

Open Reduction and Internal Fixation of Fractures of the Proximal Part of the Humerus

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Introduction

We describe the surgical technique for open reduction and internal fixation (ORIF) of proximal humeral fractures with a locking plate.

ORIF of proximal humeral fractures with locking plates is still a valuable treatment option, despite a reportedly high complication rate (between 10% and 45%, depending on the fracture type¹⁻⁷). The three major principles are (1) choose the right patient for ORIF (know the predictors of potential complications), (2) perform minimal soft-tissue dissection (be aware of the fragile blood supply), and (3) restore a stable medial buttress (calcar). If any of these three points cannot be addressed properly, consider alternative treatment options^{8,9}.

ORIF of proximal humeral fractures with a locking plate is performed with the following steps, which include our techniques for the specific fracture types that we think are good indications for the procedure.

Step 1: Preoperative Planning

To choose the right candidate, obtain a full understanding of the patient's fracture pattern, activity level and demands, and bone quality; be aware of predictors of complications and poor outcomes.

- A full understanding of the fracture pattern is crucial. Therefore, a preoperative computed tomography (CT) scan with three-dimensional (3D) reconstructions is helpful (Video 1)¹⁰⁻¹².
- Choose the right patient for ORIF. Know his or her activity level and demands. We have a low threshold for nonoperative therapy for patients with low demands.
- Be aware of predictors of complications and poor outcomes (four-part fracture, fracture-dislocation, and poor bone quality). Be prepared to switch intraoperatively to either hemiarthroplasty or primary reverse arthroplasty if needed.
- The effect of bone quality on the outcome of ORIF of proximal humeral fractures is con-

troversial¹³⁻¹⁵. However, we agree with other authors^{10,16,17} that assessment of bone quality should be a part of the preoperative planning. We think that osteoporosis complicates both fracture fixation and outcome. Therefore, we have a low threshold for either nonoperative treatment or primary arthroplasty for patients with osteoporosis.

- Perform simple radiographic measurements to get a quick idea of the bone quality that you will encounter. For example, combined cortical thickness as defined by Tingart et al.¹⁸ or the deltoid tuberosity index¹⁹ correlates with low local bone mineral density of the humeral head (Fig. 1).
- Although several classifications of proximal humeral fractures have been introduced, none of them seem to be readily reproducible^{1,5}. However, we still use the Neer classification, which defines four segments of the proximal part of the humerus (lesser tuberosity, greater tuberosity, surgical neck, and anatomical neck). A segment becomes a part of the fracture pattern if it is displaced >1 cm or >45°^{20,21}. The Neer classification ranges from one-part fractures (none of the segments meet the displacement criteria and thus the fracture is “undisplaced”) to four-part fractures (all segments meet the displacement criteria). For clinical use, we made a few alterations to the original Neer classification in terms of varus/valgus displacement of the head and in terms of fracture height and hinge displacement as described by Hertel et al.^{8,22} (Fig. 2).
- We agree with other authors^{10,12,23} that valgus impacted proximal humeral fractures are more amenable to ORIF than fractures with varus displacement of the humeral head.

Step 2: Patient Positioning

Place the patient in the beach-chair position with the arm draped free or in a hydraulic device (Fig. 3) with good access for the image intensifier (Fig. 4).

- Place the patient far enough laterally on the beach-chair table to allow full access to the shoulder.
- A hydraulic device (e.g., Spider Limb Positioner; Smith & Nephew, London, U.K.) may be used to fix and position the arm.
- Place the image intensifier (c-arm) over the shoulder, entering from the head of the table, to facilitate intraoperative fluoroscopy; this provides anteroposterior and axial views.

Step 3: Approach

The deltopectoral approach is generally preferred because of the exposure obtained, the possibility of distal extension, and the minimal risk of nerve injury.

