

“Strings” (Multiple Tendon Interposition Autografts) for Reconstruction of Presumably Irreparable Rotator Cuff Tears



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Abstract: Irreparable rotator cuff tears are challenging to treat. Especially in younger patients without concomitant osteoarthritic changes, joint-preserving procedures are warranted. To date, no treatment guideline exists because none of the available techniques has shown superiority over the others, and long-term survivorship data are missing. The aim of the “Strings” is to provide an arthroscopic solution to anatomically reconstruct presumably irreparable rotator cuff tears by bridging the gap with multiple string-like tendon interposition autografts.

Massive irreparable rotator cuff tears (IRCT) account for approximately 40% of all rotator cuff tears and over time can lead to superior migration of the humeral head because of altered glenohumeral biomechanics and progressive secondary osteoarthritic changes, called *cuff-arthropathy*.¹ Although reverse total shoulder arthroplasty is a viable treatment option in the elderly suffering from progressed cuff-arthropathy, controversy exists in the management of young and active patients with massive IRCTs with no or mild secondary osteoarthritis.^{2,3}

Several joint-preserving treatment options, including debridement with or without biceps tenotomy, partial rotator cuff repair, subacromial spacer implantation, tendon transfers, and the modern superior capsular reconstruction (SCR) have been described.³⁻⁶ Nevertheless, no treatment guideline exists because long-term survivorship data are missing, and none of

these techniques has shown superiority over the others.^{3,7}

In the case of an IRCT, partial rotator cuff repair has been proven beneficial in regaining a biomechanically functional shoulder in patients with IRCT by restoring the horizontal force couple.^{8,9} Above proposed techniques aiming at mechanical lowering and coverage of the head (e.g., subacromial spacer, SCR), as well as tendon transfers acting as rotator cuff surrogate, are used separately or in addition to partial rotator cuff repair in an attempt to improve the outcome. However, complete reconstruction of the entire rotator cuff is of capital importance to restore shoulder functional range of motion and strength.¹⁰ In this Technical Note we present the “Strings” technique for treatment of IRCTs in an attempt to fully reconstruct presumably irreparable rotator cuff tears by means of multiple string-like tendon interposition autografts.

Surgical Technique

Indication

Patient selection bears special mention including a thorough preoperative workup. Strings are indicated if (1) patients suffer from shoulder pain and strength deficit with or without loss of range of motion based on a massive IRCT, (2) irreparability of the rotator cuff is revealed on magnetic resonance imaging (MRI) because of severe tendon retraction (and confirmed during surgery) (3) at least residual muscle volume is visible on preoperative MRI, and (4) only mild to moderate osteoarthritic changes are present. Our

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The authors report the following potential conflicts of interest or sources of funding: P.M. is a consultant for Arthrex Inc. and Depuy Synthes Mitek Sportsmedicine. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received October 8, 2019; accepted November 22, 2019.

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2212-6287/191236

<https://doi.org/10.1016/j.eats.2019.11.018>



Fig 1. Positioning of the patient in the beach chair position with the affected arm, as well as the ipsilateral knee, prepared and draped.

technique is contraindicated if the head shows static superior migration with full contact to the acromion on x-rays films taken in standing patients.

Preoperative Setup

The patient is placed in the beach chair position and the affected shoulder and ipsilateral knee are prepared and draped. The arm is placed in a pneumatic limb positioner (Fig 1).

Diagnostic Arthroscopy and Repair of the Horizontal Force Couple

After the bony landmarks (clavicle, spine of the scapula, acromion, coracoid process, acromioclavicular joint) are identified and marked, a standard posterior portal is placed.

