Technical Note

Whole Glenoid Reconstruction for Multidirectional Instability of the Shoulder

Jinzhong Zhao, M.D.

Abstract: The surgical results of shoulder multidirectional instability are not satisfactory. To address the structural and biological factors that are related to the low success rate of surgical treatment, we developed a whole glenoid reconstruction technique, which includes mainly 270° glenoid bone grafting and capsule labrum reconstruction, and glenohumeral ligament reconstruction. Our clinical experience indicates that the application of this technique can result in optimal shoulder stability. We consider the introduction of this technique will shed light on the surgical treatment of shoulder multidirectional instability.

The surgical results for shoulder multidirectional instability (MDI) still leave room for improvement,[1] which are supposed to be mainly related to the anatomic abnormality and the nonoptimal healing effects after repair. The anatomic abnormality includes mainly glenoid and labrum dysplasia that results in a small and flat glenoid without labrum concavity and the capsule ligament dysplasia featured by too thin and redundant capsule.[2,3] Nonoptimal healing may be related to the special physical features of the patients. Thus we developed a procedure named whole glenoid reconstruction, which includes mainly 270° glenoid bone grafting and capsule labrum reconstruction to address the glenoid and labrum dysplasia, and glenohumeral ligament reconstruction with internal bracing to address the capsule dysplasia and the low healing potential. The indication for this technique is symptomatic shoulder MDI, which is recalcitrant to conservative treatment.

Surgical Techniques

The patient is placed in lateral decubitus position. The arm and the leg of the same side are draped. The arm is placed in 60° abduction with 10-lb traction.

Preparation of Bone Graft

Two 30-mm long and one 20-mm long dry frozen allogenic bone grafts are used, with the same width of 10 mm and a thickness of 8 to 9 mm (Fig 1). Two 2.5-mm wide holes are drilled through each of the 2 longer grafts along the mid-surface line with 7.5-mm distance to the graft end. One 2.5-mm wide hole is drilled through the shorter graft at the middle of the mid-surface line (Table 1).

Preparation of Tendon Graft

The semitendinosus and gracilis tendon are harvested from same side as in routine knee ligament reconstruction. The tendons are truncated to 16-cm long, placed together, and braided with no. 2 UHMWPE

From the Department of Sports Medicine, Shanghai Sixth People's Hospital, Shanghai Jiao Tong University, Shanghai, China

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Address correspondence to Jinzhong Zhao, M.D., Department of Sports Medicine, Shanghai Sixth People's Hospital, Shanghai Jiao Tong University, 600 Yishan Road, Shanghai 200233, China. E-mail: zhaojinzhong@vip.163

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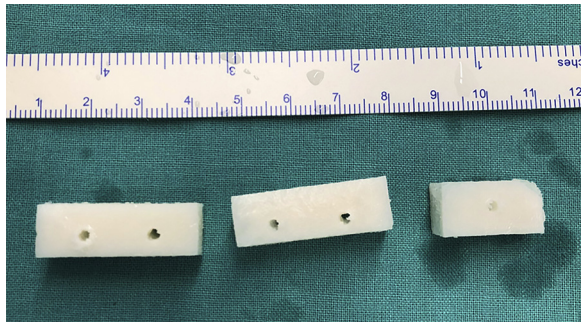

Fig 1. Bone fragments used for glenoid grafting.

Table 1. Step-by-Step Surgical Procedure of Whole Glenoid Reconstruction for Multidirectional Instability of the Shoulder

1. Corresponding holes for later suture fixation are drilled through the bone fragments.
2. The semitendinosus and gracilis tendons are harvested. Both ends of the graft are braided and mounted on adjustable loops with mini plates to form a tendon graft complex.
3. The anterior, inferior, and posterior labrum is released from the glenoid. The labrum ring is broken at 1:30 and 7:30 position, respectively, to facilitate subsequent graft placement.
4. Five holes for anchor placement are drilled at the glenoid edge respectively at 1:30, 4:30, 6-o'clock, 7:30, and 10:30 positions.
5. Two humeral tunnels are made for glenohumeral ligament reconstruction. The posterior-band humeral tunnel is created from the lowest point of the bare area of the humeral head anteriorly. The anterior-band humeral tunnel is created from the lower edge of the lesser tuberosity posteriorly. One guide suture is placed through each humeral tunnel.
6. A transverse glenoid tunnel, in which the center is located 7 mm below the glenoid surface, is created from the 9 to 3-o'clock position. The tendon graft complex is pulled through the glenoid tunnel and the subscapularis from the posterior to anterior side.
7. A double-loaded suture anchor is placed into the glenoid edge at the 6-o'clock position. One suture limb is pulled out of the inferior posterior portal through the bone grafting trocar. The graft is pushed along the suture limb to the inferior side of the glenoid and fixed with the guide suture. The inferior capsule labrum is repaired over the bone fragment to the glenoid edge.
8. Two double loaded anchors are placed into the glenoid edge respectively at the 1:30 and 4:40 positions through the anterior portal. One suture limb from each anchor is pulled out of the anterior portal through the bone grafting trocar. One of the longer bone fragments is placed in along the 2 suture limbs to the anterior side of the glenoid and fixed with the sutures. The anterior capsule is repaired over the bone fragment to the anterior glenoid edge.
9. Two posterior anchors are placed into the glenoid edge at the 7:30 and 10:30 positions. One suture limb from each posterior anchor is pulled out through the bone grafting trocar. The other longer bone fragment is pushed along the guide sutures until it is close to the posterior glenoid and fixed with the guide sutures.
10. The anterior end of the tendon graft is pulled into the anterior-band humeral tunnel and fixed by flipping the mini plate.
11. The posterior end of the tendon graft is pulled into the posterior-band humeral tunnel for 2-cm long and fixed by flipping the mini plate.
12. The posterior capsule labrum is repaired to the glenoid.
13. Both the anterior and posterior bands of the reconstructed glenohumeral ligament are tensioned.