- Mark the anatomical landmarks: the acromion, acromioclavicular joint, clavicle, and tip of the coracoid (Fig. 5).
- Start the incision slightly (1 cm) lateral to the tip of the coracoid and aim toward the middle of the humerus. The incision should be approximately 10 cm long.
- Find and protect the cephalic vein and mobilize it laterally.
- Open the deltopectoral interval proximally first by placing an 8-mm Hohmann retractor above the coracoid.
- Extend the interval distally to the humeral shaft and place a blunt Hohmann retractor underneath the deltoid and around the humeral shaft.
- Identify and retract the conjoined tendon medially (for example, with a Langenbeck retractor or a self-retaining retractor).
- Resect the bursa from the humeral head (everything that can be nibbled off easily with a rongeur) and create a plane between the deltoid and the humeral head with a periosteal elevator proximally.
- Finally, place a Browne Deltoid Retractor (Arthrex, Naples, Florida) or a blunt Hohmann retractor around the head to push it gently forward while protecting the deltoid muscle laterally.
- Identify the long biceps tendon (a soft-tissue landmark of the deltopectoral approach). In cases of severe comminution, it can always be found disappearing underneath the proximal border of the pectoralis major insertion (Fig. 6).

Step 4: Reduction and Fixation of the Tuberosities: the Key to Obtaining Marionette-Like Control

The control, reduction, and fixation of the tuberosities

are crucial to restore the anterior-posterior force couple of the shoulder and must therefore be done properly no matter what the fracture pattern looks like.

- Abduct the shoulder to take tension off of the deltoid muscle and simplify access to the humeral head.
- Identify the greater and lesser tuberosities.
- Place at least two stay sutures using number-5 nonabsorbable braided suture (Ethibond; Ethicon) or braided composite suture (FiberWire; Arthrex) in the subscapularis tendon (Video 2).
- Place the first stay suture in the supraspinatus tendon (Video 2). To counteract the posterior and external rotation of the greater tuberosity (by the pull of the attached infraspinatus and teres minor), apply anterior traction to the first stay suture in the supraspinatus and place a second suture posteriorly.
- Repeat this maneuver until the greater tuberosity can be fully controlled and reduced. Place at least four sutures: two in the supraspinatus and two in the infraspinatus and teres minor.
- The proximal part of the humerus can now be controlled in a marionette-like manner by pulling on the stay sutures in the cuff without further dissection of the soft tissue.
- Traction on the infraspinatus and teres minor force couple results in internal rotation of the proximal part of the humerus, which is helpful for later, dorsolateral placement of the plate (Fig. 7 and Video 3).

Step 5: Fracture Reduction

After carrying out Steps 1 through 4, perform the reduction techniques for the specific fracture type as described below for types that we think suitable for ORIF with a locking plate.

Surgical Neck (Neer Two-Part) Fractures

- Impacted surgical neck fractures can be treated nonsurgically depending on the amount of varus displacement¹³. We prefer angular stable ORIF for very active patients with varus displacement and for fractures with >50% displacement of the head in relation to the shaft¹⁶ (Fig. 8). The key to treating these fractures is to stabilize the medial calcar to prevent varus collapse later. We therefore aim for impaction rather than anatomical alignment with possible distraction.
- Gently dissect the soft tissue lateral to the bicipital groove to expose the anatomical references for reduction. The bicipital groove is the landmark for correcting rotation deformity. Restore rotational alignment by moving the arm until the bicipital groove is aligned.

- Use the stay sutures in the cuff to steer the humeral head into the correct rotation (Video 3).
- Hold the reduction temporarily with Kirschner wires from distal to proximal or vice versa. However, make sure the wires do not interfere with the subsequent positioning of the plate.
- Check the reduction of the medial calcar under c-arm fluoroscopy. If it is impacted, leave it that way rather than restoring an anatomical position and risking destabilizing the fracture any further (Fig. 9).
- Insert the plate and hold it in position with additional Kirschner wires through the plate (Fig. 10).
- Achieve the final reduction indirectly by tightening the plate to the shaft with a conventional screw in the long hole (Fig. 11).
- Insert the locking head and shaft screws (see Step 6 and Fig. 12).
- Despite the “simple” nature of this fracture pattern, the humeral head can secondarily displace into varus. Thus, fix the tuberosity stay sutures to the plate, creating a tension-band-type construct, at the end of the procedure.

