Systematic Review

Systematic Review of the Anatomic Descriptions of the Glenohumeral Ligaments: A Call for Further Quantitative Studies

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Purpose: To perform a systematic review of the glenohumeral ligament anatomic attachments on the glenoid and humeral neck. **Methods:** A systematic review was performed according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines using the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed, MEDLINE, and Embase from 1980 to present. The inclusion criteria were as follows: cadaveric or clinical anatomic studies that qualitatively or quantitatively described the glenoid and humeral attachments of the glenohumeral ligaments in the English-language literature. Imaging and animal studies, editorial articles, and surveys were excluded from this study. **Results:** The 15 included studies analyzed a total of 983 shoulders. Only 5 studies reported quantitative measurements. The most common glenoid superior glenohumeral ligament attachment described was in the anterolateral region of the supraglenoid tubercle and was inserting on the humerus in close vicinity to the subscapularis tendon insertion. The superior labrum and lesser tuberosity were the most commonly reported middle glenohumeral ligament attachments. The inferior glenohumeral ligament was most commonly described to attach between the 2- and 4-o'clock positions of the glenoid and distally near the surgical neck of the humerus. **Conclusions:** There were limited quantitative data on the attachments of the glenohumeral ligaments. Although the literature was discordant, the most common descriptions of the attachments were as follows: The anterolateral region of the supraglenoid tubercle, the superior labrum, and the glenoid (between the 2- and 4-o'clock positions) were the medial attachments for the superior glenohumeral ligament, middle glenohumeral ligament, and inferior glenohumeral ligament, respectively. Laterally, they inserted on the humerus in close vicinity to the subscapularis tendon insertion, on the lesser tuberosity, and near the surgical neck of the humerus, respectively. **Clinical Relevance:** The glenohumeral ligaments are important anatomic structures contributing to the dynamic stability of the glenohumeral joint. Further detailed quantitative descriptions of their attachments are required for truly anatomically based repairs.

The glenohumeral joint is intrinsically unstable, and thus an integrated system of ligaments is required to maintain the stability of the joint.[1] Anterior glenohumeral instability is not infrequent in young athletic populations,[2] and arthroscopic and open stabilization procedures are among the most common shoulder surgical procedures.

Although the glenohumeral ligaments (GHLs) were first described by Flood[3] in 1829, there is no consensus

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concerning the detailed anatomy of the GHLs. Because of the anatomic variability and heterogeneous descriptions available in the literature, there is no clear understanding of the qualitative and quantitative anatomic characteristics of the GHLs. As orthopaedic surgical procedures are becoming more anatomically based, a clear consensus on the quantitative anatomic attachments of the GHLs should be defined because they play an important role in the dynamic stability of the glenohumeral joint. Recent literature has reported that restoring the native anatomy after a GHL injury can restore the shoulder's native kinematics.[4]

Therefore, the purpose of this study was to perform a systematic review of previously described GHL anatomic attachments on the glenoid and humeral neck. We hypothesized that there would be agreement in the described anatomic glenoid and humeral attachment sites for the GHLs.

Methods

Article Identification and Selection

A systematic review of cadaveric or clinical anatomic studies that qualitatively or quantitatively described the glenoid and humeral attachments of the GHLs in the English-language literature was performed using the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed (1980-2018), MEDLINE (1980-2018), and Embase (1980-2018). This study was conducted in accordance with the 2009 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[5] Registration of this systematic review was performed in March 2018 using the PROSPERO international prospective register of systematic reviews, and the queries were performed in February 2018. The search protocol can be found in Appendix Table 1 (available at www.arthroscopyjournal.org).

The inclusion criteria were as follows: cadaveric or clinical anatomic studies that qualitatively or quantitatively described the glenoid and humeral attachments of the GHLs in the English-language literature. Radiographic and imaging studies, animal studies, editorial articles, and surveys were excluded from this study. Two investigators (Z.S.A. and J.C.) independently reviewed the abstracts from all identified articles. If necessary, full-text articles were obtained for review to allow for further application of the inclusion and exclusion criteria. In addition, the reference lists from the included studies were reviewed and reconciled to verify that all eligible articles were considered.