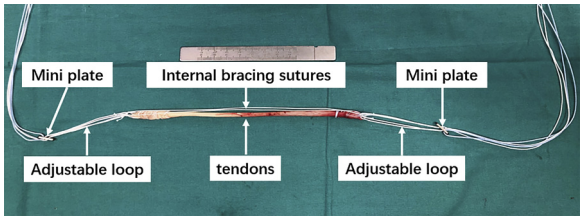

Fig 2. The tendon graft complex used for glenohumeral ligament reconstruction. The complex is composed of tendons, internal-bracing sutures, and 2 adjustable loops with mini plates.

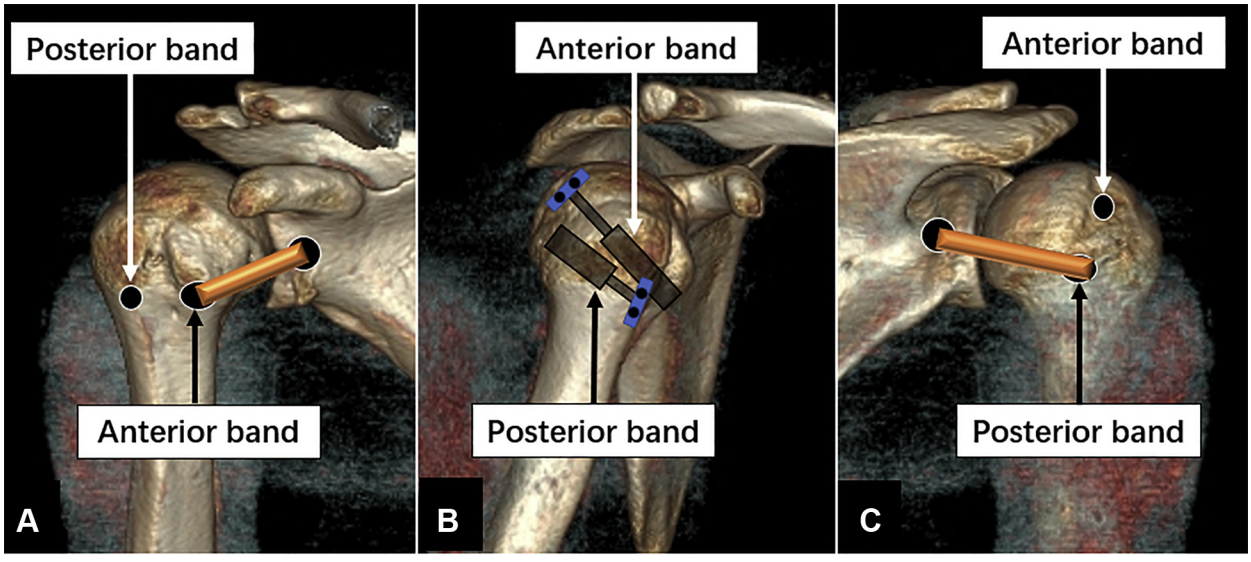

Fig 3. Illustration of the anterior orifices (A), passing lines (B), and posterior orifices (C) of the transhumeral tunnels used for the reconstruction of the anterior and posterior bands of the glenohumeral ligament (right shoulder).

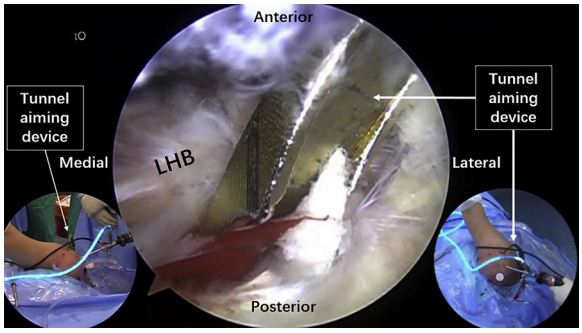

Fig 4. Locating the humeral tunnel to accommodate the posterior band of the glenohumeral ligament with a guide for posterior cruciate ligament reconstruction (arthroscopic sub-anterior deltoid view of right shoulder through lateral portal). (LHB, the long head of the biceps brachii.)

(ultra-high molecular-weight polyethylene) sutures at both ends. Each end of the graft is tied to one adjustable loop with mini plate, with a loop length of 5 cm. Two no. 2 UHMWPE sutures are used to bridge the 2 adjustable loops for internal bracing of the tendon graft to form a tendon graft complex (Fig 2). The size of the tendon graft structure is measured to determine the size of the glenoid and humeral tunnels.

Creating Two Humeral Tunnels for Glenohumeral Ligament Reconstruction (With Video Illustration)

Two transhumeral tunnels are made for glenohumeral ligament reconstruction (Fig 3, Video 1). One tunnel is created from the lowest point of the bare area of the humeral head, anteriorly to the lateral side of the bicipital groove (posterior-band humeral tunnel) (Figs 3 and 4). The other tunnel is created from the lower edge of the lesser tuberosity, posterior to the highest point of the bare area of the humeral head (anterior-band humeral tunnel) (Figs 3 and 5). One guide suture is placed through each humeral tunnel.

