Technical Note

Arthroscopic Knotless Remplissage for the Treatment of Hill-Sachs Lesions Using the PASTA Bridge Configuration

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Abstract: Recurrent glenohumeral dislocations can produce Hill-Sachs lesions—bony defects on the humeral head resulting from the humerus hitting the glenoid during dislocations. Some of these lesions can engage on the glenoid during motion, producing instability and potentially affecting the success of a labral repair. The remplissage was developed to address these Hill-Sachs lesions and improve stability. French for "filling," the goal of the remplissage is to fill the Hill-Sachs lesion with the infraspinatus tendon, preventing the margins of the lesion from engaging with the glenoid. Analogous to restoring the rotator cuff footprint during repair, a primary goal of the remplissage is to have the infraspinatus cover the Hill-Sachs lesion. The partial articular supraspinatus tendon avulsion (PASTA) bridge was originally developed for partial-thickness rotator cuff repair in situ, but additional uses have been found in other settings. The PASTA bridge uses a medial row horizontal mattress with a lateral anchor to create a linked construct to effectively distribute force and provide adequate coverage of the lesion. Knotless anchor technology used in this procedure prevents the need for arthroscopic knot tying and potentially damaging knot stacks. This Technical Note describes a remplissage technique using the PASTA bridge configuration to address Hill-Sachs lesions associated with recurrent glenohumeral instability.

Hill-Sachs lesions are problematic for the patient who requires surgery because of their association with recurrent instability and potential failure of soft-tissue procedures. When large enough, Hill-Sachs lesions can get caught, or "engaged," on the glenoid rim, which further damages the bone. To address these lesions and the recurrent instability, a variety of surgical procedures have been developed including rotational osteotomy,[1,2] filling of the bony defect with an allograft,[3,4] humeral arthroplasty,[3,5,6] and the remplissage.[1,3,7-9]

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The remplissage, French for "filling," was developed for arthroscopy in 2004 by Wolf et al.[9] Since its conception, there have been many changes to the original procedure described in the literature. Koo et al.[7] modified the remplissage by Wolf et al.[9] in many ways, including the use of a double pulley system to set the infraspinatus into the Hill-Sachs lesion with a transtendinous approach. This double pulley system was originally described by Lo and Burkhart[10] for the transtendon repair of articular supraspinatus tendon avulsion (PASTA) tears, or PASTA lesions. This system was modified by the senior author to utilize a medial row horizontal mattress while attaching 2 opposing sutures from the pulley system to a lateral third anchor—known as the PASTA bridge.[11] The PASTA bridge was developed for rotator cuff tears but has also been used in remplissage and the superior capsular reconstruction.[12,13] This Technical Note describes an arthroscopic remplissage for Hill-Sachs lesions with the PASTA bridge[11] and knotless anchor technology.

Surgical Technique

Patient Setup and Preparation

The patient is placed in the beach chair position, although the procedure can also be performed in the lateral decubitus position. A diagnostic arthroscopy is performed to assess the size of the Hill-Sachs lesion and the presence of additional pathology. Once evaluated, the exposed Hill-Sachs lesion is debrided down to bleeding bone in preparation for the remplissage (Fig 1) (Video 1).

Medial Row Anchor Placement

On viewing from the anterior portal with a 30° arthroscope, a 17-gauge spinal needle is percutaneously inserted to act as a guide for anchor placement (Fig 2). When the appropriate anchor location is determined, the inner trocar of the spinal needle is replaced with a nitinol wire (Fig 3). A small percutaneous incision is made with a No. 11 blade, and a 2.4-mm portal dilator (Arthrex, Inc., Naples, Florida) is placed over the nitinol wire (Fig 4). The nitinol wire is removed. A half-pipe spear replaces the dilator to guide the punch used to create sockets for eventual anchor placement (Fig 5). A punch is used to create a socket for the anchor (Fig 6). A 3.9-mm knotless corkscrew anchor (Arthrex, Inc.) is fixed into position in the socket (Fig 7). A second anchor is placed superior to the first anchor by following the same procedure.