Data Collection

Specific parameters of the anatomic description within each study were collected and recorded (Z.S.A. and J.C.) for the superior glenohumeral ligament (sGHL), middle glenohumeral ligament (mGHL), anterior band of the inferior glenohumeral ligament (aIGHL), posterior band of the inferior glenohumeral ligament (pIGHL), and spiral GHL, including the glenoid attachment, humeral attachment, length of the glenoid attachment, and any available qualitative or quantitative details regarding glenoid or humeral anatomy. The level of evidence of all available clinical studies was assigned according to the classification specified by Wright et al.[6] For continuous variables, the mean and range were collected if reported.

Results

The literature search identified 513 studies from the aforementioned databases. After duplicates were removed, 489 articles were screened, and 15 articles met the inclusion criteria (Fig 1).

Study Demographic Characteristics

In the 15 included studies, 784 cadavers and a total of 983 shoulders were analyzed. The mean reported age of the studied cadavers was 69.3 years (range, 18-103 years). The sex of the studied cadavers was only reported for 291 cadavers (177 male and 114 female cadavers) (Table 1). Two studies additionally studied the anatomy in a clinical setting, consisting of a total of 149 patients. In the only study with reported patient demographic characteristics, there were 29 male and 20 female patients, with ranging in age from 28 to 65 years. Only 5 studies reported a quantitative description of an attachment site for any ligamentous structure.[7,8,16,18]

Superior GHL

Five studies described the anatomic glenoid attachment of the sGHL,[17-19,21] whereas 7 studies reported on the anatomic humeral attachment of the sGHL.[9,10,13,17-19,21] No studies reported quantitative descriptions of either the glenoid or humeral attachments of the sGHL. The most common anatomic location of the glenoid attachment and humeral insertion was in the anterolateral region of the supraglenoid tubercle and in close vicinity to the subscapularis tendon insertion, respectively (Table 2).

Medial GHL

Five studies described the glenoid attachment of the mGHL,[11,12,15,18,21] whereas 5 studies reported on the humeral attachment of the mGHL.[12,17-19,21] Only 1 study reported a quantitative description of the mGHL attachment to the humerus, in which it inserted over a distance of 2.5 cm along the subscapularis tendon.[21] No studies reported the quantitative anatomy of the mGHL attachment to the glenoid. The superior labrum was the most commonly reported glenoid mGHL origin, whereas the lesser tuberosity was the most commonly

reported site of the mGHL humeral insertion. However, there were discrepancies regarding the structure from which it originated, its location on the glenoid clock face, and its appearance. Two studies described the glenoid origin of the mGHL on the anterosuperior aspect of the glenoid labrum.[4] Ferrari[21] reported that the mGHL inserted with the subscapularis tendon on the lesser tuberosity over a distance of 2.5 cm.[21] Ide et al.[15] reported much higher variability in the presence of the mGHL, stating that the mGHL was only present in 63% of specimens. Moreover, 56.6% of specimens showed an mGHL origin on the labrum separate from that of the sGHL, whereas the remaining 43.4% showed a common origin for the sGHL and mGHL on the glenoid. Kask et al.[9] addressed the relation between the sGHL and mGHL on the glenoid, stating "the sGHL is intimately connected to the mGHL and is partially covered by it." Similarly to the authors of other studies,[11,21] Ide et al. described attenuated variants: 17.9% of specimens possessed a cord-like mGHL, and 1.2% had a Buford complex (Table 3).

Inferior GHL (Anterior and Posterior)

Nine studies reported on the glenoid attachment of the aIGHL.[8,11,15-21] The aIGHL was the most described ligament in the included studies. The most common anatomic location was obtained between the 2- and 4-o'clock positions of the glenoid. Eberly et al.[16] reported that most specimens (80%) originated on the anteroinferior glenoid labrum with extensions reaching the glenoid neck whereas the minority (20%) originated solely from the glenoid neck. Ide et al.[15] further delineated the aIGHL's origin in terms of the glenoid clock face, with the most common origin at the 3-o'clock position (64.5%). Itoigawa et al.[8] expanded on this quantitative analysis by showing the smallest insertion depth at the 2-o'clock position (4.7 mm) and the greatest insertion depth at the 4-o'clock position (8.4 mm). Overall, this description was similar to that previously given by Eberly et al. Histologically, Itoigawa et al. confirmed the 2 variants observed by Eberly et al., noting that the aIGHL attached to both the cartilage and bone in 86.7% of specimens at the 2-o'clock position and in 88.3% at the 4-o'clock position.