Preparation of Glenoid and Labrum

Routine anterior, anterior-superior, posterior, and posterior-inferior portals for the treatment of anterior

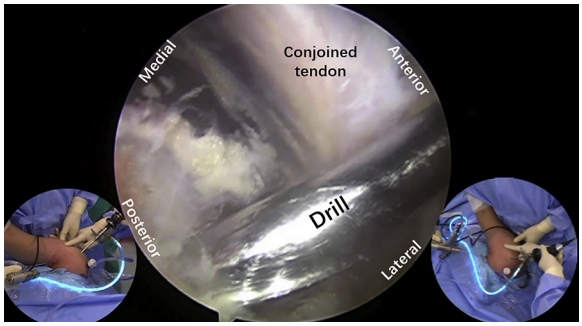

Fig 5. Creating the humeral tunnel to accommodate the anterior band of the glenohumeral ligament (arthroscopic sub-anterior deltoid view of right shoulder through lateral portal).

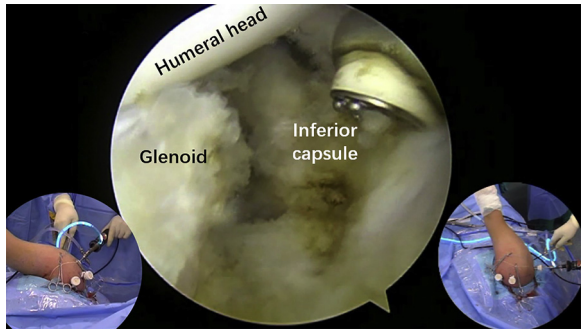

Fig 6. Releasing the inferior capsule from the inferior glenoid (arthroscopic intra-articular view of right shoulder through posterior portal).

shoulder dislocation are created. The labrum ring is cut at 1:30 and 7:30 positions, respectively, (right shoulder) to facilitate later bone graft placement. The labrum is released from the glenoid (Fig 6). The glenoid edge is freshened. Three guide sutures are placed through the capsule labrum respectively at 4:30, 6-o'clock, and 7:30 positions for later labrum reattachment. Five holes for anchor placement are drilled at the glenoid edge respectively at 1:30, 4:30, 6-o'clock, 7:30, and 10:30 positions.

Creating Glenoid Tunnel and Passing the Tendon Graft Through

A transverse glenoid tunnel, in which the center is located 7 mm below the glenoid surface, is created from the 9- to 3-o'clock position (Fig 7). A guide suture is placed through the glenoid tunnel from posterior to anterior side (Fig 8). The anterior end of the suture is passed with a suture retriever through the subscapularis to its anterior side at the 3-o'clock position of the glenoid, along the glenoid surface (Fig 9A).

A far lateral portal is created on the lateral mid-line of the upper arm, 7 cm from the acromion. A distal anterior portal is created on the anterior midline of the upper arm, over the inferior edge of the pectoralis major. The arthroscope is placed to the anterior subdeltoid space through the far lateral portal and pushed along the subscapularis medially. The suture retriever with the guide suture is found (Fig 9B). The guide suture is pulled out through the far anterior portal.

The tendon graft complex is pulled from posterior to anterior side through the glenoid tunnel and the subscapularis, and out of the distal anterior portal, until there is similar length at the anterior and posterior side of the shoulder (Fig 10).

Glenoid-Labrum Reconstruction

Inferior Glenoid Reconstruction

A set of bone grafting instruments is used (Fig 11). A double-loaded suture anchor is placed into the glenoid edge at the 6-o'clock position. The glenoid bone grafting instruments are placed in through the posterior

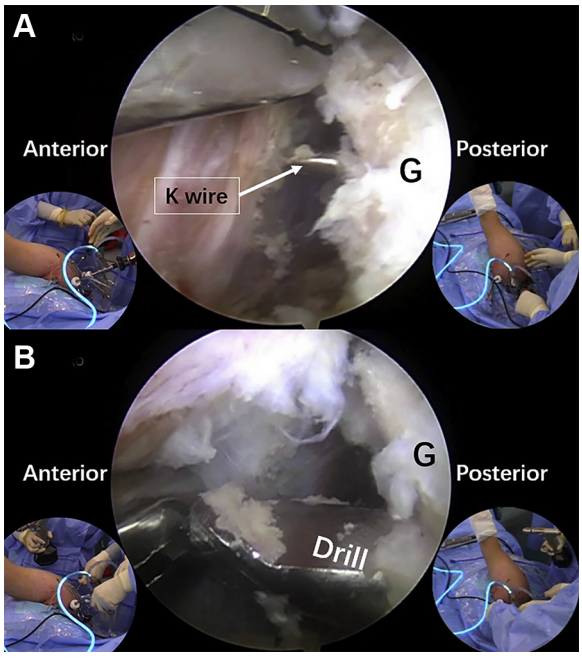

Fig 7. Creating the transverse glenoid tunnel with a K wire (A) and a drill (B) sequentially (arthroscopic intra-articular view of right shoulder through anterior superior portal). (G, glenoid.)

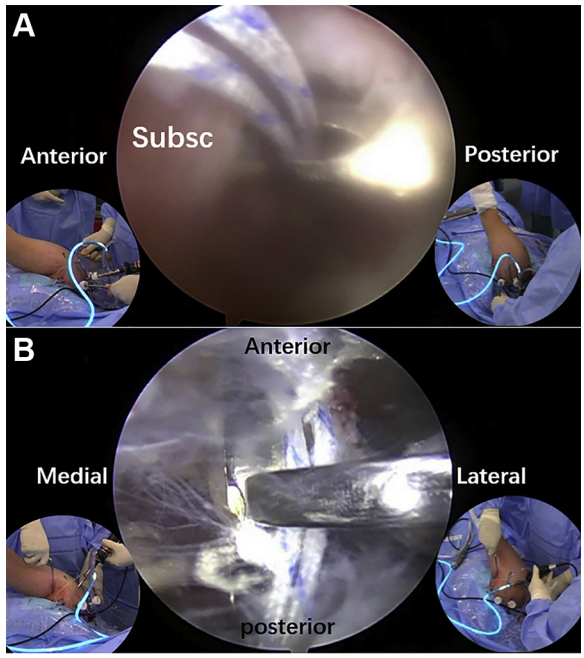

Fig 9. Passing the guide suture through the subscapularis anteriorly (A) (arthroscopic intra-articular view of right shoulder through anterior superior portal) and find the guide suture at the anterior side of the subscapularis (B) (arthroscopic extra-articular view of right shoulder at the anterior side of the subscapularis through the lateral portal). (Subsc, subscapularis.)

