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Original article

## The relationship of the anterior articular capsule to the adjacent subscapularis: An anatomic and histological study

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### ABSTRACT

**Introduction:** The purpose of this study was to delineate the anatomic relationship between the anterior articular capsule and the adjacent subscapularis by measuring the dimensions of the anterior articular capsule attachment and the subscapularis footprint on the humerus, as well as investigating the interface between the two structures.

**Materials and methods:** Three shoulder specimens underwent histological analysis; for histological analysis, cross-sections through the subscapularis-capsule complex were harvested at the tendinous and muscular insertion sites. The dimensions of the anterior articular capsule attachment and the subscapularis footprint (including the tendinous and muscular insertions) were measured in thirteen cadaveric shoulder specimens.

**Results:** Histologically, the articular capsule has thin and loosely arranged collagen fibers with many interspersing fibroblast nuclei, whereas the outer layer of the articular capsule blends into a layer of more loosely spaced and less organized collagen fibers. This interface between the subscapularis and the underlying articular capsule is filled with more loosely spaced and less organized collagen fibers. The macroscopic evaluation showed that the minimum articular capsule width (4.2 mm, SD 2.2 mm) was located at its initiation 4.9 mm (SD, 2.1 mm) inferior to the superior margin of the subscapularis; the corresponding subscapularis footprint width measured 10.1 mm (SD, 4.9 mm). The maximum articular capsule width was 11.1 mm (SD, 3.7 mm) and was located 5 mm distal to the inferior margin of the tendinous footprint. The maximum subscapularis footprint width was 15.8 mm (SD, 2.9 mm); the corresponding articular capsule attachment measured 5.2 mm (SD, 1.8 mm).

**Conclusions:** Our results suggest that the anterior articular capsule attachment of the glenohumeral joint complements the footprint of the subscapularis and occupies a larger area of the lesser tubercle and metaphysis of the humerus than previously documented. The histological study confirms the presence of a demarcation between the subscapularis and articular capsule, specifically more significant at the region medial to the tendon insertion and at the muscular insertion of the subscapularis.

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### 1. Introduction

The anterior articular capsule of the glenohumeral joint is a thin fibrous structure between the subscapularis and the joint cavity [1]. It is firmly attached to the deep surface of the subscapularis

near the tendinous insertion at the lesser tubercle. The attachment might functionally complement the insertion of the subscapularis tendon and facilitate maintenance and endurance of the subscapularis footprint [2,3]. However, no studies to date have delineated the anatomic nature of the articular capsule and its relationship to the adjacent subscapularis.

Although numerous reports in literature have described in detail the anatomy of the subscapularis footprint [4–10], most of the studies have not dissected the subscapularis tendon from the articular capsule, thus the width of subscapularis footprint may have been overestimated. Knowledge of the overall dimension of the footprint

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of the subscapularis and the attachment of the articular capsule may allow more accurate assessment of the extent of subscapularis tears and make the surgical restoration of the normal anatomic footprint more reproducible.

In addition, operative procedures addressing the anterior capsulolabral reconstruction or shoulder arthroplasty require meticulous dissection of the subscapularis from the underlying articular capsule by splitting the subscapularis or dissecting the subscapularis off of the underlying capsule [11,12]. Moreover, some orthopaedic surgeons have recently proposed the lateral “subscapularis-sparing” approach, which calls for separation of the lower subscapularis from the underlying capsule to avoid detachment of the subscapularis in order to expose and repair the humeral avulsion of glenohumeral ligament (HAGL) lesion [13,14]. However, separating the subscapularis and the articular capsule can be very challenging in the clinical setting. Thus, knowledge of the anatomical relationship between the subscapularis and the underlying articular capsule is important in facilitating our surgical treatment.

Due to the thin and minor structure, the presence of the articular capsule attachment on the lesser tubercle is negligible in the past [5–7,9]. The purpose of this study was to delineate the macroscopic and microscopic anatomical relationship between the anterior articular capsule and the adjacent subscapularis by measuring the dimensions of the anterior articular capsule attachment, and the subscapularis footprint on the humerus and also investigating the interface between the two structures at the tendinous and muscular insertions of the subscapularis. We hypothesized that the anterior articular capsule attachment would occupy a larger area of the proximal humerus than previously documented which would complement the footprint of the subscapularis; furthermore, there would be an identifiable interface between the articular capsule and the subscapularis.

