Revisiting the Anterior Glenoid: An Analysis of the Calcified Cartilage Layer, Capsulolabral Complex, and Glenoid Bone Density

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Purpose: In this cadaveric study, we aim to define the basic anatomy of the anterior glenoid with attention to the relationships of calcified cartilage, capsulolabral complex, and osseous morphology of the anterior glenoid. **Methods:** Seventeen cadaveric glenoid specimens (14 male, 3 female, mean age 53.9 ± 10) were imaged with micro-computed tomography (CT) and embedded in poly-methyl-methacrylate. Specimens were included for final analysis only if the entire glenoid articular cartilage, labrum, capsule, and biceps insertion were pristine and without evidence of injury, degeneration, or damage during the preparation process. Group 1 members ($n = 9$) were axially sectioned through 3 to 9 o'clock and 4 to 8 o'clock; group 2 members ($n = 8$) were radially sectioned through 3, 4, 5, and 9 o'clock. A scanning electron microscope (SEM) analysis quantified the percentage of bone within a 5 × 2.5 mm region at the glenoid rim. Micro-CT, SEM, and light microscopy evaluated the capsulolabral complex and calcified fibrocartilage. **Results:** A 7 ± 2.1 mm region of calcified fibrocartilage at 4 o'clock was identified from the articular face to the medial glenoid neck supporting the overlying capsulolabral footprint and was >3× thicker at the articular attachment (316 ± 153 μm) versus the glenoid neck (92 ± 66 μm). At 3 to 9 o'clock and 4 to 8 o'clock 79.2% ± 5.4% and 75.2% ± 7.8% of the glenoid osseous width was covered with articular cartilage. The labrum accounted for 13.1% ± 3.4% of the glenoid width at 4 o'clock. SEM analysis demonstrated decreased glenoid bone density at 3, 4, and 5 o'clock ($P \leq .015$) and no difference ($P = .448$) at 9 o'clock versus central subchondral bone. **Conclusions:** The capsulolabral footprint contributes significantly to the glenoid face, inserts directly adjacent to the articular cartilage, and extends medially along the glenoid neck. A layer of calcified fibrocartilage lies immediately beneath the capsulolabral footprint and is 3× thicker at the articular insertion compared with the glenoid neck. Lastly, there is a bone density gradient at the anterior-inferior rim versus the central subchondral bone. **Clinical Relevance:** Arthroscopic Bankart repair has been reported to have a significant failure rate in many settings. It is felt that reproducing anatomy with the repair could help improve outcomes. Based on this study's findings, an arthroscopic Bankart technique that most closely reproduces native anatomy and potentially optimizes soft-tissue healing could be performed. This includes removal of 1 to 2 mm of articular cartilage from the glenoid face with anchor placement at this location to appropriately reposition the capsulolabral complex.

Traumatic anterior shoulder instability is a relatively common problem, with multiple studies demonstrating an incidence in the general population of approximately 23 per 100,000.[1,2] Unfortunately, recurrent instability following initial dislocation is common, with overall recurrence rates ranging from 19% to 60%.[2-4] Among high-risk groups the recurrence rate increases dramatically and has been demonstrated to exceed 90%.[5]

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Surgical intervention following anterior instability involves addressing the resultant anterior capsulolabral deficiency, or Bankart lesion. Multiple techniques for both open and arthroscopic repair of the Bankart lesion exist; however, despite low recurrence rates at short-term follow-up,[6-10] long-term follow-up demonstrates higher rates. Arthroscopic techniques show long-term recurrence rates ranging from 12% to 38%, while open techniques show long-term recurrence rates ranging from 9% to 58%.[11-19] At 20-year follow-up, even controlling for cases of critical glenoid bone loss, recurrence rates for open Bankart repair range from 10% to 17.5%.[20-22] Major risk factors for recurrent instability have been identified in the instability severity index score as a means to predict the risk of recurrent dislocation after arthroscopic stabilization.[23,24] Importantly, the rates of redislocation persist despite recognition of these factors, causing some investigators to recommended lowering the threshold to perform a primary bony procedure (i.e. Latarjet) to lower rates of recurrent instability.[23-25]

