Technical Note

Arthroscopic Reduction and Transosseous Suture Fixation of Avulsed Displaced Shoulder Greater Tuberosity Fracture

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Abstract: The results of conservative treatment of displaced proximal humerus fractures are not satisfactory. Open reconstruction and rigid internal fixation, as well as arthroscopic-assisted reduction and internal fixation, are possible in selected cases, mostly young patients. Older patients with osteoporotic, comminuted bone accounts for 70% of the cases. We present an arthroscopic reduction and transosseous suture fixation technique for osteoporotic patients with displaced 2-part greater tuberosity fractures of the proximal humerus. The technique reduces the upward and medially displaced greater tuberosity to its anatomic position and uses longitudinal, horizontal, or a mattress suture fixation as single or combined fixation (Natofix technique).

According to Neer,[1] classification of proximal humeral fracture 2-part displacement fracture include isolated displacement of the head (anatomic neck), shaft (surgical neck), greater tuberosity, and lesser tuberosity.

Proximal humerus fractures account for 4% to 5% of all fracture,[2,3] and isolated greater tuberosity fractures account for 12% to 19% of proximal humerus fractures.[4-6] Greater tuberosity fractures are approximately present in 15% to 35% of all anterior shoulder dislocations.[7] Minimally displaced, isolated fractures of the greater tuberosity respond well to nonoperative management, but full recovery can take up to 1 year.[8,9]

Displaced fractures, particularly those with posterosuperior displacement, may benefit from fixation.[10] In conventional reconstruction of the greater tuberosity fracture, it has always been necessary to open the involved portion of the patient's shoulder over a large area to create sufficient room for the operation, and usually using screws to reconstruct the fracture. Operations within such large areas, however, always involve very high stress on the patient and require a correspondingly long period of convalescence. Nevertheless, the screws used disturb the blood supply of the bone fragments and may have fixation problems in case of osteoporotic bone.

Our experience matches the literature suggesting that the results of conservative treatment of the proximal humerus fractures are not satisfactory.[1,11-14] Open reconstruction and rigid internal fixation is only possible in selected cases, mostly young patients because of the difficulties resulting from osteoporotic, comminuted bone in older patients, which accounts for more than 70% of the cases.[11,12,15-17]

A technique of arthroscopic transosseous suture fixation of the fractured greater tuberosity was developed by the first author (B.A.N.F.) and will be presented. To our knowledge, this is the first published technique of arthroscopic transosseous suture fixation of displaced fracture of the greater tuberosity.

Diagnosis of Upper Humeral Fractures

Physical Signs

Usually, early signs are limited to direct and indirect tenderness, and continued shoulder pain subsequent to injury. Ecchymosis, which may extend from the chest wall to the elbow, appears and strongly suggests the diagnosis.

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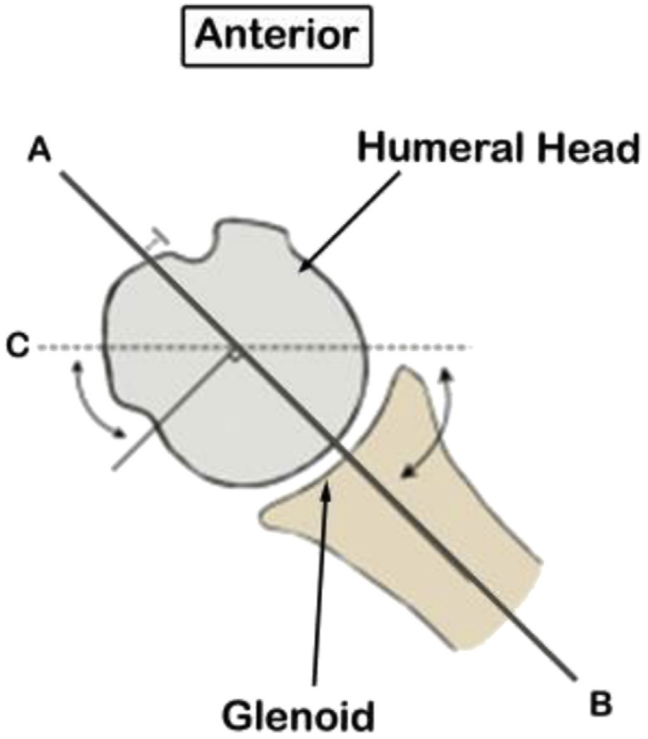

Fig 1. Line (A-B) from approximately 5 mm lateral to the bicipital groove passing through the center of the head (C) will lay perpendicular to the glenoid in neutral rotation of the shoulder with normal anatomy.

Radiographic Diagnosis

Two-plane views of the joint and the upper humerus are best made by placing the beam vertical and then parallel to the scapular plane, as well as an axillary view, which can be obtained with the patient standing, supine, or prone. Computed tomography scan is helpful for determining the size of the head defects, the condition of the glenoid, and whether the head is dislocated. The magnetic resonance imaging scan gives us good information about the soft tissue as rotator cuff tear or cartilage damage to be considered during surgery.

Fig 2. Patient in a sitting position with the arm hanging in standard neutral rotation. The C-arm imager from above for monitoring the reconstruction.

