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Original Research Article

Intrusion of mandibular incisors using single mini-implant –A finite element study

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ABSTRACT

Introduction: A deep bite is a complex orthodontic problem that is a common feature of many malocclusions. Depending on the diagnosis, a deep overbite can be corrected. Mini implants can be used for the true intrusion of anterior teeth. FEA is a computer based numerical simulation technique used to calculate deflection, stress and displacement.

Aims and Objectives: To analyze stress distribution pattern and displacement of mandibular incisors when intrusive forces are applied using three dimensional finite element analysis. To compare intrusion of lower anterior teeth when 'V' pattern force and straight vertical pattern force are applied.

Materials and Methods: A three dimensional finite element model was constructed to simulate mandibular teeth, periodontal ligament and alveolar bone. The displacement of individual tooth (central and lateral incisors) on three-dimensional planes and the von Mises stress distribution were compared.

Results: Intrusive forces when applied to four mandibular anterior teeth remarkable tipping of the labial segment was seen when straight vertical elastics were used as compared to the 'V' shaped elastics.

Conclusion: Within the limits of this study, predictable intrusion with minimum labial tipping is seen using single implant using V pattern elastics.

1. Introduction

One of the earliest definitions of 'Over-Bite' was put forward by Strang, who defined it as "the overlapping of the upper anterior teeth over the lowers in the vertical plane". The ideal overbite in a normal occlusion may range between 2-4 mm. However, overlaps greater than 40% should be considered "excessive", known as "Deep-bite".

A deep bite is a complex orthodontic problem that is a common feature of many malocclusions. It can be either skeletal or dental. Dental deep bites show either supra-occlusion (overeruption) of the incisors or infra-occlusion (under-eruption) of the molars, or a combination of the two. Either of them, have the potential to cause deleterious effects on the overall dental health and the surrounding periodontal structures and the TMJ.[1] To preserve a youthful appearance, lower incisor intrusion in deep-bite patients with reduced upper incisor display should be prioritized. Biomechanically, use of mini implants can serve the exact anchorage needed for intrusion.[2,3] Use of two mini implants has been routinely used in achieving ideal force and direction to get true intrusion. However, use of single mini implant for the same purpose can reduce the invasiveness and the cost of overall treatment.

From a single mini implants, forces can be applied on a single tooth or on all lower anterior teeth together and application of these varied forces in different directions on anterior teeth for intrusion can induce varied tooth movements.[4] However exact direction of forces from mini implants to teeth needs to be assessed that would yield true intrusion.

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This study aims to check type of intrusive movement achieved with mandibular four incisors from two different directions of force systems using single mini implant. This study was done using Finite Element Analysis (FEA).

The purpose of this study was to use 3D Finite Element Analysis to analyse and determine stress distribution pattern and displacement of mandibular incisors when intrusive forces are applied using three dimensional FEA when 'V' pattern force and vertical Pattern force are applied.

2. Materials and Methods

Finite Element Analysis, is a tool, that helps for the visual comparison, quantification of the force applied and displacement before and after, with the advantage that test can be done and repeated in a variety of conditions.

In this study, a three-dimensional finite element model was constructed to simulate mandibular anterior teeth (Figures 1 and 2) Right and left Mandibular central and lateral incisor, periodontal ligament and alveolar bone using mechanical properties of each anatomic component using SOLIDWORKS software (Table 1). Each tooth dimensions were designed as per the Ashley Wheelers textbook. To this model MBT 0.022" slot brackets were positioned and stabilized using 0.019"x0.025" stainless steel arch wire.

A power head mini implant of dimension 1.5 mm x 6 mm was placed in mandibular anterior region between two central incisors. The implant was at the centre of resistance of four mandibular incisors; 13mm apical to the incisal edge of central incisors. Pattern 1 included hook attachment on wire between central and lateral incisors in both quadrants, and pattern 2 had hook placed between central incisors (Figure 3). The intrusive force of 80 gm was applied using e chain from the mini implant to the hooks attached on the wire in both patterns.

The displacement of individual tooth on three-dimensional planes and the Von Mises stress distribution were evaluated and compared when the intrusive force vector were applied on both patterns using ANSYS Software.

3. Results

Graphical representation in Y(Vertical) and Z(Transverse) axis were plotted, representing the nodal stress data of the PDL and bone interface, the predictable sites of bone remodelling. The minimum and maximum principal stresses were obtained. The counter plots for stress distribution with red colour were with maximum compression, and green with least stress compression. (Figures 4 and 5)

In pattern 1, intrusive forces when applied, in a V Shape pattern to four mandibular anterior teeth, remarkable labial tipping and intrusion of the segment was seen. Von-Misses stress distribution patterns were more scattered on four teeth, with more stress patterns noticed with lateral incisor, predicting move intrusive movements compared to pattern 2. (Table 2)

