

Medial Advancement of Infrapinatus Insertion via Remplissage Improves Shoulder Anterior Stability but Reduces Moment Arm in the Abduction and External Rotation Position: A Computational Study

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INTRODUCTION: The remplissage procedure has been rapidly adopted in clinical practice as emerging evidence continues to demonstrate decreased recurrent instability when it is added to an arthroscopic soft tissue shoulder stabilization. Despite its widespread use, the mechanism of its efficacy and potential biomechanical drawbacks have not been elucidated. We hypothesize that medial advancement of the infrapinatus during this procedure (Figure 1) increases the posteriorly directed component of the infrapinatus' force vector on the humeral head, providing stabilization, while concurrently reducing its external rotation moment arm in the abduction and external rotation (ABER) position.

METHODS: Sixteen shoulders (13 males, 3 females; 9 right, 7 left; age 25.8 ± 7.0 years) with Hill-Sachs lesions were computationally modeled using ArtiSynth software. To capture the infrapinatus muscle-tendon's line of action, four groups of muscle fibers were modelled with identical origin points at the scapula but varying insertion sites on the humeral head: the native insertion, the lateral border, the middle valley, and the medial border of the Hill-Sachs lesion—representing progressive medial advancement (Figure 1). Fiber wrapping around the humeral head and scapula was simulated during shoulder abduction and external rotation. From these simulations, the effective force vector exerted on the humeral head was extracted. Posterior force component, abduction and external rotation moment arms, and maximum external rotation in abduction (defined as the angle at which the average external rotation moment arm reaches zero) were calculated and compared across the four groups using one-way repeated measures ANOVA.

RESULTS: Average medialized distances were 11.3 ± 3.8 mm, 18.0 ± 3.8 mm and 23.8 ± 3.9 for the lateral, middle and medial groups, respectively. There was significant effect of insertion site location on all three variables of interest (all $F(3,45) > 49.5$, $p < .001$). Post-hoc Bonferroni-corrected comparisons showed significant differences between all group pairs (all $p < .05$). As shown in Figure 2, medial advancement significantly increased the posterior force component (native: -0.095 ± 0.049 ; medial: 0.447 ± 0.227). However, it reduced external rotation moment arm (native: 15.4 ± 2.6 mm; medial: -6.2 ± 6.9 mm) and abduction moment arm (native: 13.4 ± 2.7 mm; medial: -7.7 ± 7.8 mm). Linear regression analysis showed that each millimeter of medialization was associated with 5.79% reduction in external rotation moment arm ($R^2=0.870$).

DISCUSSION: Our findings support the hypothesis: medial advancement of the infrapinatus into a Hill-Sachs lesion increases the posterior force vector; but decreases the external rotation moment arm, specifically with the shoulder in the ABER position. Incorporation of the infrapinatus within remplissage fixation therefore may increase stability, while weakening external rotation in this position. These changes are amplified with greater medialization, offering some mechanistic explanation for the clinical observations of fewer instability recurrences and reduced external rotation [1].

CLINICAL RELEVANCE: This study highlights a biomechanical trade-off in remplissage: while medial advancement improves anterior stability, it may impair shoulder function in positions critical for athletic performance. Understanding this balance can inform surgical decision-making and patient-specific treatment planning.

REFERENCE: [1] Ding Z et al. Am J Sports Med 2020, 48(11):2628-2637.

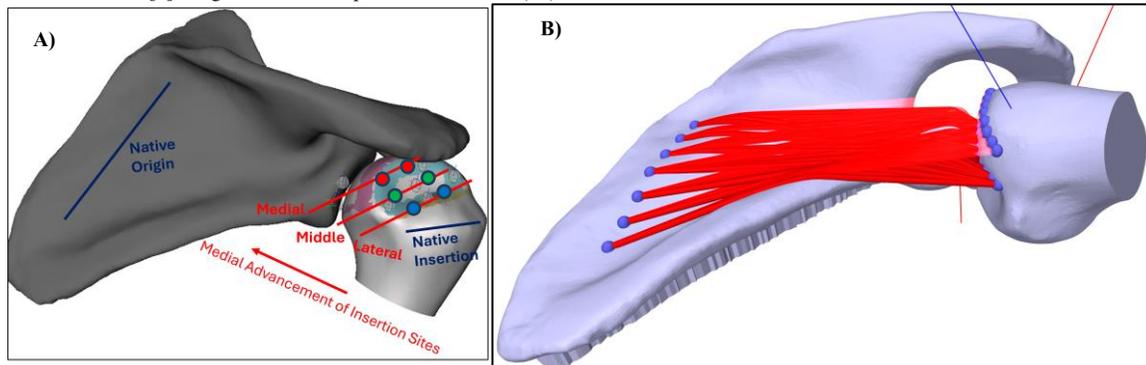


Figure 1. Diagram illustrating that when the two anchors (circular dots) are placed at the lateral border, middle valley, or medial border of the Hill-Sachs lesion during the remplissage procedure, the infrapinatus tendon insertion is correspondingly medialized to that same location (A). Fiber wrapping simulations were performed for both the native (transparent) and medialized (solid) infrapinatus muscle-tendon units in the abduction and external rotation position (B).

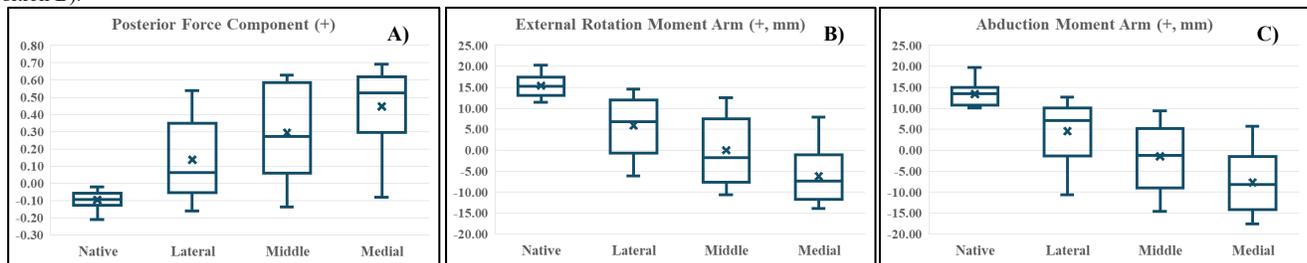


Figure 2. Box-and-whisker plots illustrate group comparisons for three metrics: A) posterior force component, B) external rotation moment arm, and C) abduction moment arm. For each metric, there is significant difference between all group pairs ($p < .05$). Note that negative values represent anterior force component (A), internal rotation moment arm (B), and adduction moment arm (C), respectively.