Comparison of Stresses Developed on the Maxillary Anterior Teeth and Mini-implant Site During Intrusion with varying Alveolar Bone Loss Levels using Mini-implants—A Finite Element Study

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Abstract:

Background: When forces are applied on a tooth with periodontal bone loss, stresses with different magnitude and pattern are produced in the periodontium when compared with a tooth with no loss of bone support. The present study was conducted to evaluate and compare the stresses developed on the maxillary anterior tooth region and mini-implant site during intrusion using single and two mini-implants with varying alveolar bone loss levels—a finite element study. **Material and methods:** CBCT scan of a normal adult human maxilla with normal occlusion is used for collecting data. For the present study, a Finite Element Model (FEM) was generated. This model was a replica of adult human maxilla. The model consisted of periodontal ligament, alveolar bone and all the teeth except third molars. The bracket system simulated will be an MBT bracket system from 3M UNITEK (0.22 slot) and the arch wire was of .019''x.025'' stainless steel. A 3- dimensional (3D) quantitative analysis requires a mathematical method, making use of a model accurate both in anatomy and physical characteristics and along with the use of a computer, which has become an indispensable aid as far as 3D analyses are concerned. It was divided into two groups i.e. FE-model Group-Includes single mid mini- implant placed at 12mm from arch wire between the upper central incisors at alveolar bone loss levels at 0mm , 2mm and 4mm. Software used for Finite element model is created using Hypermesh 13.0. FE-model Group-II includes two mini- implant placed at 12mm from the arch wire between the lateral and canine at alveolar bone loss levels at 0mm, 2mm and 4mm. Software used for Finite element model is created using Hypermesh 13.0 **Results:** The present study has showed that in intrusion orthodontic tooth movement, the stress in anterior teeth increases with increasing bone loss. Highest stresses are observed in central incisor teeth and lowest stresses in lateral incisors. In both, cortical bone and cancellous bone stresses lessen with increasing bone loss. **Conclusion:** The following conclusions were made from our study: 1).When the mini-implants were placed between the maxillary central incisors, stresses in anterior teeth increased with increase in the alveolar bone loss. proclination due to tipping was observed 2) In both the cortical bone and cancellous bone, the stresses reduced with increase in alveolar bone loss when the mini-implants were placed between the maxillary central incisors.3) At the mini-implant interface when mini-implants placed between the maxillary central incisors maximum stress of around 60Mpa was observed in the cortical bone at mini-implant site.4) When mini-implants placed between maxillary lateral incisor and maxillary canine, stresses in anterior teeth increased with increase in the alveolar bone loss. Proclination due to controlled tipping was observed which was less in magnitude as compared to mini-implants placed between maxillary central incisors 5) In both cortical bone and cancellous bone, the stresses reduced with increase in alveolar bone loss with mini-implants placed between maxillary lateral incisor and canine.6) Stresses of around 7Mpa was observed in the cortical bone at the mini-implant interface with mini-implant placed between maxillary lateral incisor and canine.7) Intrusion was observed more with mini-implant placed between maxillary lateral incisor and canine than when mini-implant placed between maxillary central incisors.8) Mini-implants placed between maxillary lateral incisor and maxillary canine are better in achieving intrusion than mini-implants placed between maxillary central incisors.

Keywords: Finite element model, two mini- implant, MBT bracket system.

Introduction:

The initiating aspects for biological changes in orthodontic tooth movements are basically initiated by the stresses that occur in the periodontal ligament. The problem lies in calculating only force rather than stress on the biological changes since the same forces can lead to difference in stresses caused from variations in tooth-bone structures and the material properties of the periodontium.[1] Heavy orthodontic force in condition with increased periodontal bone loss may mortify the periodontium, leading to a rise in hyalinization or lead to increased possibilities of root resorption, which may have an effect on tooth movement.[2]

Prevalent methods for anterior teeth intrusion includes 2x4 appliances like –Burstone intrusion arches, Ricketts utility arch, and reverse curve arches.[3-9]Temporary anchorage devices (TAD) have made specific sorts of tooth movements possible.[10-14] Earlier studies have mentioned intrusion of upper anterior teeth with the usage of mini-screws with light forces.[5-17] However, the site of force application and location for mini-screws placement are necessary in the intrusion of the upper anterior segment and consequently ought to be chosen carefully.[18]

To determine biomechanical elements such as stress, strain and displacement in teeth, PDL and alveolar bone, the Finite Element Method (FEM) was introduced.[19] This technique studies complicated elements biomechanically by means of dividing them into little portions (elements) and then cautiously analysing these assembled structures to form a mathematical model and their geometries.[20-21] This technique has the potential of assessing distinctive shapes with different properties, and enables FEM to be a good toll for analysing the changes in tooth surrounding structures following tooth movement.[22]All these temporary anchorage devices are invasive and the best recommended for malocclusion that cannot be effectively managed with conventional mechanics.

