Technical Note

Arthroscopic Autologous Iliac Crest Bone Grafting for Reconstruction of the Glenoid: A Nonrigid Fixation Technique

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Abstract: Massive glenoid bone loss in recurrent anterior instability of the shoulder represents a surgical challenge. Some clinical trials have been published assessing the role of arthroscopic iliac crest bone grafting techniques for the management of recurrent anterior instability with glenoid bone loss. However, bone graft fixation is still controversial. We developed a method for anatomic reconstruction of anterior glenoid bone defects using autologous iliac crest graft. This technique is based on the assumption that anatomic restoration of glenoid depth and width is essential to restore stability to the shoulder.

The anteroinferior glenoid bone defect has been reported as a primary lesion in traumatic anterior shoulder instability, especially in recurrent anterior shoulder dislocation.[1] When the osseous defect size of the glenoid exceeds 20%, the glenoid shape changes to an inverted-pear shape, in which the superior half is wider than the lower half. This is an indication for bone reconstruction of the glenoid.[2,3] Currently, options include the Bristow-Latarjet technique and bone grafting, both intra-articularly and extra-articularly. The Bristow-Latarjet technique has clinically been proved to be successful whether performed by an open technique or arthroscopically.[4] However, this method is not an anatomic repair, especially regarding subscapularis splitting and coracoid transfer and insertion.

The other major category of treatment to address glenoid defects is glenoid bone grafting. To our knowledge, iliac crest bone blocks are commonly used that have been used for glenoid reconstruction were either autografts or allografts. In a study by Boehm et al.,[5] allografts were used for glenoid bone grafting. This procedure was not observed to accomplish an anatomic reconstruction of the glenoid concavity owing to excessive graft resorption. Besides, some studies have reported the use of screws for fixation.[6,7] Firm hardware fixation may be biomechanically appealing. However, there is a risk of some complications, including hardware impingement, bone graft nonunion, and secondary osteoarthritic changes.[8]

Therefore, this article describes a nonrigid fixation technique for reconstructing the anterior glenoid with autologous iliac crest graft. We use a specific posterior glenoid guide of our invention for accurate graft positioning, and the bone graft is introduced through the appropriate bone graft guide and secured in place with only suture-tethering fixation. This nonrigid fixation method eliminates the use of screws and their potential problems.

Surgical Technique

General Indications

We recommend this technique for patients with recurrent anterior shoulder instability with a history of at least 2 dislocations. We consider arthroscopic

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Table 1. Indications, Contraindications, Tips, and Risks

Indications
Glenoid bone loss >20%
Glenoid bone loss between 10% and 20% in younger patients (aged <20 yr) involved in competitive or contact sports and in bipolar lesions involving glenoid and humeral head
Contraindications
Patients with multidirectional instability of shoulder joint
Tips
Three-dimensional reconstruction should be performed to define the glenoid defect in terms of width and area on the reconstructed en face view of the glenoid.
The iliac crest graft should be harvested from 3 cm behind the anterior superior iliac spine.
Coloring the superior or inferior part of the bone graft with a marking pen may help with orientation.
The implanted bone block's size and shape should be larger than those of the anterior glenoid bone defect. The sutures should be strictly managed to prevent twisting and knotting.
The special instruments should be used to deliver the bone fragment to the desired location.
Risks
Avulsion fracture of spina iliaca
Malpositioning of graft

reconstruction of the glenoid with iliac crest bone graft in cases with glenoid bone loss greater than 20%, in cases with glenoid bone loss between 15% and 20% in younger patients (aged <20 years) involved in competitive or contact sports, and in bipolar lesions involving the glenoid and humeral head (Table 1). This technique can also be applied in patients with recurrent shoulder instability after Bankart repair failure. Some tips and risks are displayed in Table 1. Several advantages and disadvantages associated with the procedure are listed in Table 2.

Preoperative Planning

Before surgery, routine radiographs and magnetic resonance imaging examinations are performed. Patients with humeral avulsion of the glenohumeral ligament can be excluded through the magnetic resonance imaging examination. On both sides, computed tomography scans are taken and 3-dimensional reconstruction is performed to define the glenoid defect in terms of width and area on the reconstructed en face sagittal view of the glenoid (Fig 1). We correctly assess the actual bone defect volume and roughly determine the size of the bone graft according to the length and width of bone loss. When taking into account the problem of absorption, the bone graft is generally larger than the amount of bone loss.

General Preparation

Under an interscalene block and general anesthesia, the patient is placed in the lateral decubitus position with additional lateral traction (Fig 2). Skin marks are made for standard shoulder arthroscopy portals (Fig 3). The arm and the ipsilateral iliac crest are prepared and draped in a sterile fashion. The arm is placed in a surgical traction frame (Arthrex) in 45° of abduction and 20° of anteflexion with 4 to 5 kg of vertical traction applied. Under the premise of ensuring the blood supply to essential organs, it is more appropriate to reduce systolic/diastolic blood pressure to around 90/60 mm Hg. In elderly patients with hypertension and other medical diseases, the risk of stroke is high, so the blood pressure can be adjusted appropriately.

