Technical Note

Autologous Tendon "Bamboo Raft" Graft for Reconstruction of Massive Irreparable Rotator Cuff Tears

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Abstract: Superior capsular reconstruction has shown long-term clinical effectiveness in treating massive irreparable rotator cuff tears, playing a key role in reducing humeral head translation and restoring the force-couple balance. Various graft techniques involving different types of grafts, such as autologous fascia lata, allogeneic dermal patches, and autologous long head of the biceps tendon, have been described. However, these approaches were often limited by factors such as extensive surgical trauma, high donor-site morbidity, and insufficient mechanical strength of the grafts. We describe autologous tendons, such as the hamstring tendon, fashioned into a "bamboo raft" configuration to create a graft for massive irreparable rotator cuff tears. This technique offers several advantages, including minimal surgical trauma, low donor-site complication rates, and superior mechanical strength of the graft.

Superior capsular reconstruction (SCR), initially performed using autologous fascia lata,[1,2] effectively manages massive irreparable rotator cuff tears (MIRCTs).[3,4] It reduces humeral head translation and restores the force-couple balance.[4-6] Alternative graft options such as allogeneic dermal patches and long head of the biceps tendon have been explored but face issues including surgical trauma,[7-9] high donor-site morbidity (16%-30%),[5] and weak graft strength.[1,6-10]

Autologous tendons, often used in ligament reconstruction and soft-tissue repair, have superior biomechanical properties and biocompatibility compared with fascia lata grafts, reducing immune rejection risks.[11,12] Moreover, patients usually experience fewer complications related to the harvest site, such as pain and limping, than with graft sources such as autologous fascia lata or patellar tendons.[13] This article presents a therapeutic approach for MIRCTs using the patient's tendon, such as the hamstring tendon, shaped into a "bamboo raft" configuration to create a graft, offering a fresh perspective on treatment options (Video 1). Pearls and pitfalls of our technique are summarized in Table 1. Advantages and disadvantages are summarized in Table 2. Additionally, a step-by-step guide can be found in Table 3.

Surgical Technique

Indications

The main characteristics of MIRCTs include an extensive tear range (tear length > 5 cm or tear involving 2 tendons) and upper migration of the humeral head.[3] Our current indications for SCR are cases in which the footprint area cannot be repaired directly after cleaning the pannus. A schema of graft placement is presented in Figure 1.

Anesthesia and Patient Positioning

The patient is placed under general anesthesia in the beach-chair position (Fig 2A). The thigh root of the opposite lower limb from which the tendon is to be removed is tied with a tourniquet.

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Table 1. Advantages and Disadvantages of Technique

Advantages
Donor-site morbidity is reduced compared with other autografts (i.e., fascia lata).
Patients avoid the complications of long-term bed rest postoperatively (vs fascia lata).
The grafts are biomechanically stronger and thicker, reducing graft tearing (vs fascia lata or dermal patch).
This technique is a good option in revision surgery, especially when the long head of the biceps tendon and fascia lata are unavailable.
Disadvantages
Further studies are needed to clarify the long-term clinical outcomes.
There is a need for biomechanical studies.

Table 2. Pearls and Pitfalls of Technique

Pearls
Preparation of the glenoid and greater tuberosity footprint should be performed before graft introduction.
Graft tensioning from the lateral portal must be maintained during fixation on the greater tuberosity.
The tendon is sutured continuously to avoid longitudinal displacement of the bamboo raft graft, and the sutures are crisscrossed 3 times to avoid its lateral displacement.
The lateral approach can be appropriately expanded when performing graft implantation.
Pitfalls
The arthroscopic view may be compromised by the size of the graft (too thick).
The length of the rotator cuff defect should be carefully estimated because it affects the construct and tensioning of the bamboo raft graft.
When the hamstring tendon is being removed, minimizing the traction and pressure on the surrounding tissue is necessary to avoid damage to the saphenous nerve. Damage to the saphenous nerve will lead to numbness on the medial side of the knee joint.