Medial Row Mattress

With the intra-articular anchors placed, the arthroscope is moved to the subacromial space (Fig 8). Each anchor comes preloaded with a TigerWire repair suture (Arthrex, Inc.) and a FiberLink looped passing suture (Arthrex, Inc.). The repair suture from 1 anchor and the looped passing suture from the opposing anchor are gathered and pulled through an 8 × 3 mm PassPort cannula (Arthrex, Inc.) with a grasper (Fig 9). The repair suture has a solid white section and a black and white striped section. The change in suture color indicates a change in size, with the solid white section having a smaller diameter. In the video, suture prototypes are being used, and the color of the sutures should be disregarded. The repair suture is passed through the looped passing suture back onto itself to the black and white striped section (Table 1). This ensures there is plenty of suture to be shuttled through

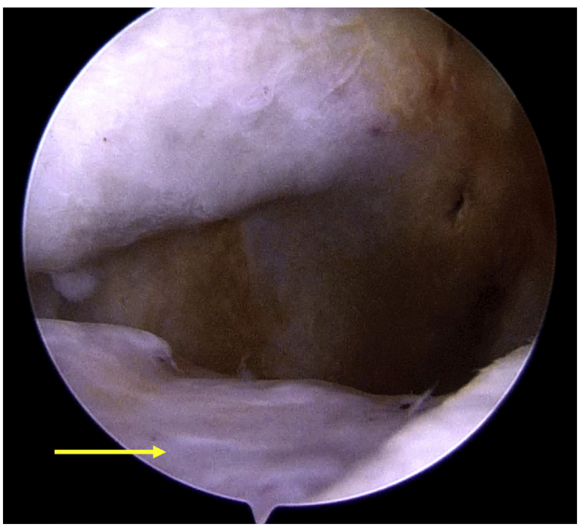

Fig 1. With the patient in the beach chair position and an intra-articular view through the anterior portal, the exposed Hill-Sachs lesion (solid yellow arrow) of the right shoulder can be seen.

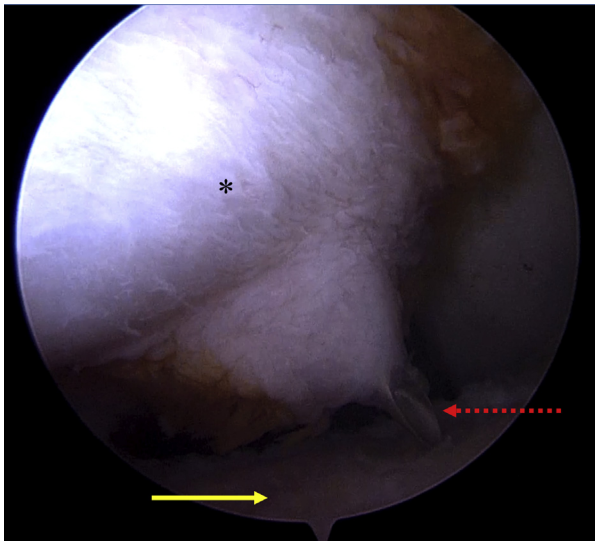

Fig 2. With the patient in the beach chair position and an intra-articular view through the anterior portal, the 17-gauge spinal needle (dashed red arrow) can be seen puncturing through the infraspinatus (asterisk) of the right arm. The spinal needle allows the surgeon to identify the correct position for anchor placement in the Hill-Sachs lesion (solid yellow arrow).