Iliac Crest Graft Harvesting and Preparation

The tricortical iliac crest graft is harvested from the ipsilateral side (Fig 4A). The most commonly used graft is 10 mm in width, 20 mm in length, and 10 mm in height, although the size can be customized depending on the case. Two 2-mm-wide holes placed approximately 5 mm apart are made through the graft and another the third hole is drilled in 1.5mm away from the edge of the bone (Fig 4B). The drill enters through the cortex and exits on the cancellous side of the bone graft, with the use of an EndoButton (Smith & Nephew) as a fixture for this technique. The 2 ends of 3-strand high-strength sutures (Smith & Nephew) are respectively passed through the hole in the EndoButton by a looped guidewire (Arthrex) (Fig 4C). Then, the 2 ends of the sutures (Smith & Nephew) are inserted into 2 holes in the iliac bone graft through the looped guidewire (Arthrex), and the suture (Smith & Nephew) is tightened (Fig 4D). With a marking pen, we color the superior aspect of the bone graft.

Surgical Portals and Arthroscopic Inspection

A standard posterior portal is created for the insertion of the arthroscope (Smith & Nephew) (Fig 5A). Viewing from the posterior portal, the labrum is detached, and all soft tissues are removed from the anterior glenoid neck. Then, 1 anteroinferior portal is placed in the rotator interval just above the subscapularis tendon, and 1 anterosuperior portal is placed in front of the biceps tendon. The arthroscope (Smith & Nephew) is introduced through

Table 2. Advantages and Disadvantages

Advantages
Reoperation for symptomatic hardware or screw removal is avoided.
The size and shape can be customized to accommodate bone loss of any amount and shape.
The procedure allows anatomic reconstruction of the glenoid.
The technique is less abrasive and achieves a better contour than use of the coracoid.
Performing the technique is less difficult and faster than performing coracoid osteotomy.
Soft-tissue balancing can be achieved.
Easy conversion in the technique is possible if larger-than-expected bone loss is found intraoperatively.
The all-arthroscopic approach offers better cosmesis, faster rehabilitation, and a return to preinjury activity levels.
Disadvantages
Donor-site morbidity is possible.
The learning curve is steep.

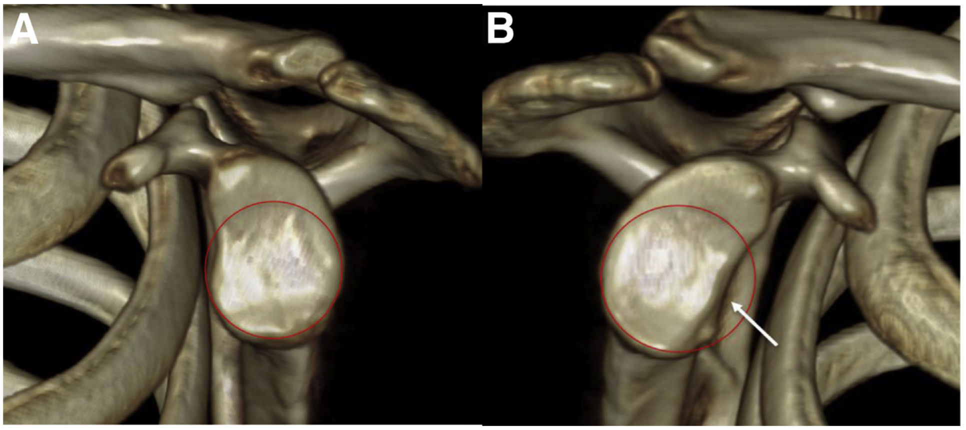

Fig 1. Preoperative 3-dimensional computed tomography scans of left shoulder (normal) (A) and right shoulder (glenoid defect side)(B). Significant anterior glenoid bone loss is shown in the right shoulder (white arrow). Preoperative circles of the same size can be drawn to roughly estimate the size of the bone defect.

the anterosuperior portal, the anterior glenoid rim is further decorticated, and the glenoid neck is prepared with a motorized burr (Arthrex) to create a flat and bleeding bony surface (Fig 5B).

Graft Passage and Fixation

The senior author (L.L.Z.) developed 2 sets of grafting instruments, including glenoid bone graft guides and a bone graft introducer. The glenoid bone graft guides are 7, 8, and 9 mm wide, whereas there is only 1 size of bone graft introducer (Fig 6). The glenoid bone graft guide is placed through the posterior portal (Fig 7A). The core bar is placed into the joint along the guide, which points to the anterior glenoid margin at the 4- to 5-o'clock position (Fig 7B). We drill 1 hole from the posterior glenoid to the anterior glenoid with a 2.0-mm drill (Fig 7C) such that the 2.0-mm drill cannot penetrate the joint surface (Fig 7D). Then, drilling is performed with a 2.4-mm hollow drill (Fig 7 E and F). We pass a 2-mm monofilament wire (Smith & Nephew) posteriorly through the hollow drill (Fig 7 G and H). The anteroinferior portal is dilated to allow passage of the bone graft. The bone graft introducer is then inserted from the anteroinferior portal (Fig 8A). The monofilaments (Smith & Nephew) are retrieved through the anteroinferior portal and taken out through the bone graft introducer to prepare for graft passage (Fig 8B). Suture tails (Smith & Nephew) from the EndoButton in the graft are placed through the monofilaments, which are pulled out from the bone graft introducer. The monofilaments are then used to pass the sutures through the transglenoid tunnels and retrieved through the posterior portal (Fig 8C). With use of the introducer, the graft is pushed into the joint (Fig 8D). A grasper placed through the anteroinferior portal is used as a stick to assist in proper placement and to ensure there is no lateralization of the graft (Fig 8E). After the final adjustments, the graft is completely