Therefore this study has been planned in our department with the following aims and objectives:

- To evaluate the stress pattern and distribution under intrusive orthodontic forces using one mini –implant between maxillary central incisors at various alveolar bone loss.
- To evaluate the stress pattern and distribution under intrusive orthodontic forces using two mini-implants between maxillary lateral incisors and canines on both sides at various alveolar bone loss.
- To compare the stress pattern and distribution between one mini-implant and two mini-implant under intrusive orthodontic forces at various alveolar bone loss levels.
- To evaluate the stress pattern in the bone around the mini- implants under intrusive forces using both systems.

Material and methods: CBCT scan of a normal adult human maxilla with normal occlusion was used for the collection of data. Materials used includes Brackets simulated will be of .022’ x.028’’ MBT prescription brackets from 3M(unitek), .019’’x.025’’stainless steel wire from 3M(unitek), Titanium self-drilling mini-implant (DENTAURUM) of 1.3mm diameter and 8mm length, Nickel-Titanium closed coil spring. For the present study, a Finite Element Model (FEM) was generated. This model was a replica of adult human maxilla. The model consisted of periodontal ligament, alveolar bone and all the teeth except third molars. The bracket system simulated will be an MBT bracket system from 3M UNITEK (0.22 slot) and the arch wire was of .019’’x.025’’ stainless steel. A 3- dimensional (3D) quantitative analysis requires a mathematical method, making use of a model accurate both in anatomy and physical characteristics and along with the use of a computer, which has become an indispensable aid as far as 3D analyses are concerned.

Steps involved in construction of finite element model are as follows:

1. Construction of a geometric model.
2. Conversion of the geometric model into a finite element model.
3. Material property data representation.
4. Defining the boundary condition.
5. Loading configuration.
6. Interceptive reading of results.

1. Construction of geometric model:

A mathematical model representing the biological properties of the teeth and the periodontium. This is represented in terms of points (grids), lines, surfaces (patterns) and volume (hyper patches). In this study, 3D Denta Scan of adult maxilla was taken. The software used for geometric modelling was HYPERMESH 13.0.

2. Conversion of geometric model to finite element model:

Geometric model was converted into FEM. The Finite Element Modelling is representative of geometry in terms of finite number of elements and nodes. This process is called discretization. The main idea behind discretization is to improve the accuracy of the results. Software used was ANSYS 12.1.

3. Material property and Data representation

The different structures involved in the study include teeth, the periodontal ligament and alveolar bone. Each structure has a specific property. The material properties were derived by McGuinness and was used in finite element study done by Tannes.[24,25]

Different material properties

Material	Young`s modulus (N/mm sq.)	Poisson`s ratio
Tooth	20300	0.3
PDL	0.667	0.49
Alveolar bone	13700	0.38
Stainless Steel	180000	0.3
Titanium	110000	0.3

4. Defining the boundary condition:

The conditions of the boundary of an FEM model have to be defined in away such that all kinds of model movements are to be restrained. This is essential to prevent bodily motions on the model during loading. In this particular study, all the conditions of the fixed body have been maintained at the maxillary base and prevented from free bodily motion in all the directions by constraining them.

5. Loading configuration:

Two different points of force applications was used and categorized in two groups as follows:

a) **Group I:** Point of force application was from a single mid mini- implant placed at 12mm from arch wire to the attachment on the wire (19x25 SS) between the upper central incisors at alveolar bone loss levels 0mm, 2mm, and 4mm.
b) **Group II:** Point of force application was from bilateral mini- implants placed at 12mm from arch wire[38,39] to the attachment on the wire (19x25 SS) between the upper lateral incisor and the upper canine on the either side at alveolar bone loss levels 0mm, 2mm,and 4mm.

Six separate finite element models were constructed at the alveolar bone loss levels: 0mm, 2mm, 4mm.An intrusive load of 120grams was applied on one implant placed between two upper central incisors and of 60grams on the two mini- implants placed between the upper lateral incisor and the canine tooth on either side of the upper jaw.[26-28]

6. Interceptive reading of results:

Finite element model consisting of nodes and elements of teeth, periodontium, brackets, arch wire, mini-implants, NiTi closed coil spring will be imported into ANSYS (12.1 version, ANSYS. NC) software for analyzing the displacement and stress pattern. The following flow chart describes the methodology of FEM.

