Anatomic Analysis of the Attachment of the Posteroinferior Labrum and Capsule to the Glenoid: A Cadaveric Study

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Purpose: To measure the height of the posteroinferior glenohumeral ligament (PIGHL) attachment to the labrum and the depth of the posteroinferior labrum to the glenoid, macroscopically, and to investigate the morphology of the attachment of the posteroinferior labrum to the glenoid, histologically. Methods: Fifty cadaveric shoulders without exposed subchondral bone on the glenoid and detached posterior labrum were used. We examined the frequency of the heights of the PIGHL attachments to the labrum and the length of the labral attachment on the glenoid rim at the 7, 8, 9, and 10 o’clock positions, macroscopically. According to morphology of the histological labral attachments, it was divided into 3 groups. Labra attached on the articular surface and the glenoid neck were defined as the SN type, while labra attached only to the glenoid neck constituted labra attached to the bone and side of the articular cartilage (Nc type) and labra attached only to bone (Nb type).

Results: The PIGHL attached from 7 o’clock to 9 o’clock in 48 shoulders (96%). The mean labral attachment at the 7 o’clock position was 6.3 ± 1.0 mm (range, 4.6-9.4 mm), which was significantly longer than at the other positions (P < .05). Histologically, the frequency of SN type attachment was 49 (98%) shoulders at the 7 o’clock position.

Conclusions: The PIGHL attached between 7 and 9 o’clock in 96% of the shoulders. In 98% of the shoulders, the labrum did not attach to the articular surface, but attached to both the articular cartilage and the bone of the glenoid neck at 7 o’clock.

Clinical Relevance: The posteroinferior labrum should be repaired widely at the 7 o’clock position and not on the articular surface because the labrum attached anatomically to the glenoid neck.

Posterior instability of the shoulder is present in 2% to 10% of all patients with shoulder instability,1,2 which is frequently seen in young athletes active in sports involving throwing, overhead movement, and collision.3,4 The posteroinferior glenohumeral ligament (PIGHL) is the most important ligamentous posterior stabilizer in internal rotation and forward flexion5; therefore, ligamentous laxity or avulsion of the PIGHL–labrum complex caused by repetitive microtrauma results in posterior instability of the shoulder.3 Detachment of the posteroinferior labrum is termed a reverse Bankert lesion, and Kim et al.6 described incomplete and concealed avulsion of the posteroinferior labrum as Kim’s lesion. Many authors have reported the arthroscopic repair of a detached posteroinferior labrum using suture anchors.7-10 However, the position of the suture anchor insertion differed in the studies; for example, anchors were placed at 1-cm intervals from the 7- to 11 o’clock positions,8 1 to 2 mm on the face of the glenoid at the 7 and 8 o’clock positions,10 or (1-3 anchors) at the medial end of the glenoid rim 2 mm from the margin of the articular surface.7
Previous anatomical studies showed that the posterior capsule is biomechanically thinner and less robust than the anterior capsule. However, few reports have described detailed investigations of the attachment of the PIGHL—labrum complex to the posterior rim of the glenoid. The purpose of this study was to measure the height of the PIGHL attachment to the labrum and the depth of the postero-inferior labrum to the glenoid, macroscopically, and to investigate the morphology of the attachment of the postero-inferior labrum to the glenoid, histologically. We hypothesized that the height of the PIGHL attachment to the labrum would not be uniform, and that the depth and morphology of the attachment of the postero-inferior labrum to the glenoid would change gradually according to the attachment position.

**Methods**

**Subject Shoulders**

Sixty-two embalmed cadaveric shoulders were available for this study, and constituted 24 male cadavers and 38 female cadavers with a mean age of 83.1 ± 10.4 years (range, 47–99 years). All cadavers were from persons who had donated their bodies to our university hospital for medical education and research. The protocol for this study was project was approved by the ethics committee of our university hospital. For tissue fixation, we injected 10% formalin into the femoral artery, followed by injecting Liquitex Professional Acrylic ink (Naphthol Crimson, Liquitex Artist Materials, Piscataway, NJ).

