Evaluation And Comparison Of The Magnitude Of Stresses Developed On The Maxillary Anterior Teeth Region Under Different Intrusive Forces Using One Implant System And Two Implant System- A Finite Element Study

Dr. Moosa Ahmed[1], Dr. Jithesh Kumar. K[2], Dr. Suresh Babu[3], Dr. Panjami Marish[4], Dr. Thrishna Ashok[5],Dr. Romario Jerie[6]

[1]senior Lecturer, Department Of Orthodontics , Mahe Institute Of Dental Sciences And Hospital, Mahe (Corresponding Author)
[2]professor & Hod, Department Of Orthodontics , Mahe Institute Of Dental Sciences And Hospital, Mahe
[3]professor,Department Of Orthodontics , Mahe Institute Of Dental Sciences And Hospital, Mahe
[4]professor,Department Of Orthodontics , Mahe Institute Of Dental Sciences And Hospital, Mahe
[5]senior Lecturer, Department Of Orthodontics , Mahe Institute Of Dental Sciences And Hospital, Mahe
[6]post Graduate, Department Of Orthodontics ,Mahe Institute Of Dental Sciences And Hospital, Mahe

ABSTRACT

Correction of a deep bite is an important part of orthodontic treatment due to the potential deleterious effects on the temporomandibular joint, periodontal health and facial aesthetics. Mini screw implants are ideally suited for absolute intrusion because they make it possible to apply light continuous forces of known magnitudes without producing any reciprocal reactionary effect on posterior teeth.The purpose of this FEM study was to evaluate and compare the magnitude of stresses generated in the maxillary anterior teeth, periodontal ligament and alveolar bone during intrusion of six maxillary anterior teeth using different intrusive forces with mini-implants placed at strategic locations.

Methods:A 3-Dimensional geometric model of human maxilla was fabricated from the DENTASCAN of human skull. The geometric model of maxilla was then converted into 3-Dimensional FEM model using HYPERMESH software 13.0 version. FEM models of brackets, arch wire, mini implant and coil spring were transferred to the FEM model of maxilla. Two separate models were generated, one with mini implant in the midline of maxilla placed between central incisor roots and in second model the mini implant was placed between lateral incisor and canine roots on both sides. Mechanical properties of the materials were applied to the two models. Intrusive loads of different magnitudes were applied on the implants.

Results: Maximum stress was observed at the head of implant at the point of attachment with the intrusion spring. The total tooth deformation was found to be more with group I.

Conclusion: Stresses developed are less and distributed more evenly, when the point of force application is bilateral rather than a single source. Hence uses of bilateral implants are more efficient and less detrimental for the teeth and surrounding periodontium, during absolute en masse intrusion of the maxillary anterior teeth.

Keywords: biomechanics, finite element analysis, force, implant system

INTRODUCTION:

One of the major challenges of fixed orthodontics is the correction of deep overbite. Deep bite is a complex feature present in different malocclusions. A decrease in vertical skeletal growth, axial inclination of the anterior teeth and posterior teeth, and loss of periodontal support are among the factors that contribute to the development of deepening of the bite. Correction of a deep bite is an important part of orthodontic treatment due to the potential deleterious effects it can cause on the temporomandibular joint, periodontal health and facial aesthetics. Different treatment protocols have been put forth by several authors for correcting the deep bite. In the 1950's Burstone developed a technique known as the segmented arch which allows genuine intrusive movement of the anterior teeth. In1976, Ricketts first described the utility arch as a way to intrude the tooth. But the major disadvantages with these intrusion arches include the extrusion and tipping of posterior teeth as they are used with anchorage on posterior teeth, they involve complex wire bending and require patient co-operation[1-4].Depending on the diagnosis and treatment objectives, deep overbites can be treated orthodontically by intrusion of maxillary or mandibular incisors, extrusion of buccal segments, or a combination of these.[3, 5]orthodontic tooth movement has always been limited to action-reaction reciprocal force mechanics in anchorage control[6].Miniscrew implants (MSI) used as fixed anchorage devices give orthodontists increased potential for versatile mechanotherapy resulting in favorable treatment outcome, and most importantly they help to reduce patient compliance during treatment, like use of headgears for anchorage preservation. MSIs are well suited for intruding teeth because they make it possible to apply light continuous forces of known magnitudes without producing any reactionary reciprocal effect on posterior teeth[7-10]. Apical root resorption associated with intrusive movements could be reduced with better control of the forces. Many studies claim that true intrusion could be achieved using implants easily because the force could be passed near to the center of resistance[11, 12].It is believed that root resorption is the result of a complex combination of individual biology and the effects of mechanical forces in orthodontics. In 1856, Bates was the first to discuss root resorption of permanent teeth. As early as 1914, Ottolengui[13] reported on apical root resorption caused by orthodontic treatment. Since then many studies on resorption after orthodontic treatment have been published[14, 15].Different kinds of movement possibly related to root resorption have been radio graphically examined during the past several decades. De Shields, [16]Linge and Linge, [17]Ronnerman[18] and Larsson[18] have studied root resorption with radiography of the anterior maxillary teeth after orthodontic movement. Various types of orthodontic movement have been reported to increase the risk of root resorption one of which is intrusion. Different types of orthodontic tooth movement may produce different mechanical stress at varying locations within the root. Thus, the measurement of stress in vivo is difficult and hence development of an effective model for this system is a worthy goal.

