Technical Note

Arthroscopic Tri-anchor Double-Pulley Suture-Bridge Reduction of Greater Tuberosity Fracture

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Abstract: Currently, cannulated screws, plates, and suture bridges are widely applied in the treatment of greater tuberosity fracture; however, further fragmentation of the fracture, risk of loss of fracture reduction, implant impingement, and anchor pullout are the drawbacks. Therefore, we present a pragmatic surgical technique called the arthroscopic tri-anchor double-pulley suture-bridge technique that uses a double-loaded metallic anchor as a lateral-row anchor. In the treatment of greater tuberosity fracture, this hybrid repair including 4 sets of double-pulley suture bridges and 2 sets of single rows can obtain powerful stiffness of the suture construct, the metallic anchor used as a lateral-row anchor can significantly reduce the risk of anchor pullout, the single-row process can lessen the overall surgical time, and implant impingement will not occur postoperatively.

Greater tuberosity (GT) fractures account for 19% of all proximal humeral fractures. Multiple methods such as internal fixation with cannulated screws and plates and arthroscopic suture-bridge techniques are used for GT fractures.[1,2] However, the controversy on the best way to address GT fractures continues.[3]

Owing to the risk of further fragmentation of GT fractures, it is difficult to obtain reliable fixation in comminuted fragments with cannulated screws.[4] The risk of loss of GT fracture reduction is subsistent because the screws on the plate cannot sustain the traction power of the rotator cuff.[5] Implant impingement is a familiar complication of screws and plates.[6] Anchor pullout[7] and excessive surgical time[8] are the shortcomings of arthroscopic suture-bridge repair.

Therefore, we present a pragmatic surgical technique called the arthroscopic tri-anchor double-pulley suture-bridge (DPSB) technique that uses a double-loaded metallic anchor as a lateral-row anchor. In the treatment of GT fracture, this hybrid repair including 4 sets of DPSBs and 2 sets of single rows (SRs) can obtain powerful stiffness of the suture construct, the metallic anchor used as a lateral-row anchor can significantly reduce the risk of anchor pullout, the SR process can lessen the overall surgical time, and implant impingement will not occur postoperatively.

Surgical Technique

Anesthesia and Patient Positioning

The patient undergoes general anesthesia and is placed in the lateral decubitus position (Video 1). Pearls and pitfalls are described in Table 1, and advantages and disadvantages are presented in Table 2. The study was approved by the ethical department in our hospital, and the patient gave informed consent.

Diagnostic Arthroscopy

A posterior portal is created for diagnosis. Intra-articular fractures and the rotator cuff are evaluated. Any treatable pathologies in the joint are addressed at this time. The scope is then directed into the subacromial space, and bursectomy and acromioplasty are applied.

The fracture margin and native anatomic contour are localized; it is determined that the supraspinatus tendon is attached to the fracture fragment (Fig 1). Debridement is performed on the underside of the fracture

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Table 1. Surgical Pearls and Pitfalls

Surgical indication consideration
A small- or medium-sized GT fracture is the optimal indication for this surgical technique.
Anchor insertion considerations
A double-loaded metallic anchor is the sole implant used for the surgical process.
Owing to loss of bone mass, a suture anchor may experience pullout when it is inserted in immediate proximity to the fracture bed.
Attention should be paid to the depth of anchor insertion.
Two metallic anchors, used as posterior and anterior lateral-row anchors (named anchors B and C, respectively), are inserted into the posterior and anterior portions of the intact humeral metaphysis, respectively, which are placed at the margin of the fracture site.
Suture layout considerations
A total of 6 strands are passed through the supraspinatus tendon, including 4 strands from the medial-row anchor and 2 strands from lateral-row anchors.
All strands from anchor A are passed through the tendon with alternating blue and white.
Four sets of DPSBs and 2 sets of SRs are created and present in an X configuration on the upper surface of the fracture fragment.
DPSB and SR creation consideration
The blue strands from anchor A that passes through the tendon and the white strands from anchor B are created into the first and second sets of DPSBs. The white strands from anchor A that passes through the tendon and the blue strands from anchor C are created into the third and fourth sets of DPSBs. The blue strands from anchor B are created into the first of SRs. The white strands from anchor C are created into the second of SRs.

DPSB, double-pulley suture bridge; GT, greater tuberosity; SR, single row.

Table 2. Advantages and Disadvantages

Advantages
Four sets of DPSBs contain the surgical effect of tension banding and can strongly compress the main body of the fracture fragment against the fracture bed; repair with 2 sets of SRs play an auxiliary fixation role.
The metallic anchor used as a lateral-row anchor not only is a surgical innovation but also can reduce the risk of anchor pullout.
Two sets of SRs not only increase the stiffness of the suture construct but also lessen the overall surgical time.
The DPSB technique is suitable for the treatment of comminuted GT fractures, and implant impingement will not occur postoperatively.
Compared with conventional suture-bridge techniques, the inexpensive double-loaded metallic anchor used as a lateral-row anchor can significantly reduce the overall implant cost.
Disadvantages
Owing to the powerful traction strength of the rotator cuff on the fracture fragment, metallic anchors may have a risk of pullout.
The limited fixation strength of DPSBs may result in insufficient reduction of the fracture fragment.
The reduction strength of an SR is not as good as that of a DPSB; 6 sets of DPSBs, instead of 4 sets of DPSBs and 2 sets of SRs, will achieve better clinical outcomes.
The use of 3 suture anchors for fracture reduction is not enough; performing the repair with 4 suture anchors, which can create 8 sets of DPSBs, is a better choice.

