Technical Note

Arthroscopic Humeral Bone Tunnel—Based Tendon Grafting and Trapezius Transfer for Irreparable Posterior Superior Rotator Cuff Tear

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Abstract: Irreparable posterior rotator cuff tears pose challenges to orthopaedic surgeons, especially when the medial remaining rotator cuff is not reusable. Trapezius transfer is biomechanically favorable due to the similar vector of the transferred muscle to the native posterior superior rotator cuff. Regarding combined tendon grafting in trapezius transfer, onto-surface tendon attachment to the humerus was reported in most previous reports. For better tendon—humeral head connection, we introduce an humeral bone tunnel—based tendon grafting technique. In this technique, we use the hamstring tendons and the anterior half of the peroneus tendon to make 3 grafts. The most critical steps of this technique are the proper creation of the humeral tunnels and graft implantation. We consider the introduction of this technique will shed light in the field of trapezius transfer for Irreparable posterior rotator cuff tears.

For irreparable posterior rotator cuff tears (IPSRCTs), treatment depends on the functional and structural status of the remaining rotator cuff. When the remaining rotator cuff is functionless and not reusable, muscle transfer is one of the suitable choices to restore similar function of the native rotator cuff. Regarding muscle transfer, latissimus dorsi transfer has long been applied.[1] However, the results of latissimus dorsi transfer are still unpredictable, resulting trapezius transfer as an alternative.[2]

Biomechanical studies have indicated that trapezius transfer can make up the functional loss of the posterior superior rotator cuff more effectively.[3,4] Due to the shorter span and limited elongation potential of the lower trapezius, a graft or grafts must be used in trapezius transfer to connect the trapezius and the humeral head in case of IPSRCT.[5] In most previous reports regarding trapezius transfer, the grafting structure was attached to the humeral head through onto-surface repair,[6] which may lead to unreliable tendon—bone healing. Thus, we would like to introduce an humeral bone tunnel—based tendon grafting technique. Our clinical experience indicates that humeral bone tunnel—based tendon grafting is simpler and can obtain better time-zero tendon anchorage to the humeral head and better tenon-bone healing eventually. This technique is indicated to patients with IPSRCT and not reusable posterior superior rotator cuff (Table 1).

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Surgical Technique (With Video Illustration)

The procedure is performed in lateral decubitus position. Both the upper and lower limbs are prepared (Table 2, Video 1).

Graft Preparation

Through a 2- to 3-cm incision at the proximal medial side of the lower leg, the semitendinosus tendon (ST) and the gracilis tendon (GT) are harvested as for knee ligament reconstruction. From a 2-cm incision at the proximal posterior side of lateral malleolus, the anterior half of the peroneus longus tendon (AHPLT) is harvested.[7] Each of the 3 tendons is sutured with ultra-high-molecular-weight polyethylene sutures, folded, and mounted on an adjustable loop with mini-plate to make a 2-stranded graft. The size of the graft is

Table 1. Terms Regarding Irreparable Posterior Superior Rotator Cuff Tear With Unusable Posterior Superior Rotator Cuff

1. Posterior-superior rotator cuff tear.
Posterior superior rotator cuff tear is defined in our clinical practice as a tear that involves mainly the supraspinatus and infraspinatus. When the superior part of the subscapularis or teres minor is also involved, but is reparable, the entire tear is also defined as posterior superior rotator cuff tear.
2. Irreparable posterior superior rotator cuff tear.
Irreparable posterior superior rotator cuff tear is defined as after routine rotator cuff release and lateralization, as well as footprint medialization, the tendon–footprint overlap at the apex of the rotator cuff defect is less of 5 mm, in case of large or massive U- or V-shaped rotator cuff tear.
3. Single usable or unusable rotator cuff in case of rotator cuff tear.
The usability of a single rotator cuff (the supraspinatus or infraspinatus) is evaluated according the atrophy and fatty infiltration evaluated on magnetic resonance images, as well as the tendon length evaluated during operation. When rotator muscle atrophy is over two thirds or fatty infiltration is grade IV, or the tendon length is less than 5 mm, the torn rotator cuff is defined as unusable. When rotator muscle atrophy is less than two thirds, fatty infiltration is grade III or less, and the tendon length is 5 mm or greater, the torn rotator cuff is defined as usable.
4. Usable and unusable entire posterior superior rotator cuff in case of posterior superior rotator cuff tear.
When one of the supraspinatus and the infraspinatus is usable, the entire posterior superior rotator cuff is defined as usable. When both the supraspinatus and infraspinatus are unusable, the entire posterior superior rotator cuff is defined as unusable.