FE-model Details (Group-I)

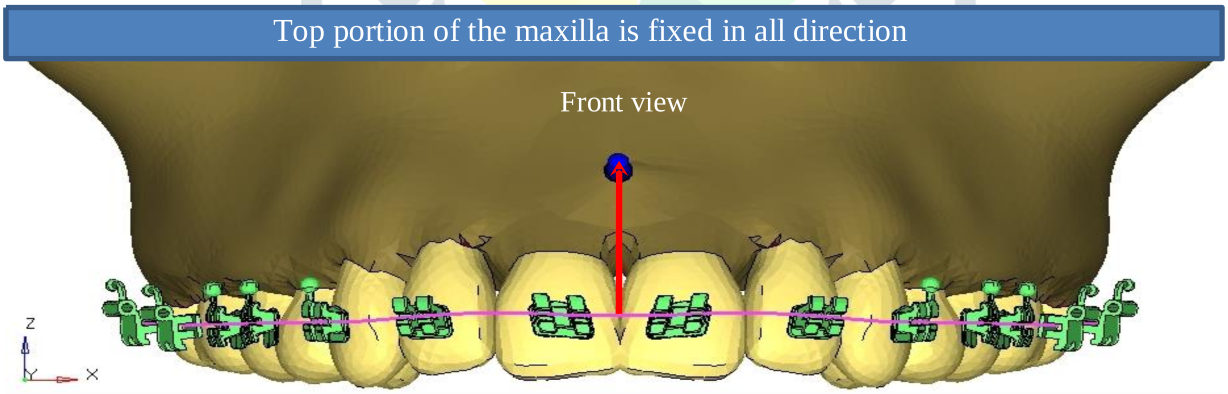
Single mid mini- implant placed at 12mm from arch wire between the upper central incisors at alveolar bone loss levels at 0mm , 2mm and 4mm. Software used for Finite element model is created using Hypermesh 13.0

Software Used:-Hypermesh 13.0 was used to create Finite element model ANSYS 12.1 was used for FEA simulation

Units Followed:-Teeth Movement in 'mm' Stress in 'MPa' Strain 'mm/mm'

Directions followed:-X is lateral direction, Y is anterio-posterior direction and Z- is vertical direction

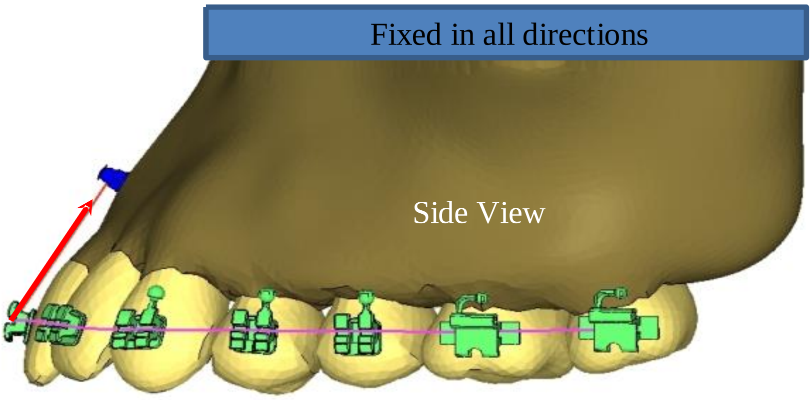
Applied Loads and Boundary Conditions



Total Nodes = 80017

Total Elements = 351237

3D tetrahedral elements were used to create the Fe-model



Intrusive force of 120gms was applied

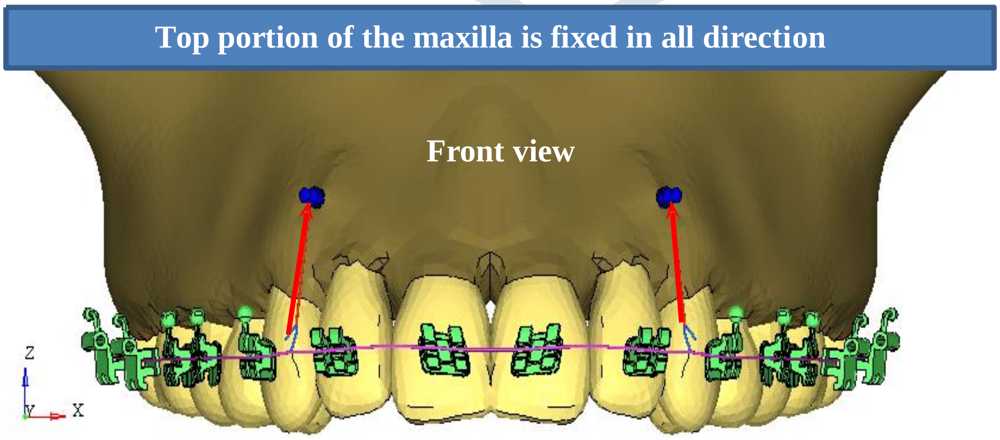
FE-model Details (Group-II)