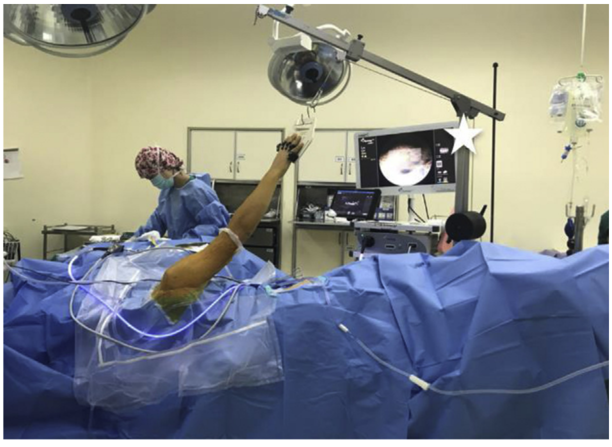

Fig 2. Two 2-mm-wide holes placed approximately 5 mm apart are made through the graft (white arrow) and the third hole is drilled in 1.5mm away from the edge of the bone by an electric drill (white star). Then a high-strength suture (black arrow)penetrate the hole.

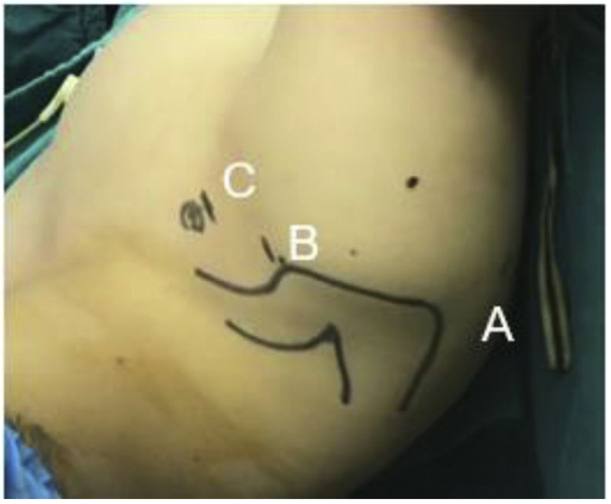

Fig 3. Skin markings for standard shoulder arthroscopy portals (right shoulder): posterior (A), anterosuperior (B), and anteroinferior (C) portals.