Fig 3. Portals. AL, anterior-lateral for instrumentation; L, posterior-lateral for the arthroscope; P, posterior-medial for water inflow and intra-articular optic placement; and AM, anterior-medial for intra-articular instrumentation.

Anatomic Considerations

Anatomic reduction and stable fixation of the greater tuberosity are of the utmost importance, as they govern long-term shoulder function. In normal anatomy, usually a line from approximately 5 mm lateral to the bicipital groove passing to the center of the superior glenoid border will lay perpendicular to the glenoid in neutral rotation of the shoulder (Fig 1, lines A and B). This guideline will help us in the reduction and fixation of the greater tuberosity fracture using intra-articular endoscopic visualization.

Triad Fixation Technique (With Video Illustration)

Three types of suture fixation are used depending on the size and shape of the greater tuberosity fracture. This triad suture technique consists of the following:

1. Longitudinal transosseous suture fixation using the giant needle technique
2. Transverse transosseous suture fixation using the suture-wire or penetrating suture-wire technique
3. Mattress tendon to tendon suture fixation using the giant needle.

The longitudinal suture fixation using the giant needle technique is especially used for upward displacement of the greater tuberosity to push the fragment downward and fix it in anatomic position. The transverse suture fixation using the suture-wire fixation technique is especially for posterior medial displacement of the greater tuberosity. The mattress suture fixation using the giant needle is used for security

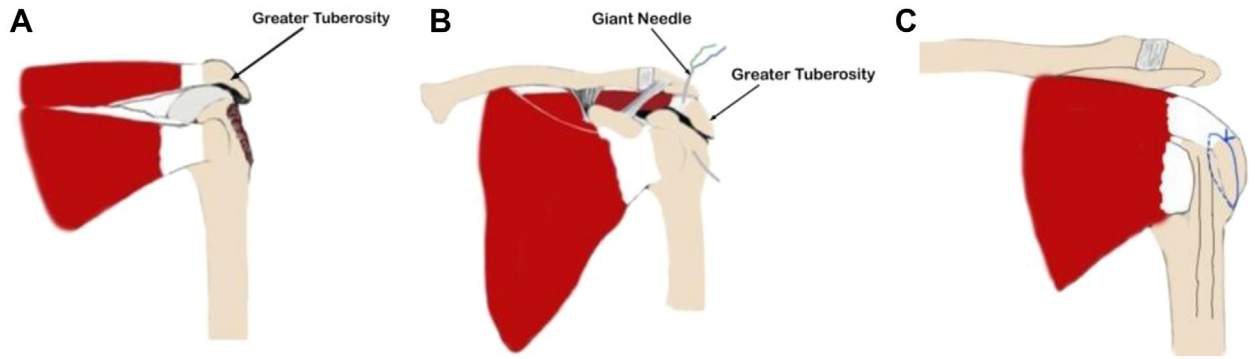

Fig 4. Strategy of fixation; (A) upward displaced fractured greater tuberosity, (B) reduction and fixation with the giant needle, (C) after transosseous suture fixation.

fixation of both upward and medial displacement of the fragment. The complete procedure is indicated in Video 1.

Installation

Anesthesia and Patient Positioning

Anesthesia is a combination of general endotracheal anesthesia and interscalene block for postoperative pain control. The arthroscopy is done with the patient placed in a sitting position (Fig 2). The installation must provide space for an image amplifier (toward the head of the patient) and must allow free upper-limb motion in all planes (adduction, flexion, and extension).

Arthroscopy Portals

The usual portals used are the anterior-medial, anterior-lateral, posterior-medial, and posterior-lateral portals. Additional portals can be used when needed (Fig 3). A standard 30° arthroscope is used and introduced in the subacromial space through the lateral posterior portal. A motorized shaver is introduced in the lateral anterior portal.

Reposition and Transosseous Longitudinal Suture Fixation with the Giant Needle Technique for Upward Displacement

In case the fractured greater tuberosity is displaced upward, anatomic reposition is made by reduction and fixation of the tuberosity using the giant needle transosseous suture fixation technique (Fig 4). In this technique, the instruments used are a giant needle holder to firmly hold the needle; the concave 2-hole knot driver, which drives the sliding knot to the place required; the arthroscopy hook to pull the suture through the instrumentation portal at its exit from the lateral cortical bone of the proximal humerus; and the chop needle suture puller to pull the upper end of the suture through the insertion of the supraspinatus (Fig 5).

Under both image intensification and arthroscopic vision, the fracture fragment is visualized (Fig 6A). The reduction is done by bringing the shoulder through internal and external rotation to reduce the greater tuberosity.

Usually a pointed hook retractor (Fig 6B 1-2) (Maeratec GmbH, Bonn, Germany) is inserted into the subacromial space to manipulate the greater tuberosity fragment anteriorly, laterally, and inferiorly into

Fig 5. Instruments used in the giant needle transosseous suture fixation technique; (A) from above down, the arthroscopy hook, the giant needle holder, the giant needle (Maeratec GmbH). (B) The concave knot driver, (Arthrex), (C) the chop needle suture puller (Maeratec GmbH).