Aim: To evaluate and compare the magnitude of stresses developed on the maxillary anterior teeth region under different intrusive forces using one implant and two implant system.

Objectives:

1. To evaluate the magnitude of stresses developed in the anterior teeth, periodontal ligament, alveolar bone and mini implants.
2. To predict the areas of root resorption in maxillary anterior teeth under different intrusive forces.
3. To study the pattern of stress distribution on mini implant, teeth, periodontal ligament and alveolar bone under different intrusive forces.
4. To analyze the labial flaring of maxillary anterior segment during intrusion under different loads.

MATERIALS AND METHOD

Materials used:

1. Dentascan of human maxilla.
2. MBT 0.022 slot prescription brackets from 3M Unitek.
3. 0.019 inch×.025 inch rectangular stainless steel arch wire from 3M Unitek.
4. Model of Titanium self-drilling implant of 8mm length and 1.3mm diameter (Dentaurum).
5. Closed coil spring of Nickel-Titanium**.**

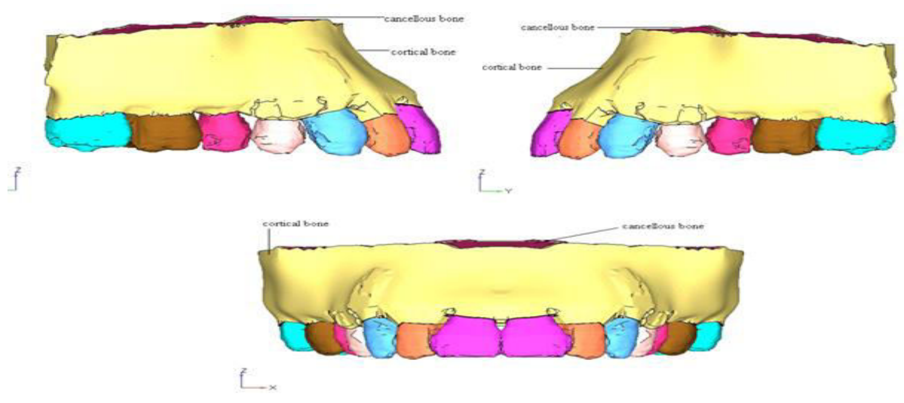
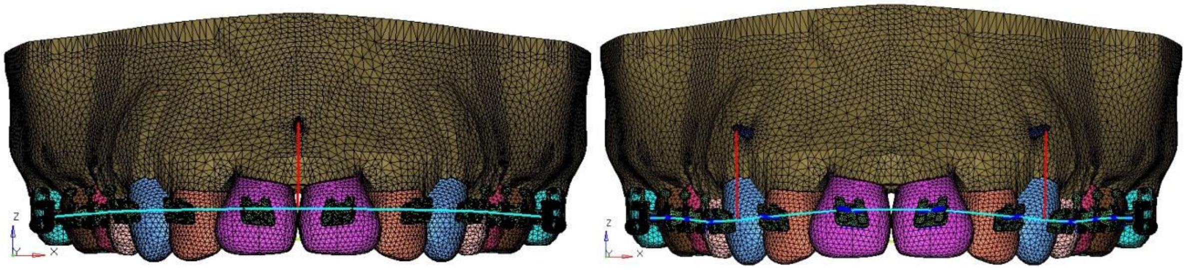


Fig 1: - A 3-Dimensional geometric model of human maxilla was fabricated from the DENTASCAN of human skull.



Case I Case II

Fig 2: - The geometric model of maxilla was then converted into 3-Dimensional FEM model using HYPERMESH software 13.0 version.

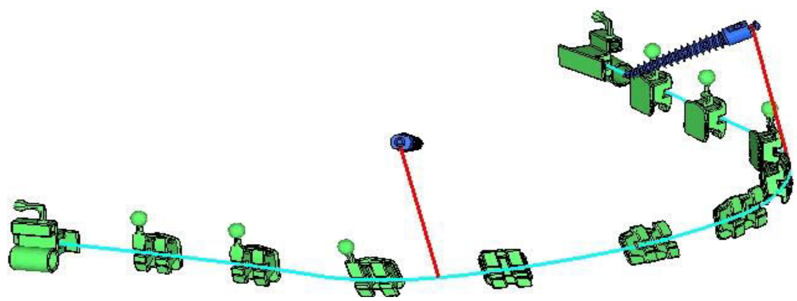


Fig 3: - FEM models of brackets, arch wire, mini implant and coil spring were transferred to the FEM model of maxilla.