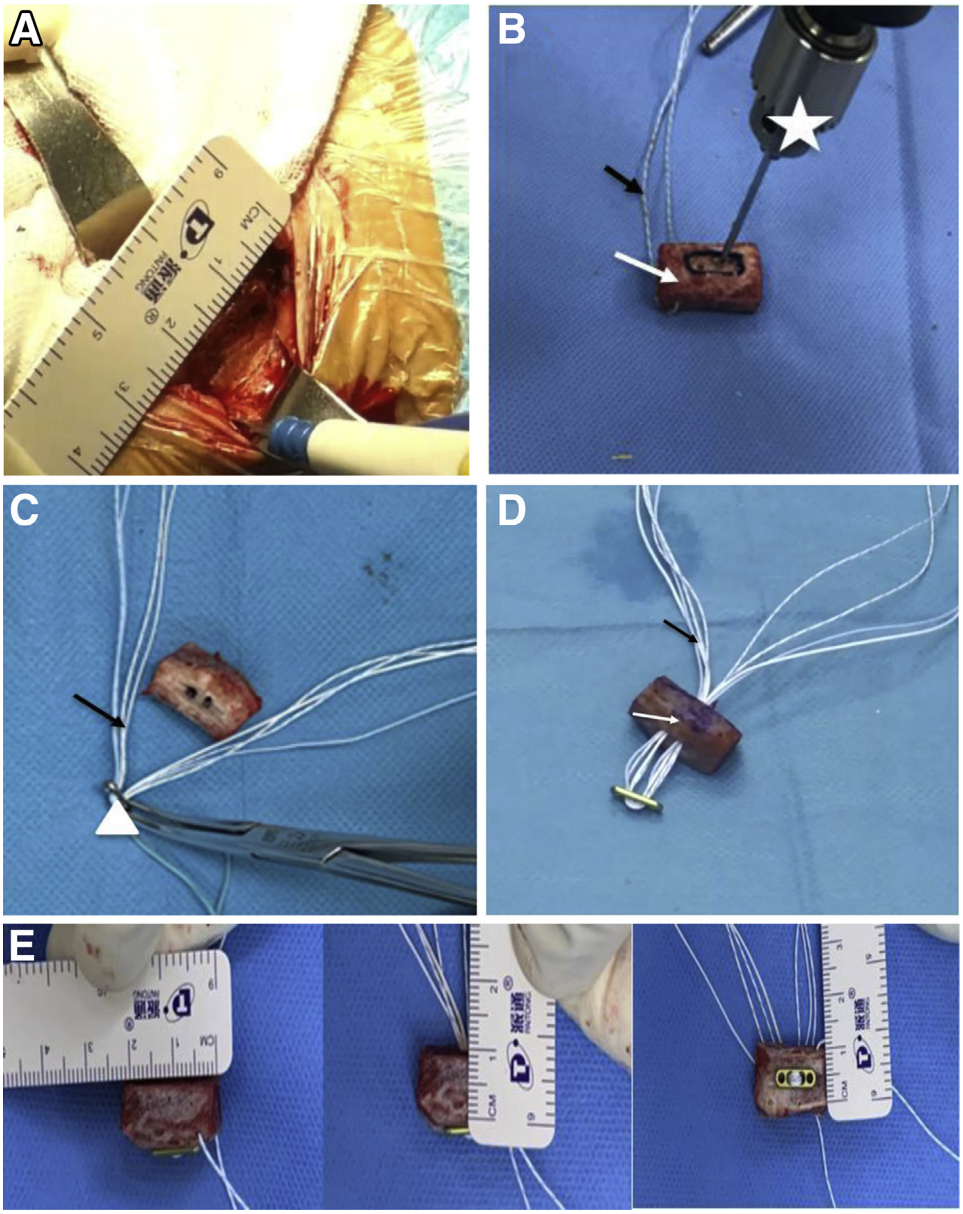

Fig 4. A 20 × 10 × 10—mm tricortical iliac crest graft is harvested from the ipsilateral side. (A) A 25-mm-long bone graft, including 3 cortices, is taken 3 cm behind the anterior superior iliac spine with an osteotome. (B) Two 2-mm-wide holes placed approximately 5 mm apart are made through the graft (white arrow) and the third hole is drilled in 1.5mm away from the edge of the bone by an electric drill (white star).Then a high-strength suture (black arrow)penetrate the hole. (C) An EndoButton (white triangle) is used as a fixture for our nonrigid technique. The 2 ends of 3-strand high-strength sutures (black arrow) are respectively passed through the hole in the EndoButton by a looped guidewire. (D) The 2 ends of the sutures (black arrow) are inserted into 2 holes in the iliac bone graft (white arrow) through the looped guidewire, and then the suture is tightened. (E) The most commonly used graft is 10 mm in width, 20 mm in length, and 10 mm in height, although the size can be customized depending on the case.

released from the introducer, which should be outside the joint capsule (Fig 8F). Tensioning the sutures allows anatomic reduction of the graft. An EndoButton is placed posteriorly, and the graft is secured using a knot for each suture (Fig 8 G and H).

Bankart Repair

Next, the capsule-labrum structure is pulled over the bone graft and attached to the glenoid bone strap using the remaining suture on the 2 anchors (Smith & Nephew) (Fig 9A). In this way, the bone graft is kept outside the joint, forming a backup to the repaired capsule-labrum structure (Fig 9B). The entire surgical technique is shown in Video 1, which includes audio narration.

Rehabilitation

After surgery, the shoulder is immobilized in a neutral external rotation brace for 6 weeks. During the first 6 weeks, only scapulothoracic closed-chain exercises are allowed. Full range of motion is encouraged during the second 6-week period. Muscle-strengthening exercises begin from the fourth month. The patient is allowed to take part in contact activities 6 months after the operation.

Discussion

Although the specific threshold for a significant scapular glenoid defect is still controversial, it is generally believed to be when the osseous defect size of the

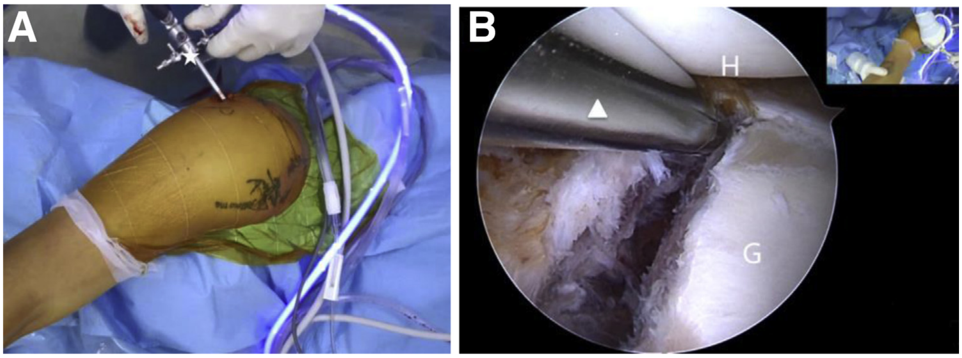

Fig 5. Surgical portal and arthroscopic inspection. (A) A standard posterior portal is created for the insertion of the arthroscope (white star) (Smith & Nephew). (B) The arthroscope is introduced through the anterosuperior portal, the anterior glenoid rim is further decorticated, and the glenoid neck is prepared with a motorized burr (white triangle) (Arthrex) to create a flat and bleeding bony surface. (G, glenoid; H, humerus.)

glenoid exceeds 20%, and soft-tissue procedures performed in such cases have shown unacceptably high recurrence rates.[9] Most of the defects are bipolar lesions and can be managed with glenoid-based surgery. Such defects are indications for bone reconstruction. Various open, minimally invasive, and arthroscopic techniques have been reported to restore glenoid bone loss.[10-12] On the glenoid side, the Latarjet procedure and its variations are gaining increasing popularity in dealing with such significant glenoid bone loss. Despite success and the widespread application, many of the procedures were associated with many complications, such as hardware failure and protrusion, bone nonunion, displacement and absorption, and the development of arthrosis.[13,14]

The other major workhorse category of treatment to address glenoid defects is glenoid bone grafting, including the use of autologous or allogeneic iliac crest graft, autologous distal clavicle graft, or distal tibial allograft. To restore the anatomic structure of the glenoid and facilitate fixation, autogenous iliac bone graft can be polished according to the shape of the glenoid bone defect. Thus, autogenous iliac bone graft is the most widely used.[8,15] We polished the autogenous iliac bone into cuboid bone blocks with a length of 20 mm and width of 10 mm. The bone blocks have also been made into cylinder, ladder, and J shapes in previous articles in the literature.[8] However, no study has compared the effect of different bone mass morphologies on the surgical results.