Arthroscopic Approach and Microscopic Exploration and Cleaning

The conventional posterior, anterolateral, lateral, and Neviaser approaches to the shoulder joint are used. Initially, a standard posterior portal is established, followed by the insertion of a 30° arthroscope into the glenohumeral joint (Smith & Nephew Arthroscopy, Andover, MA) (Fig 2B). The conditions of the subscapularis, labrum, articular cartilage, and long head of the biceps are evaluated, and repair is performed via the anterolateral portal (Fig 3A). Subsequently, the arthroscope is transferred into the subacromial space from the posterior approach to explore the extent of rotator cuff injury and the acromion's shape. Subacromial debridement and decompression are conducted through the lateral channel (Fig 3B). The anterior, posterior, and medial rotator cuff stumps are fully released, and tissue-grasping forceps are used to assess the tension on the rotator cuff repair. SCR is performed if the rotator cuff stump cannot be restored to the footprint area under appropriate tension. The graft width is measured from the anterior to posterior edge of the rotator cuff tendon lesion. The graft length is determined by the distance from the rotator cuff footprint's lateral edge to the scapular glenoid's upper edge.

Harvesting Autologous Tendon Bamboo Raft Graft

The autogenous tendon is folded into a patch resembling a bamboo raft (Fig 4 A and B). A 2- to 3-cm oblique incision is made on the medial side of the tibial tubercle of the opposite knee joint. After the fascial layer is incised, the footprint area of the anserine bursa is exposed. The semitendinosus and gracilis muscles are separated to extract the entire tendon (Fig 4C). The

Table 3. Step-by-Step Guide to Performing Proposed Technique

Step 1: The patient is placed under general anesthesia in the beach-chair position, and the conventional posterior, anterolateral, lateral, and Neviaser approaches to the shoulder joint are used (Fig 2).
Step 2: An arthroscope is transferred into the subacromial space from the posterior approach to explore the degree of rotator cuff injury and the shape of the acromion, and subacromial debridement and decompression are performed through the lateral channel (Fig 3).
Step 3: The anterior, posterior, and medial rotator cuff stumps are fully released, and tissue-grasping forceps are used to assess the tension during rotator cuff repair. The graft width is measured from the anterior to posterior edge of the rotator cuff tendon lesion. In contrast, the graft length is determined by the distance from the rotator cuff footprint's lateral edge to the scapular glenoid's upper edge.
Step 4: A 2- to 3-cm oblique incision is made on the medial side of the tibial tubercle of the same-side knee joint. Following the incision of the fascial layer, the footprint area of the anserine bursa is exposed, the semitendinosus and gracilis muscles are separated, and the entire tendon is extracted (Fig 4).
Step 5: Continuous edge-to-edge sutures are used to create a sealed graft after folding the tendon to match the length of the supraspinatus defect. To enhance graft stability and prevent loosening or twisting during transplantation, high-strength sutures are crisscrossed 3 times in the center of the graft for reinforcement. PDS II sutures are used for traction by passing through the 4 corners of the graft.
Step 6: The soft tissue of the superior labrum is completely removed to expose the bone surface above the scapular glenoid at the 10- and 12-o'clock positions (right shoulder). The bone canal is prepared with an opening cone, and 2 double-suture bone anchors are securely screwed in.
Step 7: The 2 inner-row double-suture bone anchors are implanted approximately 3 mm lateral to the anterior edge of the original supraspinatus key insertion point and the cartilage edge.
Step 8: The "autologous tendon "bamboo raft" graft is fixed on the glenoid side and the greater tubercle side of the humerus, maintaining moderate tension (Fig 5).
Step 9: An outer-row anchor is driven into the humeral tubercle side to strengthen the fixation of the graft in the footprint area.
Step 10: A drainage tube is placed, and the incision is closed.

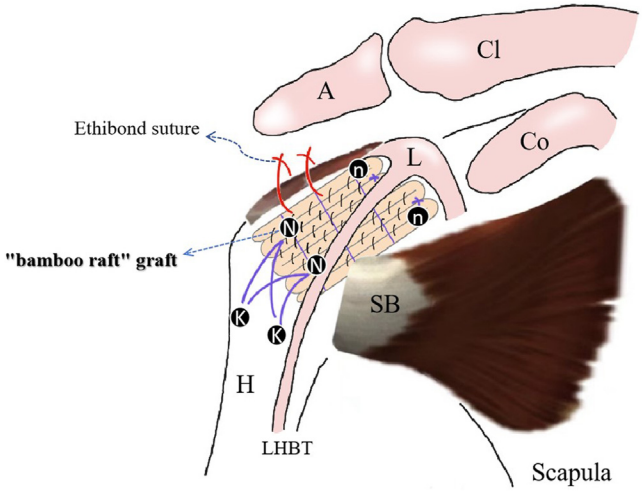

Fig 1. Bamboo raft graft placement. Initially, the semitendinosus and gracilis hamstring tendons are harvested and meticulously shaped. Subsequently, continuous suture techniques are used to reinforce the graft, particularly in the central region, thereby creating a structure analogous to a bamboo raft. This graft is then used for superior capsular reconstruction in cases of massive irreparable rotator cuff tears. (A, acromion; Cl, clavicle; Co, coracoid process; H, humerus; K, Reelx knotless anchor; L, superior glenoid labrum; LHBT, long head of biceps tendon; n, double-suture bone anchors; N, inner-row double-suture bone anchors; SB subscapularis.)

