Graft Elongation Occurs Beyond Intraoperative Dimensions after Arthroscopic Superior Capsular Reconstruction: An In Vivo Analysis

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INTRODUCTION: Patients with irreparable rotator cuff tears (RCT) exhibit functional limitations believed to be caused by superior migration of the humerus[1]. One viable treatment is superior capsule reconstruction (SCR). SCR has been shown to restore superior translational stability of the glenohumeral (GH) joint in cadavers[1], but recent *in vivo* work found a small increase in superior translation one year after surgery[2]. *In vivo* behavior of the SCR graft remains unclear. The aim of this study was to determine if the graft elongates after SCR and if graft elongation is related to graft healing.

METHODS: Ten patients with irreparable RCT provided informed consent prior to participating in this IRB approved study. Patients were tested before (PRE) and one year after (1YR-POST) dermal allograft SCR. Synchronized biplane radiographs of the shoulder were collected PRE and 1YR-POST at 50 frames/s while patients performed 3 trials of scapular plane abduction of the arm. Six degree of freedom GH and scapular kinematics were determined with sub-millimeter accuracy by matching subject-specific CT-based bone models of the humerus and scapula to radiographs using a validated volumetric tracking technique[3] (Figure 1A). Intraop graft lengths were recorded from surgical notes. T2 fat suppressed MRIs were acquired 1YR-POST to evaluate whether the graft was healed at the four anchor locations as well as to locate where the glenoid and humeral anchors were placed. A custom program was used to determine graft length between the anterior and posterior glenoid anchors and their respective humeral anchors during abduction (Figure 1B). Graft lengths were then averaged across trials at corresponding angles of GH abduction. Graft elongation was calculated as the change in length from intraop divided by the intraop length. Differences between the abduction angle at which the graft reached the intraop length in healed and not healed grafts were evaluated using a Mann-Whitney U test. Differences in the rate of graft lengthening between anterior and posterior regions were compared with a Wilcoxon signed-rank test. Significance was set at $p < 0.05$ for all tests.

RESULTS: All SCR grafts elongated beyond their intraop length. During the abduction movement, the anterior portion of the graft elongated to 31.3mm to 60.9mm, which corresponded to a 32% to 340% increase in length compared to the intraop length, while the posterior portion of the graft elongated to 19.6mm to 51.1mm, which corresponded to a 24% to 118% increase in length compared to the intraop length. On average, elongation occurred when the GH abduction was less than 66° of abduction (Figure 2) while graft shortening occurred at GH abduction angles greater than 66° of abduction. Grafts that were healed at both anterior anchors reached the intraop length at lower abduction angles than grafts that were not healed at one or both of the anterior anchors ($p = 0.02$, Figure 3), but healing did not affect posterior region elongation ($p = 0.42$). The anterior portion of the graft decreased 0.4±0.1mm for every degree of abduction while the posterior portion of the graft decreased 0.3±0.2mm per degree of abduction (Figure 2) ($p = 0.09$).

DISCUSSION AND CONCLUSION: The main finding of this study was that the graft used in SCR is stretched well beyond its intraop length during abduction, and the elongation occurs, on average, at GH abduction angles less than 66°. Concurrently, this meant the graft was shorter than its intraop length at GH abduction angles greater than 66°, suggesting the graft may not be exerting force on the GH joint beyond this point. The effects of elongation on the mechanical function of the graft remain unclear. A secondary finding was that grafts that were healed became slack at lower abduction angles than grafts that were not healed. These findings suggest the SCR graft elongates substantially after surgery and that graft healing and graft elongation may be associated. However, the time-course of SCR graft elongation after surgery remains unclear.

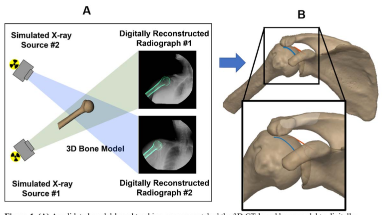

Figure 1. (A) A validated model-based tracking process matched the 3D CT-based bone model to digitally reconstruction radiographs to generate **(B)** 3D glenohumeral kinematics. Anterior (blue) and posterior (red) graft lengths were then determined based upon graft anchor locations.

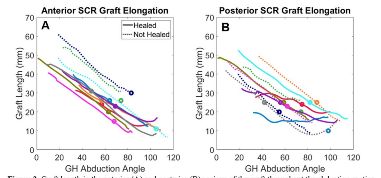

Figure 2. Graft length in the anterior (A) and posterior (B) regions of the graft throughout the abduction motion. Solid lines indicate complete healing at both anchors, while dashed lines represent incomplete healing. Each color corresponds to the same subject for anterior and posterior regions of the graft. Circles indicate the intra-op length. The graft is longer than the intra-op length at all data points to the left of the circle, and the graft is shorter than the intra-op length at all data points to the right of the circle.

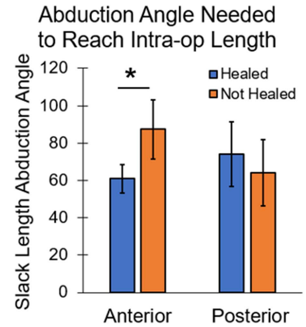

Figure 3. Abduction angle needed to reach intra-op length in both healed and not healed grafts. Error bars represent ±1SD. Asterisk represent significant differences between healed and not healed grafts.