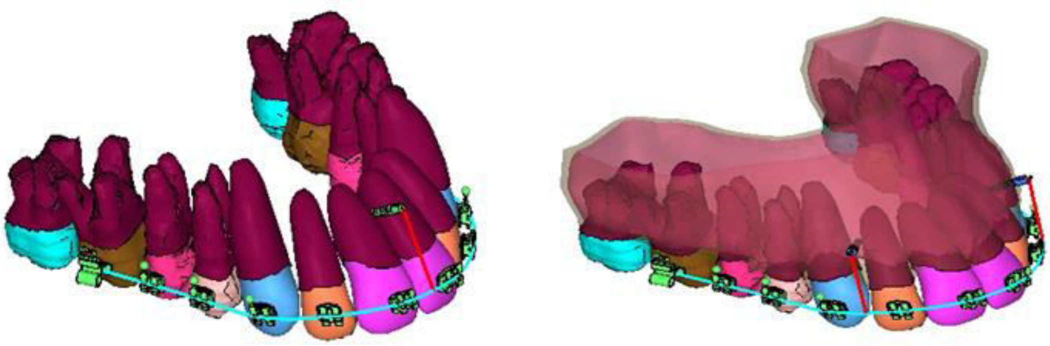


Fig 4: - With mini implant in the midline of maxilla placed between central incisor roots and with mini implant placed between lateral incisor and canine roots on both the sides.Mechanical properties of the materials were applied to the two models. Different intrusive loads of 150gm, 200gm, 250gm and 300gm were applied on the implants.The magnitude of stresses generated on the maxillary anterior teeth region under different intrusive forces were evaluated and compared by analyzing von-mises stresses using ANSYS software 12.1 version.

RESULTS

The variable loads applied to the FEM models aftersetting the boundary conditions, were in the range of 150-300gm with increments of 50gm.Resultant stress levels were represented by von Mises stresses that are depicted by different colors. The red color depicts maximum stress and the dark blue color depicts minimum stress.

By looking at the color of a particular area and matching it to the scale given on left side of the image, we can get the value of the stress developed at that particular area.

Case I (Single Implant) Results

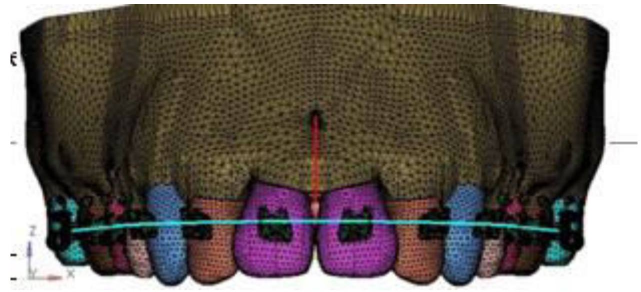
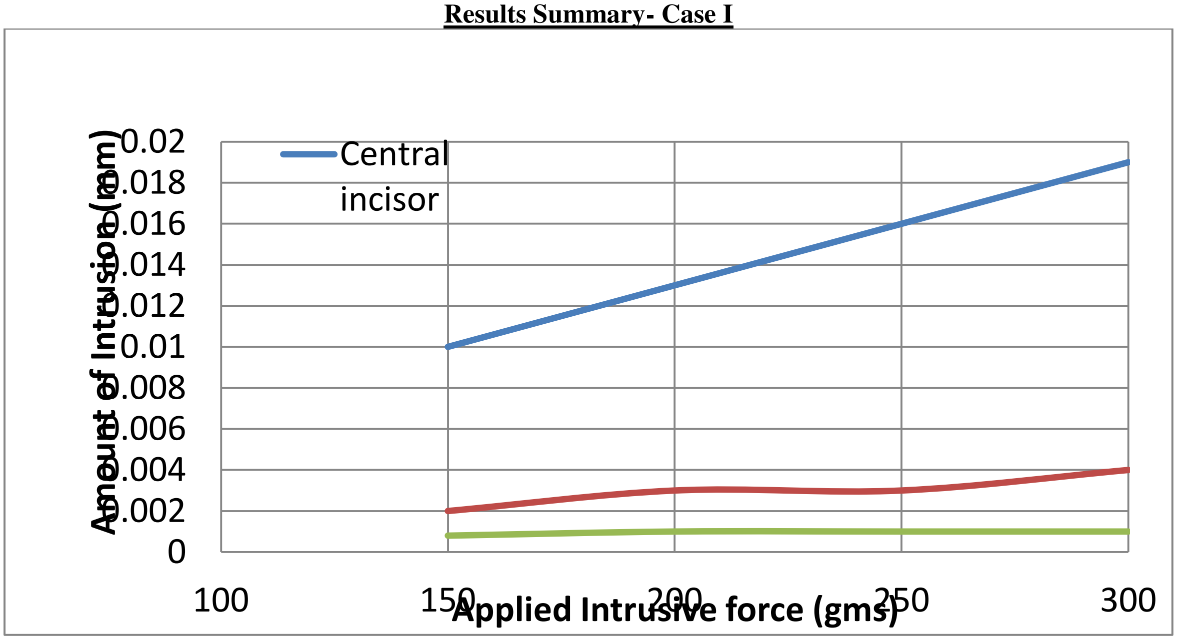