Two mini- implant placed at 12mm from the arch wire between the lateral and canine at alveolar bone loss levels at 0mm, 2mm and 4mm. Software used for Finite element model is created using Hypermesh 13.0

Software Used:-

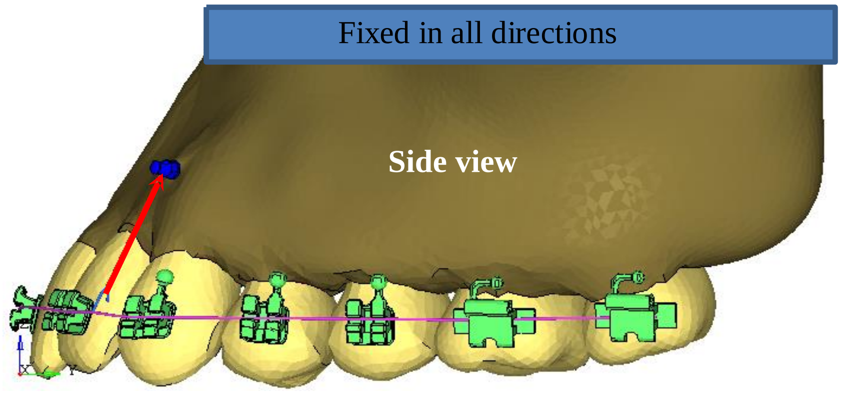
Hypermesh 13.0 was used to create Finite element model. ANSYS 12.1 was used for FEA simulation
Units Followed:-
Teeth Movement in 'mm' Stress in 'MPa'
Strain 'mm/mm'
Directions followed:-
X is lateral direction, Y is anterio-posterior direction and Z- is vertical direction

Applied Loads and Boundary Conditions



Total Nodes = 79114Side

Total Elements = 368793



Intrusive force of 60gms was applied per side

Results:

FEA Results (Group-1)

Single mid mini- implant placed at 12mm from arch wire between the maxillary Central incisors.

Units Followed:-Teeth Movement in ‘mm’ Stress in ‘MPa‘Strain ‘mm/mm’

Directions followed:-X is lateral direction, Y is anterio-posterior direction and Z- is vertical direction.

Results of Group I: Displacement of teeth in X, Y, Z-axis for all three models with mini-implant placed between central incisors

Displacement of teeth in X,Y,Z-axis for all three models with mini-implant placed between central incisors (all values expressed in mm)

GROUP-I	Model 1 (0mm bone loss)		Model 2 (2mm bone loss)		Model 3 (4mm bone loss)	
	Crown	Root	Crown	Root	Crown	Root
Central incisor						
X-axis (transverse)	0	0	0	0	0	0
Y-axis(anterio-posterior)	-0.001	0.001	-0.001	0.002	-0.002	0.003
Z-axis(vertical)	0.002	0.001	0.003	0.001	0.006	0.002
Lateral incisor						
X-axis (transverse)	0	0	0	0	0	0
Y-axis (anterio-posterior)	-0.001	0.000	-0.001	0.001	-0.002	0.001
Z-axis(vertical)	0.001	0.001	0.003	0.001	0.005	0.002
Canine						
X-axis(transverse)	0	0	0	0	0	0
Y-axis(anterio-posterior)	-0.001	0.000	-0.001	0.001	-0.002	0.001
Z-axis(vertical)	0.001	0.000	0.003	0.001	0.005	0.001

Von Mises stress observed in three models (values expressed in MPa)

	Model 1(central incisor) Maximum stress observed in cervical region	Model 2(lateral incisor) Maximum stress observed in cervical region	Model 3 (canine) Maximum stress observed in cervical region
0mm bone loss	2.855	0.773	2.875
2mm bone loss	4.459	0.910	3.058
4mm bone loss	6.844	0.991	3.242

Von- Mises stress observed in contour in cortical bone at mini-implant site in(Mpa)

	0mm bone loss	2mm bone loss	4mm bone loss
Stress in Mpa	59.840	56.309	52.152

Von-Mises strain observed in contour in cortical bone at mini-implant site in (mm/mm)

	0mm bone loss	2mm bone loss	4mm bone loss
Strain(mm/mm)	0.0044	0.00414	0.00389

Results of Group II - Displacement of teeth in X, Y, Z-axis for all three models Mini-implant placed between Lateral incisors and Canine

Displacement of teeth in X,Y,Z-axis for all three models (all values expressed in mm) Mini-implant placed between Lateral incisors and Canine