Valgus Impacted Humeral Head (Neer Three or Four-Part) Fractures (Figs. 13-A through 13-F)

- Three or even four-part valgus impacted fractures have been shown to be more amenable to ORIF than fractures with varus displacement of the head fragment¹². However, for fractures with involvement of the anatomical neck, additional exposure may be needed despite the additional soft-tissue damage incurred. To minimize this, use two windows. The first window is in the rotator interval and the second window is further lateral through the fracture between the greater and lesser tuberosities (Fig. 7).
- Establish the first window by incising the roof of the rotator interval with sturdy (e.g., curved Mayo) scissors, starting at the superior border of the subscapularis tendon insertion (opening the pulley of the long biceps tendon) and following the direction of the long biceps tendon while aiming in the direction of the coracoid base.
- For further exposure, a biceps tenotomy may be performed by cutting the tendon off close to its origin with dissection scissors. In patients who are more than fifty years old, we perform a biceps tenodesis at the end of the ORIF (whenever possible with a bone anchor back into the bicipital groove proximal to the pectoralis major insertion).
- Establish the second window. The typical fracture between the greater and lesser tuberosities is slightly lateral to the bicipital groove, where the greater and lesser tuberosities may be sepa-

rated without further damage to the anterolateral branch of the anterior circumflex artery (Figs. 7, 13-A, and 13-B).

- Address valgus displacement of the humeral head fragment by gently lifting the head up with a blunt periosteal elevator through the second window (Figs. 13-C and 13-D).
- Take great care not to overcorrect the humeral head into varus at the calcar.
- As soon as the position and height of the head fragment are acceptable in relation to the greater tuberosity, close the second window by pulling the subscapularis and infraspinatus and teres minor sutures together.
- Use 1.6-mm Kirschner wires (or an anteroposterior small-fragment screw) to temporarily fix the tuberosities to the head fragment, thereby converting this pattern into a simpler two-part surgical neck fracture pattern (Fig. 13-E).
- Reduce the remaining valgus deformity after elevation of the head fragment with the plate.
- Position the plate distally enough (8 mm distal to the tip of the greater tuberosity) to avoid impingement.
- Drill the hole for a cortical screw in the proximal long hole of the plate over the shaft. Use a screw that is longer than the bicortical width, as the plate is not yet reduced to the shaft (Fig. 13-E). (The screw length can be changed once the fracture and construct are stable at the end of surgery.)
- Tighten the cortical screw to push the proximal part of the humerus into further varus for final reduction (Figs. 13-E and 13-F; Video 4).
- Insert the locking head and shaft screws (see Step 6).

Unstable, Varus Displaced Humeral Head (Neer Three and Four-Part) Fractures

- Varus displaced three and four-part fractures are less stable than valgus impacted fractures. Thus, restoration of the medial calcar is difficult or even impossible to achieve. We therefore have a low threshold for primary arthroplasty in elderly patients (older than seventy years of age). In younger patients, we attempt ORIF, with hemiarthroplasty reserved as a backup plan.
- Open the first window, as described in the above section on valgus impacted head fractures, to obtain a view into the joint and an idea of the head displacement.
- In a three-part fracture type, the head fragment is attached to either the greater tuberosity or the lesser tuberosity. The second window (described in the section on valgus impacted head fractures

and shown in Fig. 7) can therefore be used for further exposure and reduction of the displaced tuberosity to the head.

- In a four-part fracture type, it can be difficult to reduce the tuberosities back to the head fragment without substantial soft-tissue damage. The description below facilitates performing this difficult maneuver.
- The first aim is to reduce the greater tuberosity and/or lesser tuberosity to an anatomical position relative to the head and fix them temporarily with Kirschner wires, thereby converting this pattern into a simpler two-part surgical neck fracture. The remainder of the procedure is the same as described above for a surgical neck fracture.
- The bicipital groove is the landmark for rotation deformity. Correct rotation by rotating the arm until the bicipital groove is aligned.
- To fix the head to the shaft, insert 1.6-mm Kirschner wires, aiming from the anterior aspect of the shaft (the anterior entry location avoids interfering with the subsequent plate positioning) proximally into the head fragment (Fig. 9).
- If necessary, achieve additional fixation with Kirschner wires through the plate (Fig. 10).
- As anatomical reduction of the calcar is difficult, aim for an overcorrected impacted medial calcar position to prevent further secondary varus displacement (Fig. 11). Finally insert the locking head and shaft screws (see Step 6).

