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Original Research Article

To Evaluate Stress Patterns at the Bone Mini-Screw Interface When the Maxillary Molars Are Intruded With a Mousetrap Appliance: A Fem Study

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Abstract

Mousetrap appliance is an effective treatment modality for anterior open bite that utilizes implants inserted into the anterior palate and brings about open bite correction by intruding the maxillary molars. This is a finite element study that assesses the stress contours at the bone mini-screw interface, when the maxillary molars are intruded by a mousetrap appliance. ***Materials and Methods:*** A finite element model of the maxilla and the mousetrap appliance made of 288332 elements and 64771 nodes was generated using software tools like MIMICS and HYPERMESH. A simulated force of 100 grams was applied to the maxillary molar through the appliance and the stress contours were assessed. ***Results:*** In the cortical bone Von-mises stress at the bone mini-screw interface was around 13.2MPa whereas in the cancellous bone it was around 0.198MPa. ***Conclusion:*** It is therefore concluded that the mousetrap appliance which exerts a force within the range of recommended force for molar intrusion generates stress contours at the bone mini-screw interface in cortical as well as cancellous bone. More stress is generated in the cortical bone.

Keywords: Molar intrusion, mousetrap appliance, TADs.

INTRODUCTION

Anterior open bite characterized by an absence of vertical overlap between the maxillary and mandibular incisors, appears to be the most challenging malocclusion in the vertical plane [1]. In most of the cases it is treated by extraction of molars or premolars leading to mesialization of the posterior teeth thereby resulting in an anticlockwise rotation of the mandible. Surgical options i.e. Le Fort I osteotomy and mandibular osteotomy are also considered in certain cases. Various other treatment modalities e.g. multiloop edgewise archwires, vertical elastics or extrusion arches are also available for management of such malocclusion. "Mousetrap appliance" is also an effective treatment modality for the correction of an anterior open bite. It uses TADs in the anterior palate to fix a beneplate, along with two lever arms which is connected to two mini-implants. A modified Goshgarian TPA with distal loop is fabricated with sufficient clearance from the palatal mucosa to avoid impingement during and after molar intrusion and also to prevent undesirable tipping of the molars. In the passive form the distal ends of lever arms are present cranial to the center of resistance of the maxillary molars. Activation is performed by pulling the lever arms downward and then connecting them to the molars thereby resulting in a constant intrusive force (Figure-1) [2].

This article intends to investigate the stress distribution at bone mini-screw interface in the cortical and cancellous bone around the maxillary molars, on application of an intrusive force by Mousetrap appliance on a 3-Dimensional finite element model.

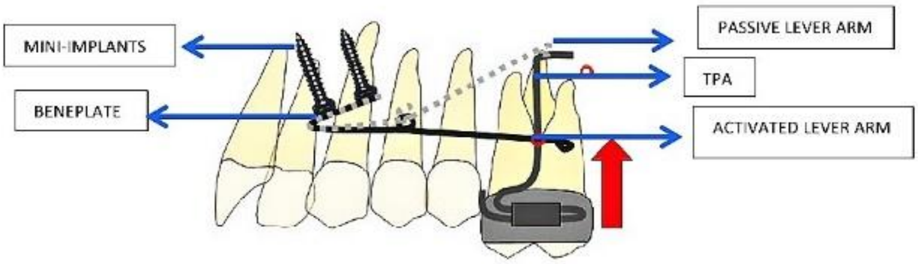

Figure 1

MATERIALS AND METHODS

Finite element analysis involves construction of complicated three dimensional models of various tissues possessing characteristic biomechanical properties [3]. In the present study, such a model was generated from the Computed Tomography images of human cranium obtained from an X-force/SH spiral CT scan machine. A geometric model was constructed using a software called MIMICS i.e. Materialize Interactive Medical Image Control System which was then converted into FEM model using the modelling tool known as 'Hypermesh'. 288332 elements and 64771 nodes were used and the material properties assigned to the various parts were acquired from an existing study (Table-1) [4]. The boundary conditions were defined by constraining the top portion of the maxillary bone in all directions so that there would be no displacement or stress in that area. An intrusive force of 100 grams was applied to the model through the appliance and the resulting effect was assessed by a finite element software known as ANSYS.