muscle attached to the tendon is removed. Continuous edge-to-edge sutures are used to create a sealed graft after folding the tendon to match the length of the supraspinatus defect. To enhance graft stability and prevent loosening or twisting during transplantation, high-strength sutures (No. 2 FiberWire; Arthrex, Naples, FL) are crisscrossed 3 times in the center of the graft for reinforcement. This results in the autologous tendon forming a graft that resembles a bamboo raft. PDS II sutures (Ethicon, Somerville, NJ) are used for traction by passing through the 4 corners of the graft (Fig 4D). The graft, resembling a bamboo raft, measures 5 cm in length, 4.5 cm in width, and 4.1 mm in thickness. It is then carefully placed in moist gauze for storage until needed for further use (Fig 4E).

Graft Implantation

By use of a plasma ablation knife, the soft tissue of the superior labrum is completely removed to expose the bone surface above the scapular glenoid at the 10- and 12-o'clock positions (right shoulder). Subsequently, the bone canal is prepared with an opening cone, and 2 double-suture bone anchors (4.5 mm × 20 mm; Arthrex) are securely implanted. The inner-row double-suture bone anchors (4.5 mm × 20 mm; Arthrex) are placed approximately 3 mm lateral to the anterior edge of the original supraspinatus key insertion point and the cartilage edge.

The graft is positioned at the superior joint capsule by pulling the reserved PDS II sutures on the graft. The anchor sutures are then passed around the graft and knotted under direct vision (Fig 5A). The graft is fixed on the glenoid and tubercle sides of the humerus, maintaining moderate tension. An outer-row anchor (4.9 mm × 20 mm, Versalok Suture Anchor; DePuy Mitek, Raynham, MA) is driven into the humeral tubercle side to further secure the graft in the footprint area. Arthroscopic examination confirms the completeness of graft coverage, absence of rotation or folding, and lack of active bleeding (Fig 5B). Finally, a drainage tube is placed, and the incision is closed.

Postoperative Rehabilitation

It is recommended to use an abduction pillow for 4 weeks after reconstruction surgery. Once the

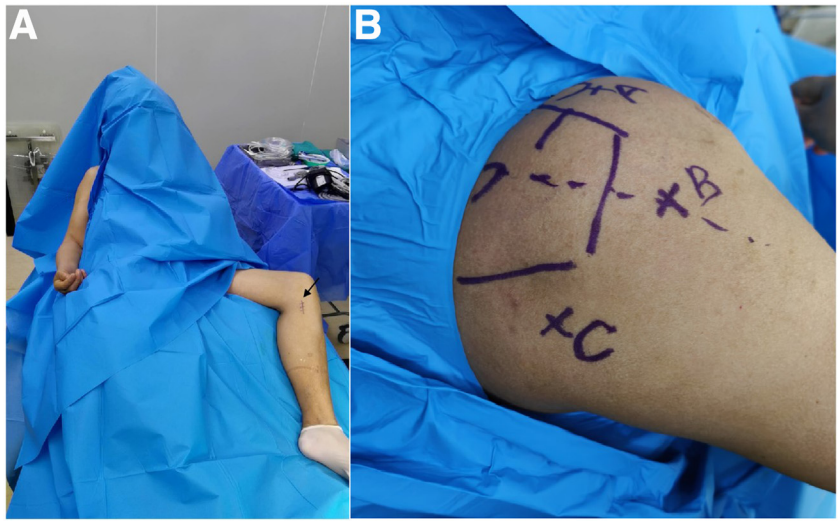

Fig 2. (A) The patient is comfortably seated on the examination table, with the backrest positioned at an angle of approximately 70° to 80° (Beach displacement, right shoulder). The shoulder and the opposite lower limb are prepared and draped in a sterile manner. The arm is placed in slight forward flexion and abduction, facilitating access to the subacromial space. Arrow indicates a 2-3 cm oblique incision. (B) Relevant surface anatomy markings include the acromion, clavicle, and coracoid. The posterior portal, which is the primary viewing portal, is made approximately 2 cm inferior and 2 cm medial to the posterolateral border of the acromion. The anterior portal is made 1 cm lateral to the coracoid. The lateral working portal is made 1 cm distal to the lateral edge of the acromion. A, anterior portal; B, lateral portal; C, posterior portal.