inferior portal. One suture limb is pulled out through the trocar and passed through the hole in the short graft fragment and the anterior hole in the core bar. The graft is pushed to the inferior side of the glenoid (Figs 12 and 13). The suture limb through the bone fragment and its corresponding suture limb are tied to fix the fragment near the glenoid (Fig 14). The inferior capsule labrum is pulled over the bone fragment and repaired to the glenoid edge.

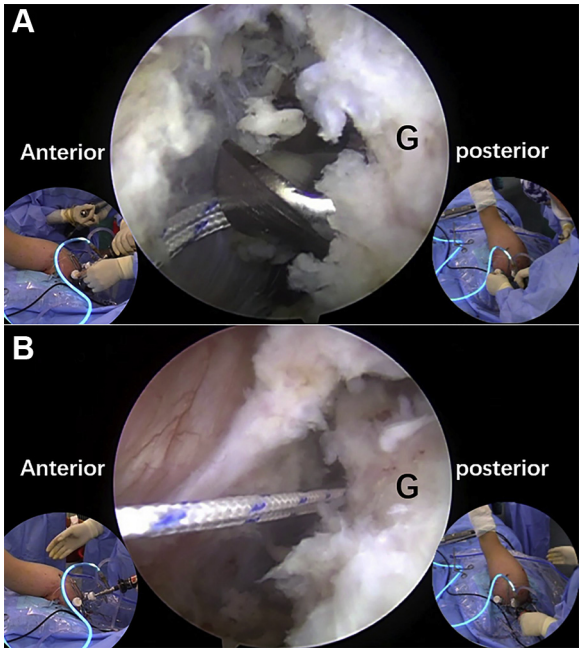

Fig 8. Passing the guide suture through the transglenoid drill (A) and leaving the guide suture in the transverse glenoid tunnel (B) (arthroscopic intra-articular view of right shoulder through anterior superior portal). (G, glenoid.)

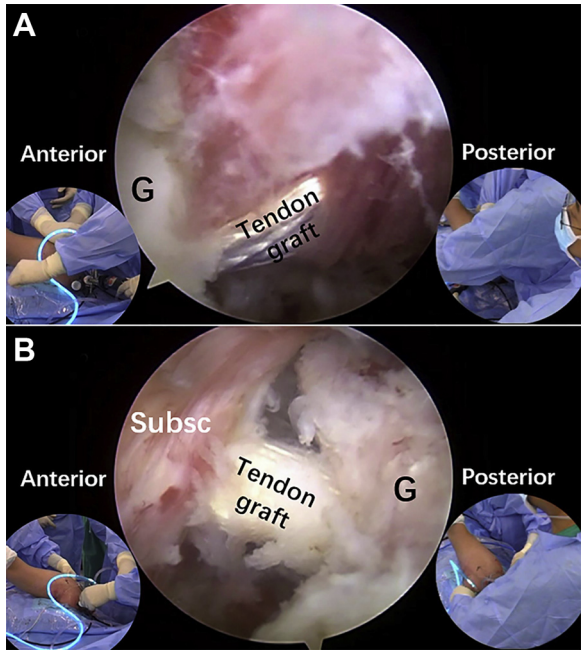

Fig 10. Passing the tendon graft through the glenoid tunnel and the subscapularis from the posterior (A) to the anterior (B) sides (arthroscopic intra-articular view of right shoulder through anterior superior portal). (G, glenoid.)

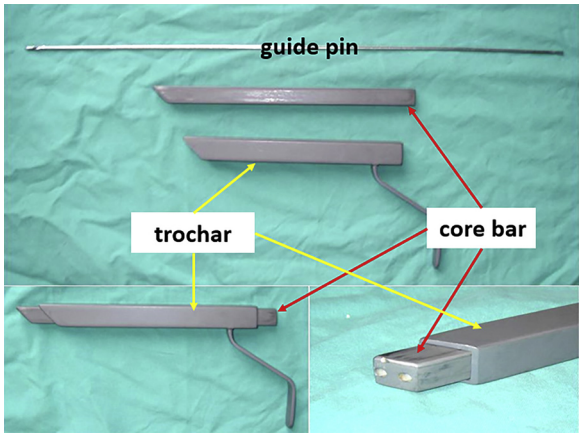

Fig 11. The shoulder bone grafting instruments.

Anterior Glenoid Reconstruction

Two double loaded anchors are placed into the glenoid edge respectively at the 1:30 and 4:30 positions. Glenoid bone grafting instruments are placed in through the anterior portal. One suture limb from each anchor is pulled out of the trocar and passed through the 2 holes in one longer bone fragment. The bone fragment is pushed through the trocar to the anterior side of the glenoid, lateral to the graft tendon (Fig 15). The suture limbs through the bone fragment and their corresponding suture limbs are pulled out and tied to fix the bone fragment softly (Fig 16). With the other suture left in each anchor, the capsule labrum structure is repaired to the anterior glenoid edge, to cover the anterior bone fragment as much as possible (Fig 17).[4]

Posterior Glenoid Reconstruction

Two posterior anchors are placed into the glenoid edge at the 7:30 and 10:30 positions. The bone grafting instrument is placed in through the inferior posterior portal to the posterior side of the glenoid, lateral to the transglenoid tunnel. One suture limb from each posterior anchor is pulled out to serve as guide sutures (Fig 18). The other longer bone fragment is placed to the posterior side of the glenoid and fixed with the transbone fragment sutures (Fig 19).