We excluded shoulders with exposed subchondral bone on the articular surface of the glenoid (osteoarthritis of only humeral side was included) and with detached labrum between the 6 and 10 o’clock positions. The shoulders with detached labrum from the 10 to 6 o’clock position were included. We excluded 12 shoulders and evaluated a final 50 shoulders.

**Macroscopic Observation**

We removed all subcutaneous soft tissues except for the capsule. The anterior half of the glenohumeral joint capsule was cut, and the joint was opened, enabling observation of the inner side of the posterior capsule.

We defined the superior intersection point of the long axis of the glenoid and the circumcircle as 12 o’clock and the inferior intersection point as 6 o’clock. The midpoint of the long axis of the glenoid was defined as the center of the glenoid. The glenoid positions in this study were described according to the right shoulder with the clock face positions determined accordingly. To examine the frequencies of the different locations of the PIGHL attachments to the labrum, we measured the locations of the PIGHL attachment as 1-hour intervals; for example, from the 7 to 8 o’clock positions.

The joint capsule was separated from the humeral-side attachment, and the glenoid side of the capsule was left at a length of 2 cm from the labral attachment. The glenoid neck was resected from the scapula using a bone saw. The labrum and the joint capsule from the 7 to 8 o’clock and from the 9 to 10 o’clock positions were resected from the glenoid as described previously (Fig 1). To measure the length of the labral attachment on the glenoid rim at the 7, 8, 9, and 10 o’clock positions, each radial cross section of the labrum was observed macroscopically. First, as shown in the radial cross-sectional area of the glenoid and labrum in Fig 2, we divided the length of the labral attachment on the glenoid rim into the 2 sections: labral attachment to the articular surface (black arrow), and labral attachment to the glenoid neck (gray arrow). The length of the labral attachment to the articular surface and the glenoid neck at the 7, 8, 9, and 10 o’clock positions was measured with a digital caliper. All measurements were performed by a single investigator (A.K.).

**Histological Assessment**

We performed histological examinations to investigate the detailed attachment of the postero-inferior labrum to the cartilage and the bone of the glenoid, and to classify the histological type by the type of labral attachment. After macroscopic observation, decalcification was performed with formic acid to soften the bone to obtain the tissue sections. Each specimen was divided into radial sections from the center of the glenoid through the labrum, perpendicular to the surface, by radial incision. Each section was then embedded in paraffin and stained with toluidine blue. Slides were examined by light microscopy, and the attachment of the labrum was evaluated histologically at the 7, 8, and 9 o’clock positions and then classified morphologically. The specimens were divided into 3 groups according to the labral attachment. In addition, a single investigator (A.K.) assessed the classification according to the histological attachment pattern of the postero-inferior labrum to the glenoid.

**Classification of Labral Attachment**

From the gross anatomical findings, labra attached on the articular surface and the glenoid neck were defined as the SN type, while labra attached only to the glenoid neck were divided into 2 groups: labra attached to the bone and side of the articular cartilage were defined as the Nc type, and labra attached only to bone were defined as the Nb type (Fig 3).

**Statistical Analysis**

We compared the length of the labral attachment at 1-hour clock-referent intervals from the 7 to 10 o’clock positions using repeated-measure analysis of variance followed by Tukey’s test as a post hoc analysis. P values < .05 were considered statistically significant. Statistical analysis was performed using Prism software, version 5.0 (GraphPad Software, San Diego, CA). All studied
data were involved in a power analysis, 35 specimens were required in each position to detect a difference equal to 1 standard deviation in this study when the power was 90% and the significance level was 0.05.

Results

Macroscopic Observation

The attachment of the PIGHL to the labrum was located from the 8 to 9 o’clock position in 22 shoulders (44%), from the 7 to 8 o’clock position in 15 shoulders (30%), from the 7:30 to 8:30 position in 11 shoulders (22%), and from the 9 to 10 o’clock position in 2 shoulders (4%). According to these results, the attachment of the PIGHL was from the 7 to 9 o’clock positions in 48 shoulders (96%) (Fig 4).