Regardless of the method of graft implantation, firm fixation is considered a prerequisite for graft healing. Screws were used in most previous studies, making the procedure difficult to perform, especially in an arthroscopic manner. This rigid fixation method has good fixation strength. However, it is difficult to operate under arthroscopy.[16,17] In addition, rigid fixation may cause a stress shielding effect, hardware impingement, nonunion of the bone graft, and secondary osteoarthritic changes and implant loosening.[15] These hardware problems are the most common cause of repeated surgery. Therefore, nonrigid fixation has gradually become the direction of scholars' exploration. We describe a nonrigid fixation technique for reconstruction of the anterior glenoid with autologous iliac crest graft, which uses a specific posterior glenoid guide of our invention for accurate graft positioning, and the bone graft is introduced through the appropriate bone graft guide. The technique of tunnel fixation through

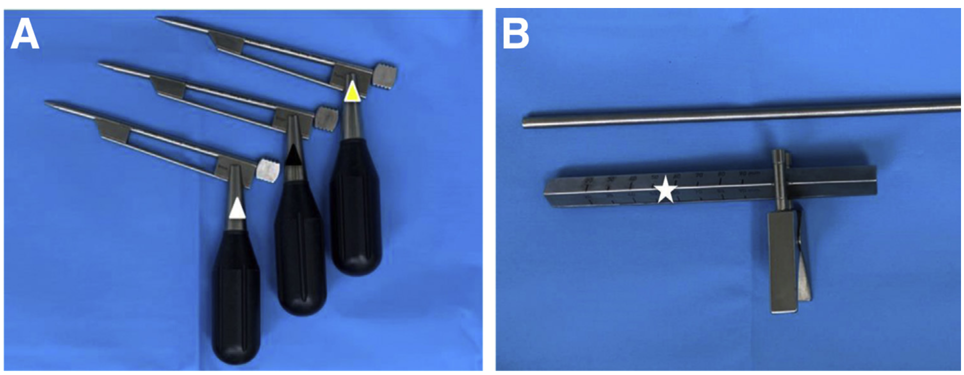

Fig 6. Two sets of grafting instruments were developed by the senior author, including glenoid bone graft guides and a bone graft introducer. (A) The glenoid bone graft guides are 7 mm (yellow triangle), 8 mm (black triangle), and 9 mm (white triangle) wide. (B) There is only 1 size of bone graft introducer (white star).