Two studies reported on the length of the glenoid attachment (11.7 ± 3.2 mm in one study[8] and >10 mm in the other[16]). Five studies reported on the humeral attachment of the aIGHL.[11,14,17,20,21] The most common site of the humeral attachment was in the vicinity of the surgical neck of the humerus (which was the

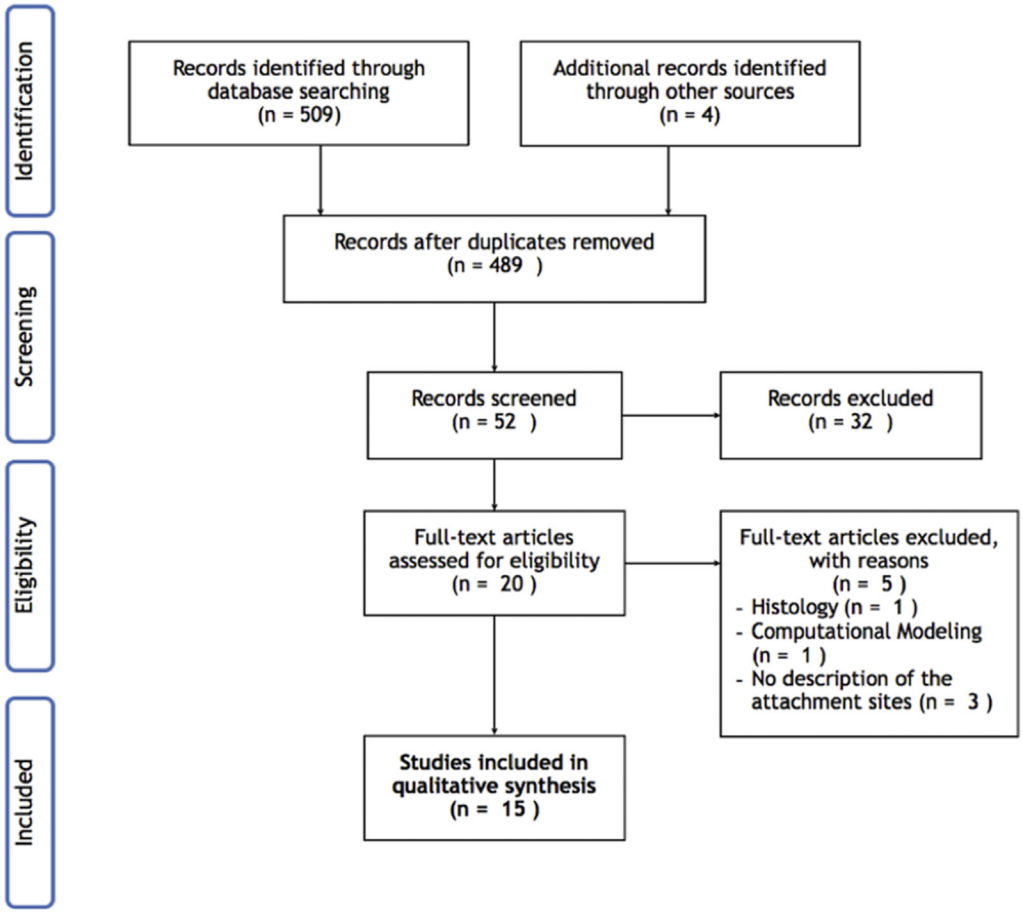

Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart of selected studies.

