Knee Surg Sports Traumatol Arthrosc
DOI 10.1007/s00167-015-3756-8

SHOULDER

# Is arthroscopic remplissage a tenodesis or capsulomyodesis? An anatomic study

**Alexandre Lädermann[1,2,3] · Paolo Arrigoni[4] · Johannes Barth[5] · Pablo Narbona[6] · Bryan Hanypsiak[7] · Stephen S. Burkhart[8] · Patrick J. Denard[9,10]**

Received: 30 April 2015 / Accepted: 7 August 2015


**Abstract**
*Purpose* Arthroscopic remplissage of a Hill–Sachs lesion is classically described as a capsulotenodesis of the infraspinatus within the posterolateral humeral head. The aim of this cadaveric study was to evaluate the anatomic relationship between the position of anchors and sutures placed for remplissage and the infraspinatus and teres minor. The hypothesis was that remplissage actually corresponds to a capsulomyodesis of the infraspinatus and teres minor muscles.

*Methods* A two-anchor arthroscopic remplissage was performed followed by open dissection of ten fresh-frozen human cadaveric shoulders. The exit point of sutures related to muscle–tendon unit as well as the distance between the anchors and the rotator cuff was measured.

*Results* The superior sutures were localized generally in the infraspinatus, near the musculotendinous junction. The inferior sutures passed through the teres minor muscle in seven of ten cases. The distance between the superior and inferior anchors and the posterolateral greater tuberosity was 14 ± 2 and 12 ± 3 mm, respectively.

*Conclusions* Arthroscopic remplissage is a capsulomyodesis of infraspinatus and teres minor rather than a capsulotenodesis of the infraspinatus alone as previously believed. Muscular damage may explain posterosuperior pain observed in patients who underwent remplissage.

**Keywords** Anterior shoulder instability · Hill–Sachs remplissage · Humeral fracture · Anatomic study · Anatomy · Capsulodesis · Tenodesis

## Introduction

In addition to soft tissue injury, bony lesions are frequent after anterior shoulder dislocation and include defects of the glenoid or impaction of the posterolateral humeral head [3, 6, 7]. The latter is commonly known as a Hill–Sachs lesion [9]. As this lesion is by definition engaging [13], some authors have proposed arthroscopic [24] remplissage in which the posterior structures are inset into the defect, rendering it extra-articular and preventing the bone defect from engaging on the glenoid rim [19]. As such, remplissage has been shown to reduce the risk of recurrence in association with an arthroscopic Bankart repair. Most

✉ Alexandre Lädermann
Alexandre.laedermann@gmail.com

1 Division of Orthopaedics and Trauma Surgery, La Tour Hospital, Rue J.-D. Maillard 3, 1217 Meyrin, Switzerland

2 Faculty of Medicine, University of Geneva, Rue Michel-Servet 1, 1211 Geneva 4, Switzerland

3 Division of Orthopaedics and Trauma Surgery, Department of Surgery, Geneva University Hospitals, Rue Gabrielle-Perret-Gentil 4, 1211 Geneva 21, Switzerland

4 Policlinico San Donato, Università degli studi di Milano, piazza Malan 1, San Donato Milanese, Italy

5 Clinique des Cèdres, Avenue Albert Londres, Echirolles, France

6 Department of Shoulder Surgery, Sanatorio Allende, Córdoba, Argentina

7 Arthrex Inc., Naples, FL, USA

8 The San Antonio Orthopaedic Group, Department of Orthopaedic Surgery, University of Texas Health Science Center at San Antonio, San Antonio, TX, USA

9 Southern Oregon Orthopedics, Medford, OR, USA

10 Department of Orthopaedics and Rehabilitation, Oregon Health and Science University, Portland, OR, USA

Published online: 15 August 2015

authors have stated that remplissage corresponds to a posterior capsulotenodesis of the infraspinatus tendon [2, 8, 20, 24–26]. A better anatomic understanding of the posterior soft tissue involvement caused by the procedure is required as it may explain some of the post-operative complications that have been described.

The aim of this cadaveric study was to evaluate the anatomic relationship between the position of anchors and sutures placed for remplissage and the infraspinatus and teres minor. The hypothesis was that remplissage actually corresponds to a capsulomyodesis of the infraspinatus and teres minor muscles.