Table-1:

Part	Elastic modulus (MPa)	Poisson's ratio
Cortical bone	13700	0.3
Cancellous bone	1370	0.3
Teeth	20700	0.3
PDL	0.068	0.45
Brackets, Wires, beneplate (SS)	200000	0.3
Mini screws (Ti)	110000	0.29

RESULTS

STRESS CONTOURS IN THE CORTICAL BONE:

Maximum Von-mises stress at the bone and screw interface was around 13.2MPa (Figure 2 & 3).

Fig-2

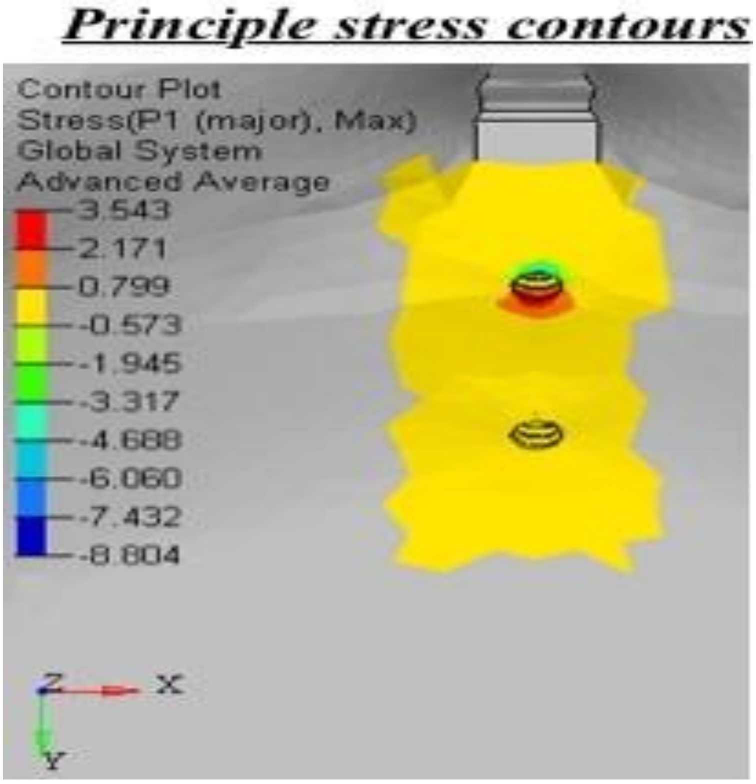

Fig-3

STRESS CONTOURS IN CANCELLOUS BONE 'MPa':

Maximum Von-mises stress at the bone and screw interface was around 0.198MPa (Figure 4 & 5).