Table 1. Individual Study Demographic Characteristics

Authors	Journal	Year	Type of Study	No. of Patients or Cadavers	No. of Shoulders	Instrument Used for Anatomic Assessment	Male Patients or Cadavers	Female Patients or Cadavers	Mean Age (SD), yr	Minimum Age, yr	Maximum Age, yr
Kordasiewicz et al.[7]	*Ann Anat*	2016	Cadaver	12 cadavers	21 fresh shoulders	Standard caliper	8	4	59 (NA)	42	71
Itoigawa et al.[8]	*Arthroscopy*	2012	Cadaver	66 cadavers	66 embalmed shoulders	Digital caliper	35	31	81 (NA)	68	95
Kask et al.[9]	*J Shoulder Elbow Surg*	2010	Cadaver	27 cadavers	12 with alcohol formalin glycerol 15 fresh-frozen shoulders	NA, qualitative descriptions	15	12	NA	60	82
Arai et al.[10]	*J Shoulder Elbow Surg*	2010	Cadaver	10 cadavers	20 (8% formalin and preserved in 30% ethanol) shoulders	NA, qualitative descriptions	5	5	73.3 (NA)	NA	NA
Merila et al.[11]	*Arthroscopy*	2008	Cadaver and clinical arthroscopy	22 cadavers 49 patients (19 retro. videos, 30 pro. videos)	22 fresh-frozen cadaveric shoulders 49 patient shoulders (20 left and 29 right)	NA, qualitative descriptions	12 (cadaveric) 29 (clinical)	10 (cadaveric) 20 (clinical)	NA	61 (cadaveric) 28 (clinical)	90 (cadaveric) 65 (clinical)
Pouliart et al.[12]	*J Shoulder Elbow Surg*	2008	Cadaver	100 cadavers (for anatomic arm of study)	80 non-embalmed 20 embalmed	NA	NA	NA	NA	50 (non-embalmed) NA (embalmed)	90 (non-embalmed) NA (embalmed)
Pouliart et al.[13]	*J Shoulder Elbow Surg*	2007	Cadaver	110 cadavers	106 non-embalmed shoulders for anatomy 4 non-embalmed shoulders for histology	NA, qualitative descriptions	NA	NA	NA	50	95
Pouliart and Gagey[14]	*Arthroscopy*	2005	Cadaver and clinical arthroscopy	200 non-embalmed cadavers, 100 patients	300 total shoulders	NA, qualitative descriptions	NA	NA	NA	49 (cadavers) NA (patients)	103 (cadavers) NA (patients)
Ide et al.[15]	*Arthroscopy*	2004	Cadaver	44 cadavers	84 embalmed shoulders	NA, qualitative descriptions	27	17	74.1 (NA)	NA	NA

(continued)

Table 1. Continued

Authors	Journal	Year	Type of Study	No. of Patients or Cadavers	No. of Shoulders	Instrument Used for Anatomic Assessment	Male Patients or Cadavers	Female Patients or Cadavers	Mean Age (SD), yr	Minimum Age, yr	Maximum Age, yr
Eberly et al.[16]	*Clin Orthop Relat Res*	2002	Cadaver	10 cadavers	10 fresh frozen (7 for gross anatomy and 3 for histology)	Scanning device, tabletop computer	NA	NA	NA	NA	NA
Kolts et al.[17]	*Ann Anat*	2001	Cadaver	12 cadavers	12 shoulders with alcohol formalin glycerol	NA, qualitative descriptions	NA	NA	NA	58	74
Steinbeck.et al.[18]	*J Shoulder Elbow Surg*	1998	Cadaver	104 cadavers	104 embalmed shoulders	Electronic slide caliper*	72	32	68.5 (NA)	51	83
Warner et al.[19]	*J Shoulder Elbow Surg*	1993	Cadaver	6 cadavers	6 fresh-frozen shoulders	NA, qualitative descriptions	3	3	60 (NA)	51	66
O'Brien et al.[20]	*Am J Sports Med*	1990	Cadaver	11 cadavers	11 fresh-frozen shoulders	NA, qualitative descriptions	NA	NA	NA	NA	NA
Ferrari[21]	*Am J Sports Med*	1990	Cadaver	50 cadavers	100 fresh shoulders	NA	NA	NA	NA	18	80

NA, not answered; SD, standard deviation.