DPSB, double-pulley suture bridge; GT, greater tuberosity; SR, single row.

fragment, as well as the fracture bed, to obtain a bleeding bone bed. Care should be taken not to perform immoderate debridement and weaken the fracture bed. The comminution, size, and traction orientation of the fracture fragment are assessed (Fig 2).

Medial-Row Anchor (Anchor A) Insertion

A double-loaded metallic anchor (TWINFIX; Smith & Nephew, Andover, MA) with blue and white strands, used as the medial-row anchor and called anchor A, is inserted into the medial aspect of the fracture bed (Fig 3). Attention should be paid to the depth of anchor insertion (Fig 4).

Strand Passage Through Tendon

A total of 6 strands are passed through the supraspinatus tendon (Figs 5 and 6). The medial-row 4 strands, which are regarded as the middle 4 of the 6 strands, are passed through the tendon with alternating blue and white (Fig 7).

Posterior Lateral-Row Anchor (Anchor B) Insertion

Owing to loss of bone mass, suture anchors may experience pullout when inserted in immediate proximity to the fracture bed. A trial of suture tensioning is used to estimate the best insertion site for the lateral-row anchor. Another TWINFIX anchor, used as the posterior lateral-row anchor and called anchor B, is inserted into the posterior portion of the intact humeral metaphysis, which is placed at the margin of the fracture site (Fig 8).

Creation of First and Second DPSBs and First SR

One blue strand from anchor A that passes through the tendon and one white strand from anchor B are grasped out of the body (Fig 9), tightly knotted, and created into a blue-white suture (Fig 10); the strands are cut above the knot. This blue-white suture is the first set of DPSBs (Fig 11).

As a result of the double-pulley effect, this DPSB is delivered into the subacromial space in a stepwise

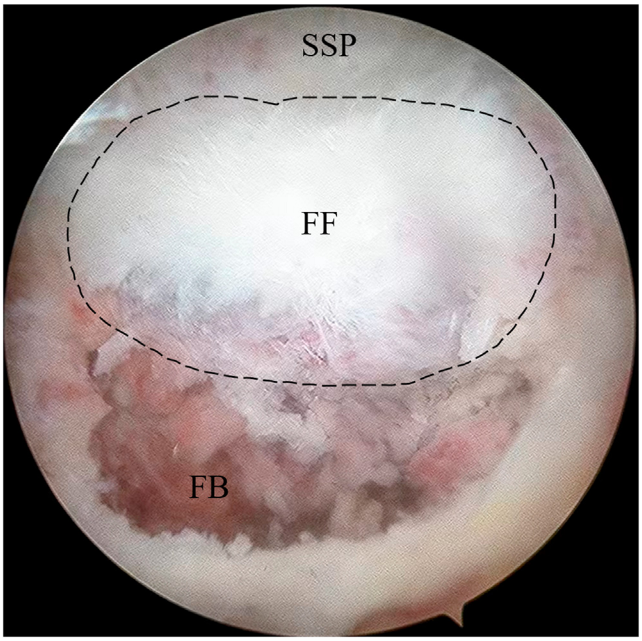

Fig 1. Arthroscopic image of left shoulder (with patient in lateral decubitus position), viewed through subacromial lateral portal, showing localization of fracture margin, fracture bed (FB), and native anatomic contour (dashed line). It is determined that the supraspinatus tendon (SSP) is attached to the fracture fragment (FF).

manner by pulling the opposite blue and white strands (Fig 12). This DPSB can strongly compress the fracture fragment against the fracture bed by pulling the opposite blue and white strands with a sufficient quantity of tension.

The opposite blue and white strands are tightly knotted with a knot pusher in the subacromial space and created into the second set of DPSBs (Fig 13); again, the strands are cut above the knot. One blue strand from anchor B is passed through the anterior portion of the tendon and created into the first set of SRs (Fig 14).

Creation of Third and Fourth DPSBs and Second SR

The third TWINFIX anchor, used as an anterior lateral-row anchor and called anchor C, is inserted into the anterior portion of the intact humeral metaphysis (Fig 15). The blue suture from anchor C and white suture from anchor A will be created into the third and fourth sets of DPSBs (Fig 16). The white suture from anchor C will be created into the second set of SRs.

Reduced Fracture Assessment

Four sets of DPSBs and 2 sets of SRs are present in an X configuration and strongly compress the fracture fragment against the fracture bed. The reduced fracture fragment attached to the supraspinatus tendon presents a nearly anatomic reduction (Fig 17).

Discussion

Arthroscopic suture-bridge techniques for GT fractures have shown good clinical outcomes in 80% to 90% of cases with minimal implant impingement and anchor protrusion.[7,9] Tension banding can distribute suture on the tension side of the fracture and convert the tension into pressure.[10] In the suture-bridge process, the cuff is used to distract the tension on the GT fracture, and suture bridges are used to reduce the fracture site; in this manner, it is similar to tension banding.[11,12] Braunstein et al.[13] described that tension banding for GT fractures was more powerful than screw fixation. Brais et al.[14] compared strength between tension banding and double-row fixation in the porcine proximal humerus and considered double-row fixation to be more stable. Suture-bridge techniques can effectively reduce comminuted GT fractures without further fragmentation.[2]