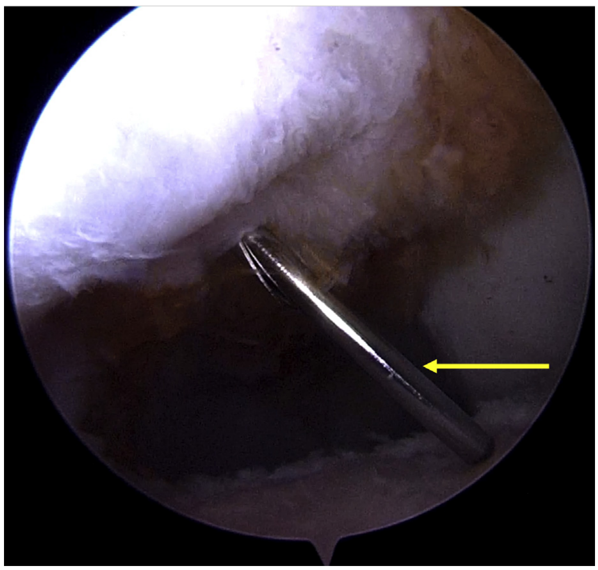

Fig 3. With the patient in the beach chair position and an intra-articular view through the anterior portal, the nitinol wire (solid yellow arrow) can be seen replacing the inner trocar of the spinal needle in the right arm.

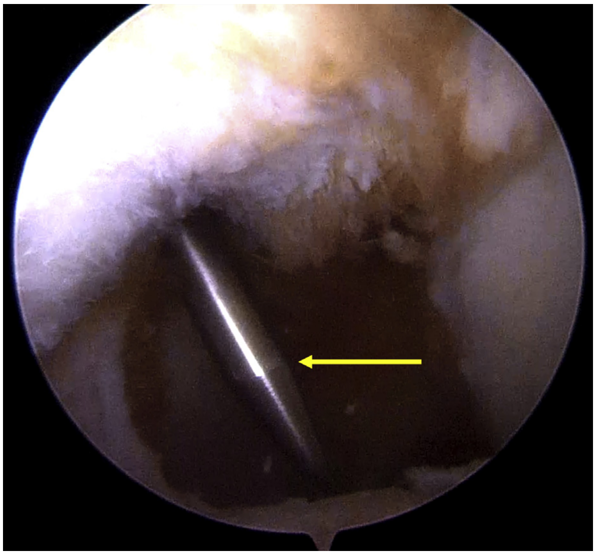

Fig 4. With the patient in the beach chair position and an intra-articular view of the right shoulder through the anterior portal, the portal dilator (solid yellow arrow) that replaced the nitinol wire can be seen.

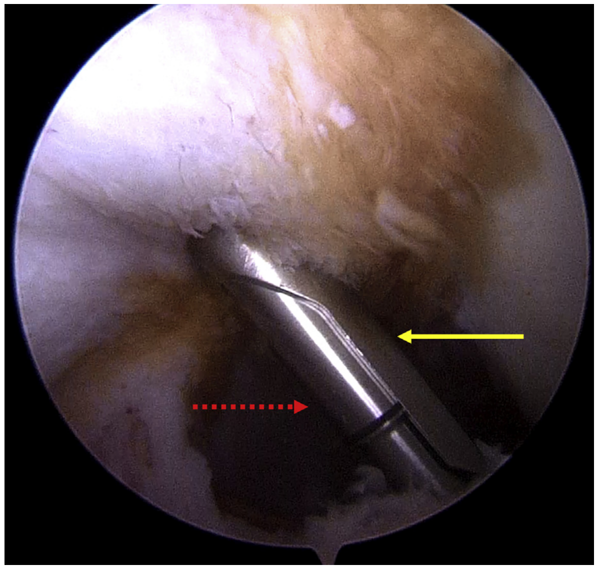

Fig 6. With the patient in the beach chair position and an intra-articular view of the right shoulder through the anterior portal, the punch (dashed red arrow) used to create the sockets for anchor placement can be seen. The punch is guided into position by the half-pipe spear (solid yellow arrow).

the anchor, and the thinnest sections are doubled over. This allows the repair suture to be pulled through the locking mechanism of the anchor with the looped passing suture. The remaining repair and passing sutures from opposite anchors are gathered, looped, and shuttled through the second anchor in the same fashion. The sutures should be pulled to take the slack out but should not be tensioned. This technique is often associated with other soft-tissue procedures such as a Bankart repair, which should be performed at this time before tensioning the sutures. Tensioning the linked construct sutures before performing the stabilization procedures will make it difficult to visualize and complete a repair. Once any additional procedures have been completed, the arthroscope can be returned to the subacromial space to continue with the remplissage.