*Steinbeck et al. reported quantitative descriptions of the length and width of the glenohumeral ligaments but did not quantitatively describe their attachment sites.

Table 2. SGHL Anatomic Descriptions by Study

Authors	Description of Glenoid Attachment	Description of Humeral Attachment	No. of Cases Identified
Kask et al.[9]	—	Direct fibers parallel with LHB tendon between LHB and SSc tendons; partial insertion at lesser tuberosity; oblique fibers ran under semicircular ligament and into bicipital groove	25 of 27 cases
Arai et al.[10]	—	Medial portion of SGHL appeared in anterosuperior part of internal wall of joint cavity; spiraled and attached at surface of SSc tendinous slip insertion just above intertubercular groove	—
Pouliart et al.[13]	Originated immediately lateral and anterior to base of coracoid process and from anterolateral part of supraglenoid tubercle	Merged with CHL medially within 2 cm of its origin in 41% of specimens; 25% merged laterally within 2 cm of biceps pulley; 11% showed no merging with CHL and inserted into anterior margin of biceps groove or merged with MGHL and SSc tendon of FO	—
Ide et al.[15]	—	—	79 of 84 cases
Kolts et al.[17]	SGHL originated from supraglenoid tubercle	Inserted into lesser tuberosity of humerus	12 of 12 cases
Steinbeck et al.[18]	SGHL originated together with MGHL at 1-o'clock position from glenoid labrum; all cases had origin from glenoid labrum	All cases had insertion at lesser tuberosity close to CHL	98 of 104 cases
Warner et al.[19]	Originated just below biceps tendon	Inserted into lesser tuberosity just above SSc tendon	—
Ferrari[21]	SGHL arose from supraglenoid tubercle anterior to LHB	Blended with CHL and inserted into fovea capitis of humerus	—

CHL, coracohumeral ligament; FO, fasciculus obliquus; LHB, long head of biceps; MGHL, middle glenohumeral ligament; SGHL, superior glenohumeral ligament; SSc, subscapularis.

only GHL that had a unanimous qualitative description of its humeral neck insertion site) (Table 4). Three studies reported on the glenoid attachment of the pIGHL (Table 5).[11,12,17] The most common site of attachment was between the 6- and 9-o'clock positions on the glenoid. There were no quantitative descriptions reported for the glenoid or humeral attachment sites of the pIGHL.

O'Brien et al.[20] analyzed the humeral insertion of the inferior glenohumeral ligament (iGHL) complex. They

Table 3. MGHL Anatomic Descriptions by Study

Authors	Description of Glenoid Attachment	Description of Humeral Attachment	No. of Cases Identified
Merila et al.[11]	Gross anatomy: originated from superior neck of scapula and anterosuperior labrum Arthroscopic view: tightly connected with anterosuperior labrum	—	—
Pouliart et al.[12]	Arose from glenoid neck directly medial to labrum and attached to labrum between 12- and 1-o'clock positions; some overlap with SGHL	MGHL inserted on lesser tuberosity together with superior part of SSc tendon	—
Ide et al.[15]	56.6% (n = 30) originated from labrum separate from origin of SGHL; 43.4% (n = 23) arose from labrum at origin of SGHL; 17.9% (n = 15) manifested as cord-like MGHL; 1.2% (n = 1) had Buford complex	—	Found in 63.1% of cases (n = 53)
Kolts et al.[17]	—	Inserted at lesser tuberosity	—
Steinbeck et al.[18]	28.8% of MGHL originated from glenoid labrum; all at 1- to 3-o'clock position	All cases crossed tendon of SSc	Found in 84.6% of cases
Warner et al.[19]	—	Inserted into humerus just above aIGHL	—
Ferrari[21]	MGHL arose from anterosuperior aspect of glenoid labrum	Inserted with SSc tendon on lesser tuberosity; attachment of distance of 2.5 cm	Present in all specimens

aIGHL, anterior band of inferior glenohumeral ligament; MGHL, middle glenohumeral ligament; SGHL, superior glenohumeral ligament; SSc, subscapularis.