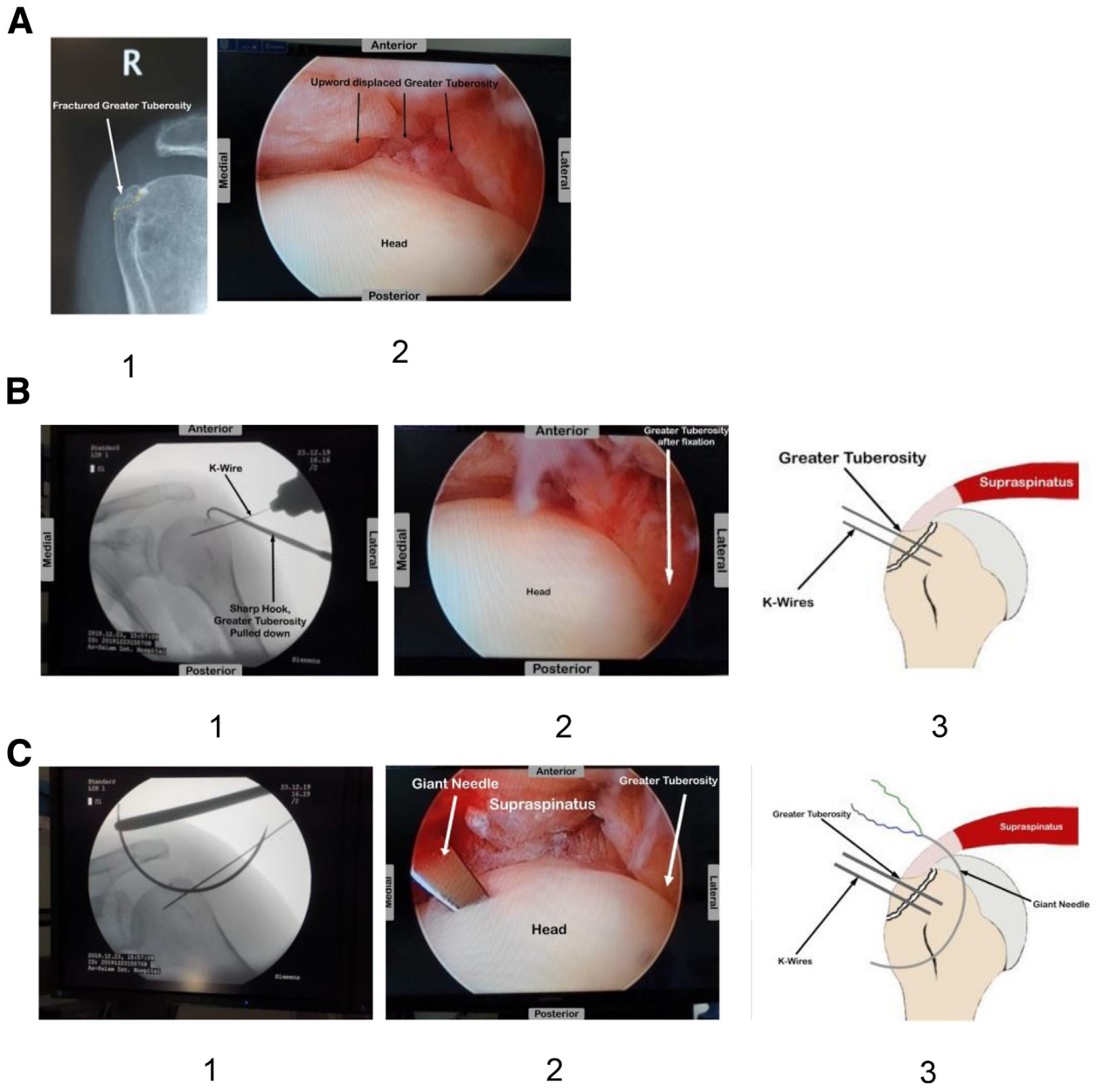

Fig 6. (A 1-2) Imager and arthroscopic view of the upper displaced fractured fragment of the greater tuberosity. (B 1-2) Reduction of the greater tuberosity using a sharp hook to reduce fractured upward displaced greater tuberosity, and (B3) fixation of the greater tuberosity with K-wires. (C 1-3) Passing the giant needle with 2 different color sutures medial to the fracture line; (D 1-3) after placing the sutures, the upper ends are pulled out one after the other through the insertion of the supraspinatus and out through the instrumentation portal using the chop needle suture puller; (E1) the upper ends are held with a clamp; (E2) the lower ends are also pulled out with an arthroscopy hook through the instrumentation portal, and a sliding knot is made with 1 of the 2 sutures to fix the fragment in its position; (E3) the K-wires are removed and second suture is tied with a sliding knot to confirm the fixation. (F 1-2) Reduction and suture fixation is completed and documented with the imager and the arthroscopic print.

anatomic position and fix it with K-wires (Fig 6B 3) (Maeratec GmbH).