In pattern 2, significant compression with more labial movement of the central incisors was observed. Stress patterns were loaded with lateral incisors. The intrusive movement of four teeth compared together, was less in pattern 2 compared to pattern 1. (Table 3)

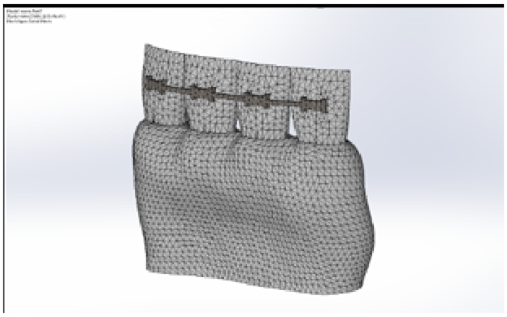

Fig. 1: SOLIDWORKS 3D finite element model with triangular mesh and mesh size of 0.76091mm of Mandibular 4 anterior teeth model.

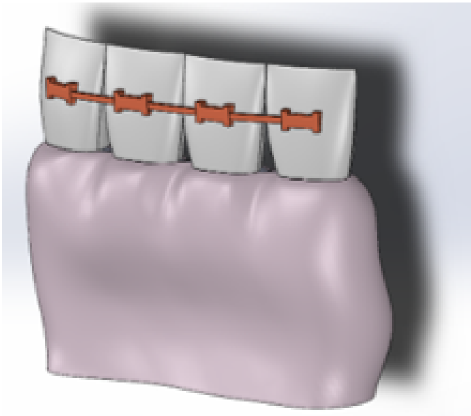

Fig. 2: Rendered Image

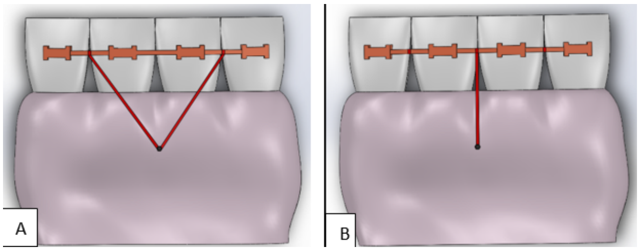

Fig. 3: A: V shaped force application (Situation 1); **B:** Vertical force application (Situation 2)

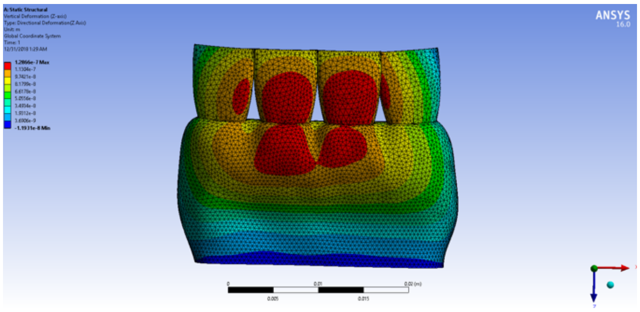

Fig. 4: Situation 1

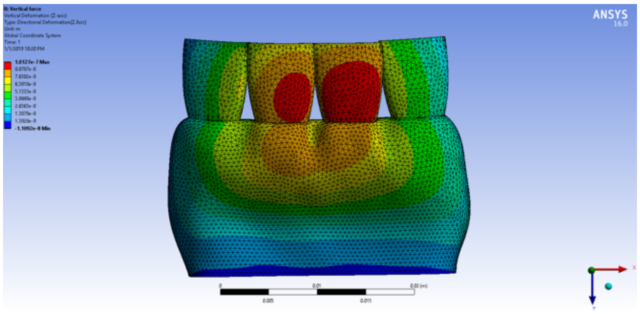

Fig. 5: Situation 2

Table 1: Mechanical properties of anatomic components

Materials	Youngs's modulus	Poisson's ratio
Teeth	2.60E+04	0.30
Periodontal Ligament	6.80E-01	0.49
Bone	1.40E+04	0.30
Cortical Bone	1.62E+04	0.30
Stainless Steel wire	2.00E+05	0.31
Orthodontic Bracket	2.14E+05	0.30
Mini Screw	2.14E+05	0.32

Table 2: Stress and deformation for pattern 1

Region		Equivalent (von-Mises) Stress, MPa	
Central Incisors		1.0736	
Lateral Incisors		1.2077	
Deformation Axis		**Y-Axis (mm)**	**Z-Axis (mm)**
Central Incisors	Incisal edge	3.8336e-5	1.4315e-4
	Apex	1.1831e-5	4.8336e-5
Lateral Incisors	Incisal edge	1.3189e-5	5.9041e-5
	Apex	4.7533e-5	4.4511e-5

Table 3: Stress and deformation for pattern 2

Region		Equivalent (von-Mises) Stress, MPa	
Central Incisors		1.0788	
Lateral Incisors		1.9417	
Deformation Axis		**Y-Axis (mm)**	**Z-Axis (mm)**
Central Incisors	Incisal edge	6.6475e-5	1.152e-4
	Apex	1.6143e-5	3.0458e-5
Lateral Incisors	Incisal edge	2.2881e-5	3.8505e-5
	Apex	1.3113e-5	2.2793e-5

4. Discussion

Deep bites usually have a horizontal growth pattern and are characterized by growth discrepancy of the maxillary and mandibular jawbones, convergent rotation of the jaw bases, and/or deficient mandibular ramus height. In such situations the anterior facial height is often short, particularly the lower facial third. The choice of treatment in such cases would depends on several factors, as amount of upper incisor display at rest and smile, the interocclusal space, and vertical dimension of face.[5] Lower incisor intrusion would be a treatment option in cases with reduced upper incisor display.

