THE INFLUENCE OF DIFFERENT PIN MATERIALS USED FOR UNILATERAL EXTERNAL FIXATORS ON TRANSVERSE TIBIAL FRACTURE

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INTRODUCTION

External fixation is typically used by surgeon when internal fixation is contraindicated to treat open tibial fractures. It has been significantly improved by the passing years. Recently, the manufacturers have been suggesting the use of a 'better' fixator material (titanium alloy). This alloy is a biocompatible material that has a relatively low modulus of elasticity (which is closer to that of bone than stainless steel 316L) and it is also well-known to be MRI-safe. Despite its advantages, the drawback of using this material is its higher cost when purchasing one.

The goal of this study is to look at the mechanical effects when implementing pins of different materials (stainless steel 316L and titanium alloy) for the external fixation. It is hoped that we can suggest the most inexpensive but yet rigid fixation for the transverse tibial fractured patient.

METHODS

The 3D tibia model used was derived from Mesh Repository. The total length of the tibia was approximately 400 mm. To simulate a mechanical worst case situation for tibial fracture, an 11mm cortical deficiency in the shaft region was generated [1]. Additional mechanical support by the fibula was neglected due to the associated fibular fracture that frequently happens for such injury type.

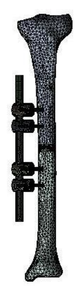

Figure 1: Finite element model of tibia.

The tibia model consists of cortical bone, trabecular bone, and fracture gap material with a lower stiffness. The fixator model is assembled using stainless steel rod, stainless steel clamps and stainless steel/titanium alloy pins (Figure 1). The fixator was attached anteromedially to the bone. The modeling process and finite element analysis were done using two softwares, Solidworks and Ansys. All materials were modeled as linear elastic, isotropic and homogenous (Table 1).

The finite element analysis was performed at an instant in gait with maximum muscle activity and high joint contact loading (45% of the whole gait cycle). To reflect this single instance in gait, an axial compressive force of 500 N was applied to the tibial plateau parallel to the long axis of the tibia [1]. The distal part of the tibia was fixed at three nodes to restrict rigid body motion [2]. Sixteen different FEA models were built. The von Mises stress in fixators, the von Mises stress along the pin-bone interfaces and interfragmentary strains in the gap were evaluated.

Table 1: Material properties.

Material	Young's Modulus (MPa)	Poisson's Ratio
Compact Bone	17,000	0.30
Trabecular Bone	700	0.20
Gap	5	0.45
Stainless Steel	200,000	0.30
Titanium Alloy	115,000	0.31

RESULTS AND DISCUSSION

The values of maximum von Mises stress occurs in all fixator models varies approximately from 190 to 225 MPa, which are below the material's yield strength. Thus, the fixators will not undergo failure. The values of maximum von Mises stresses occur along the pin-bone interfaces are also below the tensile strength of tibia (cortical) [3]. The bone will not undergo further mechanical damage at the area of the pin attachments when the static load was applied, thus sustains the fixation rigidity. The values of interfragmentary strains are approximately 33%, which is still considered as an acceptable value to undergo optimal fracture healing process [1].

From our result, it can be seen that by using titanium alloy as one of the pins, they do not significantly change the value of interfragmentary strains to a lower value than Model 1 (which consists of all four stainless steel pins). This concludes that the time taken for the fracture healing process will not be affected. By putting the titanium alloy pins into the bone, the maximum von Mises stresses along pin-bone interface seem to have higher values than Model 1. After several months of weight bearing, the fractured tibia will undergo cyclic loading. Based on the values from this instant of gait cycle, we predict that pin loosening might happen even though the resultant values are only one-third of the bones' tensile strength. Thus, achieving lower maximum von Mises stress has to be the main concern when considering real life application on the external fixator. Taking that into considerations, applying all four stainless steel pins will make the fixation more rigid. Thus, surgeons do not have to opt for titanium alloy pins.

REFERENCES

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