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Biomechanical Characteristics of Microimplant for Anchorage in Orthodontics: A 3D Finite Element Model Study

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ABSTRACT

In orthodontic treatment, anchorage control is essential for success. A recent development, stationary anchorage (microimplants) eliminates one of the uncertainties of orthodontic tooth movement by offering absolute control over potentially undesirable counter movements. The objective of this study was to establish a 3D finite element model for microimplant and to analyze the influence of different angulations to the long axis of the teeth (30-90°) on the biomechanical characteristics of orthodontic anchorage implant-bone interface. Results of this study showed that largest stress and deformation was seen in the cortical bone and upper region of trabecular bone. Stress and deformation increased as the angulations of the implant to the long axis of the tooth increased. As the angulation of the implant to the long axis of maxillary 1st molar increased, stress and deformation also decreased. Maximum stress and displacement were recorded when implant was placed perpendicular to the long axis of maxillary 1st molar.

Keywords: Anchorage, Microimplants, Finte element model.

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INTRODUCTION

In orthodontic treatment, anchorage control is essential for success.[1] If there is an imbalance of force, unwanted tooth movement occurs. A recent development, stationary anchorage (microimplants) eliminates one of the uncertainties of orthodontic tooth movement by offering absolute control over potentially undesirable counter movements.

Load transfer from implants to surrounding bone depends on the (A) type of loading, (B) the bone-implant interface, (C) the length and diameter of the implants, (D) the shape and characteristics of the implant surface and (E) the quantity and quality of the surrounding bone.

In the past two decades, finite element analysis (FEA) has become an increasingly useful tool for the prediction of the effects of stress on the implant and its surrounding bone.

A key factor for the success or failure of a dental implant is the manner in which stresses are transferred to the surrounding bone.

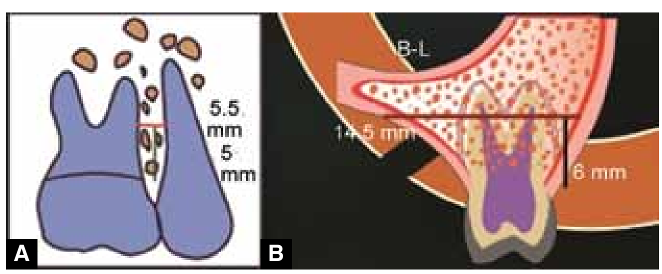
Finite element analysis allows us to predict stress distribution in the contact area of the implants with cortical bone and around the apex of the implants in trabecular bone (Figs 1A and B).[2]

One of the main use of implants is to retract anteriors in maximum anchorage cases.

Implants are usually placed at 30° to 60° angulations to long axis of the teeth. This will improve retention while reducing the risk of striking a root.[3-6]

OBJECTIVES

To establish a three-dimensional (3D) finite element model (FEM) for microimplant and to analyze the influence of different angulations to the long axis of the teeth (30-90°) on the biomechanical characteristics of orthodontic anchorage implant-bone interface.



Figs 1A and B: (A) Position of microimplant between 2nd premolar and 1st molar (B) cortical surface thickness of 2 mm, 3D finite element model (FEM) of micro-implant

MATERIALS AND METHODS

Three-dimensional models from implant and bone were generated to analyze anchorage load.

Computations of stress arising in the implant bone interface was made with FEA using NISA-II, Display-III marketed by EMRC (Engineering Mechanics Research Corporation) — A 3D computer software.

A model of orthodontic implant measuring 1.2 mm diameter and 8 mm in length was generated (Fig. 2).

The results were recorded during static loading in the bone around the implant.

The implant was simulated at the following angulations—30, 45, 60 and 90° (Fig. 3) to the long axis of the max 1st molar. A simulated orthodontic force, which was 200 gm loaded mesiodistal (MD) to the mathematical model (Figs 4A and B). The stress and displacement on the implant-bone interface were analyzed.