The giant needle with 2 different color no. 2 absorbable sutures is then passed through the head approximately 1 cm medial to the fracture line and out distal to the fractured fragment, thus placing the sutures passing through the skin, the supraspinatus tendon, the head, the lateral surface of the shaft, and out through the skin (Fig 6C 1-3). If the fracture is at the border between the tuberosity and the cartilaginous head, as with most of the cases, the needle is passed through the head approximately 1 cm medial to the line of fracture, and

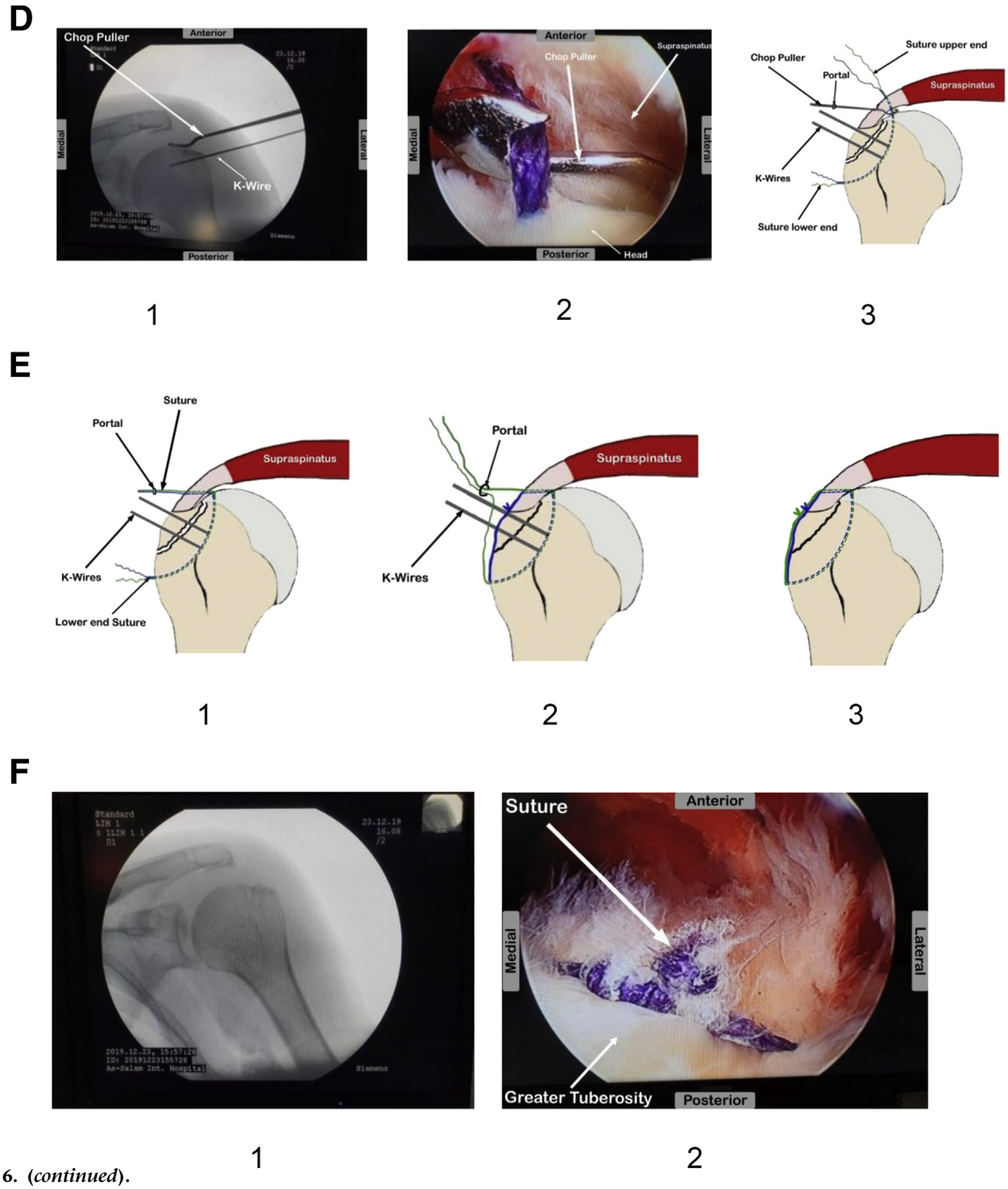

Fig 6. (*continued*).

in this case, we always use an absorbable suture as it is needed for the fixation of the fracture until bone healing occurs.

After passing the suture using the giant needle through the head and the shaft, the upper end of the suture is pulled out through the instrumentation portal using a chop needle puller by passing it through the supraspinatus tendon at its insertion in the fractured greater tuberosity, and then pulling the suture at its entrance in the head (Fig 6D 1-3).