Table 2. Step-by-step Procedure of Arthroscopic Humeral Bone Tunnel–Based Tendon Grafting and Trapezius Transfer for Irreparable Posterior Superior Rotator Cuff Tear

1. The semitendinosus tendon, the gracilis tendon, and the anterior half of the peroneus longus tendon are harvested.
2. Each end of the tendon is sutured with one no. 2 UHMWPE suture. Each tendon is mounted on an adjustable loop with mini-plate to make a 2-stranded graft. The size of the graft is measured.
3. Three tunnels through the tuberosities are created from anterior to posterior side (tunnels I, II, and III). The inner orifices of the tunnels are located at the cartilage edge, facing respectively the anterior and posterior edge of the bicipital groove and the middle of the greater tuberosity. One guide suture is placed through each tunnel.
4. A 4-cm long horizontal incision (posterior thoracic incision) is made at the medial edge of the scapular spine. The trapezius insertion at the scapular spine is identified.
5. The inferior half of the trapezius is released through blunt dissection underneath, medially to close to its attachment on the spinal spine.
6. The inferior half of the trapezius is detached from the scapular spine.
7. The proximal end of the guide suture from tunnel I is retrieved through the infraspinatus fossa out of the posterior thoracic incision. The semitendinosus graft is pulled from the posterior thoracic incision, the inferior scapular fossa, and the subacromial space into the anterior humeral tunnel. The mini-plate is flipped for graft fixation.
8. The AHPLT and the GT graft are pulled into tunnels II and III, respectively. The mini-plates are flipped for graft fixation.
9. The free ends if the grafts are sutured to the trapezius aponeurosis.
10. Tension on the grafts is adjusted by reducing the adjustable loop on the humeral side.

AHPLT, anterior half of the peroneus longus tendon; GT, gracilis tendon; UHMWPE, ultra-high-molecular-weight polyethylene.

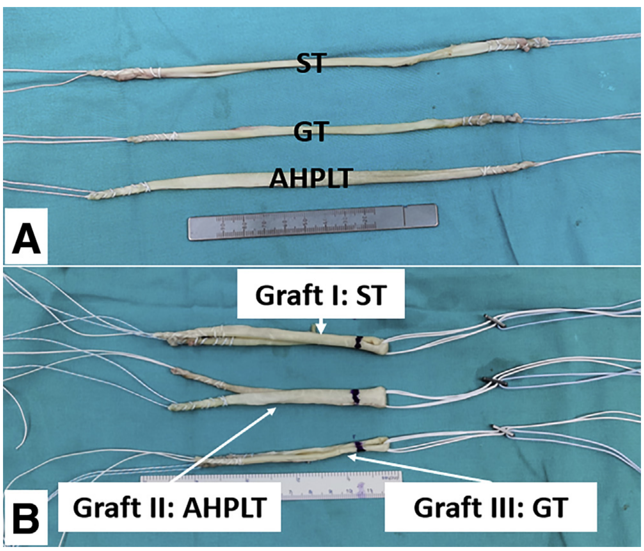


Fig 1. The semitendinosus tendon, gracilis tendon and the anterior half of the peroneus longus tendon are harvested (A) and made into 3 grafts complex (B). (AHPLT, anterior half of the peroneus longus tendon; GT, gracilis tendon; ST, the semitendinosus tendon.)

measured. A mark is made at a point 1.5 cm from the folded end on each graft. The ST, AHPLT, and GT grafts are named graft I, II, and III, respectively (Fig 1).

Creating Humeral Tunnels Through the Tuberosities

The subacromial and subdeltoid space is debrided. A 7-mm offset point-to-point tibial tunnel locating device (Smith & Nephew, Andover, MA), which is usually used for anterior cruciate ligament reconstruction of the knee, is used to create humeral tunnels through the tuberosities (Video 1). Three longitudinal tunnels, which are arranged from the anterior to the posterior side and named tunnel I, II, and III, respectively, are fabricated through the tuberosities. Tunnels I and II are located at the medial and lateral side of the bicipital groove, respectively; tunnel III passes through the middle part of the greater tuberosity. The proximal orifices of the humeral tunnels are located at the cartilage edge and arranged sequentially from anterior to posterior side (Fig 2). The lateral orifices of the humeral tunnels are located approximately 3 cm distal to the tip of the corresponding tuberosities (Fig 3). The tunnels are 0.5 mm smaller than the tendon.

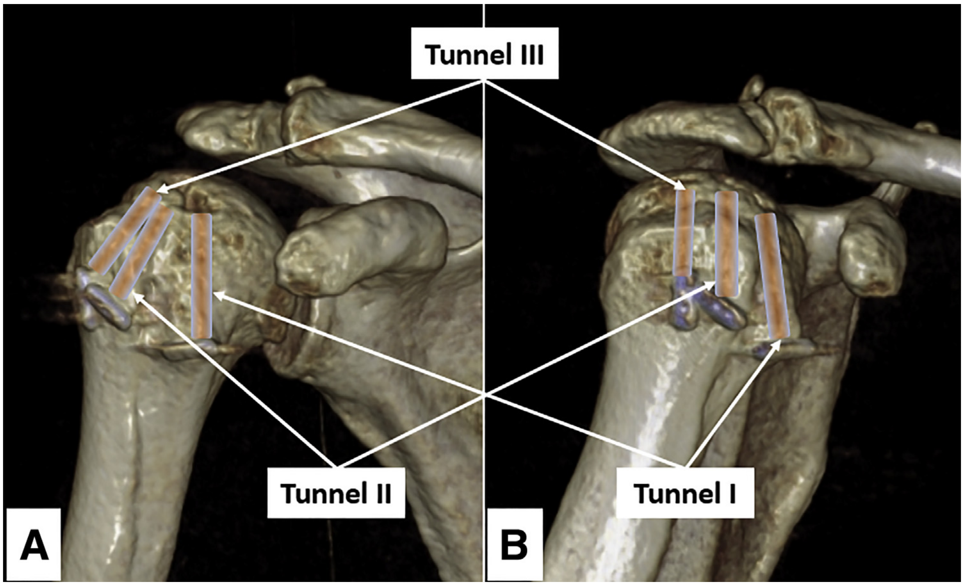


Fig 2. Illustration of the position of the humeral tunnels. (A) Anterior view of the right shoulder. (B) lateral view of the right shoulder.