The mean length of the total labral attachment (the articular surface and the glenoid neck) was 6.3 ± 1.0 mm (range, 4.6-9.4 mm) at the 7 o’clock position, 5.8 ± 0.9 mm (range, 3.6-8.1 mm) at the 8 o’clock position, 5.4 ± 1.1 mm (range, 3.3-8.5 mm) at the 9 o’clock position, and 5.7 ± 0.9 mm (range, 4.2-8.1 mm) at the 10 o’clock position (Fig 5). In some shoulders, the labrum attached to the articular surface as follows: 0 shoulders at the 7 o’clock position, 1 shoulder (2%) at the 8 o’clock position, 2 shoulders (4%) at the 9 o’clock position, and 4 shoulders (8%) at the 10 o’clock position.

Statistical analysis showed that total length of the labral attachment was the longest at the 7 o’clock position and significantly greater than at the 8 o’clock position (P = .01), 9 o’clock position (P < .001), and 10 o’clock position (P = .003). No significant difference was found for the length of the labral attachment to the articular surface.

Histological Assessment

The macroscopic assessment showed that the attachment of the PIGHL to the labrum was from the 7 to 9 o’clock positions in 96% of the specimens; therefore, we performed histological assessment at the 7, 8, and 9

![Fig 1. Photographs of the resected labrum and glenoid capsule from the glenoid in 1 shoulder specimen. (A) Articular side of the glenoid of the right shoulder with labrum and capsule. (B) The labra from the 7 to 8 o’clock positions and from the 9 to 10 o’clock positions were resected to measure the length of the labral attachment viewed from a cross section of the glenoid neck at each position.](image)

![Fig 2. Radial cross-sectional area of the glenoid and labrum. We divided the length of the labral attachment on the glenoid rim into the 2 sections. The lengths of the labral attachments on the articular surface (black arrow) and the glenoid neck (gray arrow). Each length was measured separately at 1-hour clock-referent intervals from the 7 to 10 o’clock positions.](image)
Fig 3. Histological classification of the labral attachments. (A) Labra attached on both the articular surface and on the glenoid neck were defined as the SN type. Labra attached only to the glenoid neck were divided into 2 groups as follows: (B) labra attached to the bone and side of the cartilage were defined as the Nc type, and (C) labra attached only to bone were defined as the Nb type.

Discussion
This study demonstrated that the location of the PIGHL attachment to the labrum was from the 7 to 9 o’clock positions in 96% of the shoulders. The length of the postero-inferior labral attachment to the glenoid viewed from a cross section of the glenoid neck at each clock position was the longest at the 7 o’clock position.

Previous anatomical studies investigated the length of the labral attachment viewed from a cross section of the glenoid at clock-referent positions of the labral attachment. Yoshida et al.14 investigated the length of the labral attachment to the glenoid at the 2, 4, 6, 8, 10, and 12 o’clock positions. The authors reported that the mean length of the labral attachment for all clock positions was 4.6 mm. On the posterior side of the shoulder, there was no significant difference in the length of the attachment of the labrum at the 6, 8, 10, and 12 o’clock positions. Although the authors examined the length of the labral attachment using 2-hour clock-referent intervals, they did not provide the detailed values for the respective length at each clock position. Momma et al.15 reported that the length of the labral attachment viewed from a cross section of the glenoid neck was 7.4 mm at the posterior edge of the origin of the long head of the triceps brachii, which was slightly inferior to the 7 o’clock position, and the length was greater than at the 9 o’clock position. However, the position of the posterior edge of the origin of the long head of the triceps brachii was unclear. In our study, we measured the length of the labral attachment using 1-hour clock-referent intervals, and our results showed that the measurement at the 7 o’clock position was greater than at the 8, 9, and 10 o’clock positions. These results demonstrated that from the 7 to 9 o’clock positions, where 96% of the PIGHLs...
attached, the length of the inferior part of the labral attachment was the greatest, and the length shortened gradually as the position progressed to the posterior aspect. According to this finding, anatomically, the posteroinferior labrum might be repaired widely at the 7 o’clock position. However, we did not perform a biomechanical evaluation in this study, and further research is needed.