A 30° arthroscope is used for viewing throughout the procedure (Fig 2). An anteroinferior working portal within the rotator interval is then established with an outside-in technique, and a diagnostic arthroscopy is performed to assess any glenohumeral pathology. The long head of the biceps tendon is usually treated with tenotomy or tenodesis (Fig 3). Further concomitant interventions include chondroplasty, synovectomy, as well as debridement as deemed necessary. Specific attention is then given to the rotator cuff tear. An attempt is made to perform

at least a partial repair of the torn rotator cuff both to regain the horizontal force couple and to reduce the superior tendon defect. This may involve the teres minor tendon, infraspinatus tendon, or the subscapularis tendon. For this purpose the footprint of the cuff is prepared by removing the soft-tissue with a radiofrequency device and then debrided using a motorized shaver and burr until a bleeding surface is achieved to favor tendon-to-bone healing. After an extensive release and trial reduction of the tendons using a grasper device, a single-row or double-row repair of the tendon is then performed (Fig 4).

Portals and Preparation Used for the Strings

If complete repair of the rotator cuff cannot be achieved, the decision is made to proceed with Strings. (Video 1) For that purpose an anterolateral, lateral as well as posterolateral portal is established if not already present and the arthroscope is inserted into the subacromial space from lateral. Any excessive bursal tissue is debrided using a motorized shaver to gain the best visualization of the remaining rotator cuff tear. The free tendon edge is debrided from all tissue that does not seem adequate for refixation.

Mediolateral measurements are taken to size the autograft correctly. Therefore an arthroscopic ruler is inserted through the lateral portal while lateralizing the retracted tendon with a grasping device. It is crucial to start measuring at least 20 mm medially

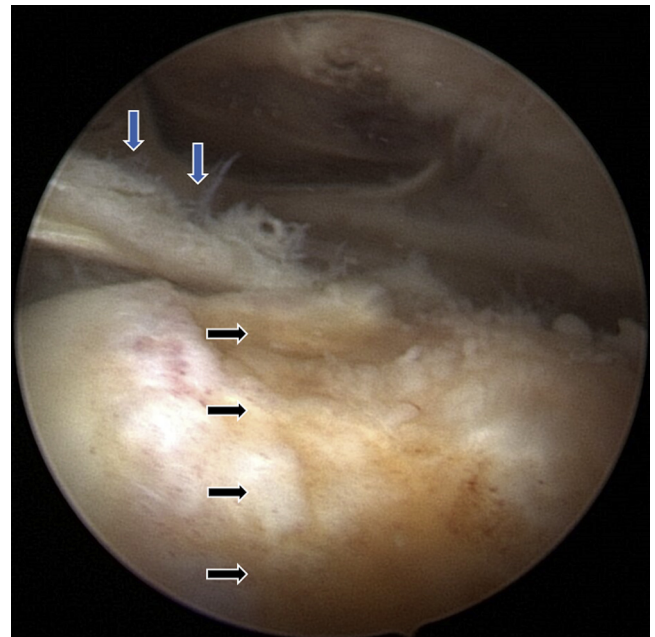


Fig 2. Arthroscopic image viewing from the posterior portal of the right shoulder. The posterosuperior rotator cuff is completely detached from its footprint at the greater tuberosity (black arrows). The long head of the biceps tendon is partially torn (blue arrow).