Table 4. Anatomic Descriptions of aIGHL by Study

Authors	Description of Glenoid Attachment	Length of Glenoid Attachment	Description of Humeral Attachment	No. of Cases Identified
Itoigawa et al.[8]	aIGHL-LC attachment from 2- to 3-o'clock position in 60% of shoulders; aIGHL attached from 2- to 4-o'clock position in 98% of shoulders; attached to both articular cartilage and bone in 88% of shoulders	11.7 mm (± 3.2 mm) of glenoid attachment; medial to lateral origin was 4.7 mm (1.7 mm on articular cartilage and 3.0 mm on glenoid neck) at 2-o'clock position, 6.7 mm (2.4 mm and 4.3 mm, respectively) at 3-o'clock position, 8.4 mm (3.0 mm and 5.4 mm, respectively) at 4-o'clock position, and 6.8 mm (2.5 mm and 4.3 mm, respectively) at 5-o'clock position	—	—
Merila et al.[11]	Arthroscopic view: aIGHL originated between 2- and 4-o'clock positions of glenoid	—	Arthroscopic view: aIGHL inserted at anatomic neck of humerus	aIGHL was found in 46 of 49 cases (93.6%)
Pouliart et al.[12]	—	—	Inserted together with FO forming V-shaped insertion from outside and collar-like on inside	—
Ide et al.[15]	14.5% (n = 11) originated at 2-o'clock position, 64.5% (n = 49) at 3-o'clock position, 6.5% (n = 5) at 5-o'clock position, and 14.5% (n = 11) of 4-o'clock position	—	—	Found in 90.5% of cases (n = 76)
Kolts et al.[17]	Originated from anterior and inferior parts of glenoid neck below MGHL at height of coracoid process	—	Attached to surgical neck of humerus	—
Steinbeck et al.[18]	IGHL (no separation between anterior band and posterior band) originated between 2- and 9-o'clock positions in all cases and between 3- and 8-o'clock positions in 87.6%	—	—	Clearly defined in 72.1% of cases
Warner et al.[19]	aIGHL originated at 1- to 3-o'clock position	—	—	—
O'Brien et al.[20]	IGHLC originated from glenoid, labrum, or neck of glenoid adjacent to labrum; precise class not possible; aIGHL originated between 2- and 4-o'clock positions	—	IGHLC inserted just below articular margin of head either in collar-like attachment, in which entire IGHLC attaches (n = 6), or in shape of V distal to articular edge	—
Ferrari[21]	Glenoid rim	—	Humeral neck	—
Eberly et al.[16]	All shoulders had attachments to labrum and bone at glenoid origin; 8 had attachment from labrum from 3- to 5-o'clock position; 2 joints primarily attached to glenoid bone and neck; thickest and longest at 3-o'clock position and thinnest at 5-o'clock position	>10-mm (length) attachment on glenoid	—	—

aIGHL, anterior band of inferior glenohumeral ligament; FO, fasciculus obliquus; IGHL, inferior glenohumeral ligament; IGHLC, inferior glenohumeral ligament complex; LC, labrum complex; MGHL, middle glenohumeral ligament; SSc, subscapularis.

Table 5. Anatomic Descriptions of pIGHL by Study

Authors	Description of Glenoid Attachment
Pouliart et al.[12]	pIGHL originated between 6- and 8- or 9-o'clock position
Warner et al.[19]	pIGHL originated from 7- to 9-o'clock position
O'Brien et al.[20]	pIGHL originated from 7- to 9-o'clock position

pIGHL, posterior band of inferior glenohumeral ligament.

noted that the complex attached to the humeral neck in 2 variations. One was a collar-like attachment, in which the entire complex inserted just inferior to the articular edge of the humeral head. The other variation formed a V shape, with the anterior and posterior bands inserting adjacent to the articular surface and the axillary pouch inserting on the apex of the V distally. Pouliart and Gagey[14] also noted that the iGHL inserted in a V-shaped pattern on the humeral neck. They reported that the point of the V was covered by the latissimus dorsi tendon. Whereas O'Brien et al. found this V-shaped attachment in 50% of specimens, Pouliart et al.[13] identified it in all cases.[10]