The inferior glenohumeral ligament complex is a hammock-like structure of the articular capsule extending from the anteroinferior to posteroinferior areas of the shoulder joint, and the PIGHL is the posterior edge of that structure.16 Pouliart et al.17 inspected the inferi or glenohumeral ligament complex by dissection and arthroscopy. The authors stated that the PIGHL was a fold in the capsule when viewed from the intra-articular side during arthroscopy. Momma et al.15 also reported that the thick posteroinferior part of the capsule corresponded to the superior margin of the PIGHL. These studies discussed the running position of the PIGHL in the posterior capsule, but no studies have determined the anatomically detailed position of the PIGHL attachment to the labrum. Our results provide fundamental information to determine the repair height of the PIGHL. From the results of our macroscopic observation, we suggest that the PIGHL is repaired from the 7 to 9 o’clock positions, and that the labrum might be repaired widely at the 7 o’clock position.

According to our histological assessment, the posteroinferior labrum in most shoulders was attached to both the bone of the glenoid neck and the side of the articular cartilage (Nc type). The frequency of the Nc type was 98% at the 7 o’clock position, 92% at the 8 o’clock position, and 84% at the 9 o’clock position. Itoigawa et al.13 reported that the anteroinferior labrum attached most often to both the articular surface and the bone of the glenoid neck (SN type), with frequencies of 86.7% at the 2 o’clock position and 88.3% at the 4 o’clock position. These results suggest that the structure of the attachment of the inferior labrum may be quite different between the anterior and posterior aspects. We believe that the posteroinferior labrum should not be repaired in the same manner as anteroinferior Bankart repair.

Cooper et al.18 inspected the macroscopic, histological, and vascular anatomy of the glenoid labrum. The authors reported that the glenoid labrum was vascularized by vessels from the capsule and periosteum of the glenoid neck rather than being vascularized through the articular cartilage; therefore, healing of the repaired labrum to the articular cartilage may not be expected. Additionally, anatomically, our results showed that the frequency of the labral attachment to the articular surface was 0 shoulders at the 7 o’clock position, 1 shoulder (2%) at the 8 o’clock position, 2 shoulders (4%) at the 9 o’clock position, and 4 shoulders (8%) at the 10 o’clock position. Therefore, we suggest that the posteroinferior labrum should not be repaired by attaching the labrum to the articular surface.

Limitations

Our study has several limitations. First, the age of the donors in our study was higher than that of the patients requiring posteroinferior labrum repair. Second, our results may be affected by a female sex bias. Third, the

<table>
<thead>
<tr>
<th>Location</th>
<th>SN Type</th>
<th>Nc Type</th>
<th>Nb Type</th>
<th>Total</th>
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<td>7-o’clock position</td>
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<td>49 (98)</td>
<td>1 (2)</td>
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<tr>
<td>8-o’clock position</td>
<td>1 (2)</td>
<td>46 (92)</td>
<td>3 (6)</td>
<td>50 (100)</td>
</tr>
<tr>
<td>9-o’clock position</td>
<td>2 (4)</td>
<td>42 (84)</td>
<td>6 (12)</td>
<td>50 (100)</td>
</tr>
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digital caliper used in this study measures only linear distances, and the forms of the labral attachments were not straight but varied. Fourth, all measurements and classifications were performed by a single investigator; therefore, we did not evaluate reproducibility. Fifth, all cadavers used in this study were embalmed with 10% formalin. Although the stiffness of the soft tissues was affected by the fixation method, the attachment of the labrum to the glenoid was not affected.

**Conclusions**

The PIGHL attached between 7 and 9 o’clock in 96% of the shoulders. In 98% of the shoulders, the labrum did not attach to the articular surface, but attached to both the articular cartilage and the bone of the glenoid neck at 7 o’clock.

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