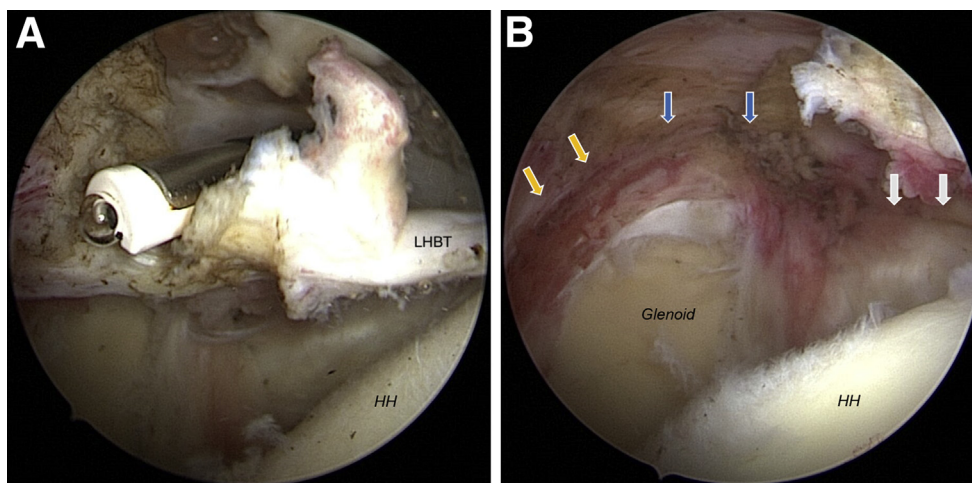


Fig 3. Arthroscopic images viewing from the posterolateral portal of the right shoulder. (A) A tenotomy of the long head of the biceps tendon (LHBT) is performed to further improve visualization of the glenohumeral joint. (B) The extensive injury to the rotator cuff is confirmed, as is an irreparable massive tear including the supraspinatus tendon (blue arrow) and the infraspinatus tendon (orange arrow). Both tendons are retracted to the level of the glenoid. The subscapularis tendon is macroscopically intact (gray arrow). HH, Humeral head.

from the free tendon edge to both grasp vital tendon tissue avoiding a cut-out of the sutures and to guarantee an overlap of the autograft to enhance tendon healing. Furthermore, the measurement

must extend to the lateral aspect of the greater tuberosity in order to fully cover the anatomic footprint.

Graft Harvesting and Preparation

Hamstring tendon harvest is performed according to the surgeon's preference. In our setting, the fascia is opened slightly superior to the semitendinosus tendon insertion. The tendon is then identified and freed from vinculae. Then the tendon is placed through an open tendon stripper and released from its muscular attachment proximally and finally also distally using a knife. Excess muscular tissue is removed, and the tendon and is then sized (approximately 25 cm in length). Depending on the tear dimension, the tendon graft is then divided into several Strings. Usually 4 to 5 pieces of 5 cm length are obtainable. The needed number of Strings is then assessed, and each of them is armed with nonabsorbable no. 2 sutures (Fiberloop; Arthrex, Naples, FL) in a running stitch technique at both ends (Fig 5).

Tendon Graft Delivery and Medial as Well as Lateral Fixation

Once the tendon graft has been prepared, a working cannula (Passport; Arthrex) is placed into the lateral portal to ease suture management and allow autograft passage. With the arthroscope in the posterolateral portal, a strand from String no. 1 is passed through the posterior tendon stump (approximately 20 mm medial to the lateral edge of the tear) using a retrograde suture-passing device (Scorpion; Arthrex) in a reverse fashion (Fig 6). This step is then repeated for the second strand to complete the reversed horizontal mattress stitch meaning that the Strings end up on top

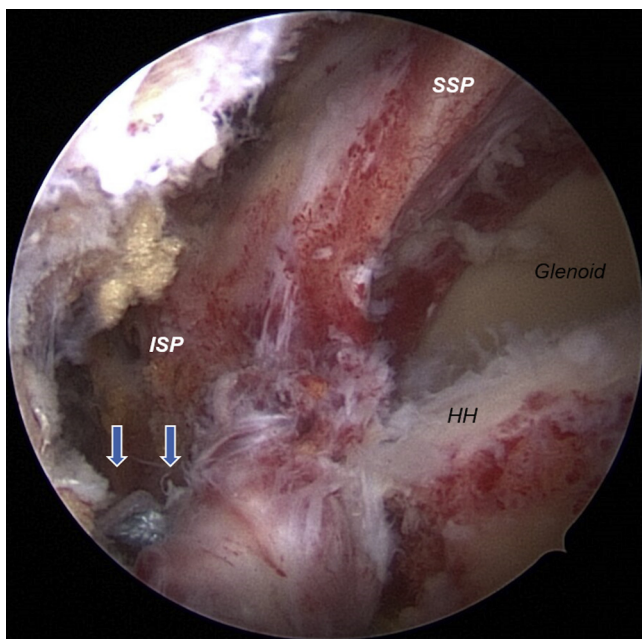


Fig 4. Arthroscopic images viewing from the lateral portal of the right shoulder. A surgical release of the rotator cuff is performed, and the reducibility of the tendons and the potential for achieving a tension-free repair to the native footprint at the humeral head (HH) is assessed. If possible for the infraspinatus tendon (ISP), a horizontal mattress stitch repair using a double-loaded suture anchor is accomplished (blue arrow). SSP, Supraspinatus tendon.

