Virtual Mechanical Testing for Non-Destructive Assessment of Bone Regeneration in Large Ovine Tibial Defects

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INTRODUCTION

Virtual mechanical testing is a non-destructive image-based approach to evaluating bone healing that preserves the sample for other analyses.

PREVIOUS WORK

Previously, we developed and validated the computational methods for measuring the virtual torsional rigidity (VTR) of intact and healing ovine osteotomies \(^1\). For small defects (3 mm) and moderately large (17 mm) defects with autograft, we demonstrated that the virtual torsion tests are a reliable surrogate for destructive and labor-intensive physical biomechanical tests in ovine surgical models that progress to union within 9-12 weeks.

OBJECTIVE

The goal of this study was to assess the validity of virtual torsion tests in an independent dataset with a large-defect limb salvage model that heals much more slowly. Our **hypothesis** was that virtual torsional rigidity (VTR) is strongly correlated with the torsional rigidity measured in physical biomechanical testing.

RESULTS AND DISCUSSION

**IN VIVO IMAGING DATA**

Thirty-four sheep had 30-mm tibial ostectomies stabilized by external fixators with two different resorbable graft containment systems. **In vivo** CT scanning was performed at intervals of 4 weeks up to euthanasia at 18 weeks post-op. In both groups of 17 sheep, 12 animals were used for postmortem torsion testing and 5 were reserved for histology.

**METHODOLOGY**

Virtual torsion tests were performed using ANSYS (2020 R2) by rigidly fixing the distal end of the tibia and applying a 1° rotation through the bone’s long axis on its proximal end. Torsional rigidities for the physical tests (GJ) were determined by dividing the inertial bending moment (M) by the corresponding gauge length (L).

**VIRTUAL TORSION TESTS**

Virtual torsional rigidity (VTR) and torsional rigidity determined from physical tests (GJ) had no significant difference between means (p = 0.350). VTR and GJ were strongly and significantly correlated, and the linear slope approached unity (slope = 1.014) indicating high absolute agreement.

**CONCLUSIONS**

The results of this study demonstrate that the virtual torsion test is a robust methodology that is adept at evaluating the healing progress of a bone regardless of surgical techniques, sample types, and other experimental characteristics. Compared to the previous validation study, the dataset utilized in this investigation had lower resolution scans and had larger defects. Despite these differences, strong agreement was observed between physical and virtual torsional rigidities. This suggests that virtual mechanical testing is a valid and reliable surrogate for physical mechanical tests and can be used to expand the available data.

**MORE INFO**

Representative slice views demonstrate a wide range of healing in the dataset as seen by the range of values of E, indicative of callus development throughout healed tibiae.

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\(^1\) Schwartzberg et al., J Orthop Res. 38(4), 727-738 (2021)