Step 6: Fixation: Implant-Specific Considerations

Plate length and positioning, humeral head screw placement, distal locking, confirming the screw tip position with the image intensifier, and securing the tuberosities.

Plate Length and Positioning

- We use the three-hole PHILOS plate (Synthes; Bettlach, Switzerland) for most proximal humeral fractures. We use the five-hole plate for displaced isolated surgical neck fractures, to have a longer working length distally, and an even longer plate when there is metaphyseal comminution and osteoporotic bone.
- Use the stay sutures and the marionette-like control described earlier to bring the humeral head into the proper position, usually with tension on the infraspinatus and teres minor (internal rotation) so that it is possible to place the plate dorsally enough (Video 3).
- Place the tip of the plate about 8 mm distal to the tip of the greater tuberosity to avoid subsequent subacromial impingement (Fig. 10). (A

guide may be used.)

- Drill the cortical screw into the long shaft hole first and make sure that the plate is in the center of the shaft distally.

Humeral Head Screw Placement

- To avoid primary humeral head screws from cutting out through the articular surface, take care to avoid drilling into the joint.
- Use the aiming device for the locking tower to drill and place the screws at the correct angle as determined by the plate (Fig. 14). Otherwise, the screws may be misdirected, thereby precluding proper locking to the plate.
- To avoid drilling into the joint, use the “woodpecker” method (Videos 5-A and 5-B). With gentle drilling and intermittent pushing, the resistance of the opposing bone can be felt. When the far cortex is reached, palpate with the drill-bit tip and the depth gauge in order to appreciate increased resistance. Alternatively, drill only the lateral cortex and then push the depth gauge bluntly forward under fluoroscopic control or until resistance is felt.
- Choose screws about 3 mm shorter than measured with the depth gauge to avoid intra-articular penetration.
- Take care to insert the screws in the right direction (as determined by the plate) to enable proper locking.
- Use at least seven screws in the head.
- Position screws in the inferomedial portion of the head to buttress against varus displacement later.

Distal Locking

- In osteoporotic bone, use two additional locking shaft screws in addition to the cortical screw in the long hole to get a minimum attachment purchase of six cortices (Fig. 12).
- Use the locking tower to drill the shaft screws.
- The screws should be long enough to allow the threaded portion, with the tip fully penetrating the medial cortex, to engage the entire cortical width to get maximum purchase.

Confirming the Screw Tip Position with the Image Intensifier: Two Views Are Not Enough

- As the likelihood of primary screw intra-articular penetration (cutout) is reported to be high⁵, we use a specific four-projection protocol (the “cutout series”) for final c-arm confirmation of the screw tip position²².
- Place the c-arm to obtain a true anteroposterior

view of the glenohumeral joint (with the joint space visible, also known as the *Grashey view*).

- Obtain the first view with the humerus in internal rotation (with the forearm lying on the belly). This view places the screws in profile relative to the anterior hemisphere of the humeral head.
- Then obtain a view with the humerus in neutral rotation (with the forearm parallel to the direction of the x-ray beam—i.e., the original anteroposterior view).
- The next projection is an anteroposterior view with the forearm in 30° of external rotation in relation to the x-ray beam (about 10° of external rotation of the shoulder). This projection enables you to see the head screws in the posterior hemisphere of the humeral head.
- Finally, switch the c-arm into the axial position (cross table) with the shoulder in a 30° abduction angle. This is a good projection to view the screw tips in the inferior hemisphere of the humeral head (Fig. 15).

Securing the Tuberosities: the Tension Band Mechanism

- No matter how stable the fracture appears, always place stay sutures into the cuff and fix them tightly to the plate. This tension band fixation counteracts the varus deformity forces of the humeral head and prevents displacement of the tuberosities by bypassing them with direct rotator cuff insertion into the plate (Fig. 16 and Video 6).
- In the case of displaced tuberosities, use one stay suture each in the subscapularis and in the infraspinatus and teres minor and tie them together to neutralize the anterior-posterior force couple.
- Fix the remaining sutures (usually one in the subscapularis, at least one in the supraspinatus, and one in the infraspinatus and teres minor) to the plate.
- Close the rotator interval (the first window, as described in the section on reduction of valgus impacted head fractures) at the end.