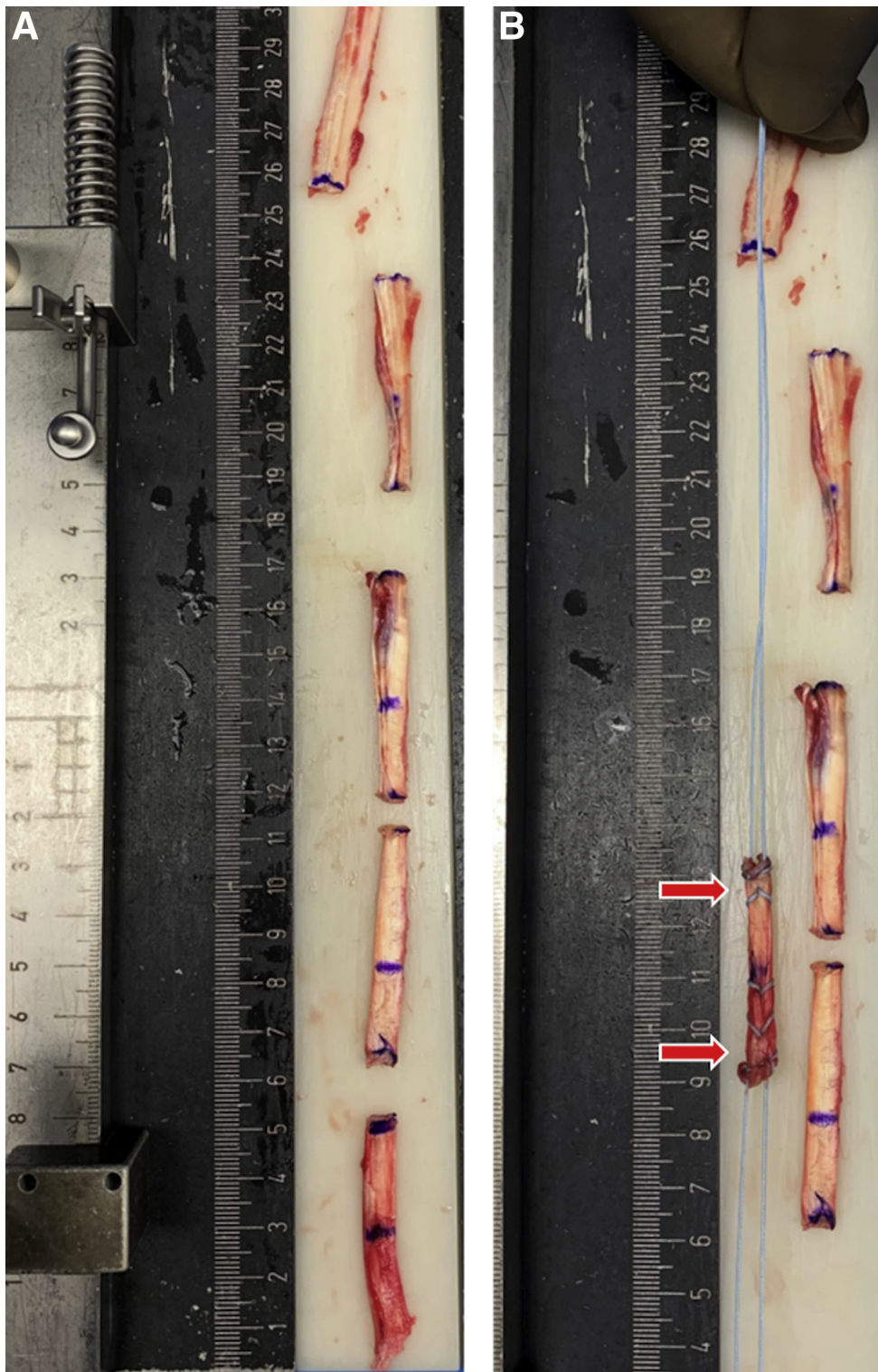


Fig 5. Preparation of the harvested autograft. (A) The tendon graft is divided into several Strings of approximately 5 cm each. (B) The Strings are armed with nonabsorbable no. 2 sutures in a running stitch technique at both ends (red arrows).

of the tendon stump and the knot on the bottom. Alternative configurations with Strings on the bottom and knot on top, as well as both on top, can be created.