Fig 5: single implant in anterior segment

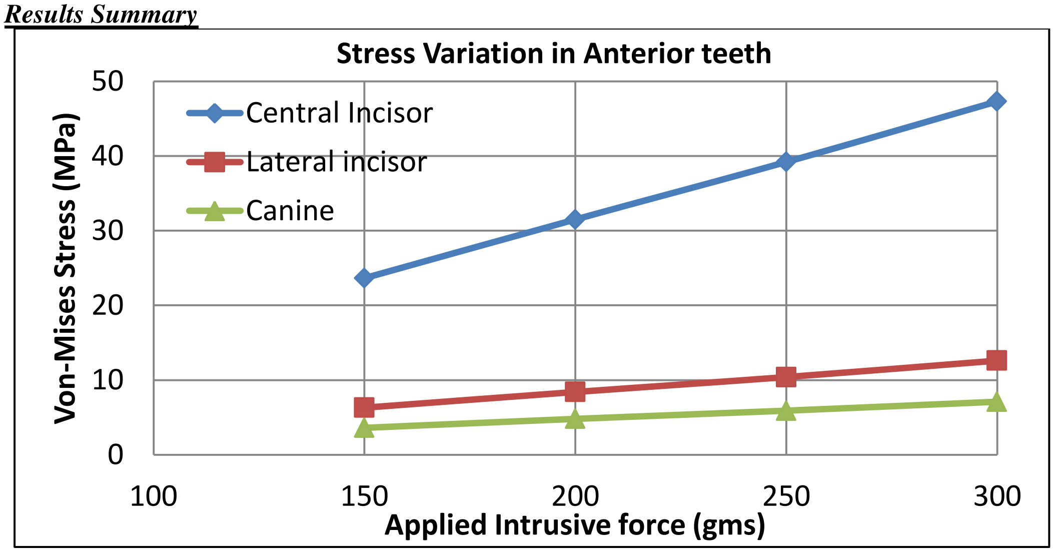
Results Summary- Case I



Graph 1: Amount of intrusion occurred in anterior single implant system.

- Maximum Intrusion happens in Central incisors
- Minimum intrusion happens in Canine

Results Summary



Graph 2: Stress variation (MPa) in anterior single implant system.

- Maximum Stress is observed in Central incisors
- Minimum Stress is observed in Canine

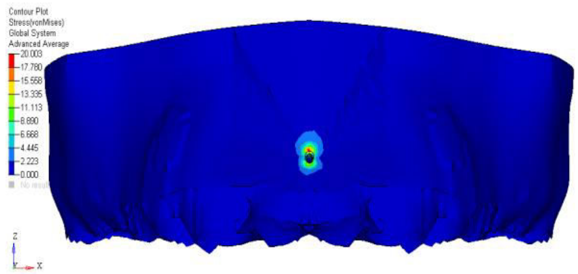
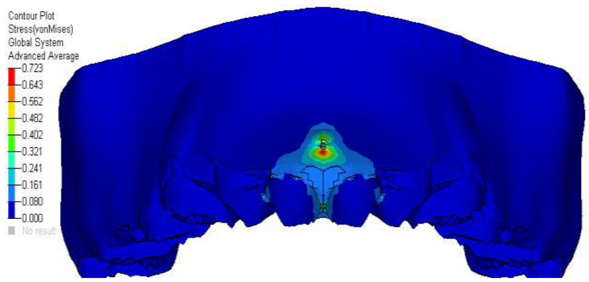


Fig 6: Von-Mises Stress in Cortical bone (MPa)



Central incisor Lateral incisor Canine

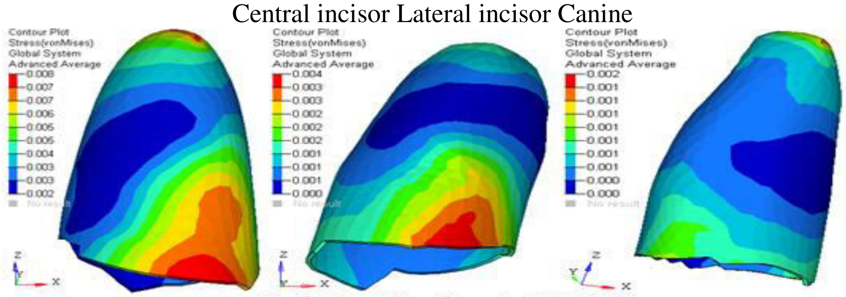


Fig 8: Von-Mises Stress in PDL (MPa)