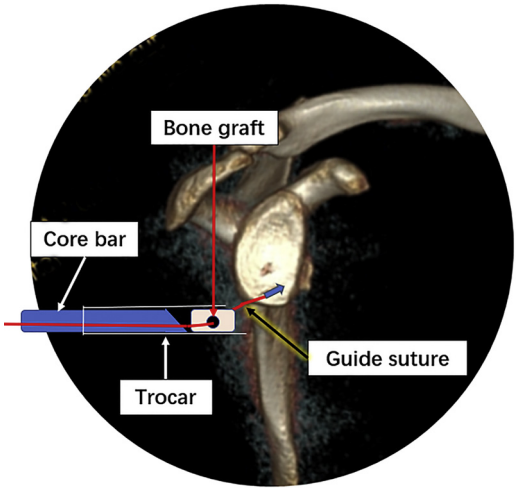

Fig 12. Illustration of placement of the inferior bone graft (right shoulder).

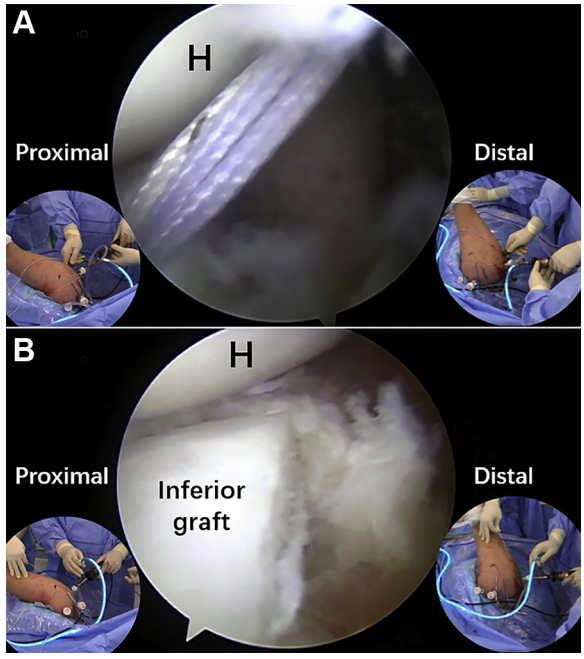

Fig 13. Placement of the inferior suture anchor (A) and the inferior bone graft (B) (arthroscopic intra-articular view of right shoulder through the posterior portal). (H, humeral head.)

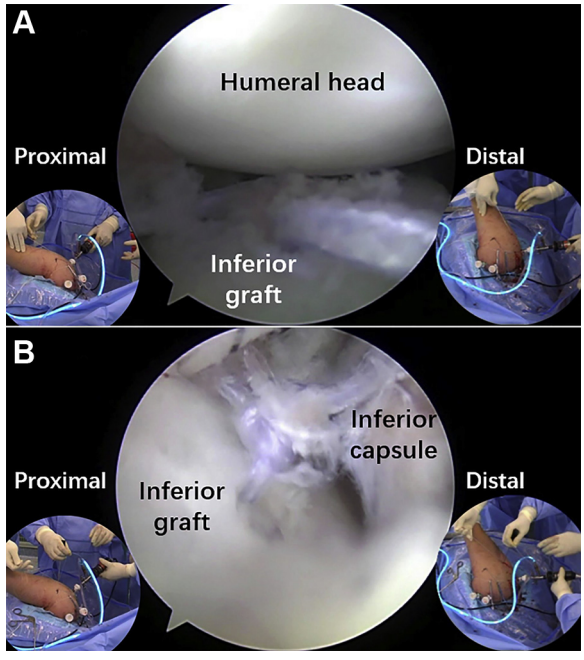

Fig 14. Using the suture passing through the bone graft (A) for graft fixation (B) (arthroscopic intra-articular view of right shoulder through the posterior portal).

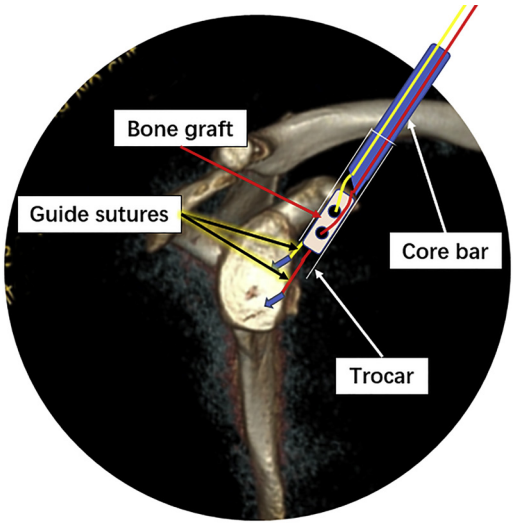

Fig 15. Illustration of placement of the anterior bone graft (right shoulder).

Completing Glenohumeral Ligament Reconstruction

With the arthroscope placed in through the far lateral portal for observation, the anterior end of the graft complex is pulled into the anterior-band humeral tunnel (Fig 20A). The mini plate leading the anterior end of the graft complex is pulled out of posterior orifice and flipped. The mini plate at the end of the posterior band of the tendon graft is pulled through the posterior-band humeral tunnel out of the anterior orifice and flipped (Fig 20B).