Both suture strands are then passed out of the anterolateral portal for appropriate suture management. A grasper or clamp is then used to push String no. 1 into the joint through the portal while pulling on both

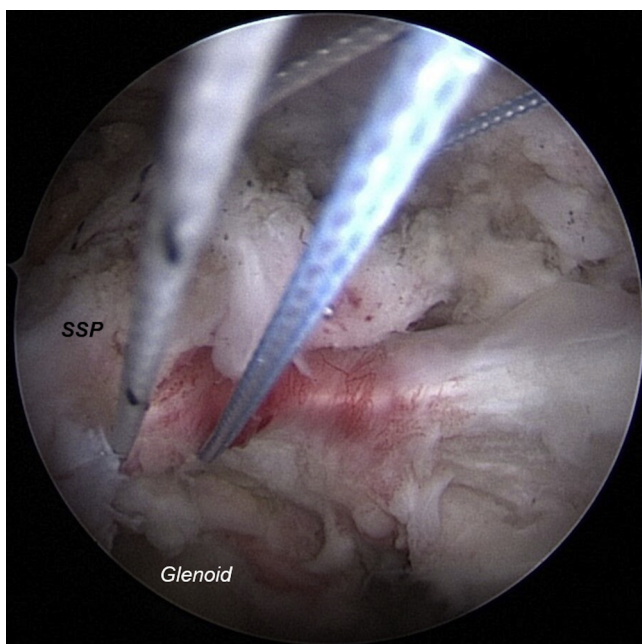


Fig 6. Arthroscopic view through the posterolateral portal in a right shoulder. Both suture strands from one side of the String are passed through the tendon stump of the supraspinatus tendon (SSP) using a retrograde suture-passing device in a reverse fashion.

strands previously passed through the cuff (Fig 7). The medial end of the graft is now overlapping the free tendon edge. To complete the inverse mattress stitch, an arthroscopic knot is securely tied. After medial fixation, the graft is tensioned and then fixed to the tuberosity under slight tension using a knotless suture anchor (Swivelock; Arthrex). These procedures are now repeated one-by-one with further Strings. Although medial attachment remains individual per String, lateral attachment can be achieved in pairs to minimize implants (Fig 8). In a large IRCT, approximately 4 Strings with 2 lateral suture anchors are necessary to reconstruct the rotator cuff (Figs 9 and 10).

Postoperative Care

Directly after surgery, the affected arm is supported in an abduction brace for 6 weeks. Rehabilitation protocol is equally to that after arthroscopic repair of a large rotator cuff tear. Within the first 6 weeks, only pain-free passive range of motion is permitted. To improve both tendon and autograft healing, a gradual increase in passive motion starting with week 4 is encouraged. At week 7, active full range of motion exercises are started. Strength exercises are added after 3 months.

Discussion

Recently, different joint-preserving surgical options have been evolved to treat IRCTs in younger patients with no to mild secondary glenohumeral arthritis. Both, insertion of a subacromial balloon spacer and SCR combined with an arthroscopic partial rotator cuff repair were found to be effective to a certain extent with promising short-term results.^{11,12} The concept of both procedures is to stabilize the humeral head to produce functional gains. Current techniques for SCR using either an autograft or allograft use bone to bone fixation of the graft resulting in a static structure. Thus the graft loses its tension and thus its stabilizing effect at higher abduction levels.¹³ Furthermore, previous studies demonstrated that graft material¹⁴ and thickness¹⁵ influenced both biomechanics and graft healing. A repair failure of approximately 50% was found using an allograft and of approximately 5% using an autograft, respectively. In a recent systematic review the overall complication rate was 17% for SCR.¹⁶

From a technical point of view, interposition grafting seeks to restore rotator cuff continuity by extending the retracted tendon and thus to recruit the former nonfunctional muscle. The basic concept is not new because different open, as well as arthroscopic, techniques have been described to bridge the gap in IRCTs. In 2008, Rhee et al.¹⁷ demonstrated the clinical and radiographic results after autologous long head of the



Fig 7. The arthroscope is placed through the posterolateral (PL) portal of a right shoulder. After both suture strands are passed out of the anterolateral (AL) portal for proper suture management, a clamp is used to insert the String (orange arrows) into the joint through the working cannula (lateral portal).