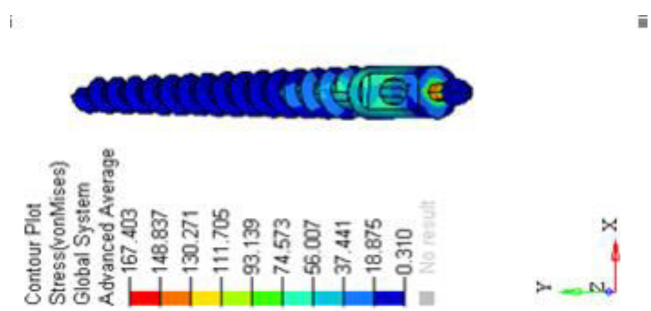


Fig 9: Von-Mises Stress in Miniscrew (MPa

Case II (Two implant system) Results

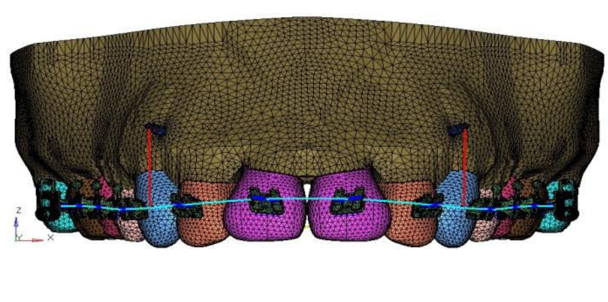
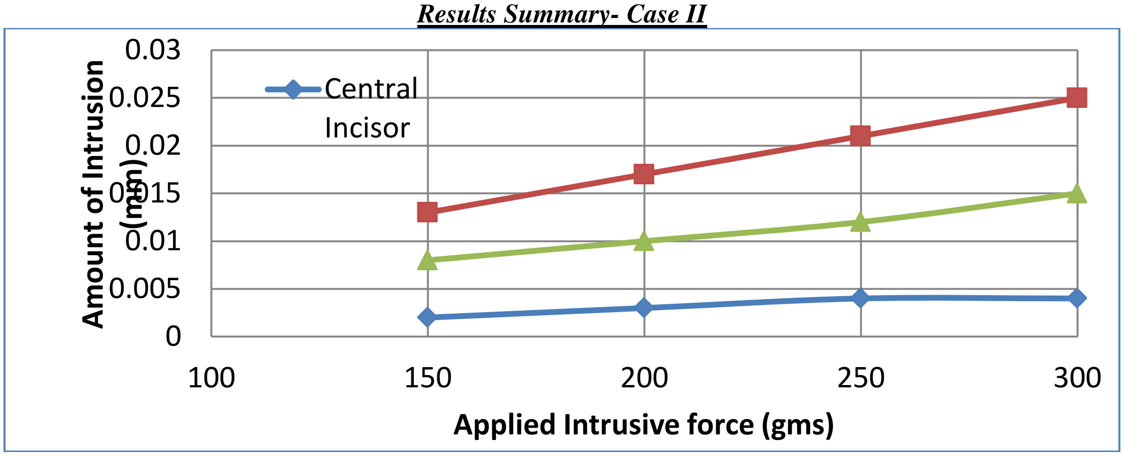


