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Influence of miniscrew sizes on stress distribution

Influence of Orthodontic Miniscrew Implant Sizes on Stress Distribution: Finite Element Method

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Introduction

Recently, a wide variety of miniscrews with several sizes and designs have been developed (1-5). Changes in miniscrew geometry have great influence on biomechanical performances of both the implant and surrounding bone (6,7). Hence, what are the appropriate sizes of miniscrew implant?

Objectives

The purpose of the present study was to evaluate the influence of miniscrew implant diameter and length on the stress distribution in bone and miniscrew implant using finite element method.

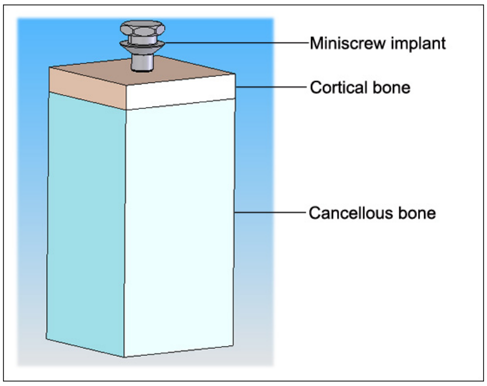
Material and Methods

The finite element models were established and verified by mathematical methods in the following sequences.

Pre-processing
a. Geometry of model
Miniscrew implant and surrounding bone were modeled with no penetration situation by Software (SolidWorks 2004, SolidWorks Corporation, U.S.) (Fig. 1). (diameter 1.2 mm, 1.4 mm, 1.6 mm and 1.8 mm; length 6 mm, 8 mm, 10 mm and 12 mm)
b. Loading and constrained condition
Loading force of 50.0 cN was applied at 90 degrees (horizontal direction) to the long axis of the miniscrew implant in all models. The lower part of the bone was constrained (Fig. 2).

Processing
The models were divided into finite elements by means of the ten nodes tetrahedral method. The Maximum von Mises stress in the miniscrew (Octahedral shear stress yield criterion theory) and Maximum principle stress in the cortical bone (Maximum normal stress fraction criterion theory) were calculated (8).

Post-processing
Stress distribution patterns in the miniscrew implant and the surrounding bone were described and illustrated in a color scheme diagram. Maximum stresses values in each model were collected.



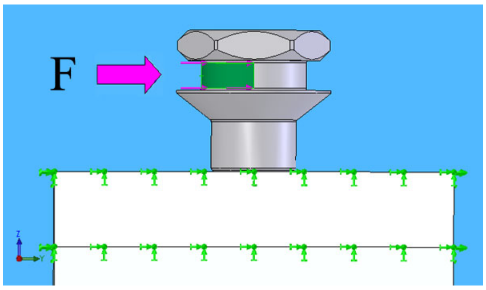


Fig. 1: Dimension of miniscrew implant and bone model

Fig. 2: Direction and position of loading force

Results

Stress distribution patterns were identical in all models. Stresses were largely concentrated around the cervical portion of the miniscrews (Fig. 3-6).

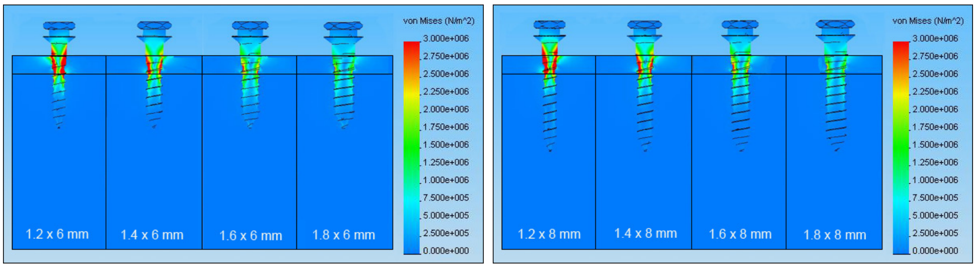


Fig. 3 and 4: Patterns of stress distribution in various sizes of miniscrew implant