With the linked construct in place and other soft-tissue procedures completed, the remplissage sutures

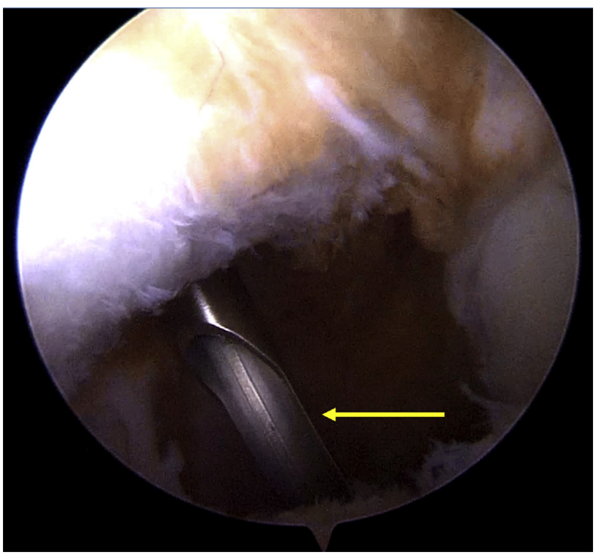

Fig 5. With the patient in the beach chair position and an intra-articular view of the right shoulder through the anterior portal, the half-pipe spear (solid yellow arrow) can be seen.

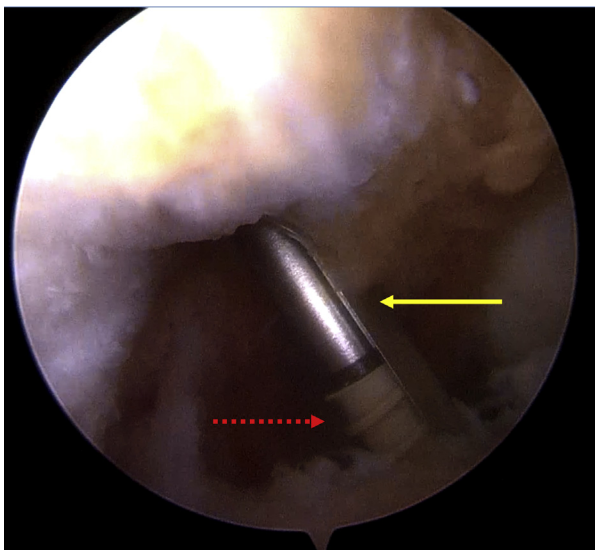

Fig 7. With the patient in the beach chair position and an intra-articular view of the right shoulder through the anterior portal, the Knotless Corkscrew anchor (dashed red arrow) can be seen being fixed into position. The anchor is guided into position by the half-pipe spear (solid yellow arrow).

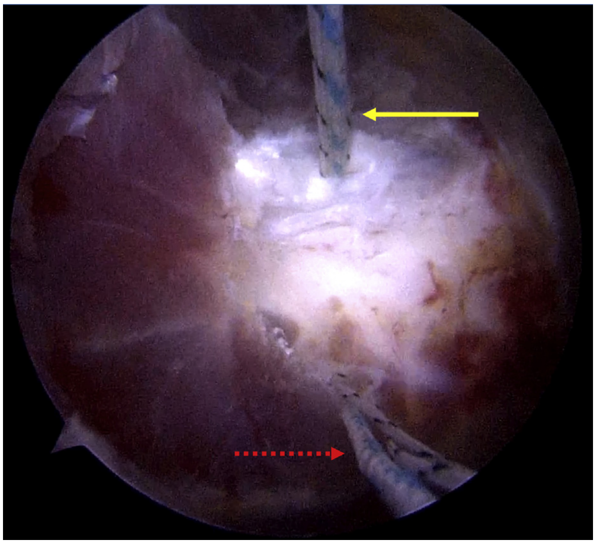

Fig 8. With the patient in the beach chair position while the subacromial space of the right shoulder is viewed through the posterior portal, the sutures from the inferior (solid yellow arrow) and superior (dashed red arrow) anchors can be seen. These sutures will create the horizontal mattress and also be used to attach the lateral anchor.