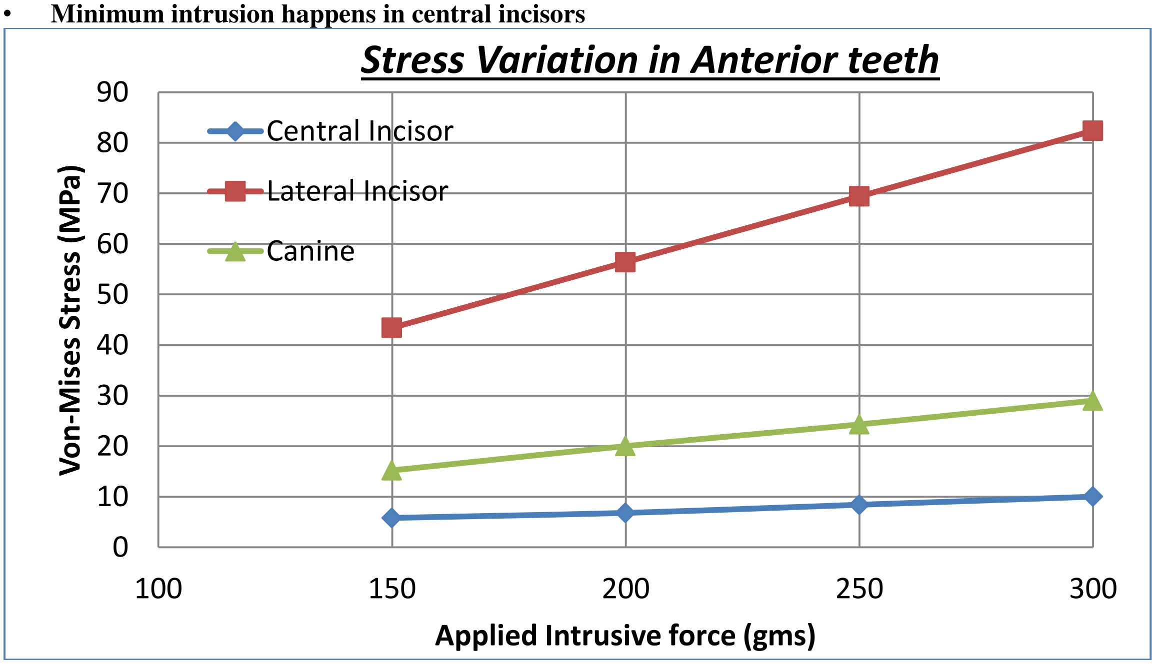
Fig 10: Two implant system in anterior segment

Results Summary- Case II



Graph3: Amount of intrusion occurred in anterior two implant system.

- **Maximum Intrusion happens in lateral incisors**
- **Minimum intrusion happens in central incisors**



Graph 4: Stress variation (MPa) in anterior two implant system.

- **Maximum Stress is observed in lateral incisors**
- **Minimum Stress is observed in central incisors**

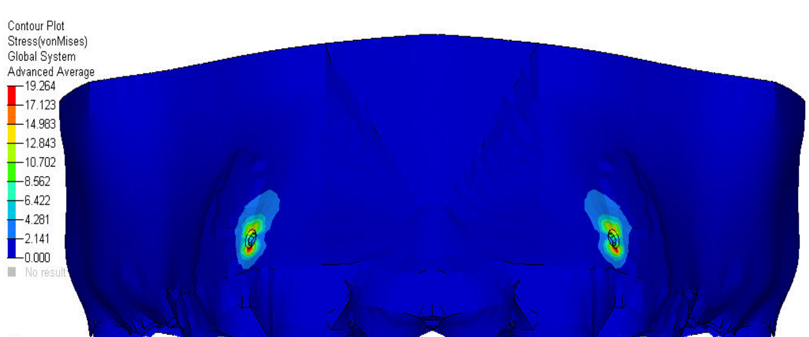


Fig 11: Von-Mises Stress in Cortical bone (MPa) of two implant system

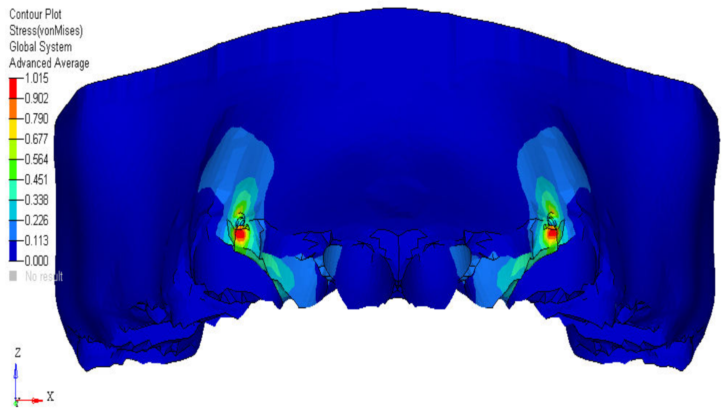


Fig 12:Von-Mises Stress in Cancellous bone (MPa)

Central incisor **Lateral incisor** **Canine**

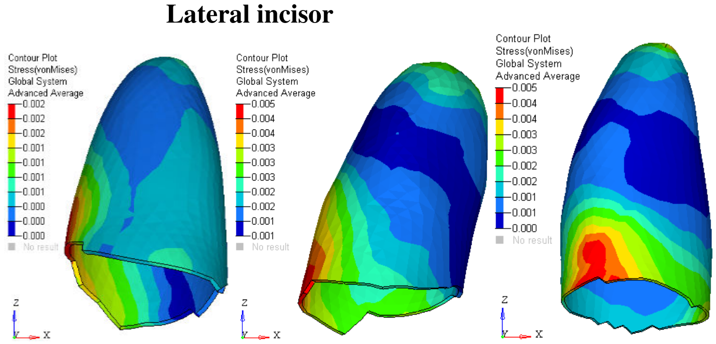


Fig 13: Von-Mises Stress in PDL (MPa)

Fig 14:Von-Mises Stress in Miniscrew (MPa)

DISCUSSION

This FEM study was carried out to evaluate and compare the magnitude of stresses generated in the maxillary anterior teeth, periodontal ligament and alveolar bone during intrusion of six maxillary anterior teeth using different intrusive forces with mini-implants placed at strategic locations.