GROUP-II	Model 1 (0mm bone loss)		Model 2 (2mm bone loss)		Model 3 (4mm bone loss)	
	Crown	Root	Crown	Root	Crown	Root
Central incisor						
X-axis (transverse)	0	0	0	0	0	0
Y-axis(anterio-posterior)	-0.001	0.000	-0.002	0.000	-0.003	0.000
Z-axis(vertical)	0.002	0.001	0.004	0.002	0.006	0.002
Lateral incisor						
X-axis (transverse)	0.001	0	0.002	-0.000	0.003	-0.000
Y-axis(anterio-posterior)	-0.001	0.000	-0.003	0.001	-0.004	0.001
Z-axis(vertical)	0.002	0.001	0.005	0.001	0.008	0.002
Canine						
X-axis(transverse)	-0.001	0.000	-0.002	0.000	-0.004	0.001
Y-axis(anterio-posterior)	-0.001	0.000	-0.002	0.001	-0.003	0.002
Z-axis(vertical)	0.002	0.001	0.004	0.001	0.007	0.002

Von Mises stress observed in three models in tooth (values expressed in MPa)

	Model 1(central incisor) Maximum stress observed at bracket site	Model 2 (lateral incisor) Maximum stress observed at bracket site	Model 3(canine) Maximum stress observed at bracket site
0mm bone loss	1.596	6.088	7.386
2mm bone loss	3.192	12.176	14.773
4mm bone loss	5.333	17.391	21.649

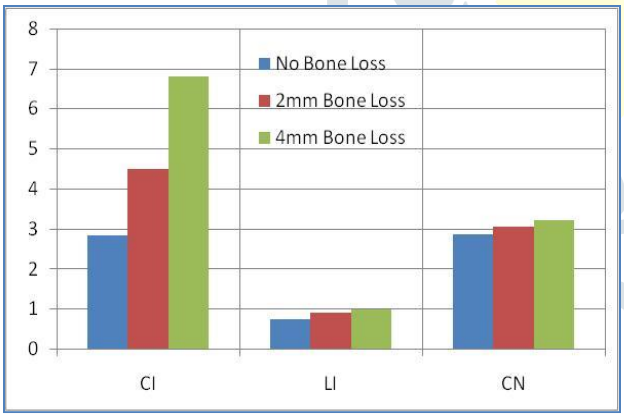
Von –Mises stress observed in contours in cortical bone at mini-implant site(Mpa)

	0mm bone loss	2mm bone loss	4mm bone loss
Stress in (Mpa)	6.566	5.837	5.446

Von- Mises strain observed in contour in cortical bone at mini-implant site(mm/mm)

	0mm bone loss	2mm bone loss	4mm bone loss
Strain(mm/mm)	0.00047	0.00042	0.00040

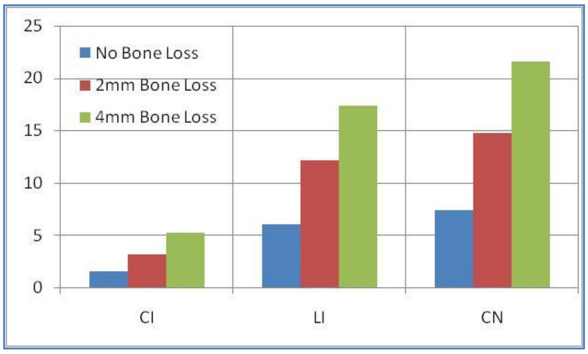
Stress Variation plots for Group I



Observations:-

- The stresses in anterior teeth increase with increase in bone loss.
- Highest stresses are observed in central incisors.
- Lowest stresses are observed in Lateral incisors.
- In both cortical and cancellous bones the stresses reduced with increase in bone loss.
- Maximum stress of around 60MPa is observed in cortical bone at implant interface region.

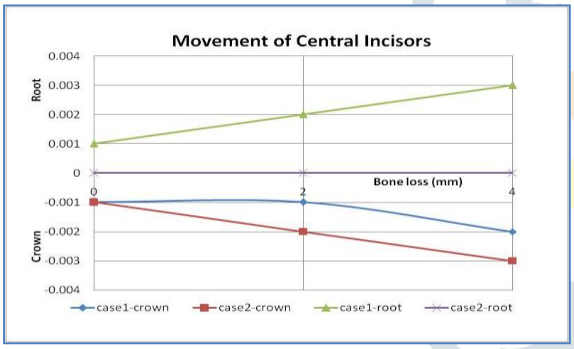
Stress Variation plots for Group II



Observations:-

- The stresses in anterior teeth increase with increase in bone loss.
- Highest stresses are observed in canine.
- Lowest stresses are observed in central incisors.
- In both cortical and cancellous bones the stresses reduced with increase in bone loss.
- Maximum stress of around 7MPa is observed in cortical bone at implant interface regions.