Cummins and Murrell[15] noted that anchor pullout was an important factor for rotator cuff repair failure. Djurasovic et al.[16] found that 10% of 80 patients with cuff retears presented with anchor migration. Ji et al.[7] reported 5 cases of anchor migration among 40 patients with GT fractures after suture-bridge repair. Anatomic reduction of GT fractures is crucial for joint function.[17] GT fractures are common in aged patients in association with osteoporosis. Anchor pullout strength is closely related to bone mineral density.[18] The anchor may be pulled out from osteoporotic bone.[5] In addition to bone quality, anchor material is an important factor for anchor stability.[19] Owing to the bone lysis and defects, bioabsorbable anchors may incur late pullout.[20] PEEK (polyether ether ketone) anchors may enlarge the peripheral bone remarkably more laterally.[21] Tingart et al.[22] revealed that metallic anchors possessed more pullout strength than biodegradable anchors. Ji et al.[7] suggested that metallic anchors with a larger pitch can maximize pullout strength and minimize the risk of anchor pullout.

Owing to complicated suture management, a conspicuous drawback of suture-bridge methods is the greater surgical time required.[8] Fortunately, a shorter surgical time is obtained when using an SR method.[23] Seppel et al.[24] described SR fixation of GT fractures with satisfactory biomechanical outcomes. Holt and Field[25] considered that both SR and double-row constructs can be used to secure the GT fracture fragment. Moreover, an increasing suture number can enhance the stiffness of the suture construct.[26] Shi et al.[27] believed that using more suture strands could lead to a higher ultimate failure load.

We believe that the arthroscopic tri-anchor DPSB technique possesses some superiorities in the treatment of GT fracture: First, 4 sets of DPSBs contain the surgical effect of tension banding and can strongly compress the

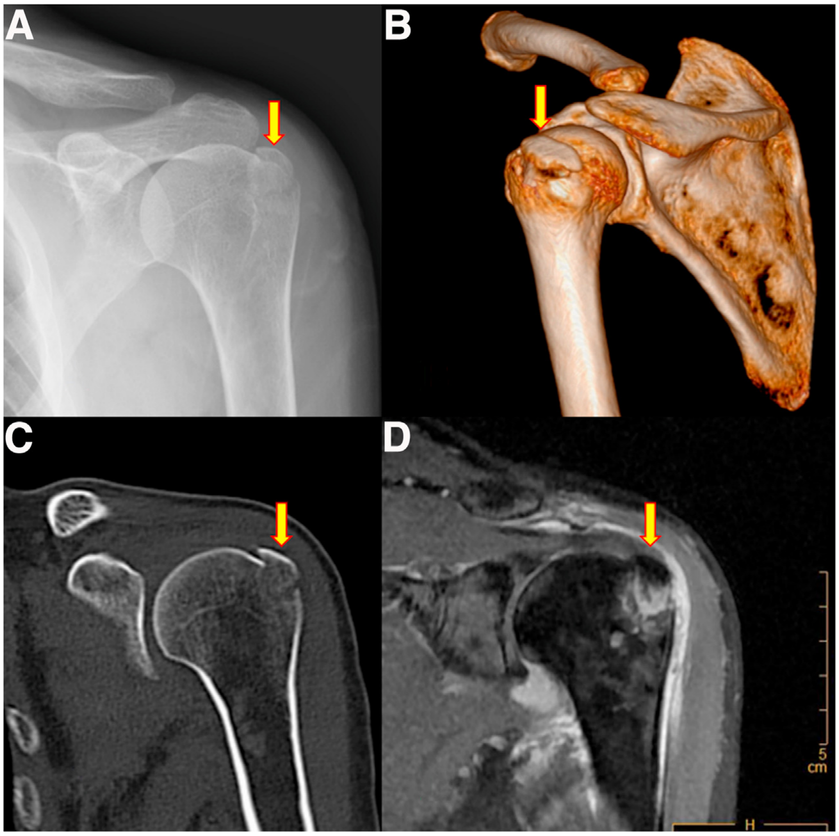

Fig 2. Displaced greater tuberosity fracture (arrows) in left shoulder on anteroposterior radiograph (A), computed tomography scan with 3-dimensional reconstruction (B), anteroposterior computed tomography scan (C), and magnetic resonance imaging (oblique coronal view) (D).

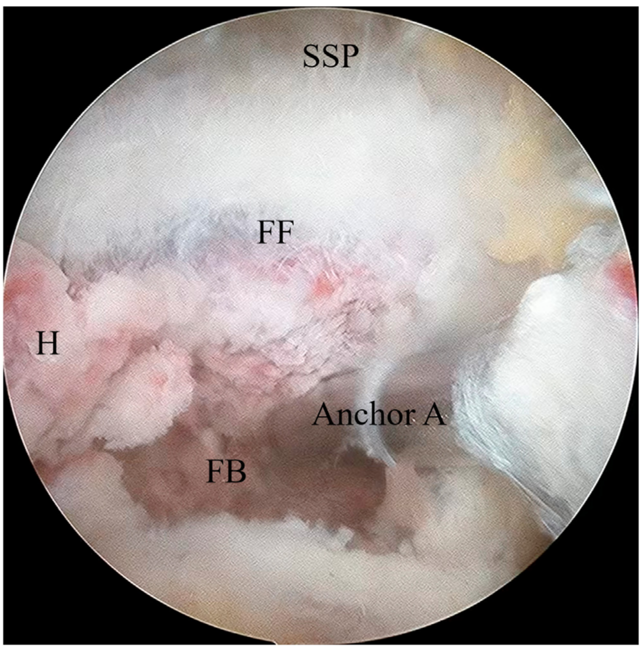

Fig 3. Arthroscopic image of left shoulder (with patient in lateral decubitus position), viewed through subacromial lateral portal, showing insertion of double-loaded metallic anchor (anchor A), as medial-row anchor, into medial aspect of fracture bed (FB). (FF, fracture fragment; H, hematoma; SSP, supraspinatus tendon.)