With the other suture left in each anchor, the capsule labrum structure is repaired to the posterior glenoid edge, to cover the posterior bone fragment as much as possible (Fig 21). The adjustable loop at each end of the tendon graft is reduced for final tensioning of the reconstructed glenohumeral ligament.

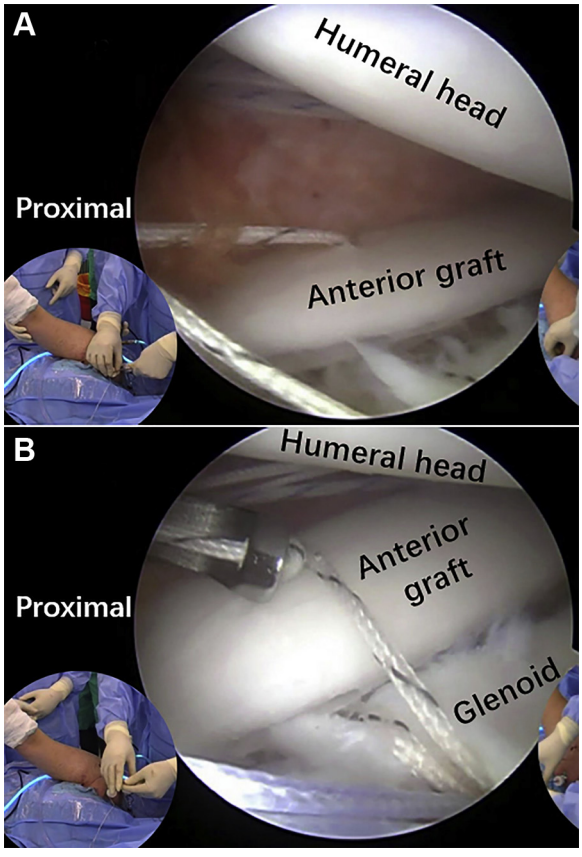

Fig 16. Releasing the graft to the anterior side of the glenoid (A) and fixing the graft with the guide sutures (B) (arthroscopic intra-articular view of right shoulder through the posterior portal).

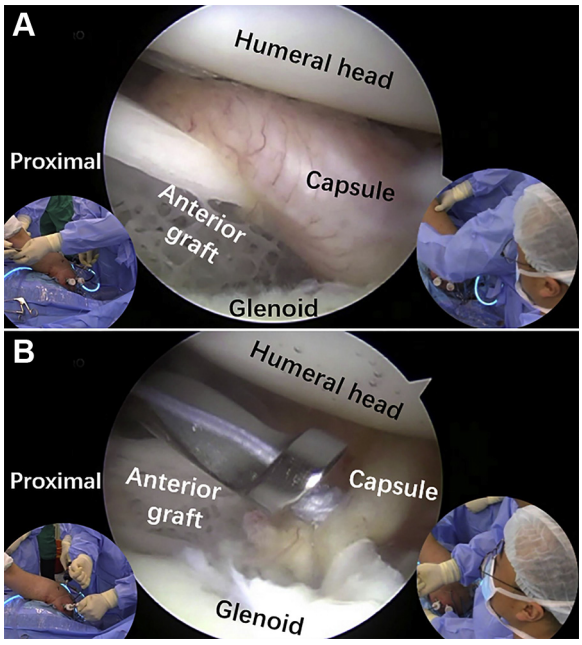

Fig 17. Reattaching the capsule labrum to the anterior glenoid over the bone graft with sutures respectively from the anterior inferior (A) and anterior superior (B) anchors (arthroscopic intra-articular view of right shoulder through the posterior portal).

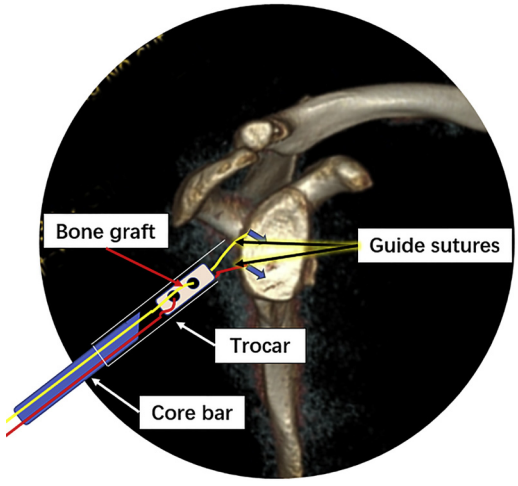

Fig 18. Illustration of placement of the posterior bone graft (right shoulder).

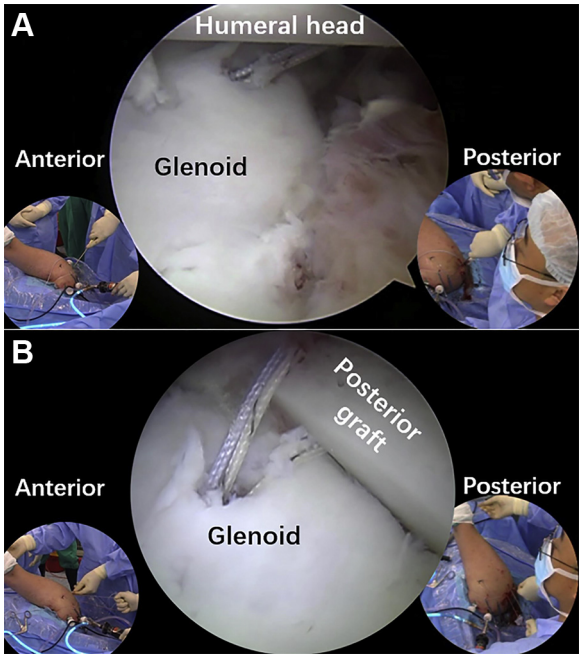

Fig 19. Placement of the posterior suture anchors (A) and the posterior bone graft (B) (arthroscopic intra-articular view of right shoulder through the posterior superior portal).