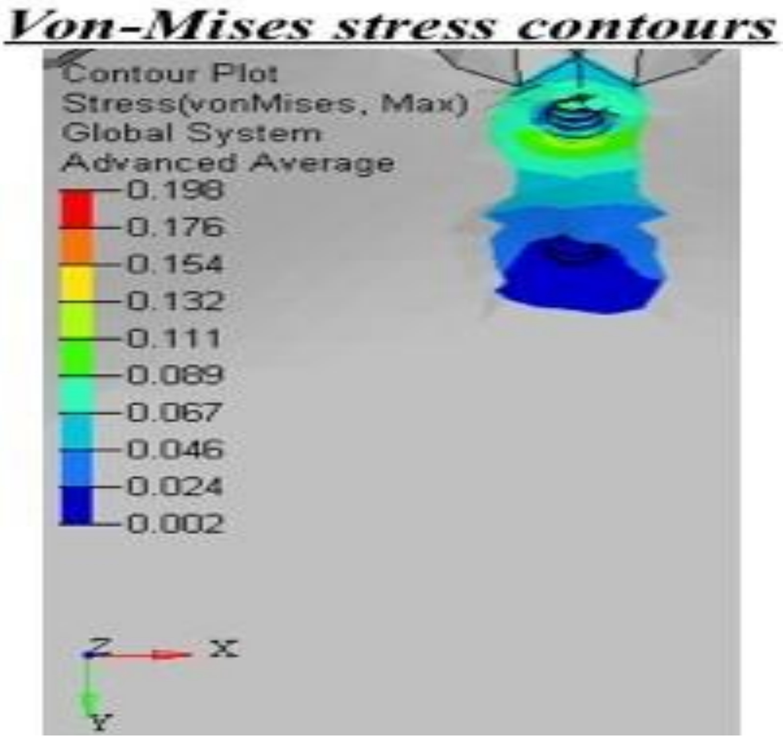

Fig-4

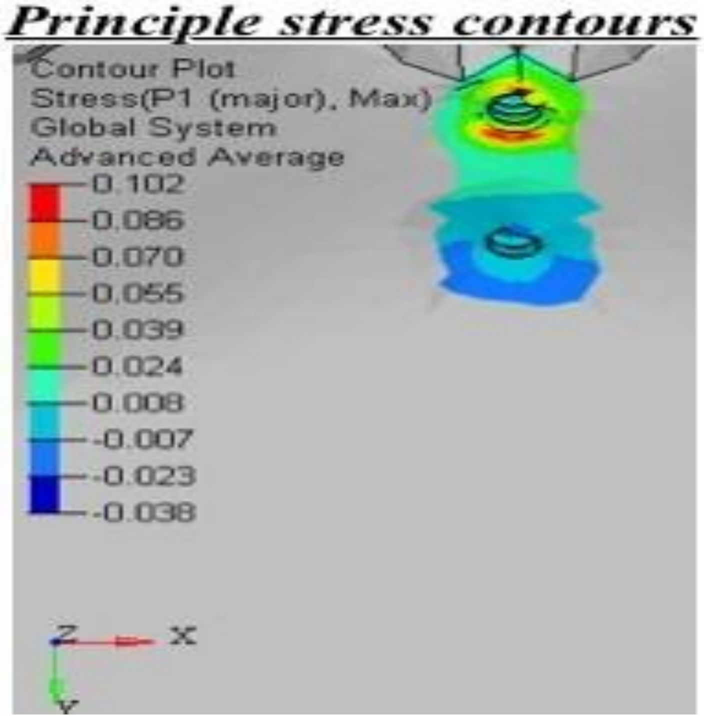

Fig-5

DISCUSSION

Conversion of mechanical stimulus generated by the orthodontic force into a biological reaction initiates an orthodontic tooth movement. The primary reaction towards application of orthodontic force is altered stress-strain relationship in the periodontal ligament as well as in the surrounding tissues leading to bending of bone and intra alveolar displacement of teeth, provided an optimum force is applied. Some investigators have pointed out that intrusive forces lead to pulpal changes like congestion, circulatory disturbances, vacuolization and fibrohyalinosis [5, 6]. Brodin et al., concluded that there was a temporary reduction in pulpal blood flow when lateral incisors were intruded with a force of 2N [7]. Proffit and Fields suggested that 10-20 grams of force was optimum for carrying out intrusion while as Woodside, Hanson and Berger recommended 50-10grams. Umemori et al., suggested that an intrusive force of 500 gms should be applied for molar intrusion while as a force of 90 gms was suggested for growing subjects by Kalra et al., [8, 9]. Melson and Fiorelli recommended a force of 50 gms buccolingually to intrude maxillary molars in adult subjects [10]. Li et al., intruded two over erupted molars by using mini-implants and applying a force of 150 grams. They evaluated the root resorption using CBCT and the results showed that the mesiobuccal root of the first molar showed highest root resorption [11]. As it is very important for the stress to be within the physiological constraints of the tissues, in the existing literature, authors recommend intrusive forces within the range of 15-200 grams [12]. There are innumerable studies on different types of posterior intrusion mechanics, however their biomechanical effects such as stress patterns have not been evaluated in detail.