PERIODONTAL LIGAMENT: In this study when different loads were applied to the anterior teeth in group I the maximum stresses in PDL were observed at the cervical region and around apex of central incisor root. Very minimal or no stress were seen around apex of lateral incisors and more stress was observed at the cervical margins. For canine maximum stress was observed at the apical region, the reason for this pattern of stress distribution was that with single mid implant, the maximum initial load was transmitted to the central incisor during initial line of force application. In comparison with group I for group II the maximum stresses were observed in periodontal ligament of lateral incisor and canine and minimum stress was seen on central incisors. The stresses in the apical area of all the teeth showed significantly lesser amount of stress compared to the crown area. This may be due to the analysis which shows the stresses generated at the initial line of force application and not over a period of time as the amount of intrusion and the duration is significantly correlated to the amount of stress generated at the apices to initiate apical root resorption. Research shows that comprehensive orthodontic treatment causes increased incidence and severity of root resorption especially when the treatment is carried out over a prolonged period of time and heavy forces are particularly harmful[8]. In this study it showsthat bilateral mini implants generate less stresses in the PDL when compared to single mid implant.

IMPLANT: The loads applied on the implant for absolute intrusion of anterior teeth with one implant and two implant systems produced the maximum stresses at the head of implant at the point of attachment of load and were in the direction of the applied load. As the maximum stress was well below the 880MPa yield limit of the titanium alloy, no deleterious effects can be seen in the implant. Hence this implant design would be able to sufficiently withstand a 300gm intrusive force. It is also suggested that implant fracture as a direct result of such loading is unlikely if there is no previous damage but failure in sucha case can occur as a result of material fatigue or cyclingloads over time. Mastication or disturbance loads causedby the patient might also play a role in possible miniscrewmobility or failure with such a treatment load as stated byHusseinet al[81].Clinical trials done by Reimann et al [71] have reported that 200gmof load is a safe limit for immediateminiscrew loading and in a study done by Benedict et al [73] on insertion angles of implants it was concluded that 60 to70 degree is the ideal range for implant placement. In this study maximum stress was observed in single mid implant when two groups were compared

Hard bone: In this study the magnitude of maximum stress values seen in cortical bone are 20.003MPa, 26.664MPa, 33.205MPa and 40.006 for one implant system and for two implant system the values were 19.264MPa, 25.043MPa, 30.820MPa and 36.601MPa under intrusive loads of 150, 200, 250 and 300respectively.As this value is very less as compared to the 133MPa yield strength of cortical bone, no significant adverse changes will be seen in cortical bone. Thisassumption was in agreement to studies by Hussein et al [81] and Gracco et al [75]in which the maximum stress was also very less than the yield strength of cortical bone and hence could not cause any deleterious effect. Among the two groups the magnitude of stresses were observed more in group

Soft bone: In this study the magnitude of maximum stress values observed in cancellous bone are 0.723, 0.964, 1.200 and 1.446MPa for one implant system and for two implant system the values are 1.015, 1.320, 1.679 and 1.929MPa under intrusive loads of 150, 200, 250 and 300gm respectively. Since the maximum stress value with 300gm of force is very close to the yield strength of soft bone which is 2MPa application of force with such magnitude must be avoided as it can lead to fracture of cancellousbone.This is in agreement with study by Gracco et al [75] in which stress levels of 1.73MPa was reached with 200gm of applied load and was very close to yield strength of soft bone. The high stress levels were seen mostly around the implant head region and as we go along the length of implant into the soft bone the stress levels decreased gradually and were minimum for most of the length of the implant in the soft bone. When two groups compared the maximum stresses were observed in group II.

Teeth

During en-masse intrusion of anterior teeth when load was applied to the teeth the maximum stresses were observed at the bracket-tooth interfaceatthe mesio-gingival corner of central and lateral incisor and distogingival corner of canine tooth in group I, and in group II at the bracket-tooth interfaceatthe mesio-gingival corner of lateral incisor and canine, gradually reducing with minimal stress on central incisor. This is in agreement with a study by Sagar et al[1] in which the point of force application was from the single mid implant to the attachment on the wire between central incisorsshowed significantly high stress distribution in maxillary anterior region and stresses on the teeth, soft bone and hard bone were concentrated more on and near the central incisors as compared to lateral incisors.

