Anterior Knee Pain after Intramedullary Nailing of the Tibia: A Finite Element Study

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INTRODUCTION:
The potential causes of anterior knee pain after intramedullary (IM) nailing of the tibia are not completely understood. Knee pain usually begins several months after IM nailing of the tibia and nail removal does not always provide pain relief1. From more than 20 factors potentially associated with knee pain, only two factors are strongly correlated with knee pain: activity level 2,3,4 and size of the tibia5. Clinical studies suggest that the knee pain is activity-related in most patients and is exacerbated by kneeling. The current study tests the hypothesis that the entry hole resulted from tibial nailing could cause anterior knee pain by significantly altering the local strain distribution in the proximal tibia. Using the finite element method, this study explores the etiology of anterior knee pain after intramedullary nailing and examines the effects of standing, walking, and kneeling on a normal tibia model, a nailed tibia model and a tibia model with the IM nail removed.

METHODS:
One matched pair of fresh-frozen human cadaver tibias was obtained for this study. The left tibia was implanted with a 10mm, unlocked intramedullary nail (Trigen IM Nail Systems; Smith and Nephew, Memphis, TN). The surgery was performed under fluoroscopic visualization to ensure proper implant placement by the surgeon. The intact and the nailed tibias were CT scanned and geometric models were obtained through volumetric reconstruction from the scans. The FE model of the IM nail was derived from CT scans. Three finite element models were developed: a normal tibia, a nailed tibia and a tibia with the IM nail removed, as described in previous work6. The assignment of material properties to the models was based on CT data. The experimental validation of the tibia model was achieved by comparing experimental strain values and finite element data.

Three load cases, representing the most common loading configurations on the tibia, were applied to each tibial model: standing, walking and single-limb kneeling. To simulate standing, the finite element models were totally constrained distally and loaded to the tibial plateau in compression with 2000N, 50% medial and 50% lateral. To simulate the effect of walking on a tibia, the models were totally constrained distally and loaded in compression with 2000N, 60% medial and 40% lateral. The single-limb kneeling activity was simulated by constraining the models distally and at the tibial tuberosity. The models were subjected to a quadriceps force (276N), a ground force for an average body weight of 70 Kg (687N) and two small contact forces in the femorotibial contact region (2x206N).

RESULTS:
The strain values recorded for the tibia with the IM nail removed for simulated walking were 30% greater than the strain values recorded for standing. The strain values around the hole for simulated walking were considerably greater than the values recorded for standing for all three tibia models considered.

The strain values recorded for the tibia with the IM nail remove in single-limb kneeling were 50% greater than the values recorded for the intact tibia. The analysis of the tibia model with a removed intramedullary nail showed a higher strain concentration and increased strain values around the hole when compared to the values obtained from the intact tibia model for all the loading configurations considered. The presence of the nail in single-limb kneeling caused a three-fold increase in strain near the entry hole when compared with the tibia with the nail removed and a five-fold increase in strain near the entry hole when compared with the intact tibia. The analysis of the nailed tibia model revealed a significant increase in strain values around the hole for standing, walking and single limb kneeling.

Figure 2. Kneeling: maximum principal strains distribution for an intact tibia (A), tibia with the nail removed (B) and tibia with an IM nail (C).

DISCUSSION:
The hypothesis of the current study was that the entry hole resulted from tibial nailing could cause anterior knee pain by significantly altering the local stress and strain distribution. The strain values recorded for the tibia with the nail removed in single-limb kneeling were significantly greater than the values recorded for the intact tibia. Strain values recorded around the hole for the tibia with the nail removed were higher than the strain values for the intact tibia for all the loading configurations considered. For each load case, the highest principal strain values were found in the nailed tibia model. Removing the nail does not reduce the strain to normal values encountered in an intact tibia. More work is required to determine other critical factors and to explore new treatments.

REFERENCES:

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