Introduction

Microgravity affects bone mineral density, microstructure and integrity, which lead to the risk of osteoporosis and fracture, as well as nonunion. Quantitative ultrasound (QUS) imaging has been demonstrated its ability to quantify bone mass [1-3] and to provide acceleration of fracture healing, as the mechanism of mechanobiology. The objective of this study was to test a QUS guided ultrasound in acceleration of fracture healing in a hindlimb suspension (HLS) model.

Methods

Guided QUS for Fracture Healing: The experimental protocol is approved by Stony Brook University IACUC. Total of 36, 5-month old Sprague-Dawley rats were divided into six groups including 1) fracture control (FC, n=12), 2) fracture with HLS (FS, n=12), and 3) fracture with HLS, plus QUS treatment (FSU, n=12). To simulate a microgravity condition, standard fractures were performed at the middle of left femur of each animal, with HLS. K-Wire (Ti) was applied to the rat’s femur from its knee condyle for stabilization [4]. Guided QUS was delivered transversally at the femur. 20 min/day, 5 days/wk for 5 weeks. Hindlimb bones were longitudinally imaged using µCT at 18 µm at week 1, 3, and 5, and evaluated for bone volume fraction (BVF) and bone volume (BV) in the callus. Mechanical testing was performed after sacrifice.

Results

QUS indicated sensitivity to identify fracture in the rat femur (Fig. 1) with resolution of 0.5mm. The SCAN image is able to identify the region of interests even in the bone under 3mm in diameter of the cross section (Fig. 1). In the week 1 and 3, there were no significant difference between control and HLS, and between QUS treated and untreated. However, in week 5, BVF in fracture with HLS (0.19±0.05) showed -6% lower than normal fracture (0.21±0.05), while QUS treated (0.27±0.06) was 30% increase than the fracture control (p<0.05) (Fig. 2). In the 4-pt bending biomechanical testing, there was no significant difference between normal fracture and fracture with HLS. However, the bone stiffness in QUS treated fracture in HLS was 48% higher than untreated HLS fracture (p<0.05) (Fig. 3).

Discussion

QUS has shown its capability to sense subtle changes in bone in the longitudinal BMD alteration. This can provide useful information for assessment of complications, such as non-union fracture. With current techniques yielding only qualitative results, ultrasound could prove to be the keystone that allows us to properly diagnose bone interdisposition. The disuse hind limb suspension indeed delayed the healing, e.g., in 5 weeks. This delay is predicted to extend to the remodeling phase. Guided ultrasound treatment develops the best callus mineralization quality, which is over 48% better than normal and HLS groups, indicating QUS can enhance healing under disuse condition, and promote the bone mineralization. Guided ultrasound is also capable to mitigate bone loss and promote healing in the identified region, which may provide early and targeted treatment for bone loss and fracture.

Acknowledgement

Supported by NSBRI through NASA Cooperative Agreement NCC 9-58, NIH, and NYSTAR.

References