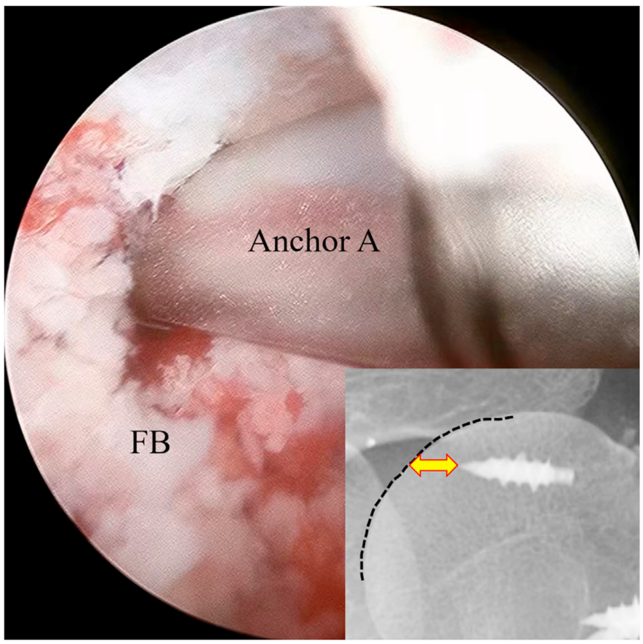

Fig 4. Arthroscopic image of left shoulder (with patient in lateral decubitus position), viewed through subacromial lateral portal, showing insertion of anchor A into medial aspect of fracture bed (FB). Attention should be paid to the depth of anchor insertion. The arrow indicates the distance from the tip of anchor A to the articular surface of the humeral head (dashed line).

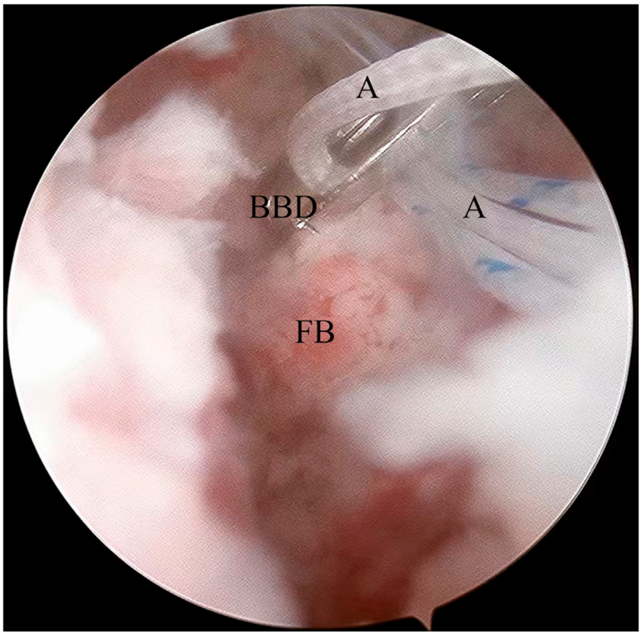

Fig 5. Arthroscopic image of left shoulder (with patient in lateral decubitus position), viewed through subacromial lateral portal, showing bird-beak device (BBD), which has been passed through supraspinatus tendon, grasping white strand (A) from anchor A. (FB, fracture bed.)

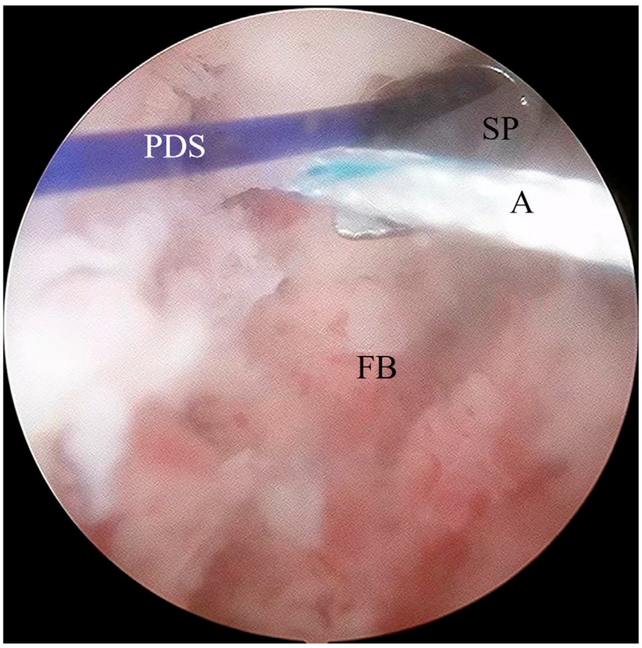

Fig 6. Arthroscopic image of left shoulder (with patient in lateral decubitus position), viewed through subacromial lateral portal, showing suture passer (SP), which has been passed through supraspinatus tendon, pushing out polydioxanone suture (PDS). (A, suture strand from anchor A; FB, fracture bed.)