Spiral GHL

Three studies reported on the glenoid attachment of the spiral GHL.[11,12,17] The origin and insertion of the spiral GHL were relatively consistent throughout the 3 studies. The most common anatomic location was described to arise from the long head of the triceps tendon origin. Only 1 study reported on the quantitative width of the glenoid attachment site (1.5 cm).[12] These studies also reported on the humeral attachment of the spiral GHL.[11,12,17] The most common site of the humeral attachment was through a tight connection with the mGHL and where it merged with the subscapularis tendon insertion (Table 6). No quantitative descriptions were reported for the humeral attachment site.

Merila et al.[11] consistently identified the spiral GHL in all specimens dissected in their study. They reported that the spiral GHL arose from the infraglenoid tubercle and triceps tendon, traveled proximally and laterally while crossing the aIGHL and mGHL, and fused with the subscapularis tendon (Table 6; Appendix Table 2, available at www.arthroscopyjournal.org).

Discussion

The most important finding of this systematic review was the lack of quantitative data on the glenoid and humeral attachment sites for each GHL structure. Qualitatively, the most common sGHL anatomic locations of the glenoid and humeral attachments were in the anterolateral region of the supraglenoid tubercle and in close vicinity to the subscapularis tendon insertion, respectively. The superior labrum was the most commonly reported glenoid mGHL origin, whereas the lesser tuberosity was the most commonly reported site of the mGHL humeral insertion. The most common aIGHL origin was obtained between the 2- and 4-o'clock positions of the glenoid, and the humeral insertion was in the vicinity of the surgical neck of the humerus. The most common spiral GHL anatomic location was described to arise from the long head of the triceps tendon origin, inserting on the humerus through a tight connection with the mGHL and fusion with the subscapularis tendon insertion.

Restoring the native anatomy after a GHL injury provides the best treatment to subsequently restore the shoulder's native kinematics.[4] However, the results of

Table 6. Spiral Glenohumeral Ligament Anatomic Descriptions by Study

Authors	Description of Glenoid Attachment	Quantitative Attachment to Glenoid	Description of Humeral Attachment	No. of Cases Identified
Merila et al.[11]	Arose as distinct band from infraglenoid tubercle and LH of triceps tendon	—	Gross anatomy: fused laterally on anterocranial surface of SSc tendon and tightly connected to MGHL; inserted onto lesser tubercle Arthroscopic view: inserted together with SSc tendon on medial part of lesser tubercle	Gross anatomy: clearly visible in all 22 cadavers Arthroscopic view: identified in 22 of 49 cases (44.9%)
Kolts et al.[17]	Arose from insertion region of LH of triceps and axillary part of IGHL	—	Connected with joint capsule as loose connective tissue; laterally built tight connection with MGHL and fused with SSc tendon	—
Pouliart et al.[12]	Arose from glenoid labrum; broad origin from tendon of LH of triceps	LH of triceps tendinous connection up to 1.5 cm wide (medial to lateral)	Inserted on humeral neck to form exterior part of anterior limb of V insertion of inferior capsule between 9- and 6-o'clock positions	—

IGHL, inferior glenohumeral ligament; LH, long head; MGHL, middle glenohumeral ligament; SSc, subscapularis.

this review suggest that when repairing these ligaments, such as when treating anterior and posterior humeral avulsions of the GHL, there may be inconsistency in anatomic anchor placement between physicians because the quantitative anatomy of these structures has not been well defined. Therefore, it is possible that surgical treatment outcomes may be negatively affected by the heterogeneity of the anatomic literature, and we believe that further in-depth quantitative and qualitative evaluations of the GHL anatomy will improve surgical techniques when treating patients with instability. On the basis of the findings of this study, it is important that physicians are aware of the inconsistency in the literature and perform surgical repair based on the most commonly described attachment sites reported in this review.