Step 7: Tenotomy or Tenodesis of the Long Biceps Tendon

Perform a biceps tenotomy if the biceps is displaced out of the groove by the fracture pattern or if you have to open the rotator interval.

- Inform the patient preoperatively about cosmetic changes (excessive bulging of the muscle belly) after a biceps tenotomy.
- In patients younger than fifty years of age or with special demands, perform a tenodesis of the

long biceps tendon into the bicipital groove proximal to the pectoralis major insertion (anchor), or to the pectoralis major insertion (soft tissue).

- If the fracture pattern allows the long biceps tendon to be left in place (e.g., a two-part fracture with the humeral head and lesser tuberosity unfractured), take care not to fix the long biceps tendon underneath the subscapularis stay suture. In this situation, do not fix the subscapularis suture to the plate (Video 7).

Step 8: Wound Closure

Do not close the deltopectoral interval.

- If bleeding is expected postoperatively (in patients with coagulopathies), one deep drain may be used.
- Close the subcutaneous layer with 2-0 Vicryl (polyglactin; Ethicon) suture.
- Perform subcuticular cutaneous closure with 3-0 Monocryl (poliglecaprone; Ethicon) suture.
- Apply a Steri-Strip (3M) and Comfeel (Coloplast) dressing, which should be left on for two weeks.

Step 9: Rehabilitation

As the failure rate of ORIF of proximal humeral fractures is high, do not force an active rehabilitation protocol.

- The patient should wear a sling for six weeks.
- No exercises should be performed for two weeks. At two weeks, the patient or physician removes the Comfeel dressing.
- Gentle pendulum exercises are started in weeks 3 to 6 after the patient receives instructions from a physiotherapist on how to perform them.
- When the patient had a valgus impacted fracture, the limb can generally be mobilized earlier than is recommended for other fracture patterns, as valgus impacted fractures are more stable. Patients with such a fracture can start physiotherapy with passive and active-assisted range-of-motion exercises (maximum flexion and abduction of 60° and maximum external rotation of 0°) in week 5 or 6.
- Patients with tenodesis of the long biceps tendon are not allowed active flexion or supination of the elbow for six weeks.
- The first clinical and radiographic examination is performed at six weeks. The patient then usually starts full passive and active range-of-motion exercises without limitations.
- The second clinical and radiographic examination is performed at three months, after which strengthening exercises are usually started.

- Additional routine checks (clinical and radiographic) are done at six months and one and two years.

Results

In our analysis of 269 fractures followed for twelve months, we found that the Constant-Murley score (CMS) and Short Form-36 (SF-36) score improved continuously during the first six months postoperatively²³. The scores usually plateaued between six and twelve months and were significantly better for younger patients (less than forty-five years old). We found that older age and greater complexity of the fracture negatively influenced the final outcome.

In a specific analysis of return to work after the procedure, we found that patients with office jobs could return to work significantly earlier than patients with physically demanding jobs. However, the cutoff CMS at which the patients were able to return to work was the same in both groups (mean, 64 points)²⁴.

Overall, the mean final CMS after angular stable ORIF of proximal humeral fractures is in the lower 70s (85% of the score on the contralateral side) after twelve months⁵. However, this is at the expense of a high complication rate (up to 45%, depending on the fracture type) in nearly all reported series. Thus, the importance of patient selection for the correct indication and meticulous surgical technique have been stressed by all authors^{2,3,5,6}.

We specifically analyzed our complications, and multivariate analysis showed the fracture pattern (AO/OTA²⁵ type 11-C) as well as heavy smoking at the time of injury (more than twenty pack-years) to be significantly associated with complications after twelve months of follow-up³.

What to Watch For

Indications

- The optimal patient is in good health, is less than sixty-five years of age, has high demands, had a high quality of life before the fracture, and has good bone quality (a combined cortical thickness of >4 mm or a deltoid tuberosity index of >1.4).
- Fractures for which the procedure is indicated are those with medial head extension of >8 mm; two-part surgical neck fractures; two, three, and four-part valgus impacted fractures; two and three-part varus displaced fractures; and those with bore-hole bleeding of the head fragment.

- The surgeon must be well trained in shoulder surgery and able to perform an arthroplasty if necessary.