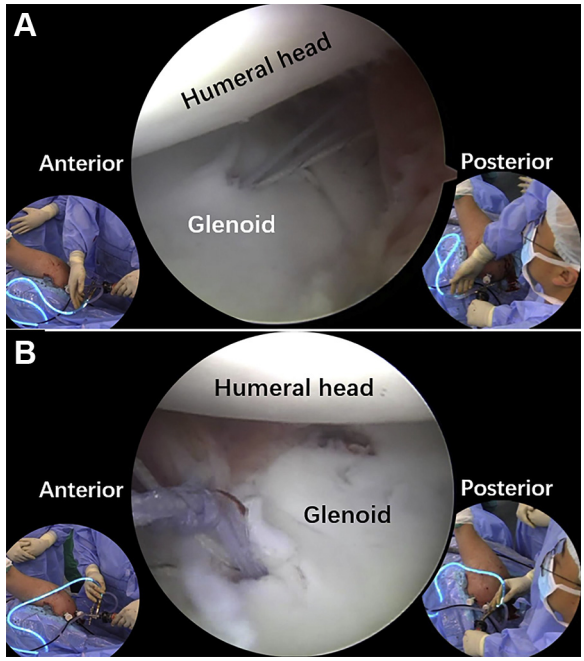

Fig 21. The posterior inferior (A) and anterior inferior (B) side of the glenohumeral joint after posterior capsule reattachment (arthroscopic intra-articular view of right shoulder through the anterior superior portal).

Discussion

The purposes of the current technique are to enlarge the glenoid, increase the concavity of the glenoid, and augment the capsule ligament (Figs 22-24). In this way, we can create a triple-block mechanism for patients with shoulder MDI. The uniqueness of this procedure are the 270° glenoid reconstruction and glenohumeral ligament reconstruction.

In the literature, simultaneous anterior and posterior bone grafting with or without capsule reattachment has been reported.[5,6] However, because the bone fragments were placed flush with the glenoid, the increase of glenoid concavity cannot be expected. Some authors tried to increase the glenoid-labrum concavity

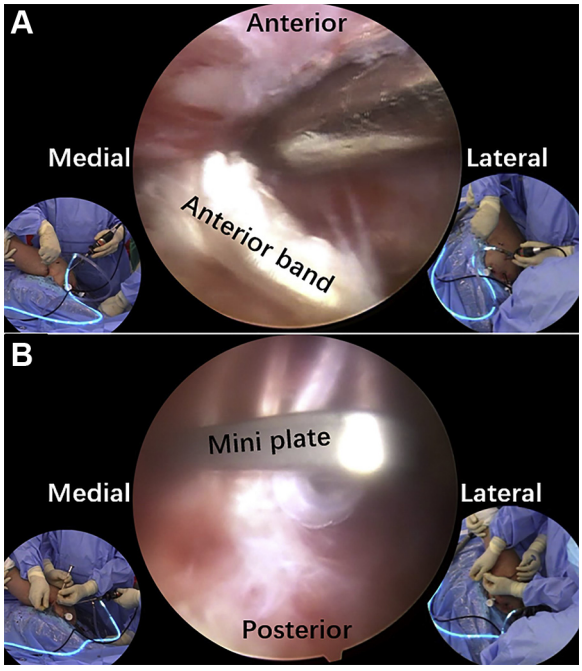

Fig 20. The anterior band of the reconstructed glenohumeral ligament (A) and the mini plate for the fixation of the posterior band of the reconstructed glenohumeral ligament (B) (arthroscopic subanterior deltoid view of right shoulder through lateral portal).

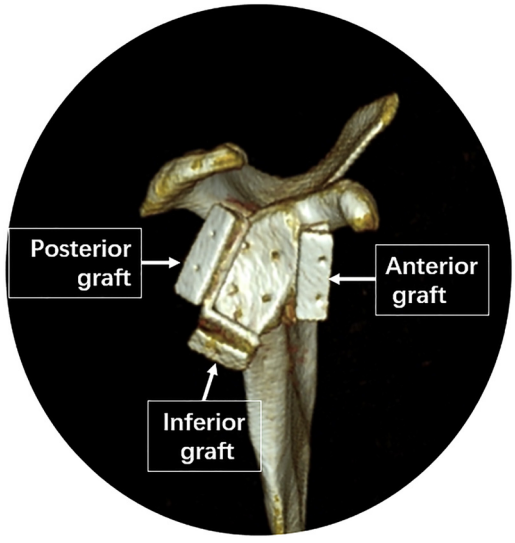

Fig 22. Postoperative 3-dimensional computed tomography of the glenoid with bone grafts (right shoulder).