The upper limb end is held with a clamp so that by pulling the lower limb out the upper end stays outside the joint. The lower limb is pulled out through the same instrumentation portal with an arthroscopy hook (Fig

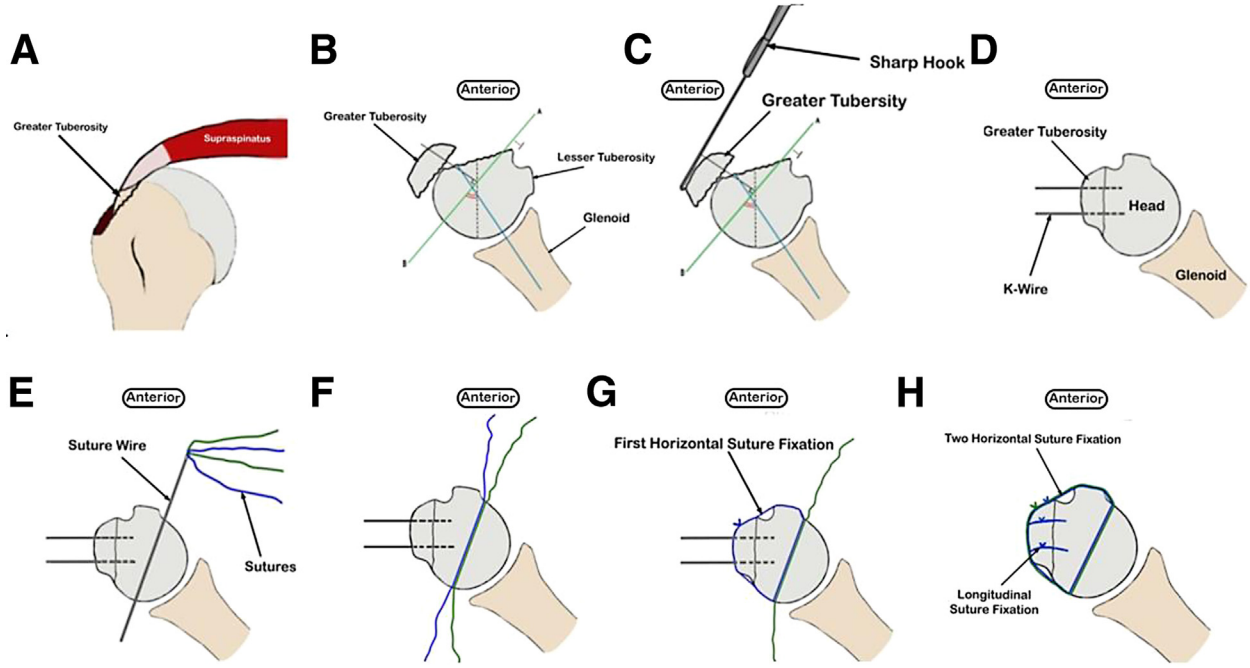

Fig 7. (A) An anteroposterior view of medially displaced greater tuberosity fracture; (B) an above view of a posterior medially displaced greater tuberosity; (C) reduction of the greater tuberosity with a sharp hook; (D) fixation of the reduced greater tuberosity with 2 K-wires; (E) placing the suture-wire guide on the hook and passing the wire with 2 sutures at the distal end; (F) after pulling the wire from its proximal end the sutures will be placed through the head; (G) by pulling the anterior and posterior end of one suture the greater tuberosity is fixed to the head with a sliding knot, then the wires are removed; (H) the second suture is tied to confirm the fixation.

6E 1). By tying the knot, the upper half of the suture will press the tuberosity down and fix it in its anatomic position (Fig 6E 2.). The K-wires are removed, and the second suture is tied over the first one to confirm the compression (Fig 6E 3). The reduction and fixation is done using arthroscopic vision, and image intensifier can be documented (Fig 6F 1-2).

Reposition and Transosseous Transverse Suture Fixation with the Hook-Wire Technique for Posterior-Medial Displacement

Sometimes the greater tuberosity is fractured and pulled medially by the infraspinatus tendon (Fig 7 A and B). In this case, the reduction of the greater tuberosity is done first. Under imager and arthroscopic vision by putting the arthroscope in the anterior lateral portal, a special pointed hook is passed through the posterior lateral portal in the posterior subacromial space (Fig 7C). With the aid of an image intensifier, the greater tuberosity is pulled by the hook lateral anterior while the head is externally rotated until it is in an anatomic position. Then the greater tuberosity is fixed with 2 K-wires (Fig 7D).

Under imager control and arthroscopic vision, a spinal needle is passed through the skin anterior to the head to be placed medial to the lesser tuberosity in a direction to pass medial to the fractured greater tuberosity if derived through the bone. The spinal needle is

Fig 8. Instruments used in transverse transosseous suture fixation (Maeratec GmbH). (A) Wire guide, (B) suture wire passed in the guide, (C) sutures placed in the distal end hole of the suture-wire.

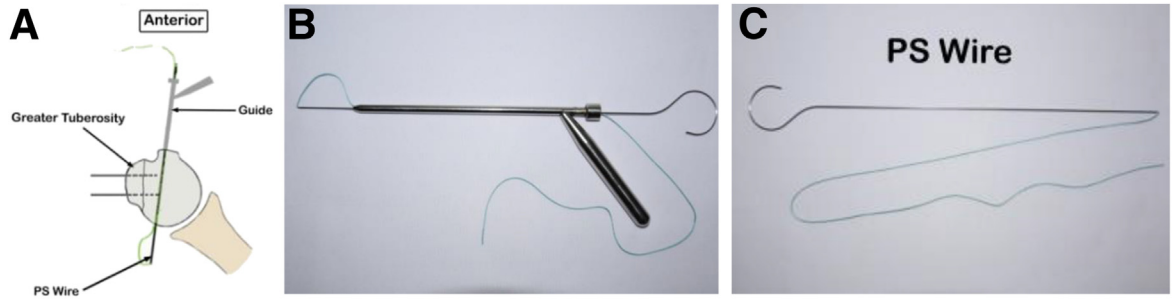

Fig 9. (A) Penetrating suture (PS)-wire passing through the head to place the suture. (B) PS wire in the guide (Maeratec GmbH). (C) PS-wire (Maeratec GmbH).