Although there were overlapping descriptions of the anatomic attachments of the GHLs among the included studies, there was a paucity of quantitative anatomic descriptions of the GHLs of the shoulder. There were only 4 studies that quantitatively described an attachment footprint for any GHL (aIGHL, mGHL, and spiral GHL).[7,8,16,18] Moreover, only 2 studies reported overlapping quantitative descriptions that could be compared (aIGHL attachment length to the glenoid).[8,16] There was 1 additional study that reported the quantitative description of the anterior capsuloligamentous complex attachment to the humerus, although its choice to combine the mGHL and iGHL was inconsistent with the other studies.[7]

A strength of this systematic review is that it summarizes the range of qualitative descriptions of anatomic characteristics of the GHLs that can be found throughout the literature. The lack of consistency may derive from the lack of quantitative measurements when identifying these structures. Therefore, we believe that further studies should be performed to report quantified measurements with respect to anatomic landmarks to clearly define these attachment sites. Consistency in our understanding of these sites is essential when repairing these ligaments, because nonanatomic repairs may lead to altered mechanics after surgery that can lead to suboptimal outcomes.[22-24]

Limitations

We acknowledge some limitations to this systematic review. As with all systematic reviews, it is possible that relevant articles or patient populations were not identified with our search criteria. The heterogeneity of anatomic studies, including attachment points, description methods, and measuring devices, makes the understanding of the anatomic variants of the glenohumeral challenging. In addition, the number of quantitative studies analyzed was low (5 studies), and they sometimes reported on different structures; therefore, the pooled data could not be analyzed for each of the structures. Finally, a risk-of-bias assessment was not able to be performed because of the low number of studies.

Conclusions

There were limited quantitative data on the attachments of the GHLs. Although the literature was discordant, the most common descriptions of the attachments were as follows: The anterolateral region of the supraglenoid tubercle, the superior labrum, and the glenoid (between the 2- and 4-o'clock positions) were the medial attachments for the sGHL, mGHL, and iGHL, respectively. Laterally, they inserted on the humerus in close vicinity to the subscapularis tendon insertion, on the lesser tuberosity, and near the surgical neck of the humerus, respectively.

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Appendix Table 1. Search Strategy

Search 1: glenohumeral[All Fields] AND ("ligaments"[MeSH Terms] OR "ligaments"[All Fields] OR "ligament"[All Fields]) AND ("anatomy and histology"[Subheading] OR ("anatomy"[All Fields] AND "histology"[All Fields]) OR "anatomy and histology"[All Fields] OR "anatomy"[All Fields] OR "anatomy"[MeSH Terms])
Search 2: ("shoulder"[MeSH Terms] OR "shoulder"[All Fields]) AND ("capsules"[MeSH Terms] OR "capsules"[All Fields] OR "capsule"[All Fields]) AND ("anatomy and histology"[Subheading] OR ("anatomy"[All Fields] AND "histology"[All Fields]) OR "anatomy and histology"[All Fields] OR "anatomy"[All Fields] OR "anatomy"[MeSH Terms])

MeSH, Medical Subject Headings.

Appendix Table 2. Additional Ligamentous Anatomic Descriptions by Study

Authors	Structure Identified	Description of Glenoid Attachment	Quantitative Attachment to Glenoid	Description of Humeral Attachment	Quantitative Attachment to Humerus	No. of Cases Identified
Kordasiewicz et al.[7]	Anterior capsuloligamentous complex (MGHL + IGHL)	—	—	Footprint in close proximity to SSc tendon insertion; "pear-shaped" insert; thin superior and thick inferior insertions	Mean area (SD): 789.09 mm^2 (460.72 mm^2) Maximum longitudinal length: 28.16 mm Transverse length range: 5.49-8.36 mm	—
Merila et al.[11]	AxIGHL	Gross anatomy: AxIGHL originated from anterior and inferior margins of scapular neck and labrum	—	Gross anatomy: AxIGHL inserted onto anatomic and surgical necks of humerus	—	Gross anatomy: AxIGHL was present in all shoulders

AxIGHL, axillary part of the inferior glenohumeral ligament; IGHL, inferior glenohumeral ligament; MGHL, middle glenohumeral ligament; SD, standard deviation; SSc, subscapularis.