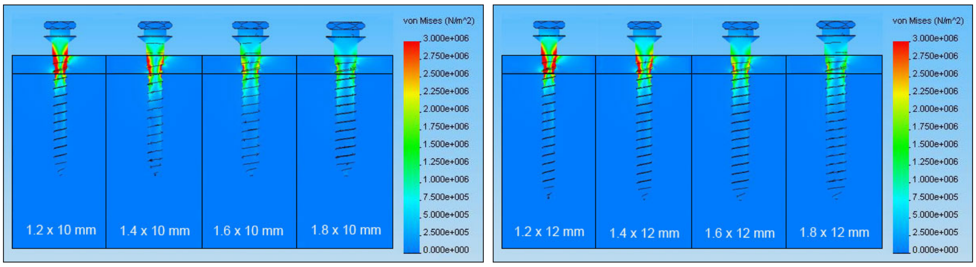


Fig. 5 and 6: Patterns of stress distribution in various sizes of miniscrew implant

An increase in diameter of a miniscrew resulted in a linear decrease of the stress values in both the screw and bone, whereas an increase in length of a screw showed little change in the stress values (Fig. 7-10).

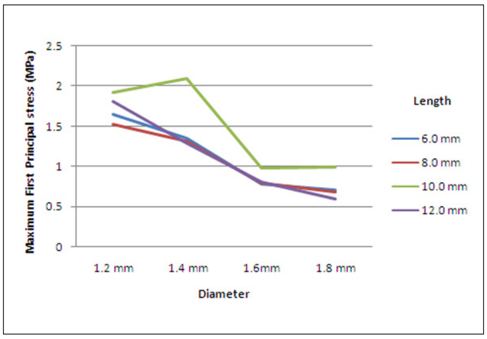


Fig. 7: Maximum first principal stress in cortical bone

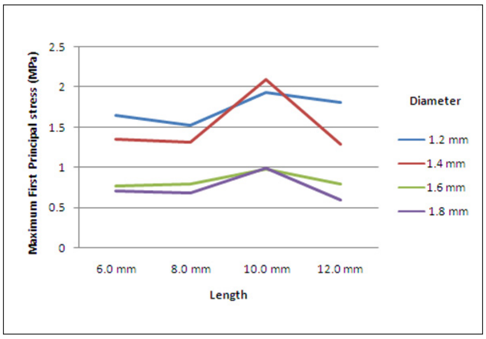


Fig. 8: Maximum first principal stress in cortical bone

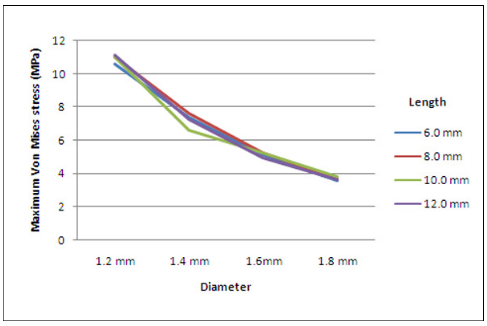


Fig. 9: Maximum Von Mises stress in miniscrew implant

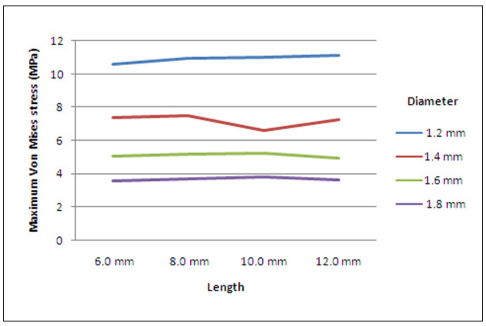


Fig. 10: Maximum Von Mises stress in miniscrew implant

Conclusions

Stress distribution pattern
Stress concentrations in all models were mainly located in the area below the platform of the miniscrew implant, the first groove between the first and second thread, on the same side as that of the applied force. The probable reason for the result is that this area was the first part of diameter reduction and the beginning of the contact area between miniscrew implant and bone.

Influence of diameter of miniscrew implant
An Increase in diameter of miniscrew implant models resulted in a lower stress value in the surrounding bone. A possible explanation for this result is that wider miniscrews increase the surface contact area at the area of stress concentration, around the first and second threads. Consequently, the optimum choice is a miniscrew implant with the maximum possible diameter allowed by the anatomy.

Influence of length of miniscrew implant
Longer miniscrews tended to bend more than did shorter miniscrews. However, longer miniscrew implants also increase contact area. Therefore, the stress concentration did not decrease with longer screw size.