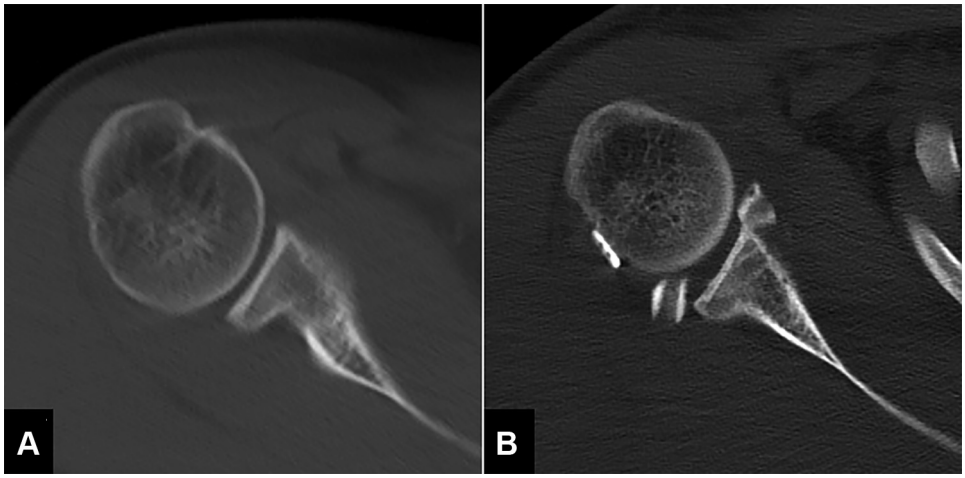

Fig 23. (A) Pre- and (B) post-operative transverse view computed tomography images of right shoulder.

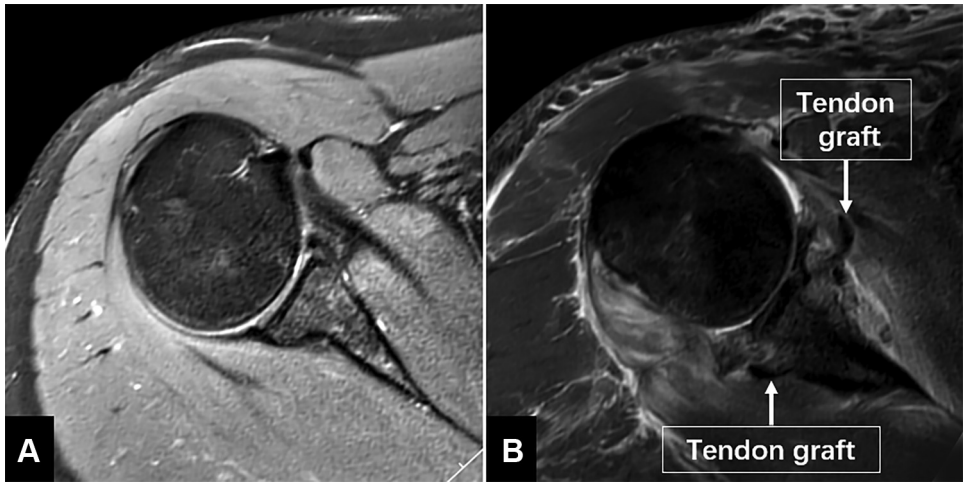

Fig 24. (A) Pre- and (B) post-operative transverse view magnetic resonance imaging of right shoulder.

Table 2. Pearls and Pitfalls of Whole Glenoid Reconstruction for Multidirectional Instability of the Shoulder

Pearls

1. Whole glenoid reconstruction combined glenoid bone grafting, glenohumeral ligament reconstruction, and capsule labrum repair. One should accumulate experience regarding the 3 basic techniques before doing this whole glenoid reconstruction.
2. In releasing the inferior labrum from the glenoid, note should be given to create enough space between the inferior capsule and the triceps tendon of the brachii.
3. Each of the humeral tunnels includes a 2-cm long thicker part to accommodate the tendon ends and 4.5-mm thinner part to suspend the tendon ends with flipping mini plate.
4. Before placing the bone graft in, the bone grafting trocar is first placed in to enlarge the space around the glenoid to accommodate the bone grafts.
5. The sutures for capsule labrum repair should be laid through the capsule before emplacement of the bone grafts.
6. After bone graft implantation, the capsule larum should be reattached to the glenoid as much as possible to seal the glenohumeral joint and separate the bone grafts from the synovial fluid to promote healing and remodeling of the grafts.
7. After placement of the tendon ends into the humeral tunnel, tensioning the graft will help to elevate the peripheral edge of the graft to form a concavity.

Pitfalls

1. A 14- to 18-cm tendon graft length is optimal. In case of too short graft, the glenoid and the humeral head cannot be connected with the tendon. Too longer graft will lead to a slack glenohumeral ligament reconstructed.
2. The glenoid tunnel should not be too close to the glenoid surface. Otherwise it will cause glenoid breakage when the reconstructed glenohumeral ligament is tensioned.
3. The most difficult and dangerous manipulation in this procedure is finding the guide suture at the anterior side of the subscapularis; step-by-step touching and going will reduce the difficulty and the danger.

Table 3. Advantages and Disadvantages of Whole Glenoid Reconstruction for Multidirectional Instability of the Shoulder

Advantages
1. This technique addresses all the structural and biological deficiency in case of multidirectional instability of the shoulder.
2. This technique includes no manipulation to pose special danger to the neurovascular structure.
Disadvantages
1. This technique is time consuming and challenging. It usually takes an experienced surgeon 3-5 hours to complete the whole procedure.
2. The glenohumeral ligament is tensioned with the arm in 60° abduction and neutral rotation. However, the best tension of the ligament graft in unknown.
3. Owing to the curved shape of the posterior glenoid, it is sometimes impossible to perfectly fit the graft to the glenoid.
4. In case of noncomplete sealing of the joint by the reattachment of the capsule-ligament, graft exposure in the joint may cause special inflammation reactions.

through larum reconstruction with an acellular dermal roll.[7] However, clinical study is needed to detect whether the glenoid-labrum concavity can be really increased after the possible labrum healing and remodeling.

The pearls and pitfalls, and the advantages and disadvantages, of this technique are listed in Tables 2 and 3, respectively. The most critical steps in this procedure are manipulation at the anterior side of the shoulder and creating 2 humeral tunnels. Regarding the glenoid bone grafting, placement of the bone fragment to the 3 desired positions is not difficult with the special set of shoulder bone grafting instruments.

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