FORCE IN gm	Group I One implant system		Group II Two implant system	
	Maximum	Minimum	Maximum	Minimum
150	23.642MPa	2.627MPa	5.761MPa	0.640MPa
200	31.515MPa	3.502MPa	6.816MPa	0.757MPa
250	39.245MPa	4.361MPa	8.389MPa	0.932MPa
300	47.284MPa	5.254MPa	9.962Pa	1.107MPa

Table 1: Stress values in central incisor under different loads

FORCE IN gm	Group I One implant system		Group II Two implant system	
	Maximum	Minimum	Maximum	Minimum
150	6.294MPa	0.699MPa	43.378MPa	4.820MPa
200	8.390MPa	0.932MPa	56.391MPa	6.266MPa
250	10.448MPa	1.161MPa	69.405MPa	7.712MPa
300	12.588MPa	1.399MPa	82.418MPa	9.158MPa

Table 2: Stress values in lateral incisor under different loads

FORCE IN gm	Group I One implant system		Group II Two implant system	
	Maximum	Minimum	Maximum	Minimum
150	3.571MPa	0.398MPa	15.205MPa	1.691MPa
200	4.760MPa	0.531MPa	19.780MPa	2.198MPa
250	5.928MPa	0.661MPa	24.344MPa	2.766MPa
300	7.142MPa	0.796MPa	28.909MPa	3.213MPa

Table 3: Stresses values in canine under different loads

CONCLUSION

- Finite element method has been used successfully over the years in orthodontics to simulate various orthodontic tooth movements and stress distribution patterns.
- After evaluation and comparison of the magnitude of stresses and pattern of stress distribution on teeth, PDL and alveolar bone, it shows that stresses developed are less and distributed more evenly leading to better tissue reaction of tooth and supporting structures when the point of force application is bilateral rather than unilateral.
- Hence the use of bilateral implants is more efficient and less detrimental for the teeth and the surrounding periodontium, when compared to single mid-implant during absolute en masse intrusion of the maxillary anterior teeth.

REFERENCE

1. Sagar S P, Anup B, Amit B, Vinay V, Rajiv S. Study of stress distribution in maxillary anterior region during true intrusion of maxillary incisors using finite element methodology. International Journal of Experimental Science; July-December2012; 1(2):89-92.

2. OmurPolat-Ozsoy , AycaArman-OzcirpiciMiniscrews for upper incisor intrusion European Journal of Orthodontics 2009;31: 412–416
3. Burstone CR. Deep overbite correction by intrusion. Am J Orthod. 1977; 72:1–22.
4. W. McFadden M, Christer E, Helene E, J.Milford A. A study of the relationship between incisor intrusion and root shortening. Am J OrthodDentofacOrthopNov *1989*; 96(5): p363-452.
5. Burstone C. *Biomechanics of deep overbite correction*. *SeminOrthod*. *2001*; 7: 26-33.
6. Creekmore TD, Eklund MK. The possibility of skeletal anchorage. J ClinOrthod. 1983; 17:266–269.
7. Costopoulos G, Nanda R. An evaluation of root resorption incident to orthodontic intrusion. Am J OrthodDentofacialOrthop 1996;109:543-8
8. Ohmae M, Saito S, Morohashi T, Seki K, Qu H, Kanomi R, et al. A clinical and histological evaluation of titanium mini-implants as anchors for orthodontic intrusion in the beagle dog. Am J OrthodDentofacialOrthop 2001;119:489-97
9. Sameshima GT, Sinclair PM. Predicting and preventing root resorption: part II. Treatment factors. Am J OrthodDentofacialOrthop 2001; 119:511-5.
10. Carrillo R, Peter. B, Lynne A, Pedro F, P. Emile R. Segmental intrusion with mini-screw implant anchorage: A radiographic evaluation. Am J OrthodDentofacialOrthop 2007; 132:576.e1-576.
11. Marc M. VandenBulcke, Luc R. Dermaut, Rohit C. L. Sachdeva, Charles J.Burstone The center of resistance of anterior teeth during intrusion using the laser reflection technique and holographic interferometry Am J OrthodDentofacialOrthop 1986; 90(3): 211-220.57
12. Michael R. Marcotte. The Mechanical Plan of the Segmented Arch Technique. Seminars in orthodontics 2001 september vol7 no.3 pgs191-205.63
13. Ottolengui R: The physiological and pathological resorption of tooth roots. Items of Interest 36: 332-362, 1914.
14. Ketcham A: A progress report of an investigation of apical root resorption of permanent teeth. Int J Orthodontia, Oral Surg, Radiogr 15: 310, 1929.
15. Newman WG: Possible etiologic factors in external root resorption. AM J ORTHOD 1975; 67: 522-539.
16. De Shields RW: A study of root resorption in treated Class II, Division 1 malocclusions. Angle Orthod 39: 231-245, 1969.
17. Linge BO, Linge L: Apical root resorptionip upper anterior teeth. Eur J Orthod 5: 173-183, 1983.
18. Ronnerman A, Larsson E: Overjet, overbite, intercanine distance and root resorption in orthodontically treated patients. Swed Dent J 5: 21-27, 1981.