removed, and the suture wire is passed through the skin to lie in the same direction as the spinal needle using a suture-wire guide (Fig 8). The suture wire is then driven with a motorized drill to pass through the head medial to the fracture out through the skin posteriorly. Finally, sutures are placed in the distal end hole of the wire (Fig 7E), and the suture wire is pulled out from the anterior end with the giant needle holder so that the 2 sutures are placed through the head medial to the fracture (Fig 7F). An alternative technique is to use the penetrating suture wire instead of the suture wire to pass the suture through the head (Fig 9).

The 2 ends of the sutures are then pulled through the instrumentation portal using an arthroscopy hook or ring forceps. One suture from the 2 will be tied using the one-way, self-locking, sliding giant knot with the concave knot driver (Fig 5B) to fix the tuberosity to the shaft (Fig 7G). Then the lateral fixation wires are removed, and the second suture will be tied in the same manner to confirm the transverse suture fixation of the tuberosity (Fig 7H). Under image intensifier the fracture before and after reduction and suture fixation is documented (Fig 10).

Reposition and Mattress Suture Fixation of the Greater Tuberosity by End-to-End Tendon Fixation Using the Giant Needle Technique

This suture fixation technique is used to confirm the horizontal and transverse suture fixation of the greater tuberosity fracture or sometimes it is used as the only suture fixation after reduction of a medial displaced greater tuberosity fracture. It is also used in 3- and 4-part fractures to fix the 2 tuberosities together.

Under image intensifier, the fractured greater tuberosity is reduced to its anatomic position with a pointed hook retractor and fixed to the head with 2 K-wires. Then under arthroscopic subacromial vision using the giant needle, the sutures are placed in the infraspinatus

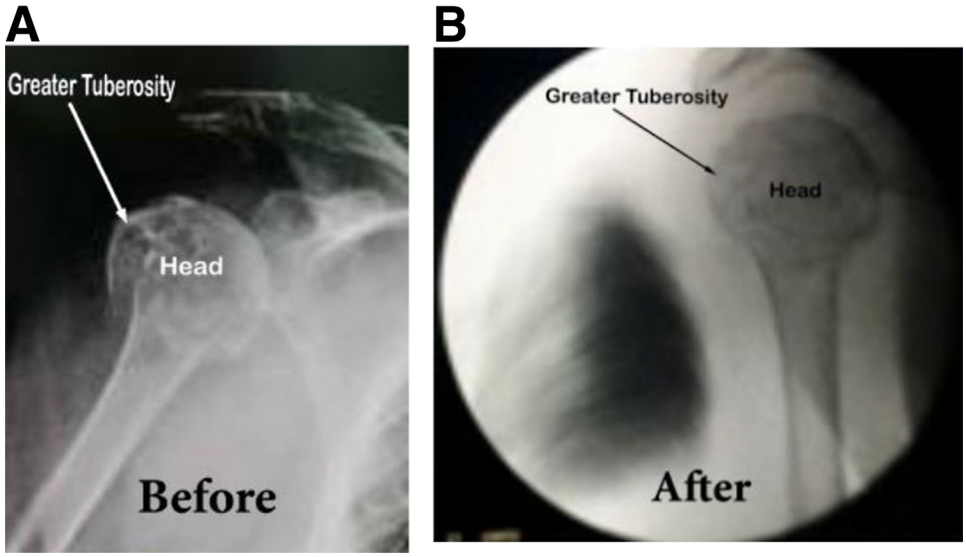

Fig 10. (A) Medially displaced greater tuberosity fracture with subcapital fissure. (B) After reduction of the greater tuberosity to its anatomic position and transosseous transverse suture fixation using the suture-wire technique (because of the subcapital fissure, a giant needle longitudinal suture repair is contraindicated owing to the risk of head displacement).