Finite element method is a viable mean for calculating these quantities. Originally the finite element method was devised for modelling in the field of Engineering but now it has also made its place in the field of dentistry to assess various materials and loading conditions. Yettram et al., in 1972 introduced it into the field of orthodontics [13]. The basic philosophy behind the finite element method is breaking down complex structures into simpler pieces called elements that can be conveniently defined by differential equations [14].

Anirban Sarmah et al., conducted a study in which they found low compressive and tensile stresses in the cortical bone with no significant differences between the two. They also advised to place the implant primarily in the cortical bone as they recorded very low strain and stress values in the trabecular bone [15]. Choi et al., found that the cortical bone exhibits more stress as compared to other structures like roots, PDL and cancellous bone [16]. In contrast to the present study Dawer et al., recorded 26.46 MPa of Von Mises stress within the hard bone surrounding the implant which was tensile in the area close to the implant and changed to compressive away from the implant [17]. Gallas et al., constructed a finite element model of mini-implant and bone complex and analyzed the stress concentration which revealed that the maximum stress was concentrated around the neck of the mini-implant and the surrounding cortical bone [18]. Duaibis et al., concluded that the stresses in the cortical bone are reduced by increasing the implant diameter and using cylindrical or tapered implant [19]. In the present study in relation to cortical bone the maximum Von-mises stress at the bone and screw interface was around 13.2MPa (Figure 2 and 3).

Anirban Sarmah et al., in their study found lower stress in the cancellous bone than the cortical bone and that the tensile stresses were slightly less than the compressive stresses, maximum stress concentrations being at the cortico cancellous junction [15]. In contrast to the present study Sivamurthy and Sundari found nonsignificant amount of stresses in the cancellous bone due to very low stress transmission i.e. 0.06 and 0.56 MPa [20]. Zang et al., found 0.63 and 0.56 MPa of stress in the cancellous bone which is less as compared to the values recorded in the present study. They concluded that larger stress was received by the cortical bone because of its high elastic modulus [21]. Jiang et al., concluded that maximum equivalent stresses in the cortical bone, cancellous bone and mini-implant were reduced by increasing the diameter and length of the mini-implant [22]. Choi et al., found in their study that with the increasing insertion angle, the Von Mises stress increased in all the areas except in the cancellous bone because most of the stress gets absorbed by the cortical bone and less stress gets transmitted to the root, PDL and cancellous bone. Moreover they concluded that the Von Mises stress is also determined by the shape of the mini-implant i.e. 2 fold greater stress is produced by tapered miniscrews than the cylindrical ones [16]. Poorsattar Bejeh Mir et al., found the maximum Von Mises stresses to be less than the yield strength of the cancellous bone, mini-implants and cortical bone. Maximum stresses were transmitted to the cortical bone and less forces are absorbed by the cancellous bone [23]. Dawer et al., recorded tensile Von Mises stress of about 2.33 MPa in the soft bone around the mini-implant which is greater as compared to the values found in the present study [17]. In the present study the maximum Von-Mises stress in the cancellous bone at the bone and screw interface was around 0.198MPa (Figure 4 & 5).

CONCLUSION

Following are the observations of this study:

1. In relation to cortical bone the maximum Von-mises stress at the bone and screw interface was around 13.2MPa.
2. In the cancellous bone the maximum Von-mises stress at the bone and screw interface was around 0.198MPa.

In the light of the above stated observations it is therefore concluded that the mousetrap appliance which exerts a force that lies within the range of recommended force for molar intrusion generates stress in cortical as well as cancellous bone at the bone mini-screw interface. More stress is generated in the cortical bone as compared to cancellous bone.

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