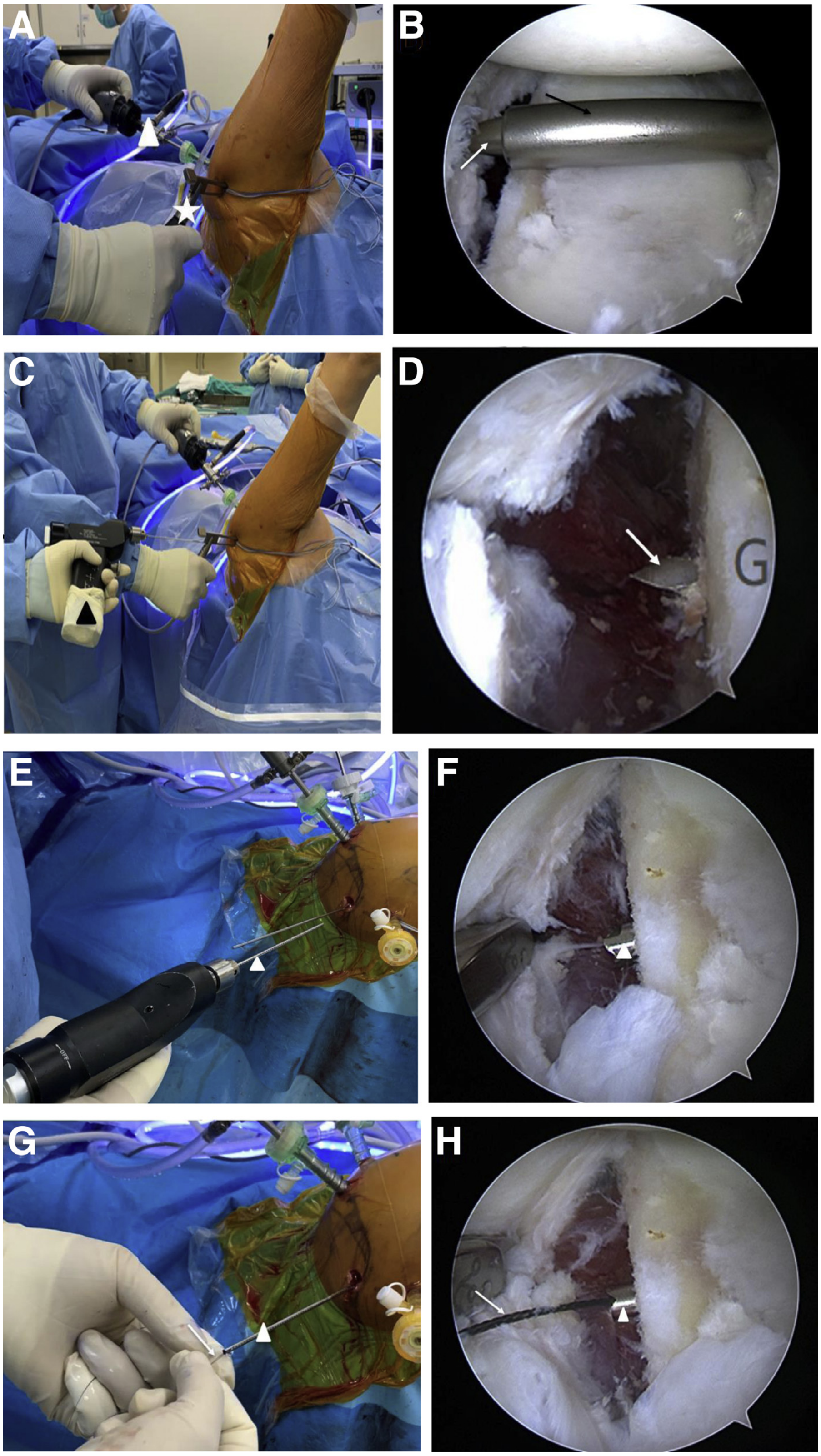

Fig 7. Transglenoid tunnel placement. (A) The glenoid bone graft guide (white star) is placed through the posterior portal (right shoulder, viewed from above). The arthroscope (white triangle) is placed through the anteroinferior portal. (B) The core bar (white arrow) of the bone graft guide (black arrow) is placed into the joint along the guide, which closes to the anterior glenoid margin at the 4- to 5-o'clock position (right shoulder, lateral decubitus position, 30° arthroscope through anterosuperior portal). (C) One hole is drilled from the posterior glenoid to the anterior glenoid with a 2.0-mm drill (black triangle) (right shoulder, viewed from above). (D) The 2.0-mm drill (white arrow) cannot penetrate the joint surface (right shoulder, lateral decubitus position, 30° arthroscope through anterosuperior portal). (G, glenoid.) (E) Drilling is performed with a 2.4-mm hollow drill (white triangle). (F) Arthroscopic view showing 2.4-mm hollow drill (white triangle) (right shoulder, lateral decubitus position, 30° arthroscope through anterosuperior portal). (G) A 2-mm monofilament wire (white arrow) is passed posteriorly through the hollow drill (white triangle) (right shoulder, viewed from above). (H) Arthroscopic view showing 2-mm monofilament wire (white arrow) and hollow drill (white triangle) (right shoulder, lateral decubitus position, 30° arthroscope through anterosuperior portal).

the scapula is similar to that of Taverna et al.[18] However, we also achieved good bone graft fixation with a single tunnel and double EndoButton and reduced treatment costs. In comparison with the method of Zhao et al.,[19] although the use of autologous iliac bone may cause a certain degree of early pain, the use of