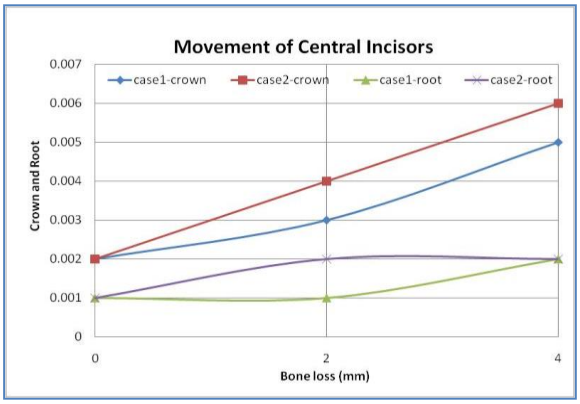
Crown and root movement variation in central incisor(Y-direction)



Observations:-

- Both root and crown movement increased with increase in bone loss.
- In Group-I, crown and root moved in opposite direction , hence uncontrolled tipping behaviour is observed.
- In Group-II, there is no root movement, hence controlled tipping behaviour is observed.

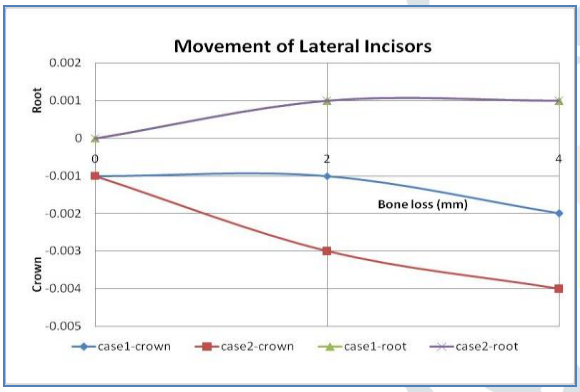
Crown and root movement variation in central incisor(Z-direction)



Observations:-

- Both root and crown movement increased with increase in bone loss.
- Intrusion behaviour is observed in both cases.
- More intrusion is observed in Group-II compared to Group-I.

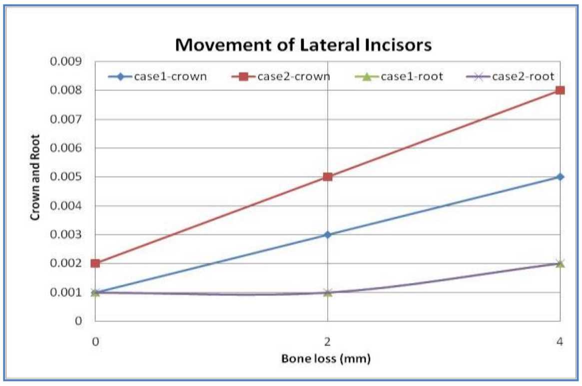
Crown and root movement variation in lateral incisor(Y-direction)



Observations:-

- Both root and crown movement increased with increase in bone loss.
- In Group-I, crown and root moved in opposite direction, hence uncontrolled tipping behaviour is observed.
- In Group-II, we observed uncontrolled tipping behaviour and it is more compared to group-1.

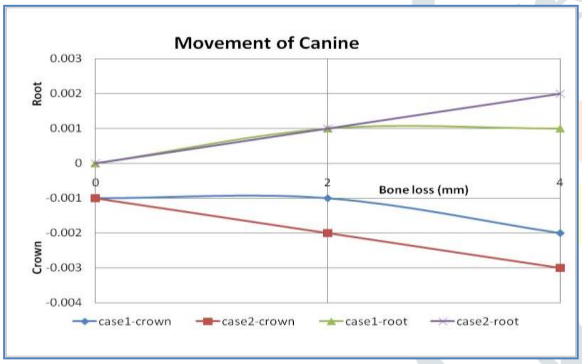
Crown and root movement variation in lateral incisor (Z-direction)



Observations:-

- Both root and crown movement increased with increase in bone loss.
- Intrusion behaviour is observed in both cases.
- More intrusion is observed in Group-II compared to Group-I.