can be pulled alternately to tension the construct appropriately (Fig 10). The correct amount of tension varies from patient to patient and should be approached as such. The linked construct should secure the

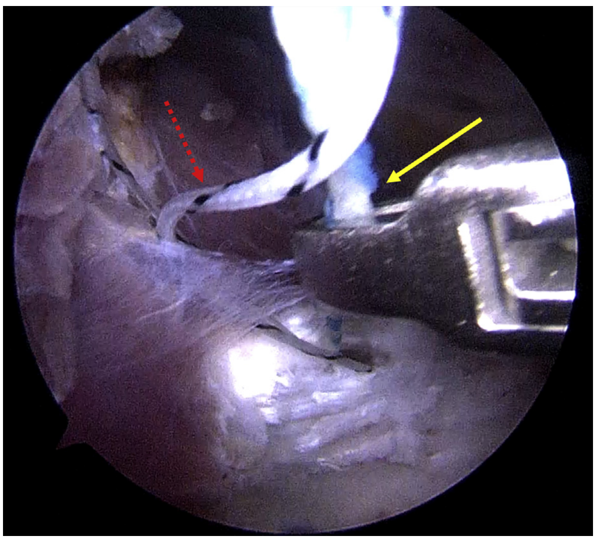

Fig 9. With the patient in the beach chair position while the subacromial space of the right shoulder is viewed through the posterior portal, a grasper is used to pull a FiberLink looped suture (solid yellow arrow) extra-articularly. The TigerWire suture (dashed red arrow) will be pulled extra-articularly from the opposing anchor and used to shuttle the sutures to create one half of the horizontal mattress. (Note: The marked TigerWire suture in the figure is identified for simplicity purposes and is not the TigerWire suture that is used to pass the FiberLink suture marked in the figure.)

Table 1. Tips and Pearls

1) When passing the repair suture, loop the white portion back onto itself so suture end reaches the black and white striped section.
2) After passing the sutures, do not tension the linked construct before associated soft-tissue procedures.
3) For tensioning, a knot pusher can be used to push down onto a suture while applying counterpressure onto the humeral head. This helps to properly tension the construct and fill the defect.
4) Move the arthroscope intra-articularly after or while tensioning the construct to ensure the infraspinatus is abutted to the humeral head and filling the Hill-Sachs lesion.
5) The lateral anchor of the construct is not technically necessary but is recommended for biomechanical strength.

infraspinatus in the Hill-Sachs lesion but should not be overly tensioned to the point of drastically limiting range of motion (ROM). The arthroscope is placed intra-articularly to ensure the infraspinatus is abutted to the humeral head (Fig 11), and ROM can be tested intraoperatively to determine appropriate levels of tension. If the infraspinatus is not fully seated to the bone, further tension can be applied to the mattress.

Lateral Anchor

The arthroscope is placed into the subacromial space, on viewing from the posterior portal (Fig 12). The remaining ends of the TigerWire repair sutures can be gathered with a grasper and pulled through the portal. The sutures are attached to a BioComposite Vented SwiveLock anchor (Arthrex, Inc.). A punch is used to create a lateral socket. The Vented SwiveLock is then placed into position (Fig 13). The remaining suture can