Contraindications

Absolute

- A patient who is medically unfit for surgery in the beach-chair position.
- A low-demand patient requiring a high level of nursing care (e.g., in a nursing home).

Relative

- Three and four-part anterior fracture-dislocations and head-split fractures in elderly patients (more than sixty-five years of age).
- Four-part varus displaced fracture.
- Irreparable rotator cuff tear or severe arthritis.
- Heavy smoker (more than twenty pack-years).

Pitfalls & Challenges

- Drill screw holes in the humeral head carefully to avoid perforation.
- Reduce the medial hinge in a stable manner.
- Be aware of secondary humeral-head screw cutout due to secondary fracture displacement or osteonecrosis up to two years after surgery.
- To avoid primary humeral-head screw cutout, use the “cutout series”²² for intraoperative fluoroscopy (see the section on confirming the screw tip position with the image intensifier under Step 6 and Fig. 15).
- To avoid secondary varus displacement, use inferomedial head screws for support and perform tension band fixation of the tuberosities to the plate.
- Soft-tissue dissection must be minimal to avoid the development of osteonecrosis.
- To detect secondary screw cutout, follow patients for at least two years, and use several images (anteroposterior internal rotation, neutral, external rotation, and axial views) or CT if cutout is suspected.

Clinical Comments

The intraoperative threshold for primary arthroplasty should be low if the medial hinge cannot be reduced in a stable manner, if the head fragment appears avascular (no borehole bleeding), or if an irreparable cuff tear is found coincidentally.

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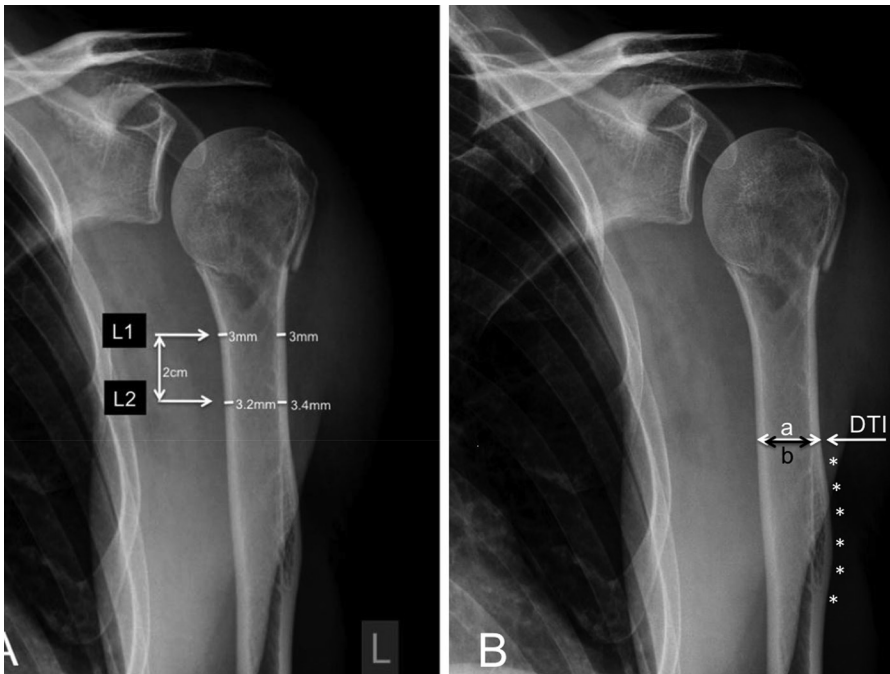


Fig. 1
Fig. 1-A Measurement of combined cortical thickness as defined by Tingart et al.¹⁸. Level 1 (L1) is where the endosteal cortical borders become parallel and L2 is 2 cm distal to L1. At both levels, the mean of the sum of the medial and lateral cortices is calculated (L1 = 3 mm and L2 = 3.3 mm). Then the sum of the two means is calculated (6.3 mm) and corrected for the magnification error. According to a cadaver study by Tingart et al., values of <4 mm correlated with a low local bone mineral density of the humeral head. **Fig. 1-B** The deltoid tuberosity index (DTI) is measured on an anteroposterior internal rotation radiograph of the shoulder (with the arm lying on the abdomen). The location for the calculation is directly proximal to the deltoid tuberosity (which is defined by the asterisks), where the outer cortical borders become parallel. The index is calculated by dividing the outer cortical diameter by the inner endosteal diameter (a/b) at this level. DTI measurements of <1.4 have been shown to correlate strongly with low local bone quality of the humeral head¹⁹.