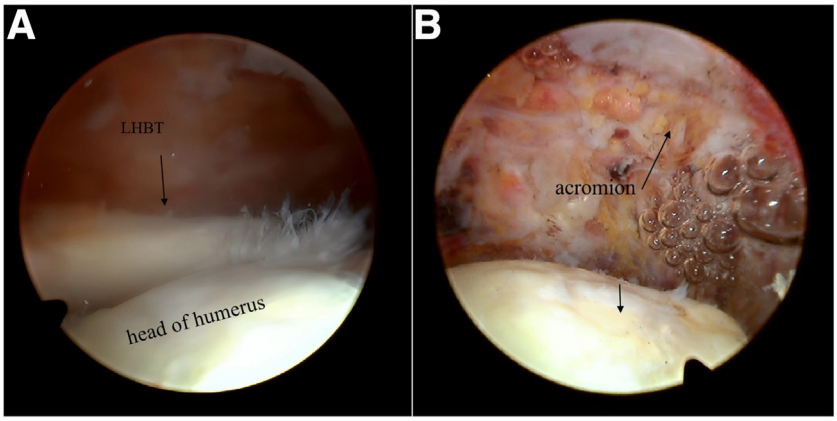

Fig 3. Arthroscopic view of right shoulder through posterior portal. (A) By use of a 2-mm shaver in the anterior portal, a subacromial bursectomy is performed to expose the lower surface of the acromion and the anterior and lateral edges. This procedure allows for exploration of the rotator cuff injury and the shape of the acromion. The bursectomy is organized from anterior to posterior and lateral to medial. (B) By use of a 3-mm NanoResection burr (Arthrex) in the anterior portal, acromioplasty is performed by gradually resecting the anterior and lateral bone spurs. Care is taken laterally to avoid damaging the deltoid muscle fibers. Depending on the surgeon's preference, an additional lateral portal can be created for further bony resection. Through this lateral portal, the acromioplasty can be continued while viewing from the posterior portal. Subsequently, the burr can be placed in the posterior portal while viewing from the lateral portal to ensure the complete resection of any osteophytes. The long arrow indicates the acromion and the short arrow indicates the humeral head. (LHBT, long head of biceps tendon.)

