

Biomechanical Analysis of Screw Fixation in Cortical Bone Following Therapeutic Levels of X-Irradiation

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INTRODUCTION:

Treatment of impending or acute fractures in orthopedic oncology patients often requires screw fixation in host bone which has been subjected to radiation. Fixation in these settings raise unique biological and mechanical considerations. Application of therapeutic levels of x-irradiation (20 Gy) results in cortical bone embrittlement (with immediate/direct changes in bone matrix), but it is not clear how this might affect screw fixation. The goal of this study was to determine if direct irradiation would substantially reduce robustness of screw fixation in using a preclinical rat femur model.

METHODS:

Right femurs from fresh-frozen cadaveric feeder rats (n=14) were irradiated ex vivo with a single 20 Gy dose of x-irradiation. Left femurs served as non-irradiated controls. Bicortical fixation with 1.2-mm stainless steel machine screws was evaluated using tensile loading to failure (Figure 1) in a mechanical test frame. MicroCT imaging was used to quantify screw-bone contact area. Peak shear stress (force/contact area), screw-bone shear stiffness, and energy to failure were calculated and evaluated for the two groups using paired t-tests.

RESULTS:

A single dose of 20 Gy irradiation reduced the energy to failure by a factor of two (p=0.02, Table 1). A smaller 18% reduction in peak shear stress (p=0.13) and 30% increased shear stiffness (p=0.17) was found with 20Gy irradiation.

DISCUSSION AND CONCLUSION:

Therapeutic levels of irradiation reduced the quality of screw fixation in cortical bone in this preclinical rat femur model. Bone embrittlement with irradiation has been shown to diminish the normal toughening mechanisms in cortical bone (e.g. reduced ability to absorb high stress without crack growth); this appears to be manifested here in less total energy required to cause screw pullout and reduced shear strength. In vivo changes following irradiation were not included in this model but should be explored further.

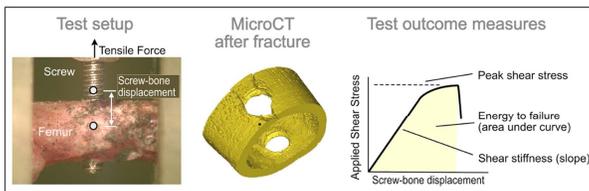


Figure 1. Test setup for screw pullout, microCT illustrating screw-bone fracture pattern, and outcome measures from pullout test.

	Energy to failure (MPa-mm) (p = 0.02)	Shear stiffness (MPa/mm) (p = 0.17)	Peak shear stress (MPa) (p = 0.14)
Control femur	0.59 (0.44)	402.2 (313.8)	11.5 (3.9)
Irradiated femur	0.25 (0.21)	524.8 (200.8)	9.4 (2.2)
% Change from control femur	-57.6 %	30.4 %	-18.2 %

Table 1. Energy to failure (MPa-mm), shear stiffness (MPa/mm), and peak shear stress (MPa) of screw pullout in control and 20 Gy irradiated femurs. Results from paired t-test, mean and standard deviation shown.