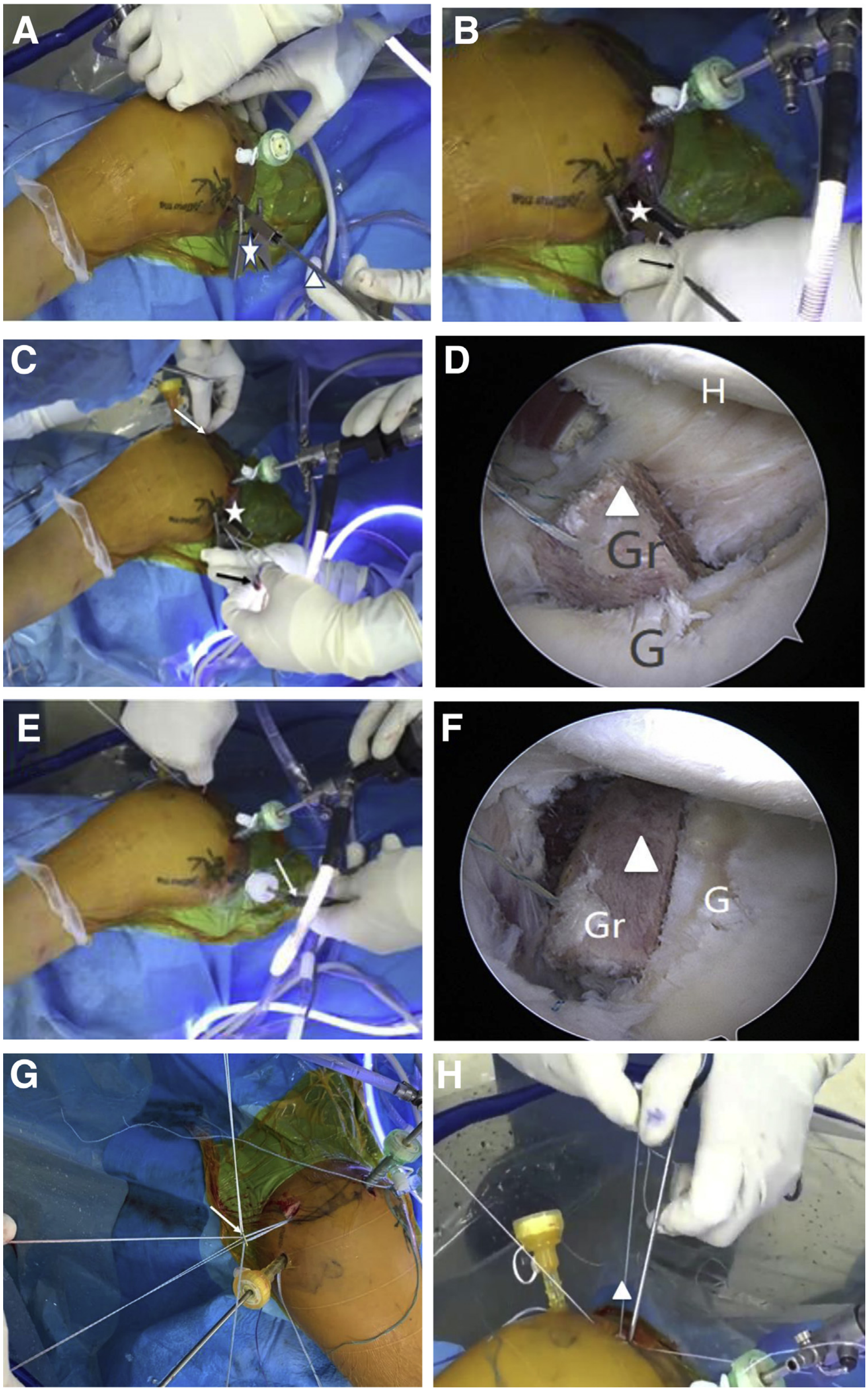

Fig 8. Graft passage and fixation. (A) The bone graft introducer (white star) is then inserted from the anteroinferior portal to allow introduction of the switching stick (white triangle) (Smith & Nephew) (right shoulder, viewed from above). (B) The monofilaments (black arrow) (Smith & Nephew) are retrieved through the anteroinferior portal and taken out through the bone graft introducer (white star) to prepare for graft passage (right shoulder, viewed from above). (C) Suture tails from the EndoButton in the graft (black arrow) are placed through the monofilaments, which are pulled out from the bone graft introducer (white star); the monofilaments (white arrow) are then used to pass the sutures through the trans-glenoid tunnels and retrieved through the posterior portal (right shoulder, viewed from above). (D) With use of the introducer, the graft (white triangle) is pushed into the joint (right shoulder, lateral decubitus position, 30° arthroscope through anterosuperior portal). (E) A grasper (white arrow) placed through the anteroinferior portal is used as a stick to assist in proper placement and to ensure there is no lateralization of the graft (right shoulder, viewed from above). (F) Arthroscopic view showing that the graft (white triangle) is in proper placement, which should be outside the joint capsule (right shoulder, lateral decubitus position, 30° arthroscope through anterosuperior portal). (G) An Endo-Button (white arrow) is placed posteriorly (right shoulder, viewed from above). (H) The graft is secured using a knot for each suture (white triangle) (right shoulder, viewed from above). (G, glenoid; Gr, graft; H, humerus.)

allogeneic iliac bone grafts is more prone to complications such as infection and graft rejection. Compared with the method of Anderl et al.,[15] our technique puts the graft into the joint through the rotator interval and avoids the subscapularis disturbance caused by muscle splitting. Because it is nonrigid fixation, it can allow a certain degree of excessive increase in the depth of the glenoid—or excessive recovery of the radian of the glenoid—without causing osteoarthritis. Moreover, during the healing process, the position of the bone graft will automatically adjust to the optimal position for healing, and the absorption and remodeling will be better, which will be closer to the original pear shape (Fig 10). Although the nonrigid fixation is not sufficient to fix the bone graft firmly, the support provided by the subscapular muscle, scapular glenoid, and joint capsule can make the bone graft firmly adhere to the bone defect and is challenging to shift, which ensures that the graft bone block and scapular glenoid can be well healed. Repairing the damaged labrum-ligament complex structure at the same time as bone grafting can further strengthen this effect.

In addition to the fixation method, the bone graft's fixed position is very important for healing and shoulder joint stability. Some studies have advocated that the bone block should be fixed at the 3-o'clock position to 5:30-clock-face position (in a right shoulder) to make up for the defect of scapular glenoid bone and achieve the function of an anatomic reconstruction as much as possible.[20] However, others have indicated the belief that when the bone mass is large, it is difficult to fix the bone mass to a lower position under arthroscopy and, even if the bone mass position is slightly higher, the final surgical effect will not be affected. When the bone block is fixed at a relatively high 3- to 4-o'clock position, where the scapular glenoid curvature is smaller, the bone block and the scapular glenoid will fit better and will help the bone block heal, so forced anatomic reduction does not occur.[21] We believe that it is better to restore the glenoid shape by fixing the bone block in the area with the largest bone defect as much as possible, but we should also pay attention to the contact surface and fixation strength between the bone block and the glenoid. Besides, Skendzel and Sekiya[22] proposed that the capsule-labrum structure should be attached to the bone block after the bone block is fixed.

