Finite Element Simulation of the MRTA Test of a Human Tibia

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INTRODUCTION: Mechanical Response Tissue Analyzer (MRTA) is an inexpensive and portable device that quantitatively tests long bone strength through low frequency, low amplitude vibration (Fig. 1). Measurement of complex stiffness against frequency offers a wealth of information on the material and structural composition of the bone. However, previous interpretation has focused on determining bending stiffness (EI)[1]. As a first step towards a more general interpretation of the MRTA results, we present here the first FE simulation of the MRTA.

METHODS & MATERIALS: We created our tibia from the *CT_Fronzen_TIBIA_DX_R1* solid model downloaded from the BEL repository[2]. We imported this into PATRAN and created a mesh of the cortex using 2760 linear hexagonal elements. We meshed the epiphyses into 8228 linear tetrahedral elements. The final 3D mesh had 16,527 degrees of freedom (Figure 2). We assigned material properties for cortical bone of E = 17.0 GPa, ν=0.33, ρ = 1.85 g/cm^3 and cancellous bone of E = 445 MPa and ρ = 0.29 g/cm. To observe the effects of viscoelasticity, we applied frequency-dependent loss and storage values shear moduli for human tibia cortical bone[3,4]. To simulate the low frequency, low amplitude MRTA vibration, we applied a direct-steady state dynamics (DSSD) procedure using ABAQUS V6.5. We applied a concentrated force of 10 N over the range of 40 to 500 Hz at the midshaft of the tibial crest. ABAQUS calculated real stiffness (N/m) responses which we compared to an experimental MRTA stiffness response for a human tibia of similar length. To determine the effects of different aspects of the model, we examined tibial models of increasing complexity. These are a solid tibia of cortical bone with no medullary canal (Model A), the addition of a medullary canal (Model B), the addition of distinct cancellous bone properties for the epiphyses (Model C) and finally, with viscoelastic properties for the cortical bone tissue (Model D).

RESULTS & DISCUSSION: All models roughly matched the peak frequency seen in the MRTA (Figure 3). The addition of the medullary canal, as well as treating the epiphyses as cancellous bone shifted the peak to a higher frequency and broadened the distance from minimum to maximum response. The addition of viscoelastic material response shifted the peak frequency lower. These preliminary results demonstrate the ability to simulate MRTA response, and provide an initial model which can be expanded upon for continuing studies.

REFERENCES:

1. Roberts SC, Hutchinson TC, Arnaud SB, Kiratli BJ, Martins RB, Steele CR, *J. Biomechanics* Vol. 29 (1) pp: 91-98 (1996)
2. Viceconti, M, *International Congress on Computational Bioengineering*, M. Doblaré, et al, Eds., Zaragoza, Sept. 24-26, (2003); and http://www.tecno.ior.it/VRLAB/researchers/repository/BEL_repository.html
3. Lakes, RS, *J. Biomech. Eng.* Vol. 104 pp:6-11 (1982)
4. Garner E, Lakes R, Lee T, Swan C, Brand R., *J. Biomech. Eng.* Vol. 122 pp:166-172 (2000)

Figure 1. The MRTA device.

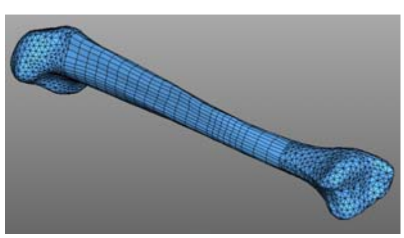

Figure 2. The FE Mesh of the tibia.

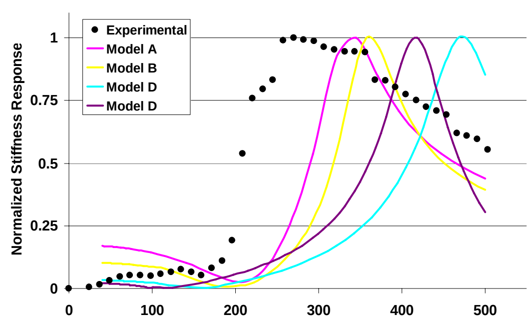

Figure 3. Results of simulation compared to experiment.