयोग करके 0, अलग हड्डी-मिमी की अलग 4 और 2 नुकसान पर 20, ग्राम बल के विभिन्न परिमाण के आवेदन प 80 और 60 और 40र FEM द्वारा चार नॉर्मोइन्क्लाइन्ड इंसुसर के शीर्ष पर तनाव और विस्थापन की गणना करने के लिए कृंतक।
- अलगअलग हड्डियों के नुकसान पर बर्स्टोन इंट्रूज़न आर्क का उपयोग करके चार मैक्सिलरी इंसुसर -अलग ताकतों और अलग-के शीर्ष पर तनाव और विस्थापन की इंट्रा ग्रुप तुलनाकरना।
- अलगअलग हड्डियों के नुकसान पर मिनीस्क्रू का उपयोग करके चार मैक्सिलरी इंसुसर के शीर्ष पर -अलग ताकतों और अलग-तनाव और विस्थापन की इंट्रा ग्रुप तुलना करना।

9. इस शोध में कौन से हस्तक्षेप दिए जाएंगे?

मान्य नहीं।

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

मान्य नहीं।

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

मान्य नहीं।

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

मान्य नहीं।

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

मान्य नहीं।

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

मान्य नहीं।

15. क्या होगा अगर कुछ गलत हो जाता है?

मान्य नहीं।

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

मान्य नहीं।

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

मैक्सिलरी के चार सामने के दांतों को अंदर ले जाने के लिए कौन सा मैकेनिक बेहतर है।

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

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

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

हां।

20. अध्ययन की समीक्षा किसने की है?

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

लोगों से संपर्क करें

21.अधिक जानकारी के लिए संपर्क करें।

डॉ. बिवेक बिजय सेनापति
ऑर्थोडोंटिक्स और डेंटोफेशियल ऑर्थोपेडिक्स विभाग
बाबू बनारसी कॉलेज ऑफ डेंटल साइंसेज।
लखनऊ-227105
मोब- 9436124448

डॉ तृप्ति टिक्कू (प्रोफ़ेसर)
ऑर्थोडोंटिक्स और डेंटोफेशियल ऑर्थोपेडिक्स विभाग
बाबू बनारसी कॉलेज ऑफ डेंटल साइंसेज।
लखनऊ-227105
मोब-9554832799

डॉ रोहित खन्ना (एचओडी)
ऑर्थोडोंटिक्स और डेंटोफेशियल ऑर्थोपेडिक्स विभाग
बाबू बनारसी कॉलेज ऑफ डेंटल साइंसेज।
लखनऊ-227105
मोब-9415037011
bbdcods.iec@gmail.com

पीआईकाहस्ताक्षर ....

नाम ....

दिनांक..

ANNEXURE -V

Document Information

Analyzed document	thesis_merged.pdf (D161401918)
Submitted	3/18/2023 5:47:00 AM
Submitted by	Kamna srivastava
Submitter email	dramitn99@bbdu.ac.in
Similarity	5%
Analysis address	dramitn99.bbduni@analysis.urkund.com

Sources included in the report

SA	**Babu Banarsi Das University, Lucknow / minerva.pdf** Document minerva.pdf (D158729796) Submitted by: 1190326003@bbdu.ac.in Receiver: 1190326003.bbduni@analysis.urkund.com	6
SA	**Babu Banarsi Das University, Lucknow / minerva thesis.pdf** Document minerva thesis.pdf (D158994325) Submitted by: 1190326003@bbdu.ac.in Receiver: 1190326003.bbduni@analysis.urkund.com	2
W	URL: http://www.endmemo.com/sconvert/n_mn_mm.php Fetched: 11/16/2020 8:47:27 PM	4
SA	**full for plagarism.docx** Document full for plagarism.docx (D47598312)	3
SA	**THESIS FINAL 1.docx** Document THESIS FINAL 1.docx (D153105754)	4
SA	**Babu Banarsi Das University, Lucknow / merge file 8-3-2023.pdf** Document merge file 8-3-2023.pdf (D160433180) Submitted by: 1190326003@bbdu.ac.in Receiver: 1190326003.bbduni@analysis.urkund.com	5
SA	**writeup - plagiarism.docx** Document writeup - plagiarism.docx (D127714020)	1