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Mechanical Model of Orthopaedic Drilling for Augmented-Haptics-Based Training

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Abstract

In this study, augmented-haptic feedback is used to combine a physical object with virtual elements in order to simulate anatomic variability in bone. This requires generating levels of force/torque consistent with clinical bone drilling, which exceed the capabilities of commercially available haptic devices. Accurate total force generation is facilitated by a predictive model of axial force during simulated orthopaedic drilling. This model is informed by kinematic data collected while drilling into synthetic bone samples using an instrumented linkage attached to the orthopaedic drill. Axial force is measured using a force sensor incorporated into the bone fixture. A nonlinear function, relating force to axial position and velocity, was used to fit the data. The normalized root-mean-square error (RMSE) of forces predicted by the model compared to those measured experimentally was 0.11 N across various bones with significant differences in geometry and density. This suggests that a predictive model can be used to capture relevant variations in the thickness and hardness of cortical and cancellous bone. The practical performance of this approach is measured using the Phantom Premium haptic device, with some required customizations.

Keywords: bone drilling; skill assessment; augmented haptics; orthopaedics; virtual reality; model prediction; force model

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