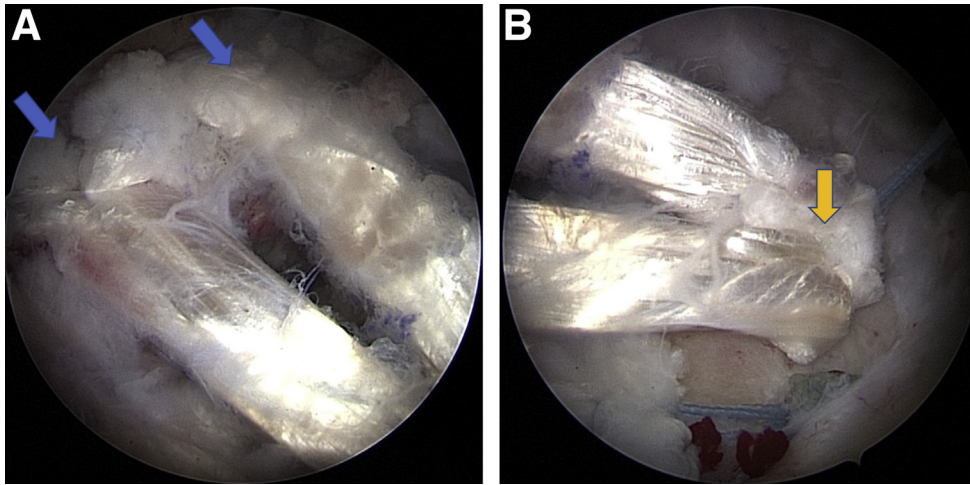


Fig 8. Arthroscopic view through the posterolateral portal in a right shoulder. (A) Two Strings are separately attached medially to the remaining cuff using a mattress stitch (blue arrows). (B) A one-point fixation (orange arrow) is used laterally to attach both Strings to the anatomic footprint.

biceps tendon grafting in 31 patients. Although no complication occurred within a 2-year follow-up, a re-tear was revealed in 21% using MRI. Overall, the constant score as primary outcome measurement improved from preoperative 48 points to 82 points at final follow-up. A comparative study between fascia lata autograft interpositioning (group A, $n = 24$) and partial rotator cuff repair (group B, $n = 24$) highlighted the clinical superiority of the bridging technique. A total of 5 patients in group A had either

a re-tear of the infraspinatus tendon (8%) or the autograft (12%), whereas the repair failure was 42% in group B. Again, no complication was reported. Some short-term studies exist reporting on the results after allograft interposition. Although clinical and radiographic outcomes were found to be equivalent, some deep infections occurred after allografts were used.^{18,19}

Strings are a feasible option including several advantages of both the minimally-invasive arthroscopic surgery and the usage of multiple interposition grafts (Table 1). First, the restoration of the native continuity of the deficient rotator cuff might lead to superior joint biomechanics as the autograft restores the cuff as a dynamic stabilizer in the throughout range of motion. Second, Strings might be superior to previously described interposition grafting techniques because the load is shared among multiple grafts, thus improving stability. Third, our procedure is technically fairly easy to perform, with multiple grafts being inserted step by step while maintaining good visibility. For example, in SCR improper suture management can lead to graft twisting and suture tangling, which constitutes an enormous technical challenge to even the most experienced surgeon.²⁰ The level of technical challenge and risks with Strings is similar to a standard large rotator cuff repair (Table 2).

