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Investigation, Modeling, and Reconstruction of the Tendon-to-Bone Insertion

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Introduction and Background

Current Knowledge

- Tendon-bone insertion tissue is structurally and functionally graded to alleviate stress concentration from soft tendon to hard bone
- Gradation in microstructure is not recreated in a healing insertion as in a native tissue

Current Limitations

- There is insufficient understanding of tissue microstructure and the property governing regeneration and repair post injury
- There is no comprehensive, three-dimensional mathematical model that may be used for modeling the insertion tissue

Objectives and Approaches

- Utilize an emerging, high-resolution cross-sectional imaging technique, cone-beam computed tomography, to obtain tissue information
- Varied scan parameters used to obtain pixel values for tendon and bone; values compared for accuracy
- Image slices obtained from reconstructions pieced together in ImageJ to create 3D rendering of tissue

Methods and Results

Imaging and Scanning

- Imaging and scanning was performed using digital flexor tendon-bone units procured from the local abattoir (Nahunta Pork Center, Pikeville, NC) immediately after slaughtering.
- Tendon-to-bone connections were dissected from the two middle digits on the pigs' feet immediately after obtaining the feet. Sample was immediately chemically fixed and critical point dried before imaging and scanning.
- Imaging was done using cone-beam computed tomography (Xradia 510 Versa, Zeiss, Germany) (**Fig. 1**). Various combinations of scanning parameters, such as voltages, filters, binning sections, detector locations, and beam hardening coefficients (for reconstruction) were used during scanning.

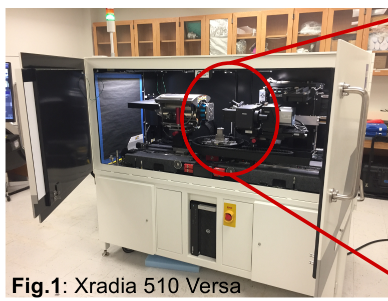

Fig.1: Xradia 510 Versa

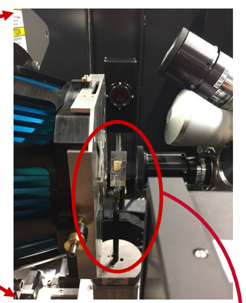

Fig. 2: Sample Setup in Xradia Versa 510.

Xradia 510 Specifications:

High Spatial Resolution
< 0.7 μm resolution

Wide Range of X-ray voltages, setups
30-160 kV,12 filters for energy selection

Contrast-optimized Detectors
2k x 2k pixel, noise suppressed charge-coupled detector

Vibrational isolation, thermal stabilization

Fig. 3: Mounted tissue, Scotch tape applied to both sides of tissue and was mounted in pin via a sample holder (**Fig. 3**).

Results and Discussion

Pixel Values

- Regions of interest (ROI) were drawn on each image slice of scan reconstructions. Pixel values within region were analyzed using ImageJ (National Institutes of Health, Maryland, USA) (**Fig. 4**).
- Mean pixel values for different sets of scan parameters taken, plotted on same axes (**Fig. 5**).

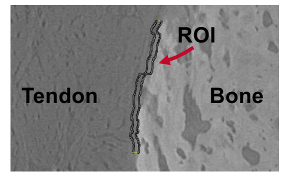

Fig. 4: Single region of interest of tendon-bone insertion

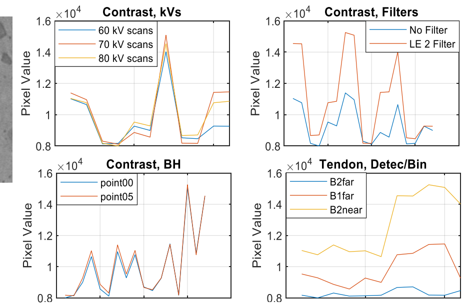

Fig. 5: Mean Pixel Values Versus Sets of Parameters

Statistical Analyses:

- Statistical significance were found (**Fig. 6**).
- Significance values were listed in **Table 1**.

Future work investigates the construction of finite element models of this tissue and the impact of these results on generation of these models.

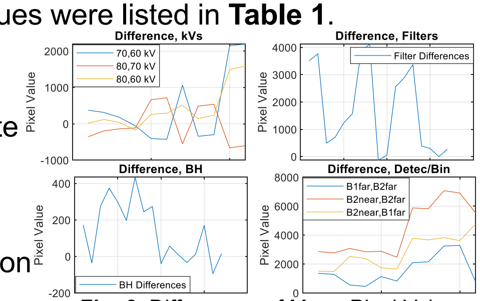

Fig. 6: Differences of Mean Pixel Values

Table 1: Tabulated Significance Values

Differing Parameters	Tendon, p-value	Bone, p-value	Difference, p-value
60 kV, 70kV	0.0916	0.0679	0.1584
60 kV, 80 kV	0.5176	0.2769	0.0258+
70 kV, 80 kV	0.0071+	0.0046+	0.9113
No Filter, LE2 Filter	$3.0854 * 10^{-4}$+	0.6101	$1.7696 * 10^{-5}$+
Beam Hardening Coefficients	0.0058+	0.6478	$7.2714 * 10^{-4}$+
B2far, B1far	$1.2346 * 10^{-13}$+	0.0309+	$8.8824 * 10^{-7}$+
B2far, B2near	$1.4189 * 10^{-14}$+	0.4790	$6.9290 * 10^{-14}$+
B1far, B2near	0.0345+	0.0908	$1.3424 * 10^{-14}$+

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