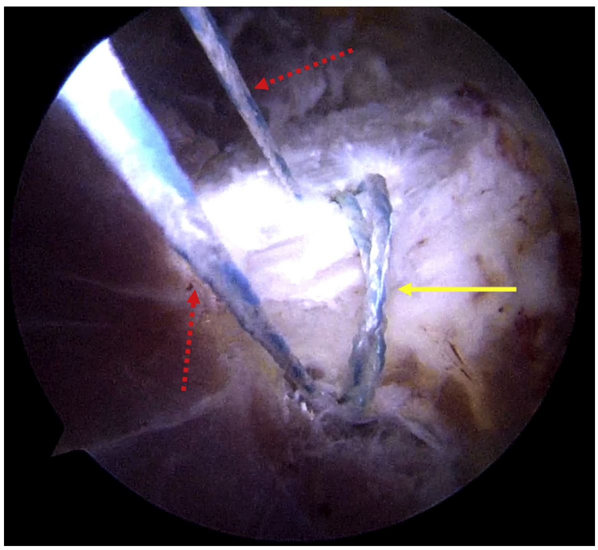

Fig 10. With the patient in the beach chair position while the subacromial space of the right shoulder is viewed through the posterior portal, the mattress construct (solid yellow arrow) can be seen after the TigerWire repair sutures (dashed red arrows) has been shuttled through with the FiberLink passing suture.

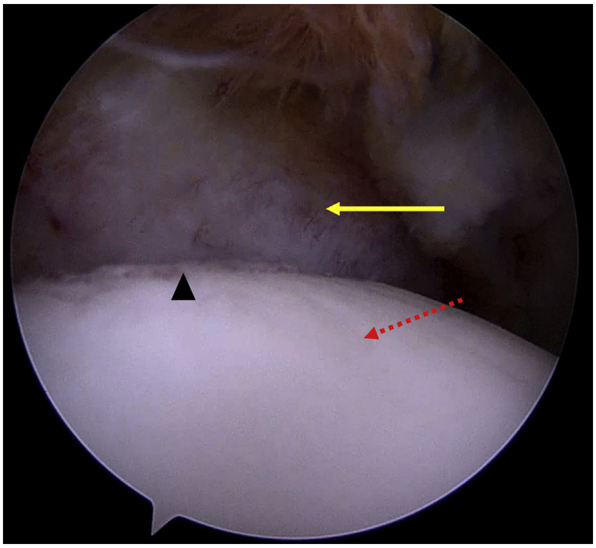

Fig 11. With the patient in the beach chair position while the subacromial space of the right shoulder is viewed, the infraspinatus (solid yellow arrow) can be seen abutted against the humeral head (dashed red arrow). After the horizontal mattress is created, the infraspinatus is set into the Hill-Sachs lesion. The margin of the Hill-Sachs lesion can be seen (solid black arrowhead).

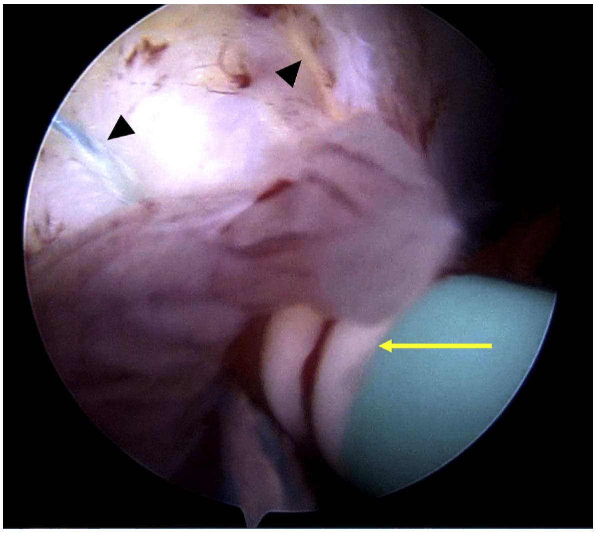

Fig 13. With the patient in the beach chair position while the subacromial space of the right shoulder is viewed through the posterior portal, the BioComposite Vented SwiveLock anchor (solid yellow arrow) can be seen being fixed into position. The TigerWire repair sutures (solid black arrowheads) are attached to the anchor for the PASTA Bridge configuration.

be cut, completing the remplissage with the PASTA bridge configuration.[11] The construct can be inspected, and the low-profile sutures without knot stacks should be noted (Fig 14).