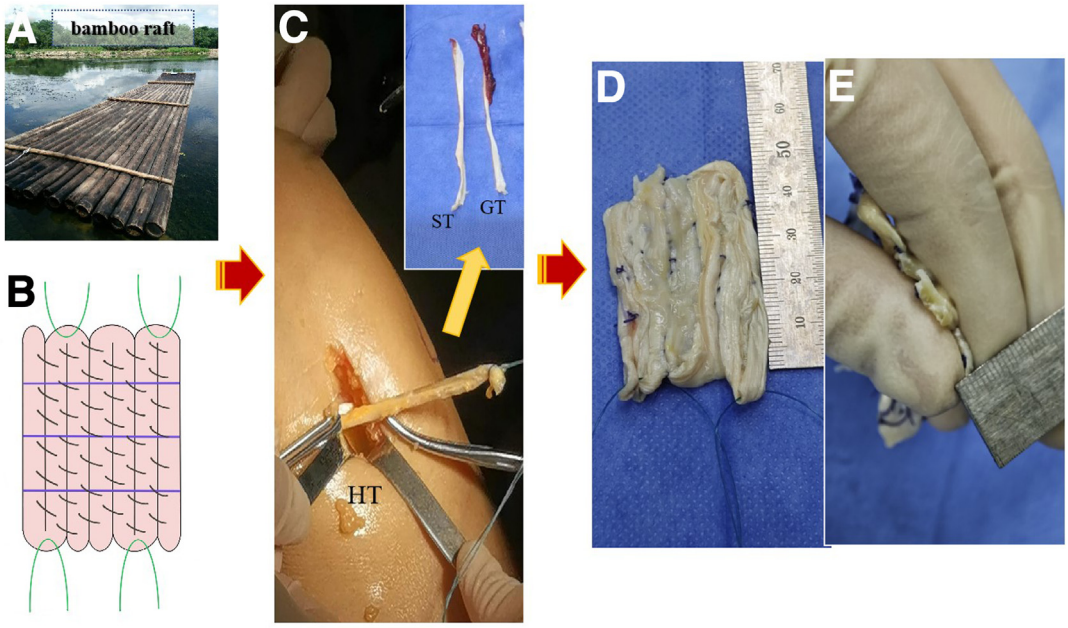

Fig 4. (A) Bamboo raft. (B) Bamboo raft graft. (C) A 2- to 3-cm oblique incision is made on the medial side of the tibial tubercle of the opposite knee joint (the left knee). After the fascial layer is incised, the footprint area of the anserine bursa is exposed. The semitendinosus and gracilis muscles are then carefully separated to facilitate extraction of the entire tendon. (D) Continuous edge-to-edge sutures are used to create a sealed graft after folding the tendon to match the length of the supraspinatus defect. High-strength No. 2 FiberWire sutures are crisscrossed 3 times in the center to enhance graft stability and prevent loosening during transplantation. This results in an autologous tendon graft resembling a bamboo raft. PDS II sutures are used for traction by passing through the 4 corners of the graft. (E) The graft measures 5 cm in length, 4.5 cm in width, and 4.1 mm in thickness. GT, gracilis tendon; HT, Hamstring tendon; ST, Semitendinosus tendon.

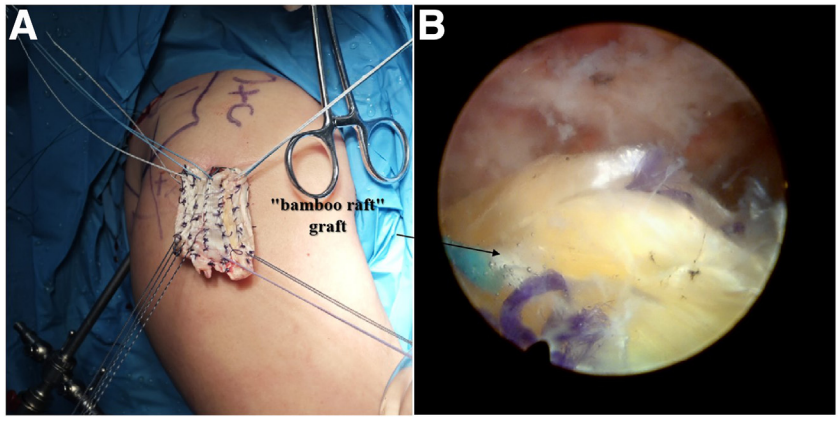

Fig 5. (A) The graft is positioned at the superior joint capsule by pulling the reserved PDS II sutures attached to the graft. Subsequently, the anchor sutures are passed around the graft and secured with knots under direct visualization. (B) Arthroscopic view of right shoulder through posterior portal. The graft is fixed on the glenoid and tubercle sides of the humerus, maintaining moderate tension. An outer-row anchor (4.9 mm × 20 mm, Versalok Suture Anchor) is driven into the humeral tubercle side to secure the graft in the footprint area further. Arthroscopic examination confirms complete graft coverage, no rotation or folding, and no active bleeding (the arrow indicates the"bamboo raft" graft).

immobilization period is over, the patient can progress to passive and active-assisted exercises. It is essential to avoid strength training, weight-bearing activities, or resistance exercises for 3 months and to refrain from lifting heavy objects for a year.[6]

Follow-Up and Clinical Efficacy Evaluation

Outpatient reviews and telephone follow-up assessments are conducted at 1 month, 3 months, and 6 months after surgery. Shoulder joint pain and function scores are assessed, and magnetic resonance imaging scans are performed to evaluate graft morphology (Fig 6). Our clinical research was approved by the ethics committee of the hospital.

