Anterior Knee Pain after Intramedullary Nailing of the Tibia
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Introduction: Although numerous studies have proposed possible causes of knee pain after intramedullary nailing of tibial shaft fractures, the definitive cause of pain remains very controversial. The presence of the nail was considered an obvious factor of knee pain. However, a large number of patients who required nail removal to control the pain, did not show pain relief after the procedure (1). From more than 20 factors potentially associated with knee pain, research shows that only two factors are linked with knee pain: the size of the tibia (2) and activity level (3). No previous studies have assessed whether the presence of the intramedullary hole resulting from nail insertion could trigger knee pain. This study tests the hypothesis that the entry hole following tibial nailing could trigger pain, based on the assumption that bone fracture typically causes severe pain and significantly alters the local stress distribution (4).

Materials and Methods: This study used one matched pair of fresh-frozen human cadaveric tibiae. A 12 mm entry reamer was used to create the insertion site. The left tibia was stabilized with a 10 mm intramedullary nail (Trigen IM Nail System; Smith and Nephew, Memphis, TN). CT images were obtained from scanning both the normal and the nailed tibia at 2.5mm transverse intervals resulting in 177 slices. Solid models of the human tibia were reconstructed from CT data using Simpleware software (Simpleware Ltd, Exeter, UK). The resulting models were meshed with a tetrahedral mesh and converted to 3D finite element models. The assignment of bone material properties to finite element models was based on CT data. Three finite element models, a normal tibia model, a nailed tibia and a reamed tibia without a nail, were generated and analyzed using ANSYS finite element analysis package (ANSYS Inc, Canonsburg, PA, USA). A convergence study was performed to determine the accuracy of the numerical models. Several FE meshes, from coarse to a very refined mesh with increased degrees of freedom were created. For the current models, a refined mesh with an average element size of 3mm was selected.

In the first phase of the project, computational stress and strain finite element analyses were performed on all models by applying two compressive forces of 1000N each on the lateral and medial tibial plateau, to simulate walking loads. Models were totally constrained at the distal tibia and maximum and minimum principal strains were evaluated around the nail entrance zone. In the second phase, experimental strain gage analyses and mechanical testing (MTS 858 Bionix Test System, MTS System Corp., Minneapolis, MN, USA) will be performed on one large and one small tibia pair to investigate the differences in stress and strain distribution for intramedullary nailing between smaller and larger tibial plateau geometries and to validate the finite element models.

Results: Geometrically accurate three-dimensional models of a nailed and normal human tibia were developed from CT images. The analysis of the normal tibia model reveal higher stress and strain values in the distal third of the tibia compared with the rest of the model. The values recorded near the “nail entrance” zone for the normal tibia model were in the “naturally permissible strains region” (1000–2000 microstrains) (5). The analysis of the tibia model with a removed intramedullary nail showed a higher strain concentration and twice the maximum principal strain around the hole when compared to the values obtained from the normal tibia model.

Discussion: The hypothesis of the current study was that the insertion hole following tibial intramedullary nailing could cause severe pain and significantly alter the local stress and strain distribution. The preliminary findings of this study reveal the considerable differences in stress and strain distribution between a normal tibia and a tibia with intramedullary hole resulting from IM nail removal. Furthermore, the results emphasize the importance of considering the modified mechanical loading and the altered local stress and strain distribution following intramedullary tibial nailing.