Regarding the choice of graft type, several options are possible. The hamstring tendon autograft is easy to harvest with little donor site morbidity.^{21,22} Furthermore, biomechanical properties of this autograft were demonstrated to be $>1400\text{N}$ ²³ and thus exceed the native requirements of 630N by far.²⁴ In contrast, the most commonly used autograft in both bridging and SCR techniques is the fascia lata with a mean load to failure of approximately 40N ,²⁵ whereas allograft

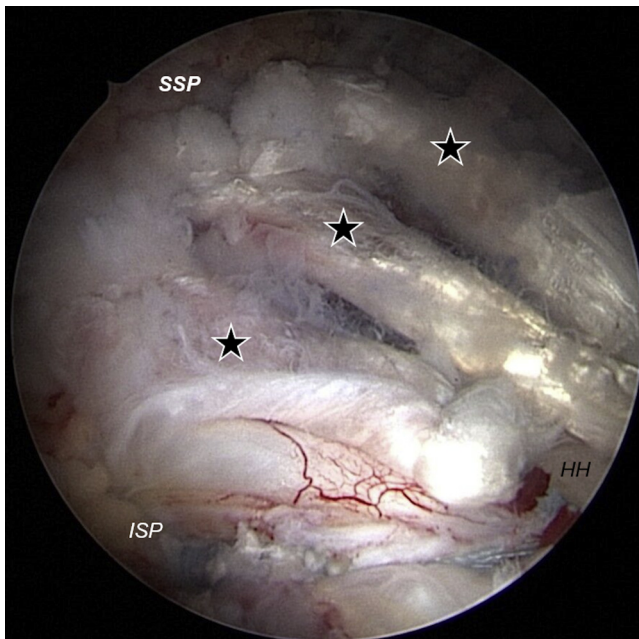


Fig 9. Final arthroscopic view through the posterolateral portal in a right shoulder. In addition to partial repair of the infraspinatus tendon (ISP), Strings (black stars) are used to bridge the gap between the irreparable supraspinatus tendon (SSP) and the humeral head (HH).