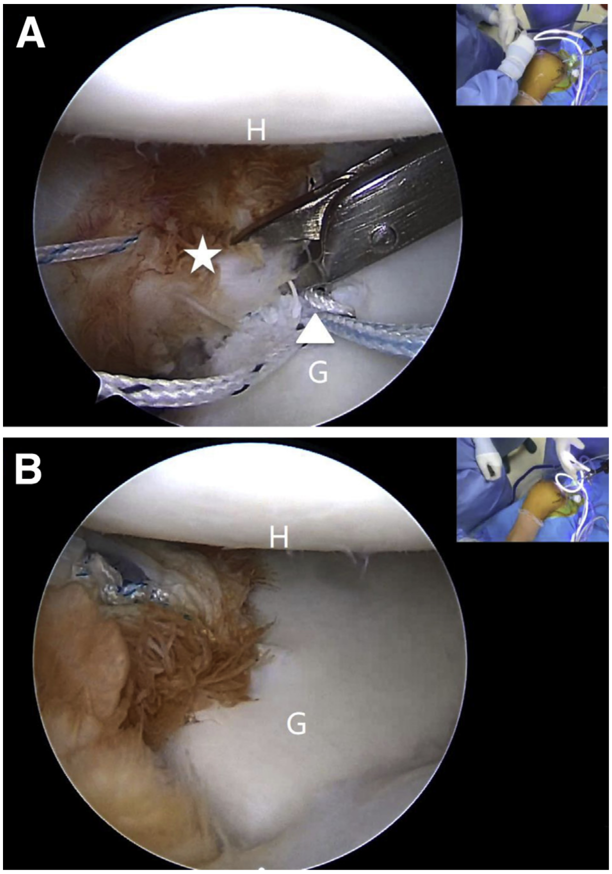

Fig 9. Bankart repair. (A) The capsule-labrum structure (white star) is pulled over the bone graft and attached to the glenoid bone strap using the remaining suture (white triangle) on the 2 anchors (right shoulder, lateral decubitus position, 30° arthroscope through anterosuperior portal). (B) The Bankart repair is completed; the bone graft is kept outside the joint, forming a backup to the repaired capsule-labrum structure (right shoulder, lateral decubitus position, 30° arthroscope through anterosuperior portal). (G, glenoid; H, humerus.)

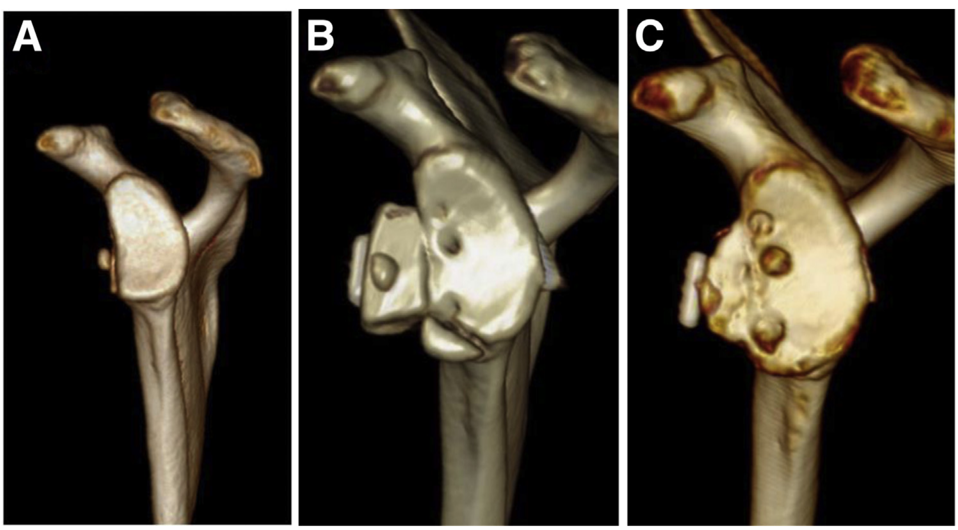

Fig 10. Three-dimensional computed tomography images showing en face views of glenoid. (A) Image obtained preoperatively. (B) Image obtained after operation. (C) Image obtained at 6 months, showing complete bone healing and remodeling.

However, we advocate that the capsule-labrum structure should be pulled over the bone fragment and attached to the glenoid bone strap. In this way, the bone fragment is kept outside the joint, forming a backup to the repaired capsule-labrum structure.

The grafting instruments used in this technique should be noted. With these special sets of instruments that we invented, the tunnel can be drilled with notable accuracy and safety and it is easy to deliver the iliac bone graft to the desired location.

The arthroscopic nonrigid fixation technique permits minimally invasive reconstruction of anterior glenoid defects. We prefer this arthroscopic technique for cases of large glenoid bone deficiency. However, there are 2 limitations to the nonrigid fixation technique of arthroscopic autologous iliac crest bone grafting for reconstruction of the glenoid: Donor-site morbidity can occur, such as an avulsion fracture of the spina iliaca. In addition, this technique has a steep learning curve, which requires the use of special surgical instruments.

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