## Materials and methods

Ten fresh-frozen human cadaveric shoulders were used. The mean donor age was 80 ± 9 years. Eight of the donors were male, and two were female. The specimens were mounted in a simulated lateral decubitus position, secured with a clamp on the medial scapula, and mounted onto an aluminium frame. The rotator cuff of all specimens was intact.

Simulated Hill–Sachs remplissage was performed as previous described [11, 24]. The procedures were performed by two surgeons who worked together on each cadaver to confirm proper anchor location (blinded for review purposes JB and PN). A posterior portal was established, and a diagnostic arthroscopy was performed to confirm that the rotator cuff was intact. An anterosuperolateral (ASL) portal was then established above the biceps tendon. The arthroscope was directed to the ASL portal, and the posterolateral humeral head was visualized. Since the cadavers did not have Hill–Sachs lesions, the location of the anchors was based on previous studies [21, 23]. The superior anchor was placed medial to the superior aspect of the posterior bare area of the humeral head. Once this location was confirmed, a calibrated probe was inserted through a posterior cannula to find a point 12-mm medial to the rotator cuff insertion. This distance was determined to be consistent with a small to moderate Hill–Sachs lesion width and a conservative placement since larger defects extend more medial and would make anchor placement more likely to be through muscle [5, 23]. Once the location was confirmed, a spinal needle was placed to determine the angle of approach. Rotation of the humeral head was controlled so that the needle arrived perpendicular to the humeral head. A 3-mm single-loaded anchor (SutureTak; Arthrex, Inc., Naples, FL) was then placed percutaneously to simulate superior anchor placement for remplissage. The second anchor was then placed through a separate percutaneous incision, 20 mm inferior to the first anchor.

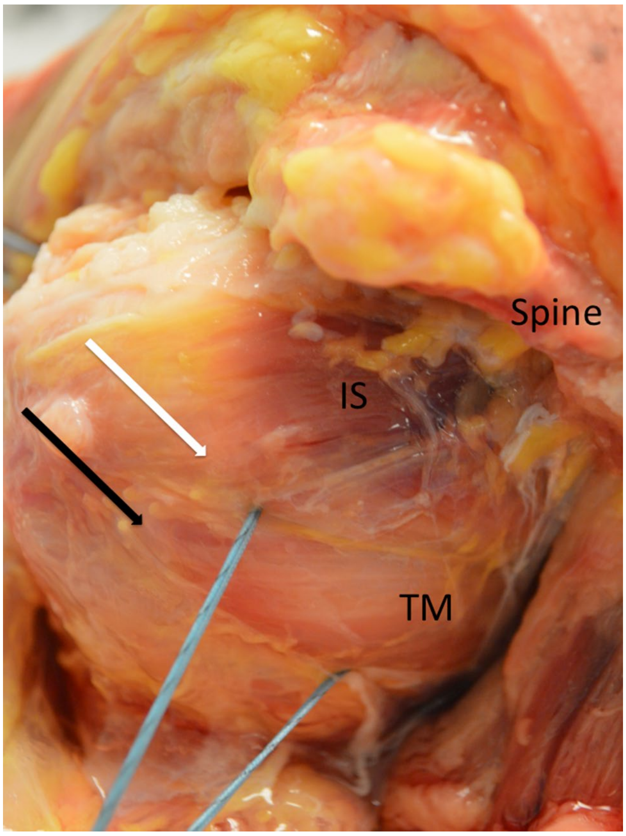


**Fig. 1** Posterior view from a left shoulder after skin and deltoid removal. The superior suture exits near the interval between the infraspinatus and the teres minor, in proximity to the musculotendinous junction of the infraspinatus (*white arrow*). The inferior suture exits in the teres minor muscle, far away from its musculotendinous junction (*black arrow*). *IS* infraspinatus, *TM* teres minor, *Spine* spine of scapula

