

# Finite Element Analysis of Glenoid Anchor Insertion Angle to Mitigate Postage Stamp Fracture Risk

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**INTRODUCTION:** Anterior glenoid “postage stamp” fractures after arthroscopic Bankart repair have been repeatedly linked to young, male, athletic patients and to constructs with  $\geq 3$  anchors or conventional knot-tying anchors, suggesting that technical factors can create stress risers at the rim [1]. Clinical series also indicate that linear placement of multiple soft anchors along the anterior-inferior glenoid can precede recurrence due to new rim fractures [2]. While some in-vivo work found that insertion angle did not independently predict fracture, inferior “on-the-face” placement near the 5 o’clock region (right-shoulder designation) appeared to increase risk [3]. *Because most surgeons conceptualize the anterior glenoid on a right-shoulder clockface (3–6 o’clock anterior–inferior), we adopted that nomenclature here for clarity, even though the model was left-sided.* At the same time, on-the-edge placement has been suggested to protect the rim from erosion [4]. Therefore, our objective was to use simulation finite element analysis (FEA) to isolate the effect of anchor insertion angle at common anterior glenoid positions on local cortical stress under functional shoulder loading. We hypothesized that moderate obliquity would reduce peak three-dimensional effective stress below a validated cortical failure threshold. **METHODS:** A subject-specific 3D left glenoid model was reconstructed from CT scan images and prepared/meshed for FEA. Three suture anchors were positioned at clinically relevant anteroinferior sites 2 mm from the rim, the rim at locations that correspond to right-shoulder clockface positions of approximately 3:00 (anterior), 4:30 (anteroinferior), and 6:00 (inferior) to match common Bankart repair configurations and the way these are reported in the clinical literature [2], [3]. Anchor insertion angle relative to the glenoid plane was tested at 0° (perpendicular), 30° (moderate), and 60° (more oblique) (Figure 1). Compressive load was applied to the humeral head against the anterior glenoid at neutral (0° ABD/0° ER) and at risk (90° ABD/60° ER) to simulate positions associated with traumatic re-instability, similar to in-vitro loading paradigms used to study postage-stamp fracture risk with multiple anchors [5]. Peak cortical effective 3D stresses (von Mises stresses) were extracted at each anchor site and compared across angles and positions. The FEA model was validated through glenoid cadaveric test failure. **RESULTS:** Across both shoulder positions, the 30° insertion angle produced lower peak cortical effective 3D stresses (von Mises stresses) than either 0° or 60° at the anterior inferior position (Figures 2 and 3). Perpendicular placement at the inferior position and very oblique placement at the more anterior position created stress patterns consistent with a focal stress riser along the anchor line—the same pattern suspected clinically when multiple anchors are placed in a linear fashion. The 30° condition maintained a safety margin below the 110-MPa cortical yield value used for validation [6]. **DISCUSSION:** This FEA showed that, in a 3-anchor anteroinferior Bankart construct, a moderate (~30°) insertion angle kept anterior glenoid cortical stress lower than either perpendicular (0°) or very oblique (60°) trajectories. Stress rose specifically when an unfavorable angle was combined with an at-risk site (inferior/anterior) or with an abducted/external-rotation load, which mirrors clinical reports that fractures often occur along a linear anchor line in young, athletic patients [1], [2]. Our result also helps explain why inferior/anterior placement has been flagged as higher risk [3]: the position becomes problematic when the angle does not distribute load well. The finding aligns with in-vitro data that certain anchor/tunnel configurations preserve glenoid strength [5] and with reports that rim-respecting placement reduces erosion [4]. Because angle is surgeon-controlled, selecting ~30° anchor angle insertion is a simple preventive step that may reduce the need for later bony procedures such as Latarjet in postage-stamp failures [7]. **SIGNIFICANCE/CLINICAL RELEVANCE:** Bankart repairs in the group most prone to postage stamp fractures—young, active, contact or overhead athletes—should aim to preserve anterior glenoid rim strength. This study suggests that choosing a moderate (~30°) insertion angle at typical anteroinferior anchor sites can reduce local cortical stress providing a simple intraoperative technique to help prevent postoperative anterior glenoid rim fracture in high-risk shoulders.

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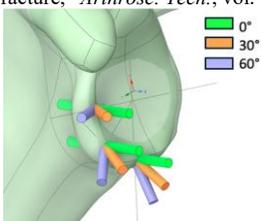


Figure 1: Anchor insertion angles of 0°, 30°, and 60° relative to the glenoid.

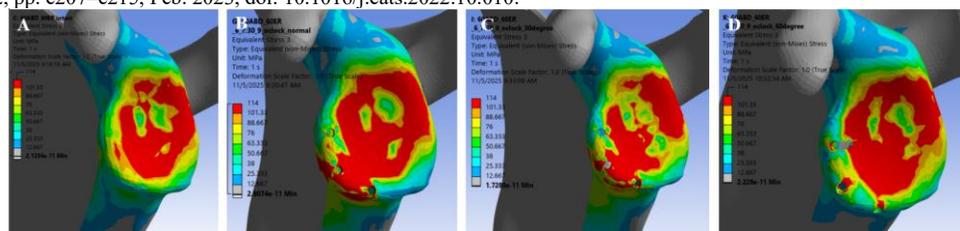


Figure 2: At-risk loading condition (90° ABD/60° ER). (A) Intact glenoid; (B) 0° anchor orientation; (C) 30° anchor orientation; and (D) 60° anchor orientation.

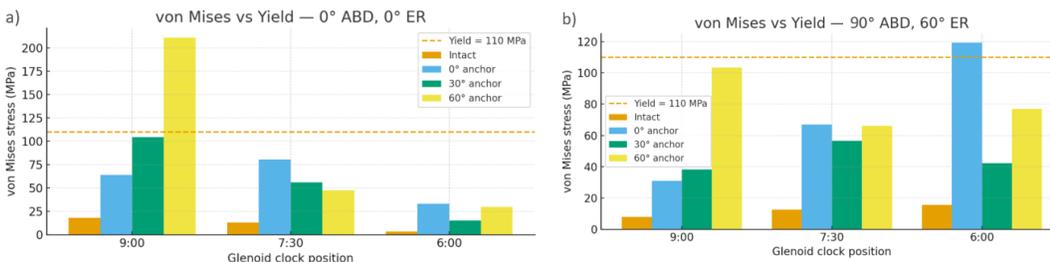


Figure 3: Maximum cortical bone effective 3D stress vs yield stress at each anchor insertion site in (a) the neutral glenoid position and (b) the high-risk position.