Introduction

Suture anchors are designed to fix soft tissues, such as tendons and ligaments, to bone. Researchers have attempted to link the properties of bone to suture anchor pullout strength. Tingart et al. focused on regional variability using computed tomography (CT), and showed correlation of increased pullout strength in areas of higher BMD.\(^1\) Meyer et al. showed a linear relationship between pullout strength of an Arthrex BioCorkscrew and a custom PLA implant to BMD measured by micro-CT (µCT) with a 78 µm resolution.\(^2\)

A complete characterization of bone microstructure can be achieved with µCT; however, to the best of the authors’ knowledge, has not been examined in regards to suture anchor pullout strength. Using high resolution scans, morphological parameters such as trabecular spacing and thickness can accurately be quantified and compared in conjunction with BMD. Therefore, the purpose of this study was to investigate how these microstructural properties influenced suture anchor performance.

Methods

Five fresh-frozen human humeri (range of 75-84 years) were received and tested. In order to perform testing in only trabecular bone, the cortical layer was removed using a burring tool.

Pullout tests were performed on an Instron 5567 universal testing machine. A self-tapping 5mm Arthrex Corkscrew metal anchor was threaded with sutures (standard USP #2) and inserted normal and flush to the surface of one of five testing sites on the humerus in the greater tuberosity, lesser tuberosity, or humeral head. The humerus was secured onto a custom mount and aligned so that the crosshead pulled along the axis of the anchor and normal to the bone surface. Pullout tests were performed with a preload of 1N and crosshead speed of 1 mm/sec.

After completion of the pullout tests, the humerus was cut at the surgical neck and right below the humeral head. A custom made punch with a 5mm diameter and length of 40mm was inserted adjacent to the testing sites. After extraction, the sample was cut to 10 mm length and analyzed using µCT. Trabecular bone samples were scanned using a µCT 40 (Scanco Medical, Bruttisellen, Switzerland). Scan settings used were E = 55kVp, I = 145µA, integration time = 300ms, 12µm isotropic voxel size. Morphometric parameters, including BMD, average trabecular thickness, spacing, number, and structural model index (SMI) was performed using direct distance transformation methods.\(^3\) Figure 1 is an example of four µCT scans.

Results

All anchors tested failed due to pullout. A summary of the statistical analysis can be seen in Table 1. Three of the microstructural properties (BMD, SMI, and trabecular thickness) showed positive linear correlations to pullout strength with 99% confidence. The highest correlation was to SMI, which is a measure of the plane- or rod-like characteristics of the trabeculae (0 being rod-like and 3 being plate-like). The remaining parameters (trabecular spacing, trabecular number, and connectivity density) were not correlated to pullout strength.

The 3 significantly influential microstructural parameters were analyzed to create a multi-variant predictive model. Pullout strength was modeled by the equation:

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\text{Pullout Strength} = a_0 \cdot \text{BMD} - b_0 \cdot \text{SMI} + c_0 \cdot \text{TbTh}
\]

Discussion

The relationship of true trabecular microstructure and suture anchor pullout strength has several important clinical applications. First, it provides the clinician with the opportunity to understand fixation failure by understanding the relationship of trabecular microstructure to strength of suture anchor fixation. Furthermore, it may lead to the development of improved fixation devices that incorporate trabecular microstructure fixation into their design. The utilization of µCT allows for a more complete understanding of osteopenic bone microstructure and will help to guide not only implant design, but also surgeon selection of implant location on the anatomic footprint of the rotator cuff. The study showed that pullout strength is highest in bone with a higher BMD, thicker trabeculae, and more plate-like structure.

The limitations of this study should be noted. This study did not take into account the presence of the cortical layer, which was removed before testing began. The presence of a cortical layer will increase the pullout strength of suture anchors. However, removal of the layer allowed the effect of microstructural parameters to be directly compared to one another. Second, the pullout testing sites were taken adjacent to the sites taken for µCT analysis and do not account for small regional variations in the testing locations. Due to sampling size limitations of the µCT machine, the entire humeral head could not have been scanned to the desired resolution. CT could have been performed on the entire humeral head to check for any abnormal regional variability in the testing locations.

References