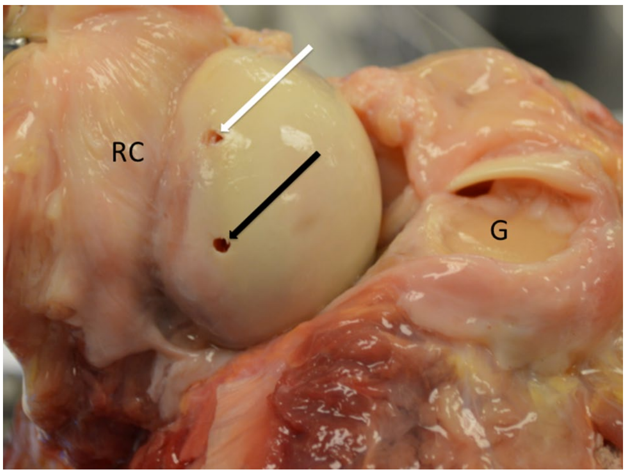


**Fig. 2** Posterior view from a left shoulder after skin, deltoid, and anchor removal, and lateral reflection of the rotator cuff. The humeral head in inferiorly dislocated. The distance between the superior hole (*white arrow*) and the reflected rotator cuff (*RC*), and the inferior hole (*black arrow*) and the rotator cuff was measured. *G* glenoid

**Table 1** Summary of results

| Cadaver no. | Side | Age (years) | Sex | Superior anchor location | Distance from superior anchor to insertion of the rotator cuff (mm) | Inferior anchor location | Distance from inferior anchor to insertion of the rotator cuff (mm) |
|---|---|---|---|---|---|---|---|
| 1 | Right | 80 | F | IS muscle | 14 | TM muscle | 9 |
| 2 | Left | 74 | M | IS MTJ | 18 | TM MTJ | 17 |
| 3 | Left | 84 | M | IS muscle | 12 | TM muscle | 15 |
| 4 | Left | 76 | F | TM MTJ | 16 | TM muscle | 12 |
| 5 | Right | 66 | M | IS muscle | 10 | IS MTJ | 13 |
| 6 | Left | 72 | M | IS MTJ | 15 | TM muscle | 9 |
| 7 | Right | 54 | M | IS MTJ | 15 | TM muscle | 10 |
| 8 | Right | 71 | M | IS MTJ | 13 | IS MTJ | 11 |
| 9 | Left | 72 | M | IS tendon | 14 | IS muscle | 9 |
| 10 | Right | 57 | M | IS MTJ | 17 | TM muscle | 14 |
| Mean (SD) | | 80 (9) | | | 14 (2) | | 12 (3) |

*F* female, *IS* infraspinatus, *M* male, *MTJ* musculotendinous junction, *TM* teres minor, *SD* standard deviation

Following anchor placement, dissection and measurements were performed by two independent examiners (blinded for review purposes PJD and PA). The skin and deltoid were removed to reveal the rotator cuff and sutures from the anchors (Fig. 1). The bursa was completely removed to accurately view the infraspinatus and teres minor. The exit point of each suture was recorded relative to the rotator cuff (infraspinatus or teres minor) and medial to lateral position (muscle, musculotendinous junction, or tendon) (Fig. 1). All locations were confirmed by mutual agreement between the two examiners. Next, the posterosuperior rotator cuff was reflected from medial to lateral to expose the glenohumeral joint. The distance between the anchors and the medial cuff insertion on humeral head was recorded (Fig. 2). These measurements were taken with a manual caliper (Etalong, Roch, Switzerland) and again confirmed by mutual agreement between the two examiners.

As the data do not contain personal identifiers, this research does not require review by an IRB under our federal law.

### Statistical analysis

Because this study was an anatomic description without a comparison group, statistical comparisons have not been made. Sample size estimation was based upon the goal of this study, which was to demonstrate that capsulomyodesis is a possible issue. To demonstrate that with a statistical power (beta) of 95 %, if the true probability of capsulomyodesis is 25 % or more, a sample size of 10 was calculated with R v3.1.2 Portable (Free Software Foundation Inc, Vienna, Austria).

## Results

The results are summarized in Table 1. The distance between the superior and inferior anchors and the medial insertion of the rotator cuff was 14 ± 2 and 12 ± 3 mm, respectively. This corresponded reasonably with the goal of a 12-mm wide Hill–Sachs defect. The sutures of the superior anchor penetrated the infraspinatus in nine cases and the teres minor in one case. The sutures were located in muscle in three cases, musculotendinous junction in six cases, and tendon (infraspinatus) in one case. The inferior anchor penetrated the teres minor in seven cases and the infraspinatus in three cases. In all cases, the inferior sutures were located in muscle or the musculotendinous junction.

