Can we improve shear stability of intramedullary nail for the fixation of distal tibial fractures?

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Introduction

Intramedullary nailing (IMN) is known as a viable option for distal tibial fractures. Potential for malalignment is the main disadvantage of IM nailing, which can occur mainly due to reduced bone-implant contact at the distal quarter, as well as high shear interfragmentary movements (IFM) [1,2,3]. The goal of this study was to evaluate the effects of a modification on the geometry of nailing system, which allows to insert an extra screw right above the fracture site, on the shear movement of the fractured segments with respect to each other. The effect of using implants with low Young's modulus on the axial interfragmentray movement (IFM) was also investigated.

Materials & Methods

- Tibia model was constructed using CT data, Mimics (V.10.01), and Catia (V5.R19). A CAD model of an intramedullary nail (Expert, diameter: 9 mm, length: 330 mm, Synthes) was constructed and assembled to the fractured bone (Figure 1-a). Two different screw configurations (SC) were considered: SC1: 123-456, and SC2: 12-456 (Figure 1-a). Model was imported to Abaqus (V6.11) to do finite element analysis.
- Boundary conditions, i.e. loads of ligaments, muscles, and body force of a 80Kg person, were extracted [3], and applied to our model (Figure 1-b). For nail and screw, three different material properties, i.e. stainless steel, titanium, and carbon/epoxy, were considered. Callus was assumed to have a poro-elastic behavior by considering material properties of granulation tissue [4].
- Tibia was modeled as an elastic non-homogenous material (Figure 1.c).
- Analysis was performed as a transient soil step by time period of 0.5s. von Mises stress, axial interfragmentary strain (IFS), shear IFM, and specific production of different tissue phenotypes [4] were calculated at the end of analysis step. In order to evaluate validity of the FE model, a separate analysis was done according to boundary conditions of experimental test.

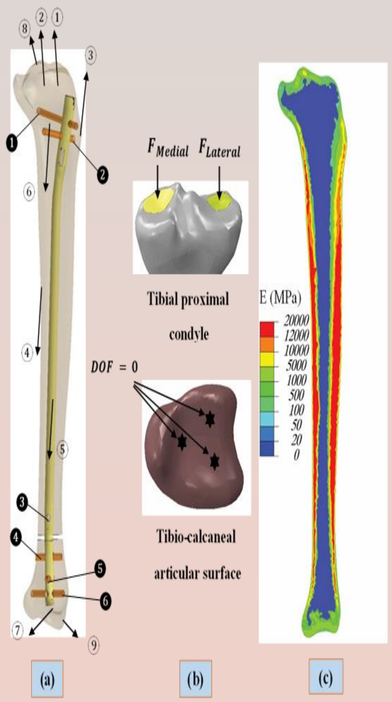
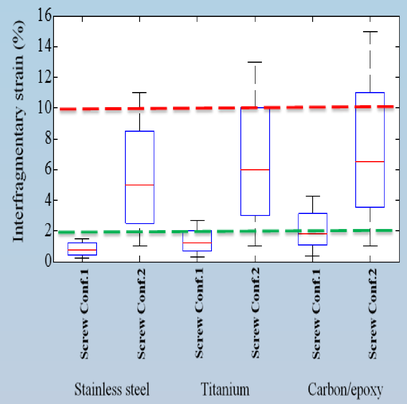


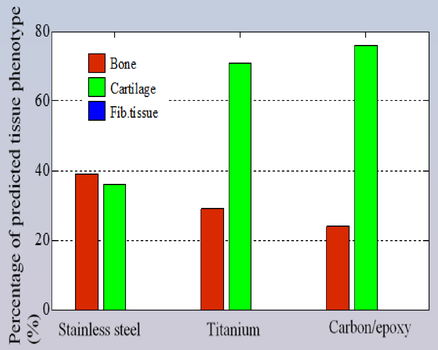
Figure 1: Finite element modeling, (a): nail-tibia construct; arrows show ligaments and muscles forces; numbers show hole position; (b): boundary condition; (c): distribution of Young's modulus on tibia

Results

Axial IFS extracted from FEA. Box plot shows min., max. and median which are calculated at different locations of the fracture site. IFS in range of 2-10% is reported to be stimulatory for healing process [5].

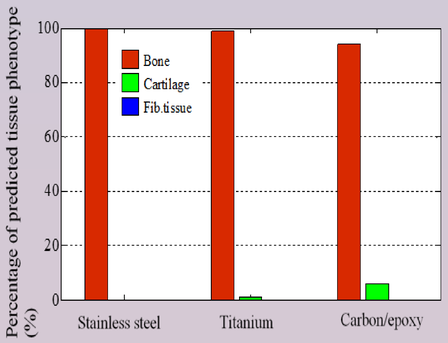


Percentage of predicted different tissue phenotypes in the gap site for screw configuration 1. As shown, by reduction in Young's modulus of implant, cartilage formation increased.



Screw config. 1

Percentage of predicted different tissue phenotypes in the gap site for screw configuration 2. Compared to screw configuration 1, production of cartilage was restricted.



Screw config. 2

Conclusions

- Inserting an extra screw, close to the fracture site on the proximal bony fragment, caused significant reduction in shear movements. However, this idea also led to relative restriction of axial IFS from which the percentage of cartilage production decreased.
- By considering screw configuration 1, inserting an extra screw, fixation with stainless steel and titanium led to excessive rigidity of nail-tibia system in which axial IFS drops below 2%.
- In order to preserve axial stimulatory movements, the proposed design is recommended when an IMN with a very low Young's modulus is used.

References

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