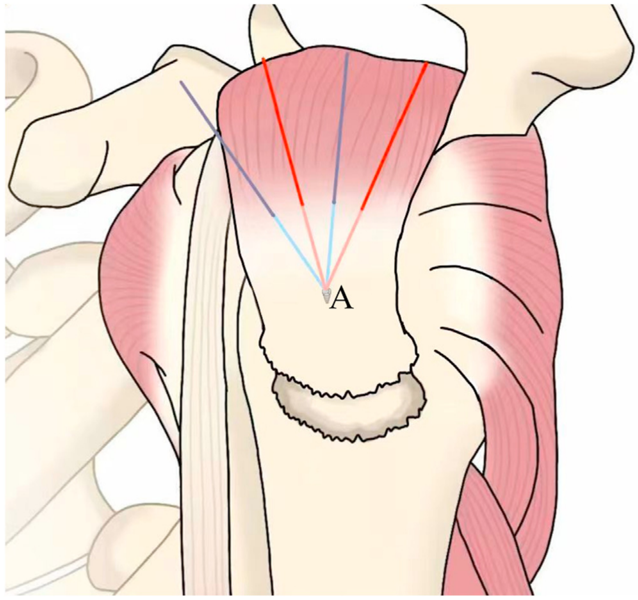

Fig 7. Illustration of left shoulder showing passage of medial-row 4 strands from anchor A (A), which are regarded as middle 4 of 6 strands, through tendon with alternating blue and white.

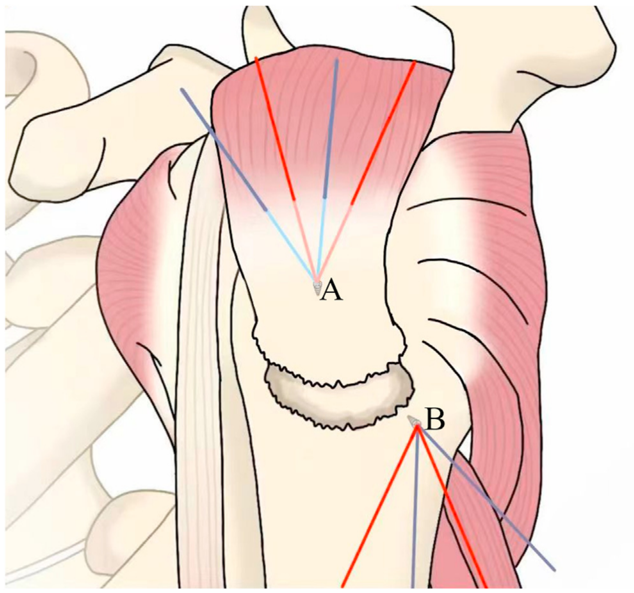

Fig 8. Illustration of left shoulder showing insertion of another double-loaded metallic anchor (anchor B [B]), as posterior lateral-row anchor, into posterior portion of intact humeral metaphysis, which is placed at margin of fracture site. (A, anchor A.)

main body of the fracture fragment against the fracture bed; repair with 2 sets of SRs plays an auxiliary fixation role. Second, the metallic anchor used as a lateral-row anchor not only is a surgical innovation but also reduces the risk of anchor pullout. Third, 2 sets of SRs not only increase the stiffness of the suture construct but also lessen the overall surgical time. Fourth, the DPSB technique is suitable for the treatment of comminuted GT fractures, and implant impingement will not occur

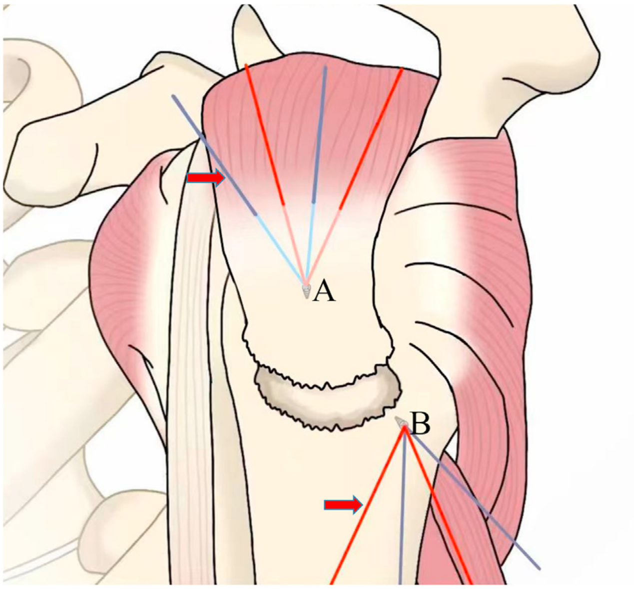

Fig 9. Illustration of left shoulder showing one blue strand from anchor A (A) that passes through tendon and one white strand from anchor B (B) that will be grasped out of body. The arrows indicate the strands from anchors A and B.