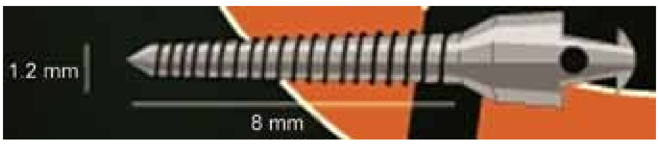


Fig. 2: Miniscrew implant

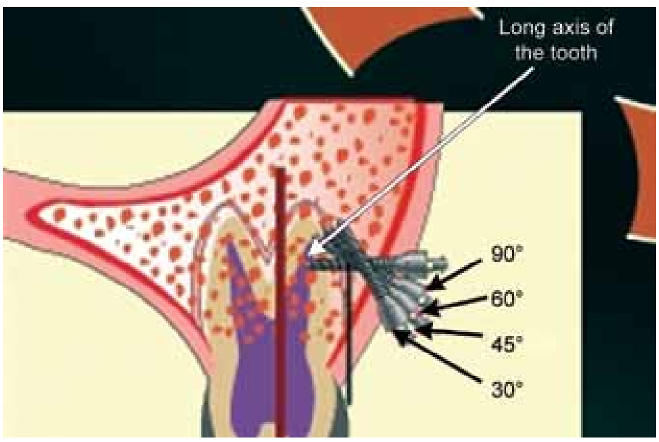


Fig. 3: Implant bone interface at different angulations

RESULTS

Stress Distribution (Fig. 5)

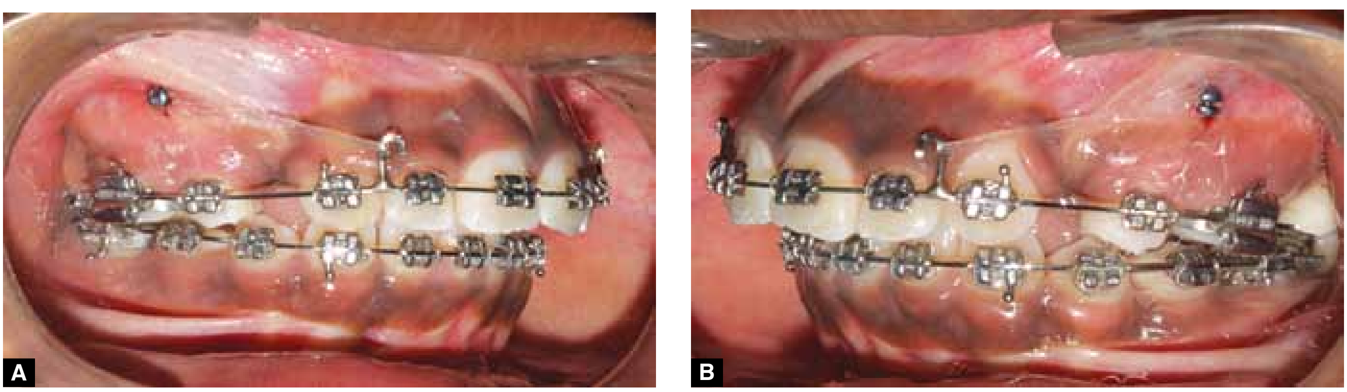
- Interface—when placed 90° to mid sagittal plane, stress at cortical bone is 15.91 Mpa and, on trabecular bone, it is 7.96 Mpa for 3 to 4 mm.
- Interface—when placed 60° to mid sagittal plane, stress at cortical bone is 15.91 Mpa and, on trabecular bone, it is 7.96 Mpa for 3 to 4 mm.
- Interface—when placed 45° to mid sagittal plane, stress at cortical bone is 7.698 Mpa and, on trabecular bone, it is 5.132 Mpa for 3 to 4 mm.
- Interface—when placed 30° to mid sagittal plane, stress at cortical bone is 7.703 Mpa and, on trabecular bone, it is 5.135 Mpa for 3 to 4 mm.

As the angulation decreased, the stress at the cervix of the implant were decreased.

Displacement of Implant (Fig. 6)

1. Interface—when placed 90° to mid sagittal plane, displacement at cortical bone is –9.444 × 10.4 and on trabecular bone, it is –5.632 × 10.4 Mpa for 3 to 4 mm.
2. Interface—when placed 60° to mid sagittal plane, displacement at cortical bone is –9 × 10.4 and, on trabecular bone, it is –5.401 × 10.4 Mpa for 3 to 4 mm.
3. Interface—when placed 45° to mid sagittal plane, displacement at cortical bone is –8.8 × 10.4 and, on trabecular bone, it is –5.215 × 10.4 Mpa for 3 to 4 mm.
4. Interface—when placed 30° to mid sagittal plane, stress at cortical bone is –8.5 × 10.4 and, on, trabecular bone, it is –5.039 × 10.4 Mpa for 3 to 4 mm.