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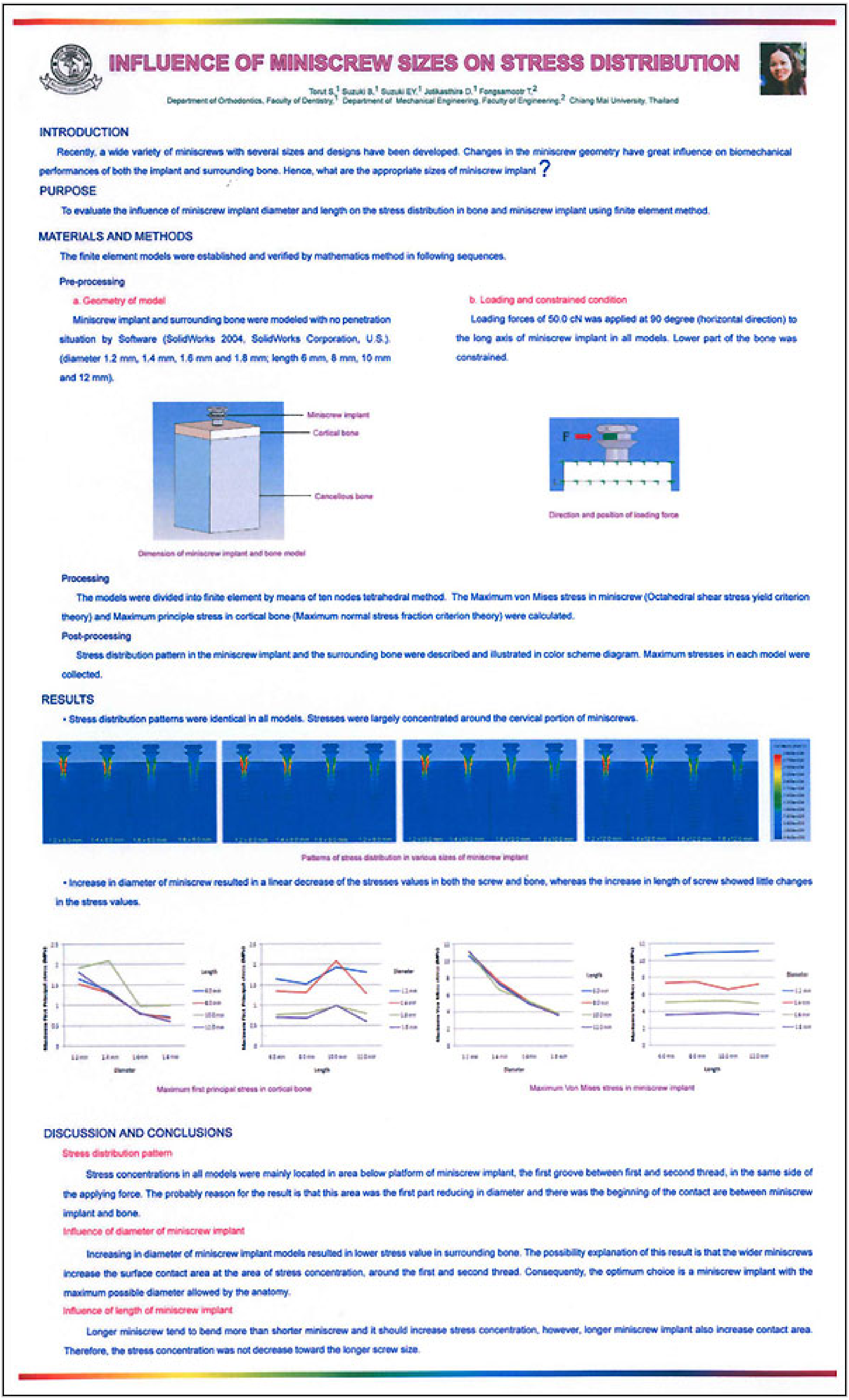

INFLUENCE OF MINISCREW SIZES ON STRESS DISTRIBUTION

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Miniscrew implant
Cortical bone
Cancellous bone

Dimension of miniscrew implant and bone model

F

Direction and position of loading force

Processing

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Patterns of stress distribution in various sizes of miniscrew implant

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Maximum first principal stress in cortical bone

Maximum Von Mises stress in miniscrew implant

DISCUSSION AND CONCLUSIONS

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