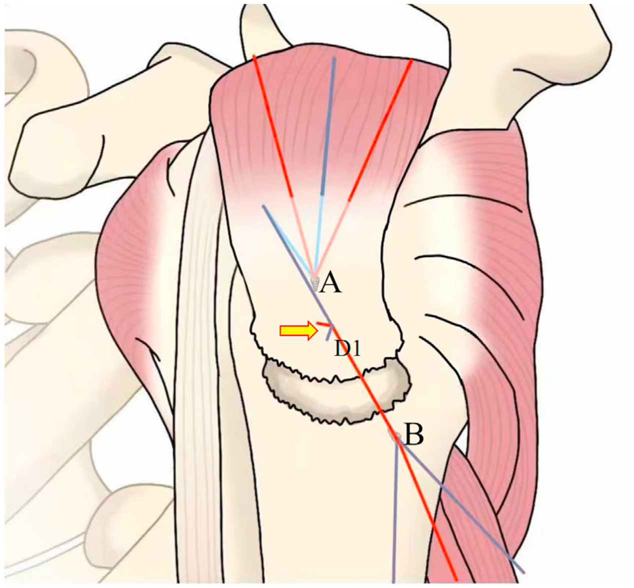

Fig 11. Illustration of left shoulder showing creation of 1 blue strand (A) from anchor A that passes through tendon and 1 white strand (B) from anchor B into first set of double-pulley suture bridges (D1).

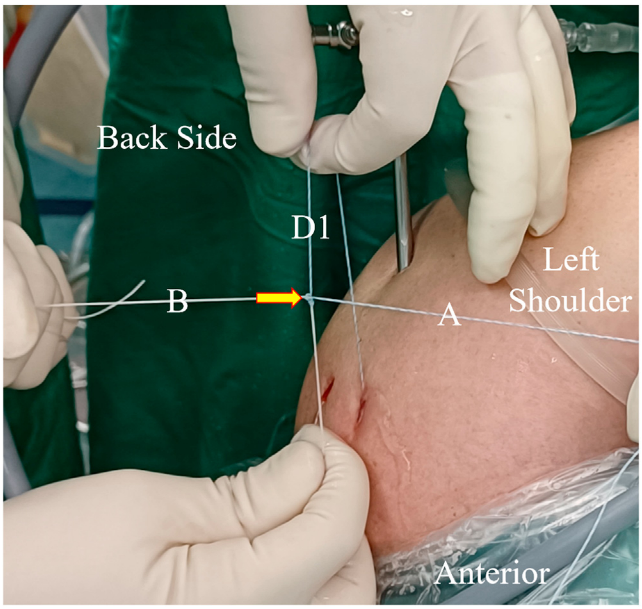

Fig 10. In an extracorporeal manner, 1 blue strand (A) from anchor A and 1 white strand (B) from anchor B are tightly knotted (arrow) and created into the first set of double-pulley suture bridges (D1).

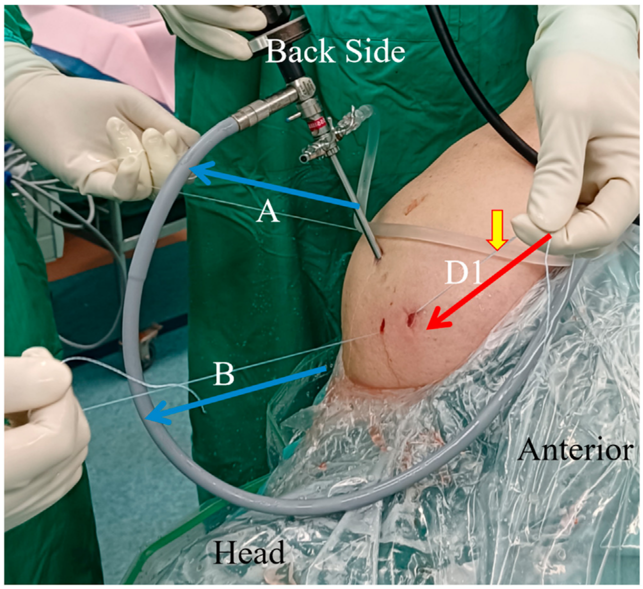

Fig 12. As a result of the double-pulley effect, the first set of double-pulley suture bridges (D1) is delivered into the subacromial space in a stepwise manner by pulling the opposite blue (A) and white (B) strands. The yellow arrow indicates the knot; blue arrows, the directions in which the opposite blue and white strands are pulled out; and red arrow, the direction in which the first set of double-pulley suture bridges is delivered into the body.

postoperatively. Fifth, compared with conventional suture-bridge techniques, the inexpensive double-loaded metallic anchor used as a lateral-row anchor can significantly reduce the overall implant cost.

Nevertheless, this technique has some shortcomings: First, owing to the powerful traction strength of the rotator cuff on the fracture fragment, the metallic

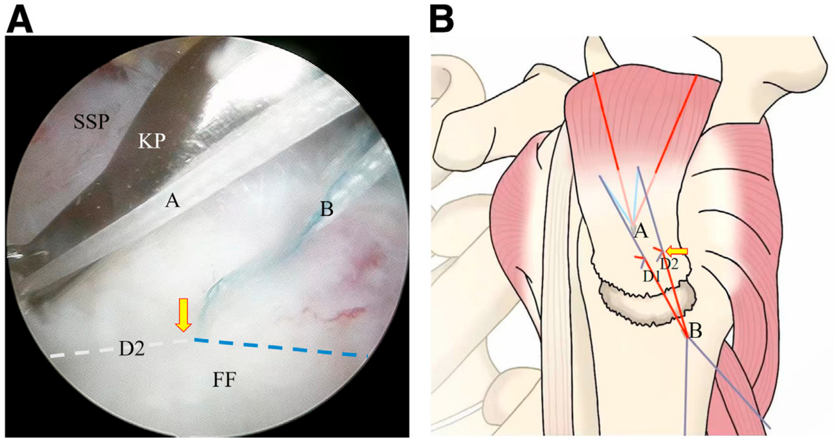

Fig 13. (A) Arthroscopic image of left shoulder (with patient in lateral decubitus position), viewed through subacromial lateral portal, showing tight knotting of 1 blue strand (A) from anchor A that passes through tendon and 1 white strand (B) from anchor B with knot pusher (KP) in subacromial space and creation into second set of double-pulley suture bridges (DPSBs) (D2, blue and white dashed lines). The yellow arrow indicates the knot. (FF, fracture fragment; SSP, supraspinatus tendon.) (B) Illustration of left shoulder showing creation of 1 blue strand from anchor A (A) that passes through tendon and 1 white strand from anchor B (B) into second set of DPSBs (D2). The arrow indicates the knot. (D1, first set of DPSBs.)