The largest stress and deformation was seen in the cortical bone and upper region of trabecular bone. Stress and deformation increased as the angulations of the implant to the long axis of the tooth increased.



Figs 4A and B: Retraction of teeth using implants

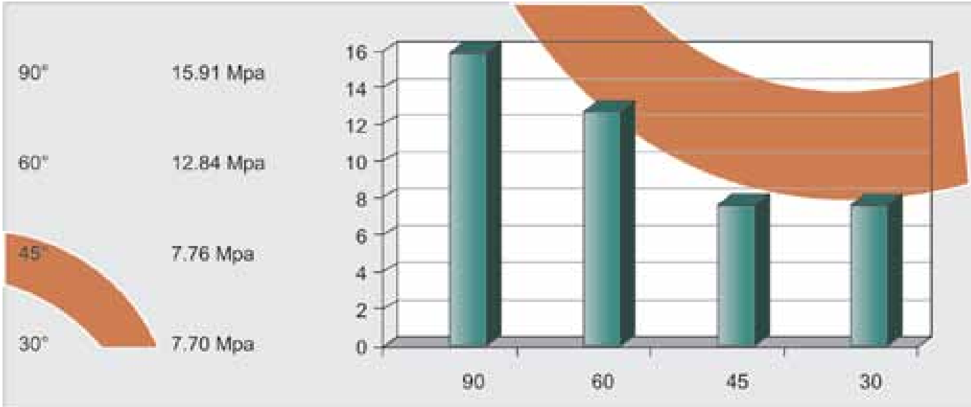


Fig. 5: Stress distribution at different angulation of implant

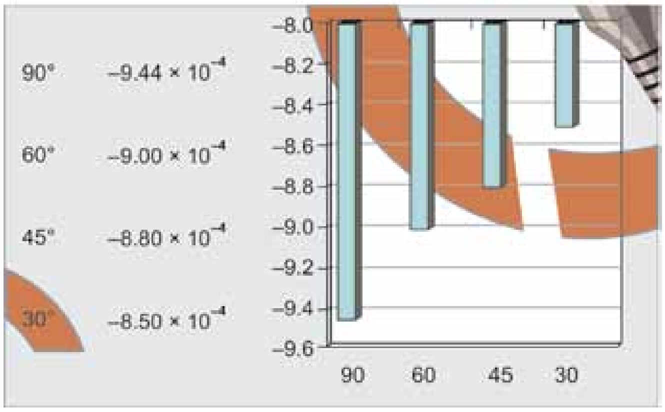


Fig. 6: Displacement of implant at different angulations

DISCUSSION

The aim of the present study was to investigate the deformation of the bone surface around an implant in response to force application in different angulation of implant placement.

Abnormally high stress concentration in the supporting tissues can result in pressure necrosis and, subsequently, in implant failure.[7]

Finite element models were used to evaluate the load transfer from the mini-screw to the surrounding bone.

The primary component of the load transfer takes place at a single revolution of the miniscrew thread with in the cortex.

Under the assumed loading condition, the miniscrew is displaced in a tipping mode, causing tensile stress in the direction of the force.[8-11]

In general, stress levels are higher in the cortical bone than in the trabecular bone.

The thickness of the cortical bone determines the overall load transfer from the miniscrew to bone and stiffness of the trabecular bone plays only a minor role.

The cortical surfaces of the maxilla are thinner and less compact than those of the mandible.

The finite element (FE) method was adapted largely to clinical conditions by selecting parameters, such as implant and bone shape, stress and its angulations.

By applying the FE method, the influence of different angulations to the long axis of the max 1st molar was observed.[12,13]

CONCLUSION

Microimplants can be safely loaded with 200 gm of MD orthodontic force. As the angulation of the implant to the long axis of max 1st molar increased stress and deformation also decreased.

Maximum stress and displacement were recorded when implant was placed perpendicular to the long axis of max 1st molar.

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