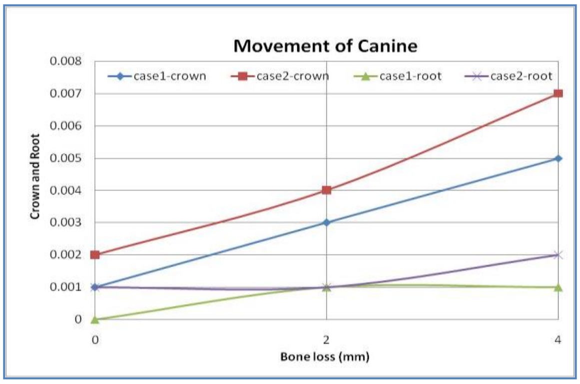
Crown and root movement variation in Canine(Y-direction)



Observations:-

- Both root and crown movement increased with increase in bone loss.
- In Group-I, crown and root moved in opposite direction, hence uncontrolled tipping behaviour is observed.
- In Group-II, we observed uncontrolled tipping behaviour and it is more compared to group-I.

Crown and root movement variation in Canine (Z-direction)



Observations:-

- Both root and crown movement increased with increase in bone loss.
- Intrusion behaviour is observed in both cases.
- More intrusion is observed in Group-II compared to Group-I.

Discussion

Recent decades have seen an increase in the number of adults who seek orthodontic treatment. These adult patients usually require a multi- disciplinary approach, especially when they are periodontally compromised.[29]

To carry out a controlled tooth intrusion with an increasing loss of alveolar bone is a major challenge without the problems arising out of an increased crown-to root ratio.[30]

In order to achieve a predictable and a physiological intrusion, estimating the location and magnitude of maximum stresses in the periodontal ligament is important.[31]

Geramy has stated that loss of alveolar bone modifies the CR of the tooth. Therefore, the strength and use of forces needs to be adjusted during an orthodontic treatment to obtain same amount of movement as in a tooth with a healthy periodontium.[30]

Tanne mentioned that the biomechanical behaviour of a tooth movement with bone loss has more influence in adults than adolescents since bone loss is found more frequently in adults.[31]

The present study has showed that in intrusion orthodontic tooth movement, the stress in anterior teeth increases with increasing bone loss. Highest stresses are observed in central incisor teeth and lowest stresses in lateral incisors. In both, cortical bone and cancellous bone stresses lessen with increasing bone loss. Finite element analysis (FEA) is used to study stresses and strain in the field of engineering and also it is practically useful to simulate situations in the maxillofacial region by elucidating stresses caused by various internal and external forces.[32]

Bone loss and increase in stress

In the present study on maxillary intrusion using mini-implants at various level of bone loss there is a steady increase in stresses with increasing bone loss levels and these stresses are compressive in nature.

Jeon had showed in his study that there was significantly high stress which had developed as the alveolar bone level reduced in maxillary molar region.[29]

Ona M had shown that with increasing resorption of supporting bone in maxillary central incisor there was an increase of stress that occurred in the periodontal ligament.[32]

Bone loss and Type of tooth movement:

In the group1, there was more bone loss tipping behaviour in the maxillary anterior teeth, which increased with the alveolar bone loss levels, and intrusion was observed. That too increased when alveolar bone loss was more.

A possible explanation for the change in the" type of tooth movement"- from the required to tipping under loading condition" is associated with the change in the CR location with increasing alveolar bone loss. As alveolar bone loss increases, the CR moves apically[31,33,34] and leads to an increase in moment of force.

Displacement in x- direction

Under Group I, 120gms of intrusive force between the maxillary central incisors led to no movement in the transverse direction in central incisor, lateral incisor and canine. In Group II, an intrusive force of 60gms between maxillary lateral incisor and canine tooth did not lead to any transverse movement of central incisors. However, the lateral incisor crown showed palatal tipping movement, which increased with increase in alveolar bone loss- as was observed in the study done by Parag Bohara et al.[35]

Displacement in Y- direction

Group I, tipping behaviour was observed along the Y-axis and the tipping increased with increase in the alveolar bone loss, in concordance with the study done by Sun-Mi Cho et al.[36] When an intrusive force of 120gmswas applied in between the maxillary central incisors, uncontrolled tipping was observed which increased with increase in the alveolar bone loss. Similar behaviour was observed in lateral incisor tooth and canine, probably because the intrusive force is applied buccally to the centre of resistance. This caused the labial tipping which increased with increased alveolar bone loss, this in concordance to the study done by Sun-Mi Cho et al.[36]

In Group II study, where intrusive force of 60gms was applied between lateral incisor and canine, controlled tipping was observed in central incisor and uncontrolled tipping was observed in lateral incisor. The canine showed rotation with its labial surface rotating distally and palatal surface rotating mesially. As the bone loss increased, the rotation in canine, the controlled tipping in central incisor and uncontrolled tipping in lateral incisor tooth increased.