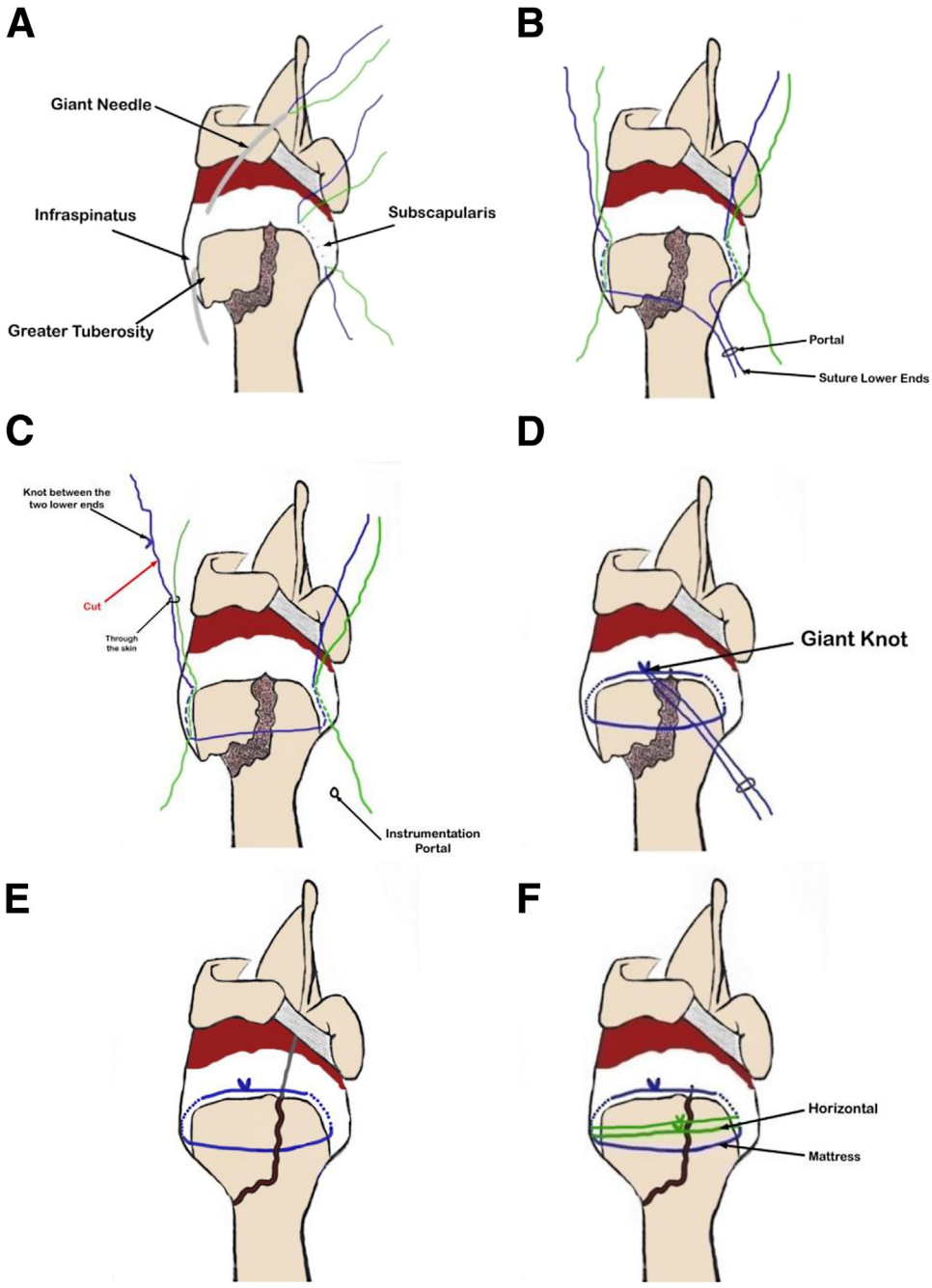

Fig 11. (A) Using the giant needle, one pair of suture is placed in the subscapularis tendon and another in the infraspinatus tendon; (B) the lower end of one suture from the infraspinatus tendon and one from the subscapularis tendon are pulled through the instrumentation portal to make a sliding knot outside the shoulder, and the sutures distal to the knot are cut; (C) the upper end of the suture passing through the infraspinatus is pulled up until the knot comes out through the skin outside the shoulder, then the knot is cut so that we have a knotless suture passing through both tendons with entry through the upper border of the subscapularis and an exit through the upper border of the infraspinatus; (D) the 2 ends of the suture are then pulled out through the instrumentation portal with ring forceps; (E) a sliding knot is made outside the joint and pushed inside with the concave knot driver to compress and fix the greater tuberosity; (F) a transosseous and horizontal suture fixation can be added to the fixation before or after the mattress suture.

tendon from above downward at the tendon-tuberosity junction, and another one through the subscapularis at the tendon-tuberosity junction (Fig 11A).

The lower ends of both sutures are pulled out with an arthroscopy hook through the instrumentation portal (Fig 11B) and tied together firmly outside the joint. Then the upper end of the suture passing through the greater tuberosity tendon is pulled up to move the already made knot between the lower ends inside the shoulder through the greater tuberosity-tendon junction and out through the skin, while having the other end that passes through the lesser tuberosity tendon junction fixed with a clamp to avoid pulling the whole suture out (Fig 11C). The knot is cut to have a knotless suture through the tendons, then the upper 2 ends are pulled outside the instrumentation portal and a mattress suture is made to fix the 2 tuberosities to each other using the one-way, secured, sliding giant knot technique and the concave knot driver, which helps compression of the bone fragment to the head (Fig 11 D-E). The head should be in external rotation while tying the knot. The K-wires, if present, are