## Discussion

The most important finding of the present study was that remplissage is a capsulomyodesis of both the infraspinatus and teres minor rather than a capsulotenodesis of the infraspinatus alone. Remplissage is commonly performed for patients with moderate Hill–Sachs defects with glenoid bone loss of <25 % and may also be useful for revision of previous failed glenohumeral instability surgery. While much focus has been placed on the evolving indications for the procedure [5], the anatomic consequences have not been completely defined.

Previously, it has been stated that remplissage is a tenodesis of the infraspinatus tendon. However, the present study demonstrates that anchors placed for remplissage commonly pass through the muscle or musculotendinous junction and involve the teres minor in addition to the infraspinatus tendon. Anatomically, it has been shown that the superior portion of the infraspinatus tendon is long and thick, while the inferior half is short and thin. Similarly, the teres minor is almost muscular until its attachment to the greater tuberosity [15, 16]. It is not surprising then that the present study shows that remplissage as currently performed corresponds to a capsulomyodesis rather than a capsulotenodesis.

Dynamic shoulder stability during activity occurs by action of the shoulder musculature; among it, the rotator cuff actively controls the direction of the net humeral joint reaction force [1]. Stability is achieved by balance of the four strong internal rotators (subscapularis, pectoralis major, teres major, and latissimus dorsi) and only two external rotators (infraspinatus and teres minor). The necessary force couple provided by the anterior and posterior cuff muscles [22] may consequently be impaired if the posterior muscles are weakened following remplissage. While further clinical study is needed, we believe there is potential for muscular damage to the posterior cuff given the location of the remplissage sutures demonstrated in this study. Such muscular damage may partially account for recurrence after remplissage [4]. Moreover, remplissage has been shown to limit post-operative external rotation by 8° ± 7° with the arm at the side of the trunk and 9° ± 7° in abduction [2]. Although the amount is small and does not appear to limit return to most sports, it could affect overhead athletes such as throwers or tennis players who require extreme external rotation to generate maximal velocity. Additionally, tying the sutures across muscle may lead to post-operative external rotation weakness. The latter has not been clinically evaluated and warrants further study.

Clinically, it has been noted that patients with remplissage have more post-operative pain than patients undergoing Bankart alone. Indeed, one study has reported posterosuperior pain in one-third of patients who underwent remplissage [18]. Muscular damage may also account for this observation (Fig. 3). However, such iatrogenic muscular lesions remain generally clinically silent [4]. Reasons for this discrepancy are probably numerous. First, the rotator cuff muscles may only provide dynamic stability in the mid- and end ranges of motion [10, 14]. Second, the contribution of the cuff muscles to joint stability may be due to passive muscle tension from the bulk effect of the muscle and this is not affected by remplissage [12, 17]. Third, the volume of muscle trapped by remplissage is perhaps insufficient to become clinically problematic. On the basis of these findings, however, consequences such as muscle damage and strength loss need to be clinically evaluated and techniques that rely on capsulodesis alone should be explored. Conversely, the tensile strength of remplissage by capsule alone might be inadequate in comparison with capsule plus tendon or muscle, so biomechanical investigation of these two techniques of remplissage should also be undertaken.

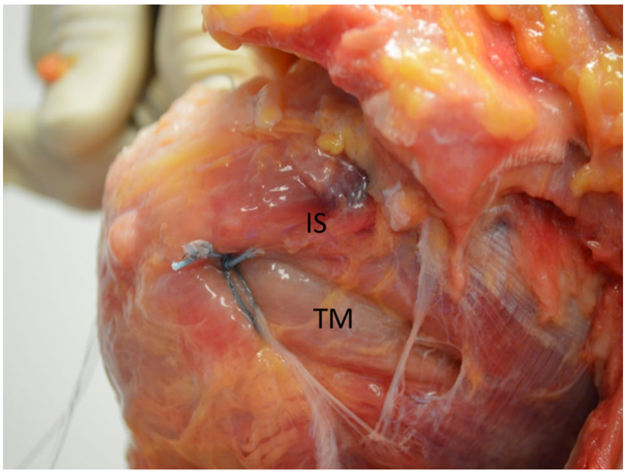


**Fig. 3** Posterior view from a left shoulder after skin and deltoid removal and arthroscopic double-pulley remplissage technique. A consequent amount of teres minor muscle is strangulated