It can be accomplished using different appliances like Connecticut intrusion arch, Burstone intrusion arch Ricketts utility arch etc. Use of these biomechanical options need complex wire bending, patient co-operation and can also induce extrusion and tipping of the posterior teeth. To overcome these disadvantages, mini implants can be used for a true intrusion of the anterior teeth. The recent use of temporary anchorage devices (TADs) in the form of intraosseous appliances, e.g., mini-screws or C-plates, has facilitated a variety of treatments such as total distalization and absolute intrusion, which were previously considered too difficult to perform. Yet as it includes a minor invasive procedure and not cost efficient at times, has not been used in routine procedures. Most of the studies and case reports done in past have made use of two mini implants to achieve incisor intrusion.[4]

In this study, efficiency of use of single mini implant for lower incisor intrusion has been assessed that would be an viable option to reduce the invasiveness and be a cost efficient treatment option. Mini implant placed at the centre of resistance of four anterior teeth together resulted a predictable labial tipping with intrusion of the anterior segment. In accordance with the study done by Hyun-Kyung Park et al in 2011 where they accomplished pure intrusion of six anterior teeth segment using mini-screws placed distal to the canine and hooks located between central and lateral incisors. They also found that when intrusive forces applied to 4 mandibular anterior teeth largely resulted in remarkable labial tipping of the segment according to the mini-screw position by using single vertical pattern force application.

On application of forces in one direction, leads concentration of stresses on sides of the root surfaces that are more closer to the force attachments. A more anterior location of the point of force application, from the mini implant to the hooks, resulted in more compression of the PDL of labial surfaces of all teeth in both the patterns.

In pattern 1, hooks were placed in between central and lateral incisor, the resultant force vector generated from a single mini implant, led concentration of forces between the two hooks, hence more compression was observed on labial surfaces of all teeth. Distribution of force was pretty even among all the incisors in vertical direction, showing more intrusive movement. Intrusive stress patterns were observed more with lateral incisors. The farther the hook from mini implant in horizontal direction, might have led counter clock wise movement giving farthest segment of the arch, leading more intrusive forces on lateral incisors than the centrals.

The single hooks placed in between the two centrals in pattern 2. As the hook was in a straight line with the mini implant, it led more concentration of forces on central incisors in all directions. The force component is far away from the centre of resistance of the anterior teeth together, hence distribution of force among all the teeth was not even. All forces can get concentrated within the area of hook and mini implant, hence pulling the teeth more labially. True intrusion could be achieved with both incisors using a single mini implant, but counter forces to avoid labial proclination of the lower anterior have to be incorporated.

For true intrusion, forces have to be directed through the C_{res} of all anterior teeth together. Through the C_{res} or closer to it, can result in more intrusive movement, as seen with pattern 1 in our study. Single direction force component can tend to produce more unidirectional movement, as more labial movement seen in pattern 2. Clinically it is essential to evaluate the C_{res} by assess the shape of surrounding bone, root morphology, position of each tooth, and structure of the periodontal attachment. These factors can vary in every individual, and so the C_{res} of anterior arch segments in these patients will also be different.

Cases with already proclined incisors have to be tackled with more counter measures to avoid any more proclination that could result due to effects seen in this study. It is necessary to determine a line of action of force that promotes a more balanced stress distribution.

As in this study, the advantage of FEM lies in construction of a desired model that can be assessed with change of all parameters within giving us to run through all possibilities of biological parameters. However yet these input in parameters do not resemble the exact biological behaviour, hence the results of the studies to apply for every individual yet remains questionable.

In this study, Cortical bone thickness and cancellous bone quality and stress analysis of soft tissues including the gingiva and facial muscle were not incorporated into the analysis, to prevent bone stress from being dominated by bone quality and potentially confounding resisting factors that can vary the outcome. Yet, this study holds to evaluate the amount of stress delivered on type of two different possible directional forces that can result with use of single implant to achieve true intrusion.

5. Conclusion

Within the limits of this study, predictable intrusion with minimum labial tipping was seen using single implant using V pattern elastics compared to the vertical pattern elastics. Further studies and trials with more possible force directions with different parameters of biologic behaviour should be carried out to confirm results that may help in clinical applications.

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7. Conflicts of Interest

None to declare.

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