Discussion

Our research shows that autologous tendon bamboo raft grafts can effectively bridge the gap created by an MIRCT. This technique helps to restore or improve the function of the upper joint capsule, enhancing the force-couple relation within the shoulder joint and ultimately improving overall shoulder strength and humeral head stability, especially when the long head of the biceps tendon is unavailable or in cases of revision surgery.[14]

Autologous grafts such as hamstring tendon graft are reliable alternatives for various ligaments owing to the ease of harvest and low incidence of donor-site complications.[12,15] Milano et al.[7] and Berthold et al.[12] performed U-shaped rebuilding of the upper joint capsule using the semitendinosus muscle. In this study, a 3-cm incision allowed for hamstring tendon harvesting in 2 to 3 minutes, significantly reducing surgical trauma compared with traditional 10- to 15-cm incisions,[8,16] enabling next-day mobilization and minimizing bed-rest complications while maintaining tendon functionality after resection.[10,17-19]

The thickness of the graft is a crucial factor in biomechanical improvement after upper joint capsule reconstruction.[9] According to Mihata et al.,[9] success

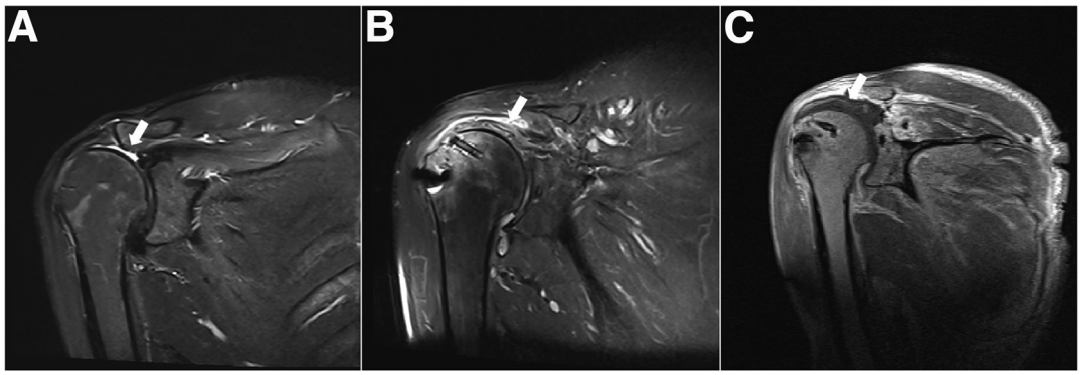

Fig 6. (A) Preoperative T2-weighted magnetic resonance imaging (MRI) in coronal plane showing massive rotator cuff tear retracted at glenoid level (arrow). (B) Postoperative T2-weighted MRI in coronal plane at 3 months showing bamboo raft graft (arrow). (C) Postoperative T2-weighted MRI in coronal plane at 12 months showing bamboo raft graft (arrow).

hinges on the graft's thickness regardless of the type of graft used. Recent research has indicated that grafts ranging from 4 to 6 mm can restore shoulder biomechanics to the intact upper joint capsule level.[20,21] Notably, the average thickness of fascia lata from the lateral part was 0.8 ± 0.2 mm, lower than that of gracilis (1.8 ± 0.8 mm) and semitendinosus (2.3 ± 0.9 mm).[22] In this study, the bamboo raft graft measured approximately 4.1 mm thick. On entering the joint cavity, this thicker graft narrowed the subacromial space and subsequent downward movement of the humeral head, as observed on postoperative magnetic resonance imaging scans.

The most common complications after SCR are graft tear and failure, and the contributing factors include subacromial decompression, excessive mobility, and the elastic modulus of the graft.[23] Lim et al.[24] reported a 29% fascia lata graft tear rate with an average follow-up period of 12.8 months. In our study, no observations of graft rupture occurred during the 1-year postoperative follow-up. Previous biomechanical research has shown that autologous tendon grafts exhibit a higher elastic modulus and higher ultimate strength than autologous fascia grafts.[11,25] Berthold et al.[12] conducted a cadaveric investigation that revealed that SCR with hamstring tendon yielded improvements in glenohumeral joint kinematics similar to those seen with fascia lata grafts.

Grafts can be configured in various shapes, including V, serpentine, L, and rectangle.[6,26,27] Berthold et al.[27] conducted a comparative study on the structural characteristics of SCR, and they found that the effect of depressing the humeral head was similar regardless of the configuration. In this study, a bamboo raft technique was used to reconstruct the superior joint capsule by folding and suturing the tendon on opposite sides with extra cross reinforcement, enhancing its strength and mimicking the joint's natural closed state.[28-30]

The bamboo raft technique could be a viable alternative to SCR, offering several benefits, such as minimal surgical trauma, low donor-site complication rates, and enhanced graft mechanical strength. However, further research and studies with more extensive samples are needed, mainly focusing on restoring supraspinatus muscle strength.

Disclosures

All authors (Y.L., X.G., Y.L., L.M., C.Y.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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