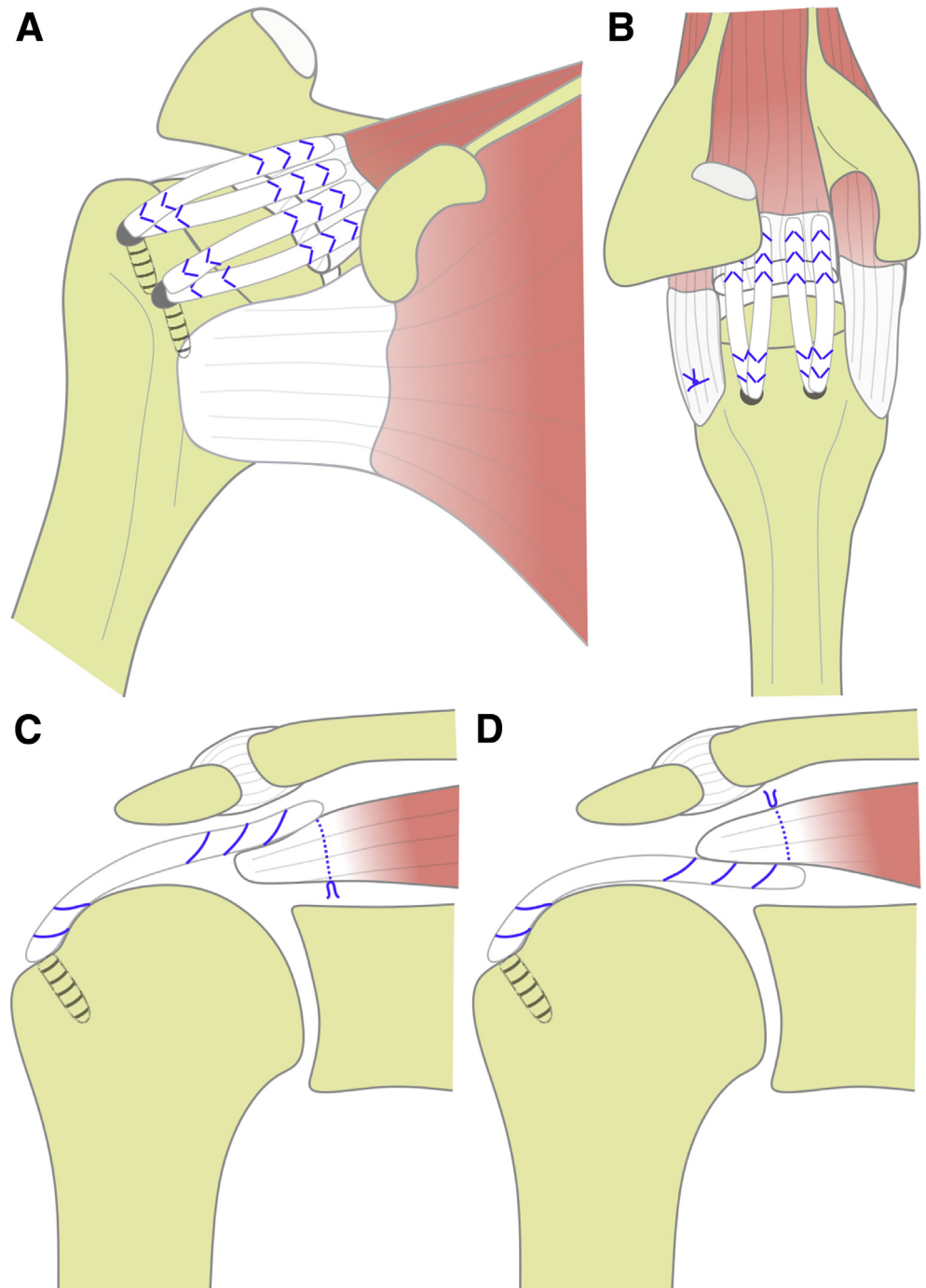


Fig 10. Schematic illustration of the use of Strings for reconstruction of an irreparable rotator cuff tear in various planes (A-D). Strings can be attached on top (C) or on the bottom (D) of the remaining tendon stump of the rotator cuff.

materials resist up to 200N.²⁶ However, potential alternative grafts for the Strings could include the long head of the biceps tendon, quadriceps, or triceps, as well as other different tendon allografts.

In summary Strings provide an arthroscopic solution to anatomically reconstruct presumably irreparable rotator cuff tears by bridging the gap with multiple string-like tendon interposition autografts.

Table 1. Advantages and Disadvantages of Strings

Advantages
Arthroscopic procedure to restore anatomy in presumably irreparable rotator cuff tears.
Hamstring tendon autografts are easy to harvest and biomechanically superior compared to other autografts like the fascia lata and available allografts.
Superior biomechanical properties as the autograft acts as a dynamic not static stabilizer with load sharing amongst multiple grafts and fixation points, respectively.
Additional procedures such as tenotomy of the long head of the biceps tendon and partial repair of the horizontal force couple can be added.
Disadvantages
The effect of the technique might decrease with increasing muscle degeneration of the cuff.
Potential donor site morbidity.
Non-“water-tight” reconstruction of the rotator cuff as gaps remain between the Strings.
Because of the required additional sutures and suture anchors the costs of the procedure are higher than for a partial repair.

Table 2. Pearls and Pitfalls of Strings

Pearls
Arm both sides of the Strings with sutures “on the table” before introducing them into the joint.
Pass the medial sutures of the Strings approximately 20 mm medial to the lateral edge of the tear to create an extensive overlap of both tendons and increase the contact area.
Introduce and fix single Strings one-at-a-time or as maximum in pairs to maintain good visibility and sufficient space during arthroscopy.
Place the suture anchors far enough laterally on the greater tuberosity in order to create slight tension on the Strings and the remaining rotator cuff.
Pitfalls
Debride the stump of the remaining rotator cuff extensively to identify viable tendon tissue of adequate quality to form the medial attachment of the Strings.
Be aware to test tendon excursion before determining the length of the Strings as tensioning of the Strings significantly lateralizes the remaining tendon which reduces the required String-length.
If using multiple strings avoid the placement of too many suture anchors on the lateral aspect of the greater tuberosity by inserting the Strings in pairs.

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