Rehabilitation

The postoperative protocol is divided into 4 phases. First, the patient's arm is placed in a sling immediately after the procedure for 4 weeks. Phase I begins within 5 to 7 days after surgery to initiate nonaggressive ROM in flexion and scaption, as well as internal rotation and external rotation with the arm at the patient's side. By 6 to 8 weeks (phase II), the patient should have regained approximately 80% of full ROM in all planes. The patient will complete active ROM exercises in a gravity-eliminated position. Phase III is split into early and late phases. Early phase III, 8 to 10 weeks, is

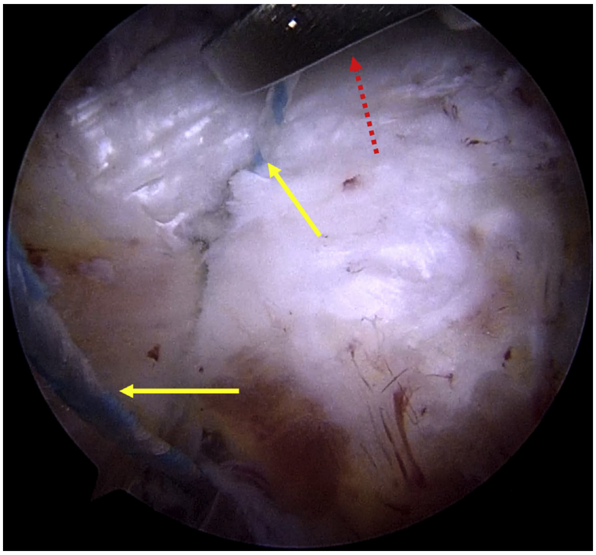

Fig 12. With the patient in the beach chair position while the subacromial space of the right shoulder is viewed through the posterior portal, a grasper (dashed red arrow) gathers the remaining TigerWire repair sutures (solid yellow arrows).

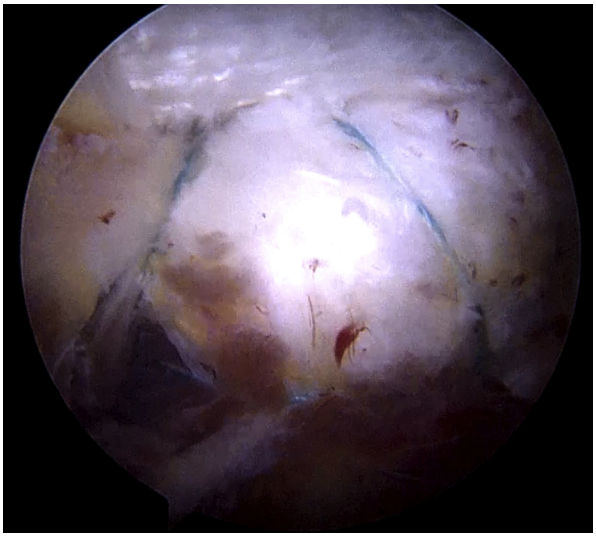

Fig 14. With the patient in the beach chair position while the subacromial space of the right shoulder is viewed, the completed remplissage with the PASTA Bridge configuration can be seen. The low-profile sutures and absence of knot stacks should be noted.

Table 2. Advantages, Disadvantages, Limitations

Advantages	Disadvantages	Limitations
1. Knotless and percutaneous, avoiding intraoperative knot tying and knot stacks.	1. May result in some postoperative loss of glenohumeral motion.	1. The remplissage is inadequate for patients who have greater than 25% glenoid bone loss.
2. Ability to precisely place the anchors and sutures easily	2. May result in postoperative loss of Abd-ER strength	
3. Lateral point of fixation takes the strain off of the medial row anchors.		
4. Adequately and reliably fills the Hill-Sachs lesions.		
5. Biomechanically tested construct.		

focused on preliminary rotator cuff strengthening exercises performed below shoulder height, but the patient needs to have full ROM in all planes. The patient can begin using light to medium weight machines by 3 to 4 months (late phase III). Neuromuscular training involving fast-twitch exercises should also be considered. Because of the nature of the procedure, physical therapists should consider avoiding or modifying exercises that can cause excessive anterior translation during this phase. In the final phase (phase IV) of rehabilitation, beginning around 4 to 6 months after the operation, patients may begin return to sport activities. Patients should strive to progress slowly from low-intensity to controlled movements. The patient may return to noncontact sports by 6 to 9 months and contact sports by 9 to 12 months after the operation.