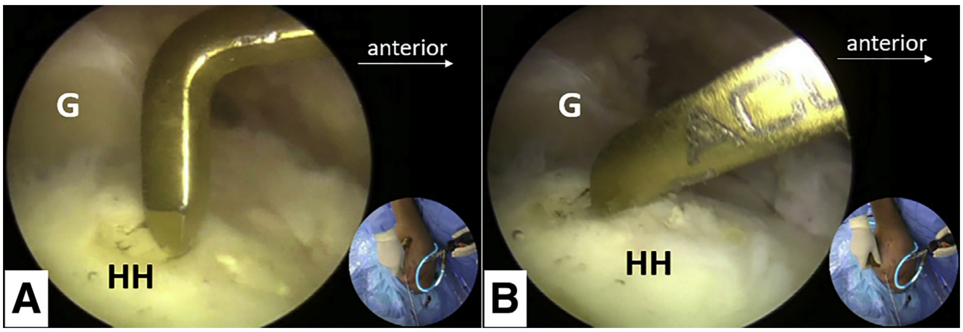


Fig 3. A tunnel locating device is placed into the subacromial space (A) and set at the desired position for tunnel I (B) (arthroscopic subacromial view of right shoulder through the mid-lateral portal). (G, glenoid; HH, humeral head.)

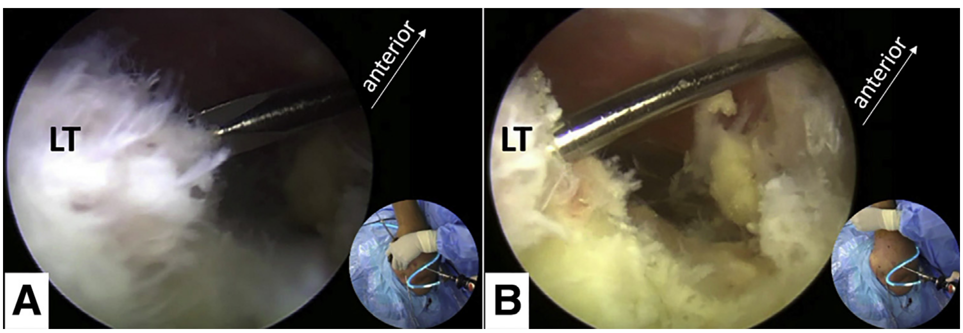


Fig 4. The tunnel aiming pin is passed through the anterior deltoid to the desire location on the lesser tuberosity (A) and a K wire is drilled in (B) to create tunnel I (arthroscopic anterior subdeltoid view of right shoulder through the mid-lateral portal). (LT, lesser tuberosity.)

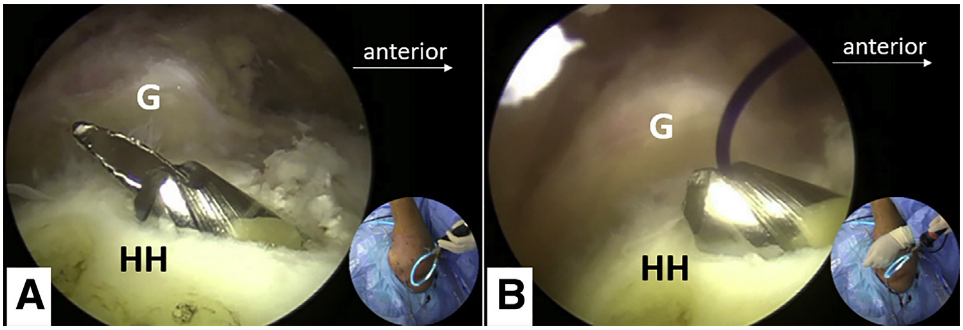


Fig 5. The K wire is overdrilled (A) to create tunnel I and a polydioxanone suture is passed through the cannulated drill (B) as a guide suture for the placement of graft I (arthroscopic subacromial view of right shoulder through the mid-lateral portal). (G, glenoid; HH, humeral head.)