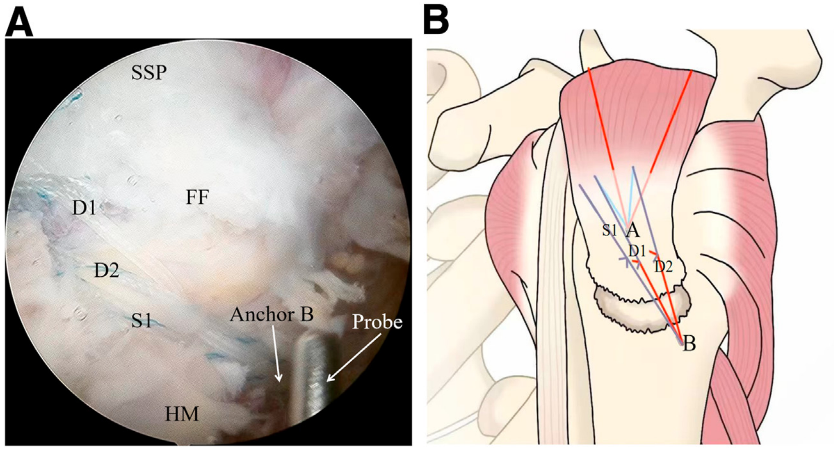

Fig 14. (A) Arthroscopic image of left shoulder (with patient in lateral decubitus position), viewed through subacromial lateral portal, showing first set (D1) and second set (D2) of double-pulley suture bridges and first set of single rows (S1). (Anchor B, location of anchor B insertion; FF, fracture fragment; HM, humeral metaphysis; SSP, supraspinatus tendon.) (B) Illustration of left shoulder showing first set (D1) and second set (D2) of double-pulley suture bridges and first set of single rows (S1). (A, anchor A; B, anchor B.)

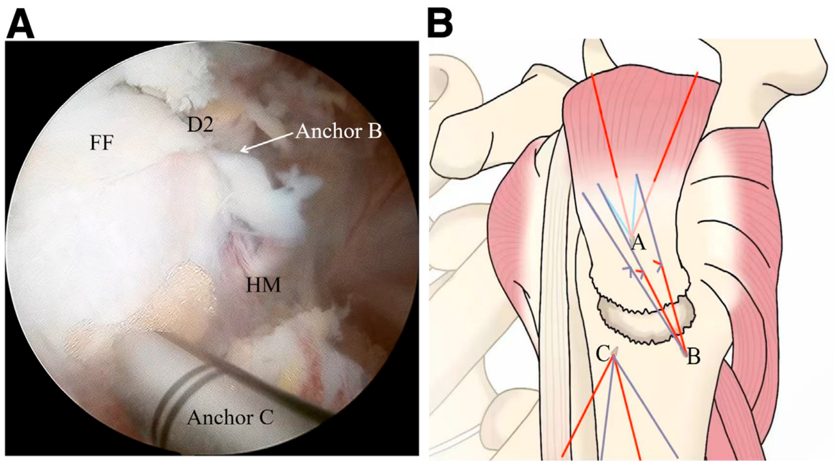

Fig 15. (A) Arthroscopic image of left shoulder (with patient in lateral decubitus position), viewed through subacromial lateral portal, showing insertion of third double-loaded metallic anchor (anchor C), as anterior lateral-row anchor, into anterior portion of intact humeral metaphysis (HM), which is placed at margin of fracture site. (Anchor B, location of anchor B insertion; D2, second set of double-pulley suture bridges; FF, fracture fragment; SSP, supraspinatus tendon.) (B) Illustration of left shoulder showing insertion of double-loaded metallic anchor (C), as anterior lateral-row anchor, into anterior portion of intact humeral metaphysis, which is placed at margin of fracture site. (A, anchor A; B, anchor B.)

