THE CONTRIBUTION OF LOWER-MINERALIZED TISSUE TO THE STRENGTH OF FRACTURED DISTAL RADII DURING HEALING

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Introduction

Distal radius fractures are common fractures in the elderly population [1]. Complications of these fractures are frequent [2]. A first step towards better outcomes is a thorough understanding of the healing process.

High-resolution peripheral quantitative CT (HR-pQCT) enables *in-vivo* assessment of distal radius fracture healing at the microscale [3]. In previous studies using HR-pQCT, low-mineralized tissue was observed at the fracture region starting at three weeks post-fracture and tended to remodel into mature bone later [3]. This tissue was not included in quantitative assessments of the healing process as standard density thresholds were used for segmentation of the fractured radii from the scans. Resultingly, the contribution of this lower-mineralized tissue to the healing process is unknown.

The aim of this study was to quantity the contribution of lower-mineralized tissue to the stiffness of the fracture region of distal radius fractures during healing using a dual-threshold approach.

Methods

HR-pQCT scans were available of a 20.4-mm region of the fractured distal radius of 48 postmenopausal women with a conservatively-treated fracture, acquired at 1-2, 3-4, 6-8, and 12 weeks post-fracture.

Two series of micro-finite element (µFE-) models were created from the scans by voxel-to-element conversion: 1) a series based on a single density threshold of 320 mg HA/cm^3 for segmentation; 2) a series based on a dual-threshold segmentation approach. In this approach, first the bone was segmented at a threshold of 200 mg HA/cm^3, followed by erosion of one voxel to remove voxels included due to partial volume effects. The resulting model was then combined with the first series of models to obtain a series that differentiates between higher-mineralized (>320 mg HA/cm^3) and lower-mineralized (200-320 mg HA/cm^3) bone. A Young's Modulus of 10 GPa and 5 GPa were assigned to the µFE-elements that represented the higher- and lower-mineralized tissue, respectively. An axial compression to 1% strain was simulated, from which stiffness of the single-threshold (S_{single}) and dual-threshold (S_{dual}) models were obtained.

Linear mixed effects models were used to quantify the changes in S_{single}, S_{dual}, and their ratio during healing.

Results

S_{dual} gradually increased over time to a significant difference from the first visit at 6-8 and 12 weeks post-fracture (Fig. 1; top). The ratio S_{dual}/S_{single} - reflecting the contribution of lower-mineralized tissue to stiffness - was significantly higher at 3-4 weeks compared to the first visit and was no longer significantly different at 12 weeks (Fig. 1; bottom).

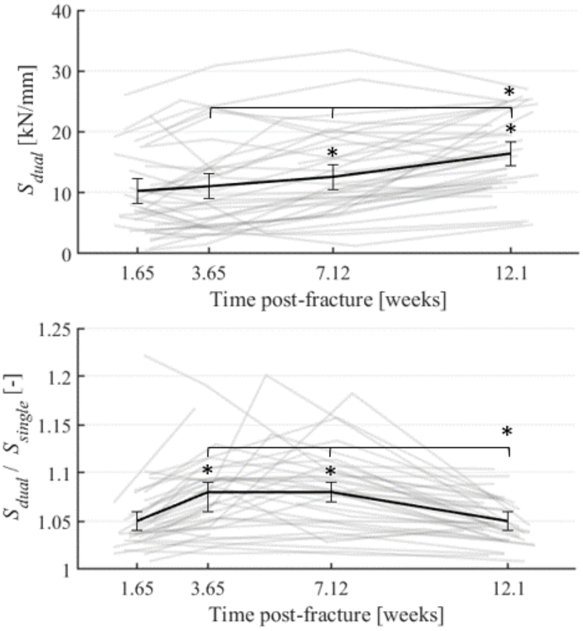

*Fig. 1: Changes during healing in stiffness of the dual-threshold model (top) and in the ratio of the dual- and single-threshold stiffness (bottom). The grey lines are individual results, the black lines estimated marginal means with 95%-confidence intervals (*p<0.05).*

Discussion

Dual-threshold segmentation enables quantification of the contribution of lower-mineralized tissue to the healing of distal radius fractures. This tissue forms after the first weeks of healing and may help in the initial stabilization of the fracture. Its contribution to stiffness varied considerably among individuals and may indicate differences in fracture severity. Quantification of the contribution may help to improve our understanding of the healing of distal radius fractures.

References

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2. McKay SD et al, J Hand Surg, 26:916:922, 2001.
3. De Jong JJA et al, Bone, 64:65-74, 2014.