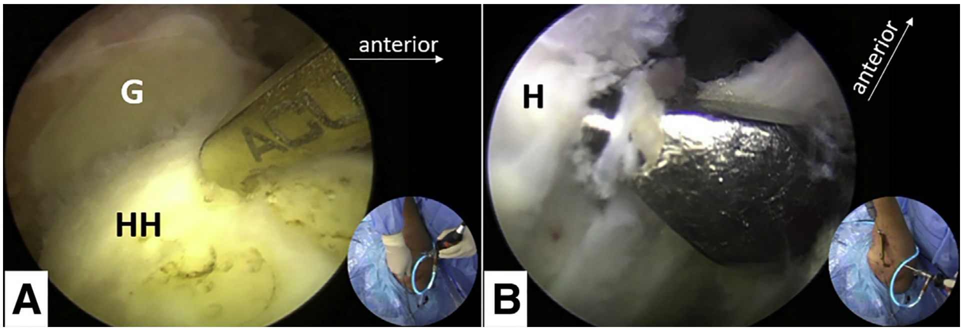
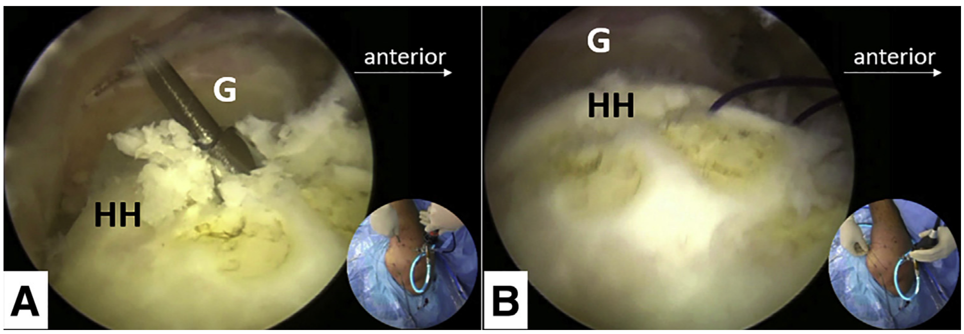


Fig 6. A tunnel-locating device is placed into the subacromial space and set at the desired position for tunnel II (A) (arthroscopic subacromial view of right shoulder through the mid-lateral portal) and the tunnel aiming pin is passed through the anterior lateral deltoid to the desire location on the posterior edge of the bicipital groove (B) to create tunnel II (arthroscopic anterior lateral subdeltoid view of right shoulder through the mid-lateral portal). (G, glenoid; H, anterolateral side of the proximal humerus; HH, humeral head.)

Fig 7. The K wire is over drilled to create tunnel II (A) and a polydioxanone suture is placed through (B) as a guide suture for the placement of graft II (arthroscopic subacromial view of right shoulder through the mid-lateral portal). (G, glenoid; HH, humeral head.)



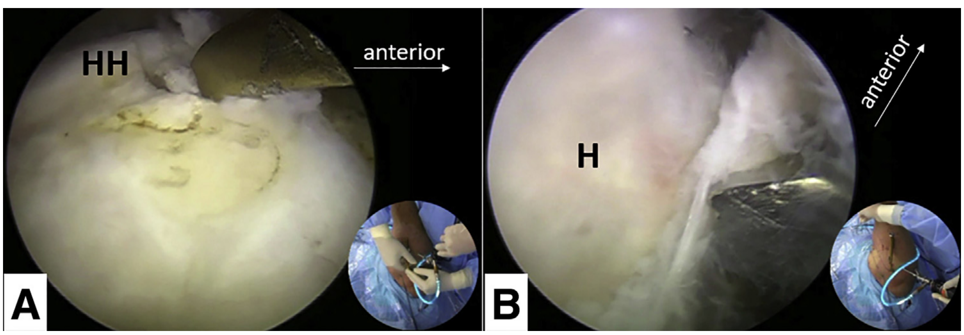


Fig 8. A tunnel locating device is placed into the subacromial space and set at the desired position for tunnel III (A) (arthroscopic subacromial view of right shoulder through the posterior lateral portal) and the tunnel aiming pin is passed through the lateral deltoid to the desire location on the lateral side of the greater tuberosity (B) to create tunnel III (arthroscopic lateral subdeltoid view of right shoulder through the posterior lateral portal). (G, glenoid; H, lateral side of the greater tuberosity; HH, humeral head.)

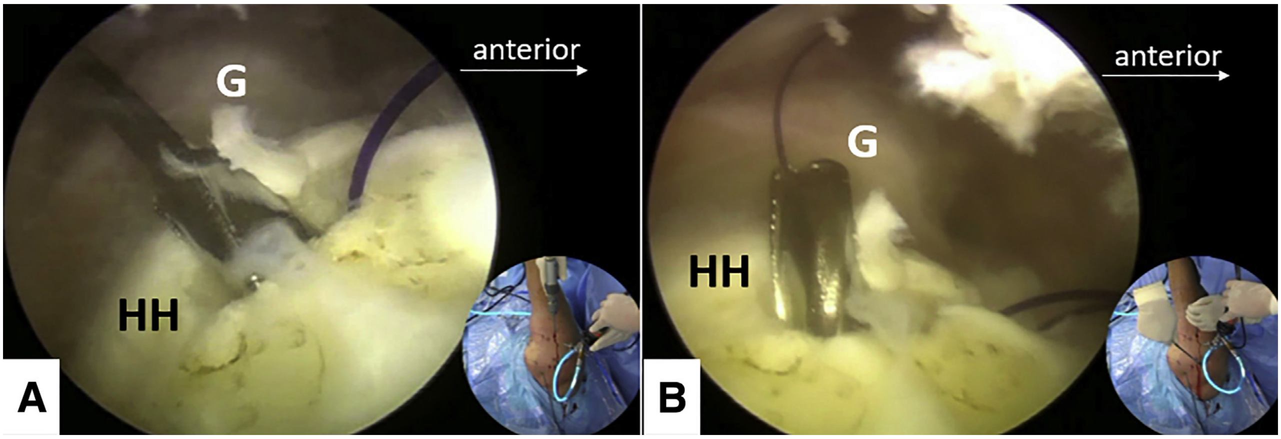
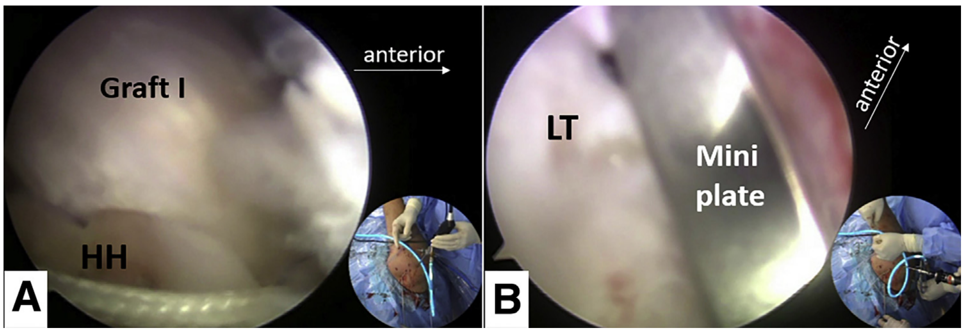