Displacement in Z-direction

In this study when an intrusive force of 120gmswas applied between maxillary central incisors, all the anterior teeth showed intrusion, which increased with increase in alveolar bone loss. However, the intrusion in Group II is more as compared to Group I. It can be ascribed that in Group II, the intrusive force is applied by mini-implants in between maxillary lateral incisor and canine which is close to the centre of resistance of maxillary six anterior teeth. Therefore, true intrusion is observed. In Group I, the mini-implants are placed between maxillary central incisors which are away from the centre of resistance of maxillary six anterior teeth-- so more tipping is observed and intrusion is also less as compared to Group II. The above results are in accordance with the studies done by Parag Bohara et al.[3]

Area of Maximum Von –Mises Stress

In Group I, when intrusive force of 120gms was applied with mini-implants in between maxillary central incisor, maximum Von-Mises stress in (Mpa) was observed in the cervical region of the teeth, which increased with increase in alveolar bone loss. Maximum stress were observed in maxillary central incisor tooth (6.844Mpa at 4mm bone loss) and least in maxillary lateral incisor tooth (0.991Mpa at 4mm bone loss) .The canine showed stress with a value of 3.242Mpa at 4mm bone loss, which was less than maxillary central incisor .The same results were obtained in the study done by Geramy et al[37] and Zhang et al.[38]

In Group II, study maximum Von-Mises stresses were observed in the crown region, where the bracket is bonded in central incisor, lateral incisor and canine. The stress increased with increase in the alveolar bone loss. Maximum stress was found in canine at 4mm bone loss (21.649) and least stress was found in maxillary central incisors (5.333) at 4mm bone loss. It was seen that stress increased approximately 3 times in canine and lateral incisor when the alveolar bone loss increased from 0mm to 4mm. Comparatively, the central incisor showed 4 times increase in stress on increase in alveolar bone loss from 0mm to 4mm. The canine showed highest stress probably because the mini-implants were placed near canine and lateral incisor tooth and away from central incisor, so there were less stresses in maxillary central incisor as compared to canine and lateral incisor.

Von-Mises Stress in cortical bone at mini-implant site

In Group I, both in cortical and cancellous bone, stresses were observed at the mini-implant site, and they reduced with increase in the alveolar bone level. Maximum stress was observed in cortical bone at mini-implant interface region (60Mpa at 0mm bone loss), which further reduced to 52.152 at 4mm bone loss levels. In Group II, stresses were observed at mini-implant site which reduced with increase in alveolar bone loss. Maximum stress was of 7Mpa observed at 0mm bone loss and 5.4Mpa at 4mm bone loss. In no alveolar bone loss situation movements were lesser and high stresses were observed at bone implant interphase because most of the applied load reached the mini-implant- bone interface however as the alveolar bone loss increased higher tooth movement was observed and less load were transferred to the bone mini-implant interface causing reduced stresses at the bone-mini implant interface. Both the Groups, the maximum stress was observed at the mini-implant interface which is in concordance with the study by Vijyalakshmi P S et al.[39]

CONCLUSION

Determining primary stability after insertion can help predict success of the orthodontic mini implant. The first methods used to clinically evaluate implant stability were the tapping method, radiography, and the Perio test. However, all these methods lack enough precision and repeatability in quantifying stability; therefore, a precise and repeatable measure of implant stability was needed.[40]The aim of this study was to ascertain the stresses and displacement in the maxillary anterior region during intrusion at various alveolar bone loss levels by Finite element method (FEM). The following conclusions were made:

1).When the mini-implants were placed between the maxillary central incisors, stresses in anterior teeth increased with increase in the alveolar bone loss. Proclination due to tipping was observed which increased with the increase in the alveolar bone loss. Uncontrolled tipping behaviour was observed.

2) In both the cortical bone and cancellous bone, the stresses reduced with increase in alveolar bone loss when the mini-implants were placed between the maxillary central incisors.

3) At the mini-implant interface when mini-implants placed between the maxillary central incisors maximum stress of around 60Mpa was observed in the cortical bone at mini-implant site.

4) When mini-implants placed between maxillary lateral incisor and maxillary canine, stresses in anterior teeth increased with increase in the alveolar bone loss. Proclination due to controlled tipping was observed which was less in magnitude as compared to mini-implants placed between maxillary central incisors.

5) In both cortical bone and cancellous bone, the stresses reduced with increase in alveolar bone loss with mini-implants placed between maxillary lateral incisor and canine.

6) Stresses of around 7Mpa were observed in the cortical bone at the mini-implant interface with mini-implant placed between maxillary lateral incisor and canine.

7) Intrusion was observed more with mini-implant placed between maxillary lateral incisor and canine than when mini-implant placed between maxillary central incisors.

8) Mini-implants placed between maxillary lateral incisor and maxillary canine are better in achieving intrusion than mini-implants placed between maxillary central incisors.

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