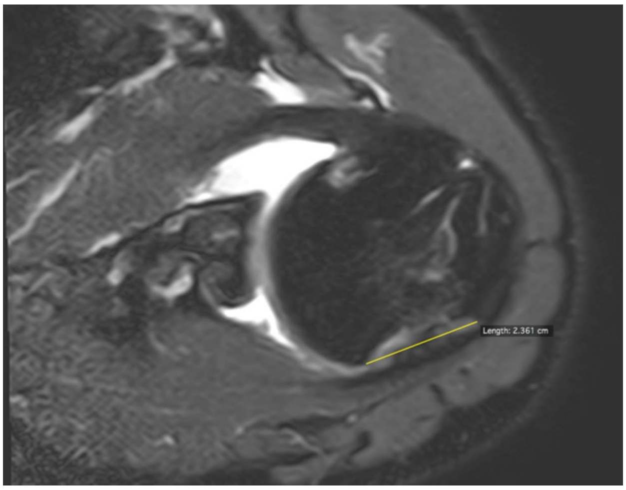


**Fig. 4** Estimation of the width of a typical Hill–Sachs lesion on T2-weighted fat-saturated MRI arthrogram axial sequence (23 mm in this example)

To our knowledge, this is the first study to describe the anatomic relationship of Hill–Sachs remplissage with the posterior rotator cuff muscles. This study has many limitations. First of all, the sample size was limited and this may have affected the results. While a tenodesis of the infraspinatus has only be noted in one case, this prevalence may have changed with a larger sample size. Second, the cadavers did not have Hill–Sachs lesions prior to anchor placement. Although creating such lesions from a posterior approach would be difficult because it would affect the subsequent remplissage, it may be possible in a future study to create Hill–Sachs lesions from an open anterior approach based on the glenoid track and then perform the arthroscopic remplissage. Anatomic references have been taken, and two surgeons confirmed the proper location of the anchors. Moreover, a conservative estimate of the width of a typical Hill–Sachs lesion (12 mm) which should have biased the location to be closer to tendon (Fig. 4) has been used.

Finally, while these findings are anatomically interesting, the clinical consequence of the post-operative muscle impairment remains to be determined. In general, the clinical results of remplissage have been promising with minimal reported complication [4]. Further study is needed to determine whether location of remplissage and/or the technique for remplissage impacts post-operative pain or the development of infraspinatus atrophy.

## Conclusions

Arthroscopic remplissage of a Hill–Sachs lesion as currently performed is a capsulomyodesis of both the infraspinatus and teres minor and not a capsulotenodesis of the infraspinatus as previously believed.