Fig 9. The K wire is overdrilled to create tunnel III (A) and a polydioxanone suture is placed through (B) as a guide suture for the placement of graft III (arthroscopic subacromial view of right shoulder through the posterior lateral portal). (G, glenoid; HH, humeral head.)

Fig 10. Graft I is placed into tunnel I (a, arthroscopic subacromial view of right shoulder through the posterior lateral portal) and fixed by flipping the mini-plate in the graft complex over the distal orifice (B, arthroscopic anterior subdeltoid view of right shoulder through the mid-lateral portal). (HH, humeral head; LT, lesser tuberosity.)



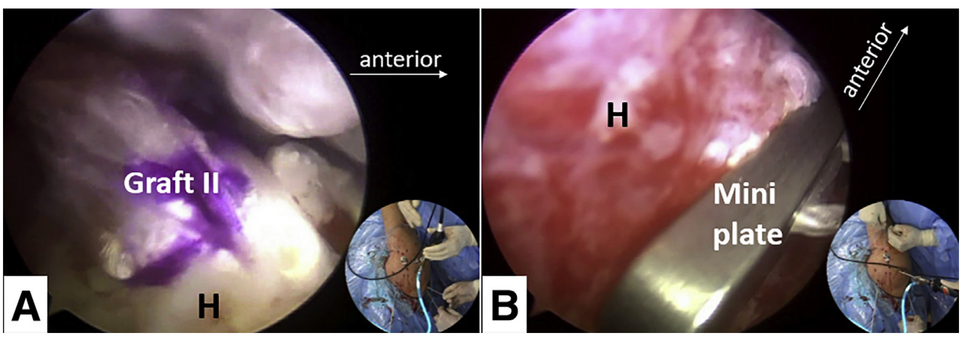


Fig 11. Graft II is placed into tunnel II (A, arthroscopic subacromial view of right shoulder through the posterior lateral portal) and fixed by flipping the mini-plate in the graft complex over the distal orifice (B, arthroscopic anterolateral subdeltoid view of right shoulder through the posterior lateral portal). H, the proximal (A) and anterolateral (B) side of the greater tuberosity.

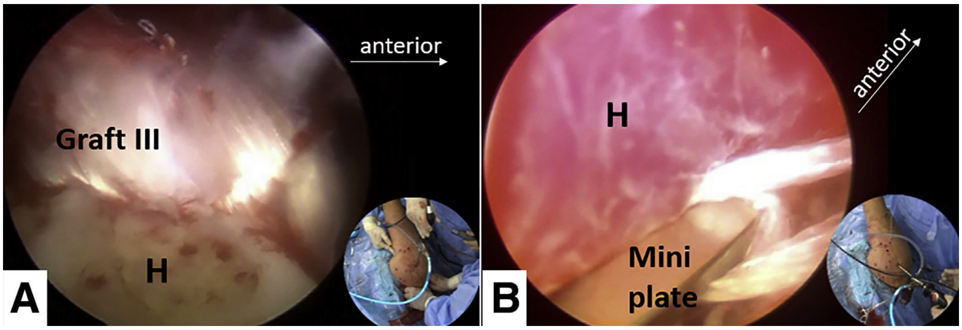


Fig 12. Graft III is placed into tunnel III (A, arthroscopic subacromial view of right shoulder through the posterior lateral portal) and fixed by flipping the mini-plate in the graft complex over the distal orifice (B, arthroscopic lateral subdeltoid view of right shoulder through the posterior lateral portal). H, the proximal (A) and lateral (B) side of the greater tuberosity.

The arthroscope is placed into the subacromial space through the mid-lateral portal. One switching stick is placed into the anterior subdeltoid space to elevate the anterior deltoid. One accessory anterolateral portal is fabricated to put the hook of the tunnel locating device into the subacromial space and set at the desired location of tunnel I near the cartilage edge (Fig 3). The tunnel aiming pin is place in through anterior deltoid to the anterior edge of the bicipital groove (Fig 4). When desired location of the distal orifice of the tunnel is confirmed, the K wire (Fig 4) and a 5-mm drill (Fig 5) are drilled in sequentially to create tunnel I. One guide suture is placed through the tunnel (Fig 5), then tunnel II is created in the same way and one guide suture is placed in (Figs 6 and 7).