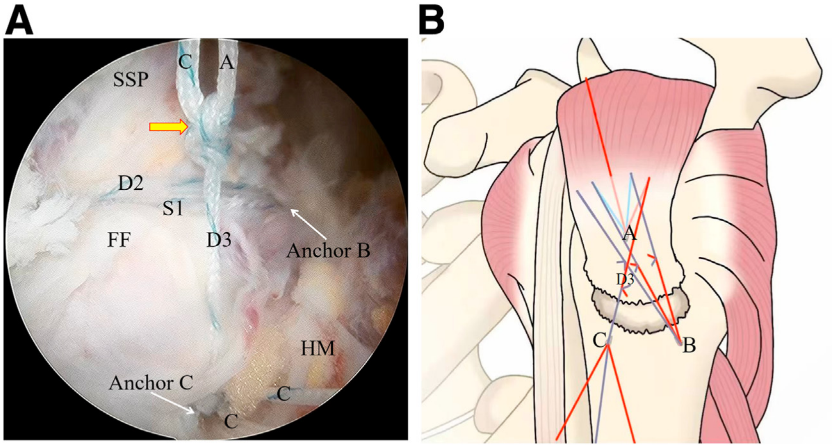

Fig 16. (A) Arthroscopic image of left shoulder (with patient in lateral decubitus position), viewed through subacromial lateral portal, showing that as a result of the double-pulley effect, the third set of double-pulley suture bridges (DPSBs) (D3) is delivered into the subacromial space in a stepwise manner by pulling the opposite blue and white strands. (A, strand from anchor A; Anchor B, location of anchor B insertion; Anchor C, location of anchor C insertion; C, strand from anchor C; D2, second set of DPSBs; FF, fracture fragment; HM, humeral metaphysis; S1, first set of single rows; SSP, supraspinatus tendon.) (B) Illustration of left shoulder showing creation of third set of DPSBs (D3) strongly compressing fracture fragment against fracture bed. (A, anchor A; B, anchor B; C, anchor C.)

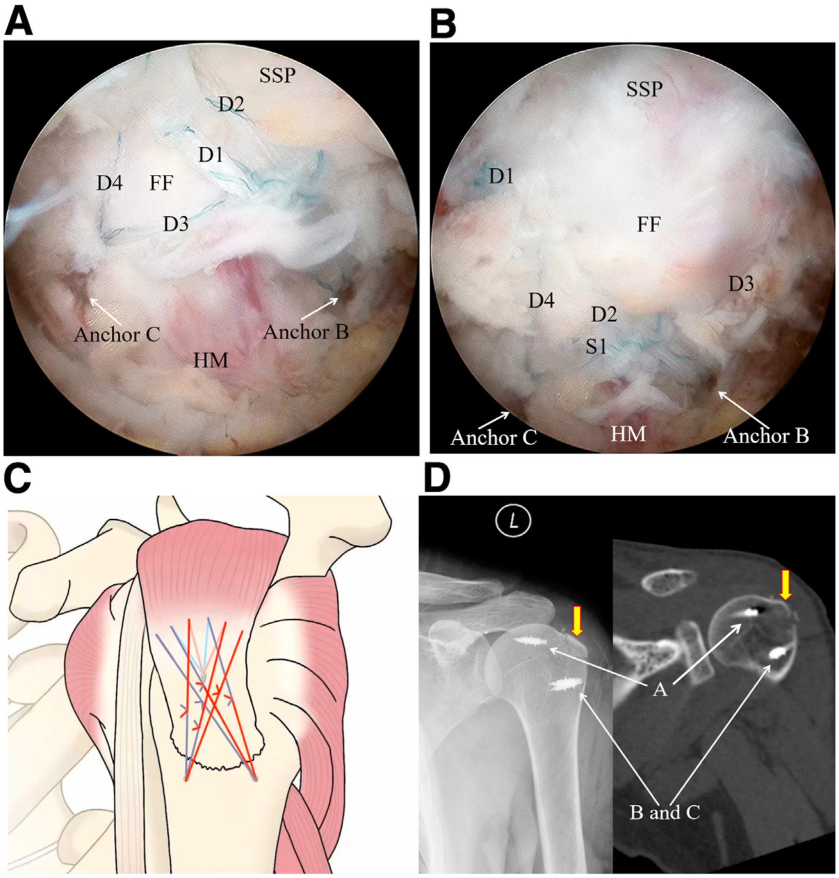

Fig 17. (A) Arthroscopic image of left shoulder (with patient in lateral decubitus position), viewed through subacromial lateral portal, showing that 4 sets of double-pulley suture bridges (DPSBs) (D1, D2, D3, and D4) are present in an X configuration and strongly compress the fracture fragment (FF) against the fracture bed. The reduced fracture fragment attached to the supraspinatus tendon (SSP) presents a nearly anatomic reduction. (Anchor B, location of anchor B insertion; Anchor C, location of anchor C insertion; HM, humeral metaphysis.) (B) Arthroscopic image of left shoulder (with patient in lateral decubitus position), viewed through subacromial lateral portal, showing that 4 sets of DPSBs (D1, D2, D3, and D4) and 2 sets of single rows are present in an X configuration and strongly compress the fracture fragment (FF) against the fracture bed. The reduced fracture fragment attached to the supraspinatus tendon (SSP) presents a nearly anatomic reduction. (Anchor B, location of anchor B insertion; Anchor C, location of anchor C insertion; HM, humeral metaphysis; S1, first set of single rows.) (C) Illustration of left shoulder showing presence of 4 sets of DPSBs and 2 sets of single rows in X configuration strongly compressing fracture fragment against fracture bed. (D) Postoperative anteroposterior radiograph and computed tomography scan of left shoulder (L) showing that the reduced fracture fragment (arrows) presents a nearly anatomic reduction; all the anchors used (anchors A, B, and C) are metallic anchors.

anchor may have a risk of pullout. Second, the limited fixation strength from DPSBs may result in insufficient reduction of the fracture fragment. Third, the reduction strength of an SR is not as good as that of a DPSB; 6 sets of DPSBs, instead of 4 sets of DPSBs and 2 sets of SRs, will achieve better clinical outcomes. Fourth, the use of 3 suture anchors for fracture reduction is not enough; performing the repair with 4 suture anchors, which can create 8 sets of DPSBs, is a better choice.

Disclosures

All authors (P.H., X.W., Y.F., Z.X., Z.L., B.P., C.H.) 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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