An additional factor leading to recurrence following Bankart repair may be that current techniques fail to adequately recreate the anatomy of the anterior capsulolabral complex. Recently, some investigators have suggested techniques to recreate the anatomic bony capsulolabral attachment on the glenoid neck through either single-[26] or double-row repairs.[27] Despite these suggestions, however, the precise anatomy of the anterior glenoid remains variably described in the literature without a clear definition of the capsulolabral "footprint."[26-30] The calcified fibrocartilage (CF) serves as a biologic glue between tendon and bone[31,32] but has poor surface healing potential.[33] While investigators have described the need for debridement of the anterior glenoid to allow for a bleeding surface,[7,12,34] no study has specifically described the anatomy of the CF layer at the anterior glenoid and the extent to which this layer extends. A quantitative analysis of the CF layer may aid surgeons in preparation of the glenoid for Bankart repair. Furthermore, little data exist regarding the bony architecture and anatomy surrounding anterior glenohumeral instability and the implications this may have regarding bone loss. Previous work has identified differences in bone density within the glenoid with increased density overall in the posterior and superior glenoid.[35-37] There have been few studies, however, regarding the specific bony anatomy of the anterior-inferior glenoid and its relationship to the articular and capsulolabral structures.

In this cadaveric study, we aim to define the basic anatomy of the anterior glenoid with attention to the relationships of calcified cartilage, capsulolabral complex, and osseous morphology of the anterior glenoid. We hypothesize there will be no regional differences in the thickness or width of the calcified cartilage layer of the anterior glenoid. Additionally, we hypothesize a decrease in bone density of the anterior glenoid compared with the central glenoid.

Methods

Gross Photography and Micro-Computed Tomography (CT)

Seventeen fresh, frozen cadaveric shoulder specimens (14 male, 3 female, mean age 53.9 ± 10) were obtained, thawed, and dissected leaving glenoid cartilage, labrum, and capsular insertions intact. The specimens were grossly inspected by an orthopedic surgeon (M.R.K.) and verified to be free of any significant glenohumeral pathology prior to processing. The glenoid was removed en bloc from the scapula, and specimens were included for final analysis only if the entire glenoid articular cartilage, labrum, capsule, and biceps insertion were pristine and without evidence of injury, degeneration, or damage during the preparation process. The glenoids were imaged by Micro-CT (Quantum GX microCT Imaging System; PerkinElmer, Waltham, MA) using a tube voltage of 90 kV, tube current of 180 μA, and a field-of-views of 73 mm, resulting in 143 μm slices.

Histological Processing

The specimens were embedded in poly-methyl-methacrylate (PMMA) and randomly split into two groups. Group 1 members ($n = 9$) were axially sectioned at 3 to 9 o'clock and 4 to 8 o'clock, and group 2 members ($n = 8$) were radially sectioned at 3, 4, 5, and 9 o'clock (Fig 1). Sections were ground, polished, and coated with a thin conductive layer of carbon (208 Carbon, Cressington Scientific, Watford, UK) to allow for visual distinction of soft-tissue structures and scanning electron microscope (SEM) analysis.

Imaging

The sections where imaged using a high-resolution digital camera equipped (D7000, Nikon, Melville, NY) with a ring light (Fig 2). Next, the sections were imaged with an SEM (JEOL JSM-6610, Peabody, MA) equipped with a backscatter electron (BSE) detector and imaging software.[38] The SEM was set to a 25-mm working distance and 20-kV accelerating voltage. Digital images were captured at 30× magnification with a resolution of 2,560 × 1,920 pixels. Image processing was done using Microsoft Research Image Composite Editor (MRICE), which mosaicked/stitched the BSE images together creating a high-resolution axial view of the glenoid (Fig 3). The specimens were then reground to a thickness of 50 to 75 μm, polished, adhered to microscopy slides, and stained with Sanderson's rapid bone stain or light green or left unstained to view under polarized light. Sanderson's rapid bone stain and light