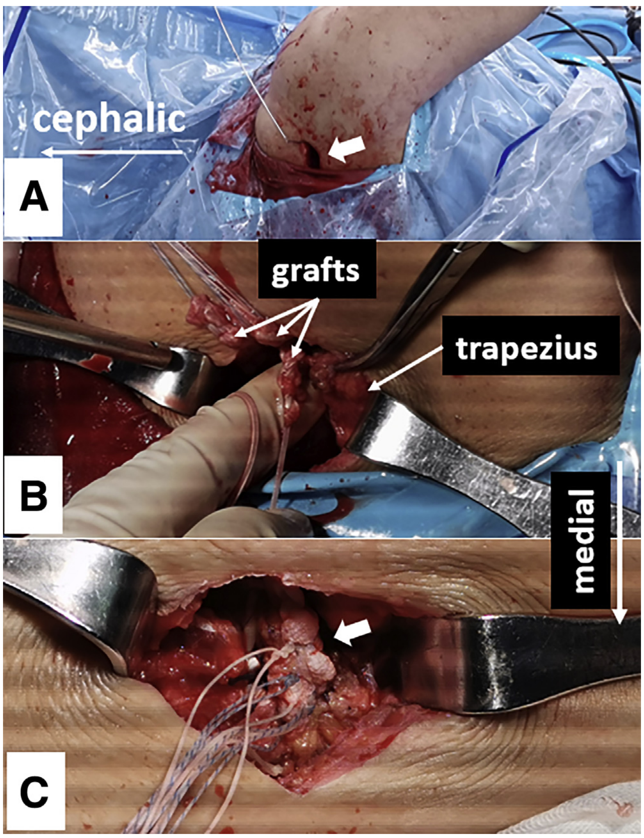


Fig 13. An incision is made at the medial edge of the scapular spine (A) and the graft ends are approximated to the lower trapezius (B) and sutured to the aponeurosis of the lower trapezius (C).

The arthroscope is placed through the posterior lateral portal to the subacromial space, the tunnel locating device is placed through the mid-lateral portal or an accessory lateral portal and set at the desired location near the cartilage edge for tunnel III (Fig 8). The tunnel aiming pin is placed through the lateral deltoid to the lateral side of the proximal humerus (Fig 8).When desired location of the distal orifice of tunnel III is confirmed, the K wire and drill are drilled in sequentially. In this way, tunnel III is created, and one guide suture is inserted (Fig 9).

Preparation of the Inferior Half of the Trapezius

A 4-cm long horizontal incision is made at the medial edge of the scapular spine (trapezius approach) (Fig 13 A). The trapezius insertion at the scapular spine is identified. The conjunction of the deltoid and the trapezius muscle is identified at the inferior edge of

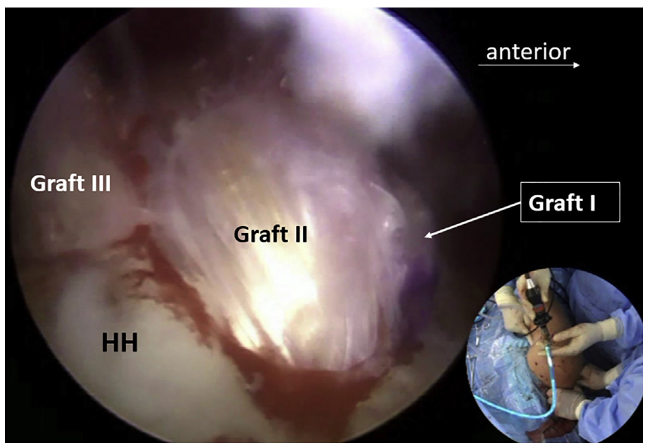


Fig 14. Arthroscopic subacromial view of right shoulder through the mid-lateral portal indicating the grafts after final tensioning. (HH, posterior part of the greater tuberosity.)

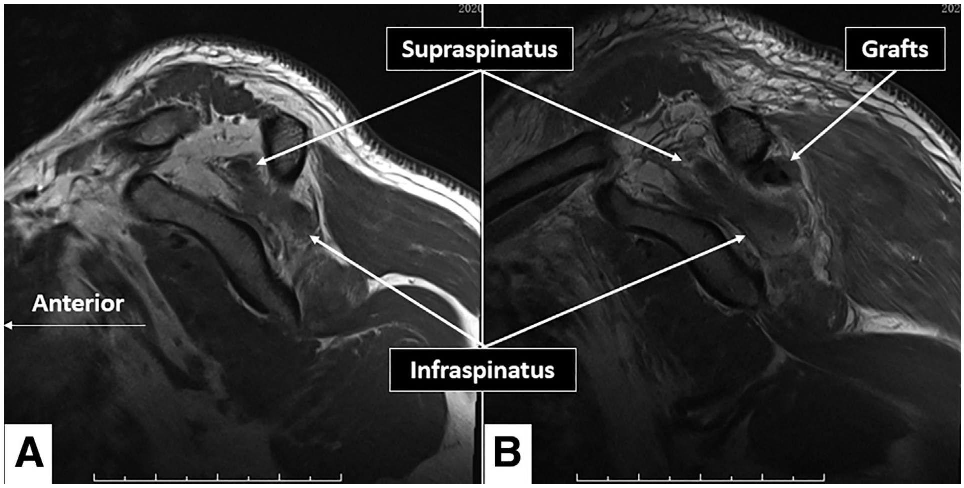


Fig 15. Oblique sagittal view of magnetic resonance imaging of right shoulder. (A) Preoperative view. (B) Postoperative view.

the scapular spine. The deep fascia is opened at this site. The inferior half of the trapezius is release through blunt dissection underneath, medially to its attachment on the spinal spine. The inferior half of the trapezius is detached from the scapular spine.