Discussion

For the patient younger than 20 years old, the likelihood of recurrent glenohumeral dislocations after a single primary anterior dislocation has been reported to be as high as 93%.[14] As patients grow older, the recurrence rate decreases to 82% for those younger than 30,[15] 63% for those younger than 40,[14] and 16% for patients older than 40.[14] Each time the humeral head dislocates, it is crushed against the glenoid. As the number of dislocations increases, glenoid bone loss and a deep, large bony Hill-Sachs lesion can develop and progressively worsen. This can cause further instability even in the setting of intact or repaired soft tissue. Instances of recurrent glenohumeral instability and bony damage have forced physicians to adopt new strategies to address these pathologies.

In the presence of substantial bone loss, contact pressures and contact areas between the glenoid and humeral head sharply increase and decrease, respectively.[16] Because of this dramatic change, an isolated Bankart repair in a patient with substantial bone loss would have to be able to withstand the elevated forces and may fail. The remplissage was developed as an adjunct procedure to fill a bony defect in the humeral head with the infraspinatus. With the muscle set into the defect, instances of the Hill-Sachs lesion engaging on the glenoid can be vastly reduced. This helps to protect labral repairs and is considered a favorable adjunct to a Bankart repair when adequate glenoid bone stock is available but a large Hill-Sachs lesion is present. Clinically, a Bankart repair performed in conjunction with a remplissage has resulted in better outcomes and fewer re-dislocations than isolated Bankart repairs.[17,18]

In response to recurrent instability after soft-tissue procedures, the concepts of engaging versus non-engaging Hill-Sachs lesions[19] and the glenoid track[20] have been combined to create an algorithm to determine whether the Hill-Sachs is "on-track" or "off-track."[21] In their investigation into this relationship, Di Giacomo et al.[21] categorized patients into 4 separate groups by addressing the classification of the Hill-Sachs lesion and the percentage of glenoid bone loss (greater or less than 25%). According to this paradigm,[21] patients with less than 25% bone loss should receive a Bankart repair and potentially a remplissage, depending on whether the Hill-Sachs lesion engages on the glenoid. Those with greater than 25% bone loss require bony procedures such as a Latarjet procedure and potentially a humeral bone graft or remplissage, depending on the engagement of the Hill-Sachs lesion after the Latarjet procedure is completed.[21]

The PASTA bridge[11] was originally developed for the repair of PASTA lesions. In the PASTA bridge procedure, a double pulley system is used for medial fixation, then the 2 opposing repair sutures are attached laterally with a third anchor. This configuration places the stress on the lateral anchor and not the repaired tissue or medial anchors. This leaves the medial anchors to act only as pivot points. For rotator cuff repairs, restoring the footprint is considered to have vital implications for the healing process,[22,23] and its restoration is analogous to the filling of the Hill-Sachs lesion with the infraspinatus. The PASTA bridge enhances contact at the rotator cuff footprint and improves coverage of the Hill-Sachs lesion.

Remplissage procedures can potentially limit internal or external rotation if the posterior capsule is overplicated. Strength with the arm in abduction—external rotation may also be limited because of a decreased moment arm from the infraspinatus having been shortened (Table 2). Additionally, the risk of recurrent instability is always present. Given these potential risks and limitations, remplissage with the PASTA bridge[11] is still preferable to use of a traditional single-row remplissage technique because of the ease of placing the sutures and anchors percutaneously associated with the PASTA bridge,[11] which allows precise determination of the amount of shift and plication of the infraspinatus. Remplissage with the PASTA bridge[11] also incorporates knotless anchor technology and is percutaneous, which allows avoidance of intraoperative knot tying and knot stacks, which can cause postoperative damage to surrounding tissues by attrition.[24-26] The combination of the knotless technology and the biomechanically sound design of the PASTA bridge configuration[11] make this technique a procedure that should be considered by surgeons looking to address recurrent glenohumeral instability with remplissage.

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