## References


1. Blasier RB, Guldberg RE, Rothman ED (1992) Anterior shoulder stability: contributions of rotator cuff forces and the capsular ligaments in a cadaver model. J Shoulder Elbow Surg 1:140–150
2. Boileau P, O'Shea K, Vargas P, Pinedo M, Old J, Zumstein M (2012) Anatomical and functional results after arthroscopic Hill-Sachs remplissage. J Bone Joint Surg Am 94:618–626
3. Buscayret F, Edwards TB, Szabo I, Adeleine P, Coudane H, Walch G (2004) Glenohumeral arthrosis in anterior instability before and after surgical treatment: incidence and contributing factors. Am J Sports Med 32:1165–1172
4. Buza JA III, Iyengar JJ, Anakwenze OA, Ahmad CS, Levine WN (2014) Arthroscopic Hill-Sachs remplissage: a systematic review. J Bone Joint Surg Am 96:549–555
5. Di Giacomo G, Itoi E, Burkhart SS (2014) Evolving concept of bipolar bone loss and the Hill-Sachs lesion: from "engaging/non-engaging" lesion to "on-track/off-track" lesion. Arthroscopy 30:90–98
6. Edwards TB, Boulahia A, Walch G (2003) Radiographic analysis of bone defects in chronic anterior shoulder instability. Arthroscopy 19:732–739
7. Griffith JF, Antonio GE, Yung PS, Wong EM, Yu AB, Ahuja AT, Chan KM (2008) Prevalence, pattern, and spectrum of glenoid bone loss in anterior shoulder dislocation: CT analysis of 218 patients. AJR Am J Roentgenol 190:1247–1254
8. Haviv B, Mayo L, Biggs D (2011) Outcomes of arthroscopic "remplissage": capsulotenodesis of the engaging large Hill-Sachs lesion. J Orthop Surg Res 6:29
9. Hill H, Sachs M (1940) The grooved defect of the humeral head. A frequently unrecognized complication of dislocations of the shoulder joint. Radiology 35:690–700
10. Howell SM, Kraft TA (1991) The role of the supraspinatus and infraspinatus muscles in glenohumeral kinematics of anterior should instability. Clin Orthop Relat Res 263:128–134
11. Koo SS, Burkhart SS, Ochoa E (2009) Arthroscopic double-pulley remplissage technique for engaging Hill-Sachs lesions in anterior shoulder instability repairs. Arthroscopy 25:1343–1348
12. Kumar VP, Balasubramaniam P (1985) The role of atmospheric pressure in stabilising the shoulder. An experimental study. J Bone Joint Surg Br 67:719–721
13. Lädermann A, Benchouk S, Denard P (2015) Traumatic anterior shoulder instability: general concepts & proper management. In: Park J (ed) Sports injuries to the shoulder and Elbow. Springer, Berlin, pp 185–204
14. McMahon PJ, Debski RE, Thompson WO, Warner JJ, Fu FH, Woo SL (1995) Shoulder muscle forces and tendon excursions during glenohumeral abduction in the scapular plane. J Shoulder Elbow Surg 4:199–208
15. Mochizuki T, Sugaya H, Uomizu M, Maeda K, Matsuki K, Sekiya I, Muneta T, Akita K (2008) Humeral insertion of the supraspinatus and infraspinatus. New anatomical findings regarding the footprint of the rotator cuff. J Bone Joint Surg Am 90:962–969
16. Mochizuki T, Sugaya H, Uomizu M, Maeda K, Matsuki K, Sekiya I, Muneta T, Akita K (2009) Humeral insertion of the supraspinatus and infraspinatus. New anatomical findings regarding the footprint of the rotator cuff. Surgical technique. J Bone Joint Surg Am 91(Suppl 2 Pt 1):1–7
17. Motzkin NE, Itoi E, Morrey BF, An KN (1994) Contribution of passive bulk tissues and deltoid to static inferior glenohumeral stability. J Shoulder Elbow Surg 3:313–319
18. Nourissat G, Kilinc AS, Werther JR, Doursounian L (2011) A prospective, comparative, radiological, and clinical study of the influence of the "remplissage" procedure on shoulder range of motion after stabilization by arthroscopic Bankart repair. Am J Sports Med 39:2147–2152
19. Palmer I, Widen A (1948) The bone block method for recurrent dislocation of the shoulder joint. J Bone Joint Surg Br 30B:53–58
20. Purchase RJ, Wolf EM, Hobgood ER, Pollock ME, Smalley CC (2008) Hill-sachs "remplissage": an arthroscopic solution for the engaging Hill-Sachs lesion. Arthroscopy 24:723–726
21. Richards RD, Sartoris DJ, Pathria MN, Resnick D (1994) Hill-Sachs lesion and normal humeral groove: MR imaging features allowing their differentiation. Radiology 190:665–668
22. Saha AK (1971) Dynamic stability of the glenohumeral joint. Acta Orthop Scand 42:491–505
23. Saito H, Itoi E, Minagawa H, Yamamoto N, Tuoheti Y, Seki N (2009) Location of the Hill-Sachs lesion in shoulders with recurrent anterior dislocation. Arch Orthop Trauma Surg 129:1327–1334
24. Wolf E, Pollack M (2004) Hill-Sachs "Remplissage": an arthroscopic solution for the engaging Hill-Sachs lesion. Arthroscopy 20:e14–e15
25. Wolf EM, Arianjam A (2014) Hill-Sachs remplissage, an arthroscopic solution for the engaging Hill-Sachs lesion: 2- to 10-year follow-up and incidence of recurrence. J Shoulder Elbow Surg 23:814–820
26. Zhu YM, Lu Y, Zhang J, Shen JW, Jiang CY (2011) Arthroscopic Bankart repair combined with remplissage technique for the treatment of anterior shoulder instability with engaging Hill–Sachs lesion: a report of 49 cases with a minimum 2-year follow-up. Am J Sports Med 39:1640–1647