## 2. Materials and methods

Thirteen fresh-frozen human cadaveric shoulder specimens (9 unpaired and 2 paired) from 8 men and 5 women were available for this study (6 right and 7 left shoulders). The mean age of the deceased was 63.7 years (range: 52–70 years). Each shoulder specimen included the entire scapula, the proximal third of the humerus and the full clavicle with the attached soft tissues. All specimens were free of subscapularis tears; biceps tendon tears or osteophytes near the intertubercular sulcus, since lesions near the tuberosities would make measurement of the insertion inaccurate. Ten specimens underwent macroscopic assessments, the other three underwent histological analysis.

### 2.1. Histological assessment

Three shoulder specimens (1 man and 2 women; mean age, 64 years) underwent histological analysis. Cross-sections through the subscapularis and the attached articular capsule (subscapularis-capsule complex) at the tendinous and muscular insertion of the subscapularis were harvested sequentially from superior to inferior in 5 mm intervals. The orientation of the section was orthogonal to the plane of the subscapularis. The harvested pieces were cut into segments of approximately 5 mm in width and 25 mm in length. The segments were embedded in paraffin and sectioned sequentially at a thickness of five micrometers in the longitudinal plane. The sequential slides from each block were stained with hematoxylin and eosin (H&E) and Masson trichrome stain for morphological evaluation and evaluation of muscle and connective tissue, respectively (Fig. 1). The histological sections were examined with light microscopy at 4×, 10×, 20× and 40× objectives

lens with the 10× magnification factor by the eyepiece (CX31; Olympus, Tokyo, Japan). Orientation of the collagen fibers was documented. Particular attention was paid to the interface between the articular capsule and the attached subscapularis, and relevant areas were digitally photographed with QIClick™ CCD Camera (QImaging Inc, Surrey, Canada) and QCapture Pro 7 software (QImaging Inc, Surrey, Canada).

### 2.2. Gross dissection and macroscopic assessment

After thawing each specimen at room temperature (22°C) for 24 hours, a deltopectoral incision was used to approach the anterior aspect of each shoulder. All soft tissues surrounding the rotator cuff were removed. The supraspinatus, rotator interval and subscapularis insertion onto the proximal humerus were inspected. The subscapularis, supraspinatus, infraspinatus and teres minor were peeled away from their origins on the scapula toward their insertions on the tubercles of the humerus. Next, the muscles were carefully dissected from the underlying capsule, without damaging the latter. Subsequently, the articular capsule was detached along the glenoid rim. Prior to cutting the remnants of the supraspinatus, infraspinatus and teres minor with their attached capsule along their humeral insertion, separation of the articular capsule from the overlying subscapularis muscle and tendon was carefully done. At the time of these determinations, we put the interface under tension to straighten the line of pull of the musculature, thus facilitating identification of the plane between the articular capsule and the subscapularis. The articular capsule and subscapularis were detached sharply from the humerus until 1 mm height of the remnants were left attached to the footprint. The attachment of the articular capsule on the humerus was then exposed and delineate with gentian violet. The tendinous and muscular footprint of the subscapularis were likewise demarcated with gentian violet. The width of the articular capsule attachment and the subscapularis footprint were measured at sequential locations (Fig. 1). A digital camera (EOS 60D, EF 100 mm, 1:2.8, Canon, Japan) was utilized to capture the image while positioned perpendicularly to the articular capsule attachment and the subscapularis footprint alongside a calibration scale. The dimension of the articular capsule attachment and the subscapularis footprint were measured and calibrated by image analysis software (SigmaScan Pro 5.0, SPSS, Chicago, IL), in which 3 consecutive measurements of each dimension were taken independently by 2 investigators; the intraclass and interclass correlation coefficients were 0.91–0.96. The mean of their measurements for each dimension in each specimen was recorded (Fig. 2).

## 3. Results

### 3.1. Histological assessment

In our histological analysis, the section of the subscapularis-capsule complex obtained at the tendinous insertion of the subscapularis, demonstrated that the subscapularis muscle tissue gradually intermingled with bundles of collagen fibers and forms a tendon tissue. The articular capsule has thin and loosely arranged collagen fibers with many interspersing fibroblast nuclei (Fig. 1C). The outer layer of the articular capsule blends into a layer of more loosely spaced and less organized collagen fibers, which is distinct from the overlying subscapularis, specifically at the region medial to the tendon tissue of the subscapularis (Fig. 1F).

In the section at the muscular insertion of the lower subscapularis, there is a clear demarcation between the subscapularis and the underlying articular capsule. This interface is filled with more loosely spaced and less organized collagen fibers (Fig. 1B).

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