Graft Placement and Fixation

The proximal end of the guide suture from tunnel I is passed through the infraspinatus fossa out of the posterior thoracic incision, using a guide pin with a tailed suture loop. With the guide suture, graft I is pulled into tunnel I. The length of the graft within the tunnel is temporarily set as 15 mm. The mini-plate is flipped, and the adjustable loop is reduced to set the mini-plate over the distal orifice (Fig 10). Then, in the same way, grafts II and III are pulled into tunnels II and III, respectively, and fixed by flipping the mini-plates (Figs 11 and 12).

Connection of the Graft and the Trapezius Aponeurosis

With the braiding suture in the graft, the ends of both grafts are sutured to the trapezius aponeurosis, with as

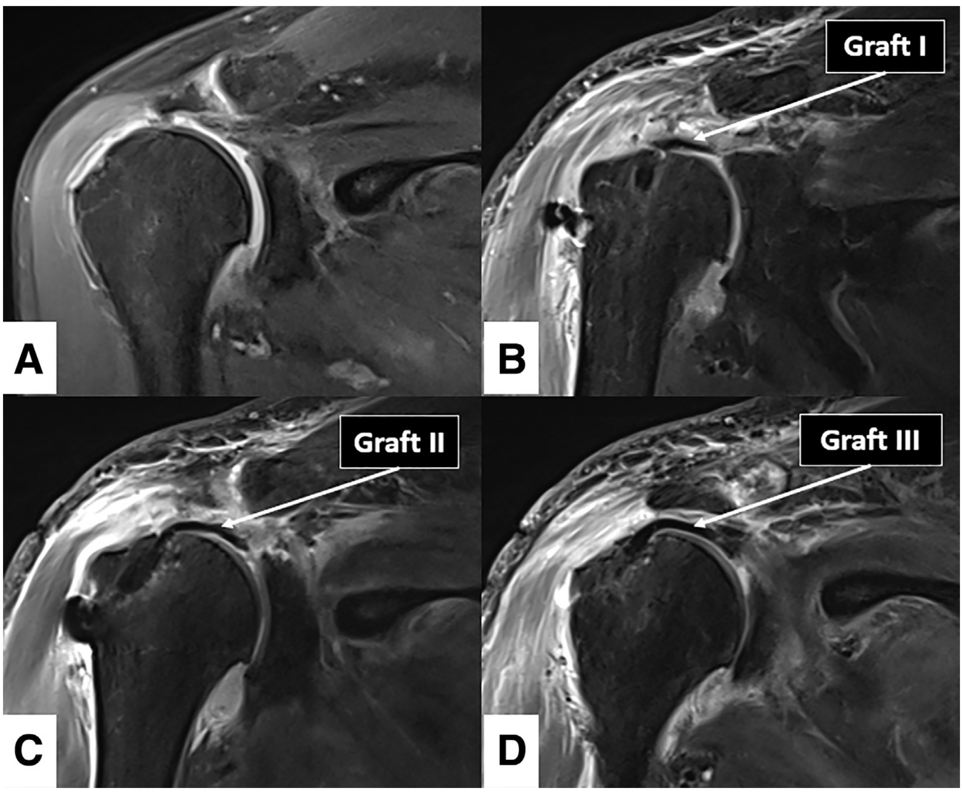


Fig 16. Oblique coronal view magnetic resonance imaging of right shoulder. (A) Preoperative view. (B, C, and D) Postoperative view indicating grafts I, II, and III, respectively.

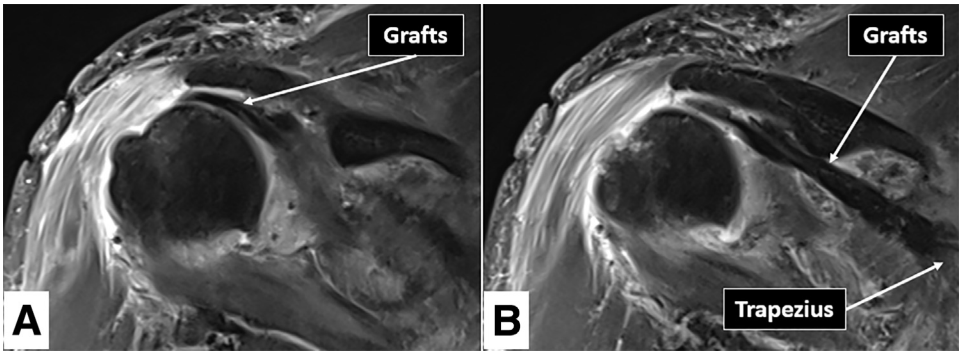


Fig 17. Oblique coronal view magnetic resonance imaging of right shoulder indicating the grafts in the subacromial space (A) and the infraspinatus fossa (B).

much as long overlaps between the graft ends and the trapezius aponeurosis (Fig 13 B and C).

Final Tensioning of the Graft

With the arm in 30° of abduction, the adjustable loop in each graft complex is reduced to increase the tension of the graft (Fig 14).