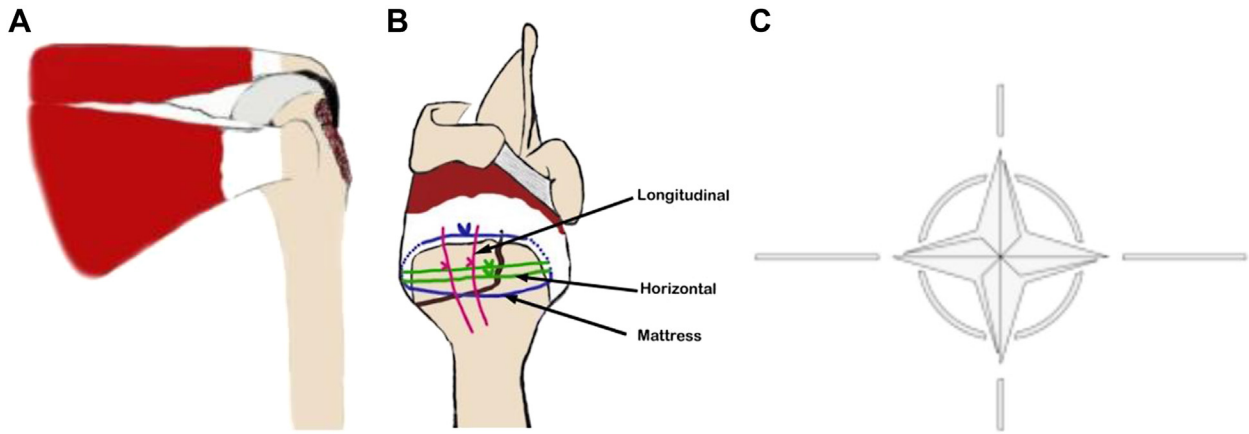

Fig 12. Natofix technique. (A) Upward and medially displaced greater tuberosity fracture; (B) reposition and fixation of the fracture with mattress suture on top of transverse and longitudinal transosseous suture fixation similar to the Nato logo (C) with a circle and a transverse and longitudinal lines.

removed and the other color sutures placed at the junction of the cuff and tuberosities (greater and lesser) can be knotted together to improve fixation stability.

Upward and Medial Displacement

In case of greater tuberosity fracture with medial and upward displacement (Fig 12A), the transverse transosseous suture fixation in combination with the transtendon mattress fixation, or the longitudinal transosseous suture fixation in combination with the mattress transtendon fixation, or all 3 together, can be used to have a solid fixation (Fig 12 B-C).

Postoperative Rehabilitation

Rehabilitation includes immobilization in an arm sling for 3 to 4 weeks; only elbow flexion and extention is allowed. Passive-assisted followed by active-assisted and active strengthening exercises are done. Usually before surgery, we inform the patient that an arthroscopic release of adhesions may be needed after fracture healing if the rehabilitation fails. None of the cases in this series needed this procedure.

Discussion

Studies on arthroscopic-assisted greater tuberosity fracture fixation are limited to individual case reports and case series. There have been newer techniques described using a double-row,[18-21] suture bridge,[22-25] and inverted mattress suture fixation.[26]

Kim and Ha[18] reported on 23 patients who underwent arthroscopic-assisted fixation of minimally displaced or nondisplaced greater tuberosity fractures associated with at least 6 months of chronic shoulder pain. Average follow-up of 29 months showed a result of good to excellent in 20 patients, and fair in 3 patients according to University of California at Los Angeles (UCLA) score. Patients participating in overhead sports had a significantly lower level of return to activity. Ji et al.[19] retrospectively reviewed 16 patients who

Table 1. Tips and Tricks

	Pearls	Pitfalls	Risks
Position	It is essential to have the patient in a sitting position with the arm hanging	If the arm is rested on the thigh it will be difficult to pass the giant needle through the bone	Incomplete bone reduction
Portals	Is essential to have the portals in the correct places—always use needle to check the path	A displaced portal is a notable problem	Mishandling the arthroscopic procedure
Preoperative planning	If possible, with help of PSI, is essential	Can lead to a long operative time	Incomplete bone reduction
Reduction and K-wire fixation	Essential for first suture tying fixation	Malfixation can result	Malunion
Second suture fixation	Essential to confirm fixation	Slight malfixation can occur	Malunion
Postoperative immobilization	Essential for healing	Movement of the fragment	Nonunion

PSI, patient specific instrument.

underwent arthroscopic double-row suture anchor fixation for comminuted or displaced greater tuberosity, average follow-up was 24 months. The UCLA score improved to 3 (excellent), 11 (good), and 2 (poor). Mean forward flexion, abduction, external rotation, and internal rotation were 148.7°, 145°, 24°, and to L1, respectively. Tsikouris et al.[20] investigated the outcomes of arthroscopic-assisted greater tuberosity fracture fixation in 12 athletes observed over a 5-year period. No major complications occurred, and all patients achieved UCLA scores over 30 at 6 months. Most notably, all athletes returned to their preoperative activity level with no residual pain. Liao et al.[21] published the largest series in the literature directly comparing arthroscopic to open fixation for greater tuberosity fractures in 26 versus 53 patients, respectively; the authors found no clinically significant difference in time to union, complications, or outcome scores between the groups. All these studies were mostly done on young patients. This technique is unique with its own tips and tricks (Table1) as a totally arthroscopic reduction and transosseous suture fixation of a displaced greater tuberosity fracture. It is also applicable in older patients without complications. The technique of suture fixation of avulsed greater tuberosity fracture is reliable in patients with osteoporosis.

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