Rehabilitation

The arm is immobilized in zero-degree abduction with a brace at rest, with passive range of motion allowed immediately after operation. Non−weight-bearing exercise and shoulder retraction with the arm at side begin 6 weeks postoperatively. Weight-bearing and muscle-strengthening exercises begin 3 months postoperatively.

Discussion

There are 4 main features in this technique. First, we use 6 strands of autogenous tendons as grafting structures, which have enough strength and better remodeling potential (Fig 15). Second, we anchor the grafting structure at 3 points that correspond to the insertion of the supraspinatus and infraspinatus (Fig 16). Third, we put the grafts into humeral tunnels instead of placing

Table 3. Pearls and Pitfalls of Arthroscopic Humeral Bone Tunnel−Based Tendon Grafting and Trapezius Transfer for Irreparable Posterior Superior Rotator Cuff Tear

Pearls
1. Our clinical experience indicated that hamstring tendons are suitable autogenous graft materials, with suitable length when folded to connect the trapezius aponeurosis and the humeral head.
2. One disadvantage of using the trapezius as a potential muscle for transfer is that the aponeurosis part of the trapezius is relatively less. It is beneficial to enhance the trapezius−graft connection by detaching the trapezius aponeurosis from the scapular spine with a thin layer of cortical bone.
3. The span and elongation potential of the most inferior part of the trapezius is the greatest. However, the muscle volume of it is the least. The span and elongation potential of the middle part of the trapezius is the least. However, the muscle volume of it is the greatest. Thus, we suggest using the inferior half of the trapezius for transfer to make a balance between muscle volume and elongation potential.
4. A tibial tunnel locating device for anterior cruciate ligament reconstruction with a hooked tip is preferred than that with a flat tip.
5. Because of the osteoporosis of the humeral head, a 6- or 7-mm wide graft can squeeze into a 5-mm tunnel. Thus, we always create 5-mm wide tunnels. In case of 2 large grafts, it is suggested to use a retrograde drill to create a larger proximal tunnel part.
6. Before placing the graft, the PDS guide sutures through the humeral tunnels should be changed to UHMWPE sutures with greater strength.
Pitfalls and disadvantages
1. The humeral tunnels should not be too shallow. It is supposed that the proximal orifices are located along the cartilage edge and the distal orifices are located at least 3 cm distal to the tip of the tuberosities. Otherwise, it may cause breakage of the tuberosities.
2. For patients with a large body figure, the tunnel-locating device, which is designed for knee surgery, is relatively small. A large device should be fitted.
3. During releasing of the trapezius, care should be taken not to injure the nerve at its inferior side. Otherwise, it will result in muscle denervation and failure of functional restoration of the rotator cuff.
4. During creation of the humeral tunnels, passing the drill through the deltoid may endanger the axillary nerve. Rotating the drill manually in a retrograde manner while passes it through the deltoid may reduce this danger.
5. Because the proximal orifices of tunnel II and III are close to each other and always merged into one following placement of the graft II, placement of the graft III is always difficult because the guide suture for graft III (GT graft) always slips to the inferior side of graft II and cause tangling. At the proximal orifice of tunnel III, keeping the guide suture at the lateral side of graft II while placing graft III is critical.
6. Arthroscopic surgery always causes shoulder edema and difficulty in locating the medial scapular spine for subsequent trapezius preparation. Preparing the trapezius before arthroscopic procedure avoids this disadvantage but causes fluid leakage to the back of the body during later arthroscopic operation. Marking the scapular spine, performing arthroscopic tunnel creation, and preparing the trapezius sequentially is preferred.

GT, gracilis tendon; PDS, polydioxanone; UHMWPE, ultra-high-molecular-weight polyethylene.

the grafts onto bone surface. Lastly, this is an arthroscopically assisted procedure.

In trapezius transfer for IPSRCT, a strong graft with enough length should be used. In the few clinical reports regarding trapezius transfer for IPSRCT, Achilles tendon allograft was used in 2, and autogenous semitendinosus tendon was used in 1. However, in the study using autogenous semitendinosus tendon, only 2 strands of tendon were used,[8] which raises the concern of the weakness of the graft. Thus, we propose to use 2 strands of ST, 2 strands of GT, and 2 strands of the AHPLT in total to ensure the strength of the graft (Fig 17).

How to fix the graft to the humeral head is another important issue. In the 2 clinical reports using Achilles tendon allograft, the grafts were fixed to the bone surface of the greater tuberosity. This kind of fixation is defined as onto-surface fixation or repair, just like in routine rotator cuff repair. We consider onto-surface repair noneffective for tendon—bone healing. We prefer humeral bone tunnel—based repair, like in anterior cruciate ligament reconstruction. The authors of an experimental study reported humeral bone tunnel—based repair is advantageous for tendon—bone healing.[9]

In the other clinical report using semitendinosus tendon grafts, the fixation methods were confused, with both humeral bone tunnel—based fixation and onto-surface fixation described. As for the length of the graft to be put into the humeral tunnel, we suggest at least 15 mm in length, as for anterior cruciate ligament reconstruction.[10] Following final tension increase by loop reducing the tendon length in the tunnels may be longer.

The pearls and pitfalls, as well as disadvantages of this technique, are listed in Table 3. The main inconvenience is tangling of the graft structures at the proximal orifices during placement.

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