Fig. 2
The depicted two-part surgical neck fracture has a high fracture line, which means <8 mm of metaphyseal head extension (straight arrow). Furthermore, it has a severely displaced hinge (bent arrow). According to the criteria described by Hertel et al.^{8,22}, metaphyseal head extension of <8 mm and hinge displacement of >2 mm are predictors of an impaired blood supply of the humeral head.



Fig. 3
Hydraulic device.



Fig. 4
The position of the image intensifier (c-arm), which should be checked prior to surgery to make sure that proper anteroposterior and axial views are possible.

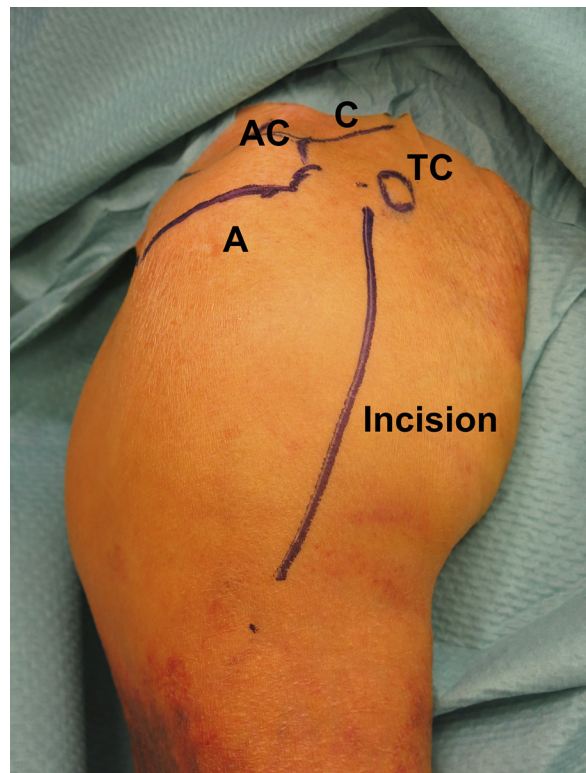


Fig. 5
The anatomical landmarks and the incision for the deltopectoral approach have been marked. A = acromion, C = clavicle, AC = acromioclavicular joint, and TC = tip of the coracoid.

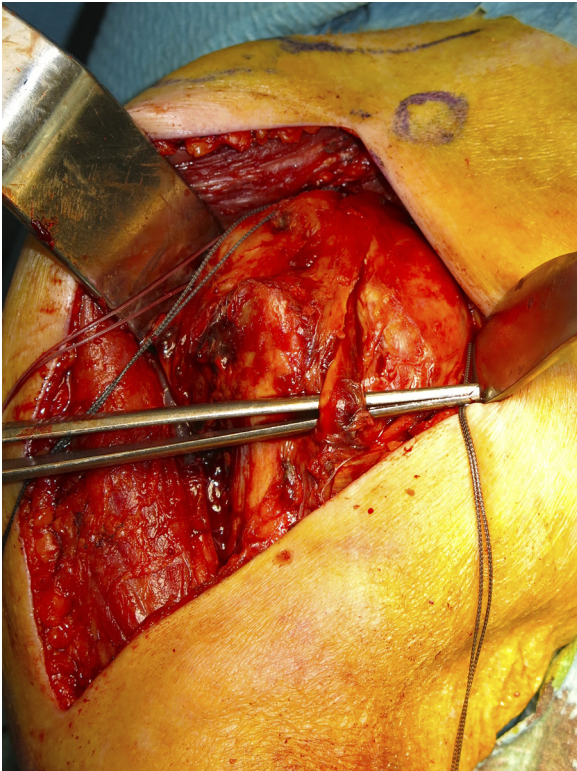


Fig. 6
Identification of the long biceps tendon, which should be done with minimal dissection whenever possible to avoid destabilizing it.

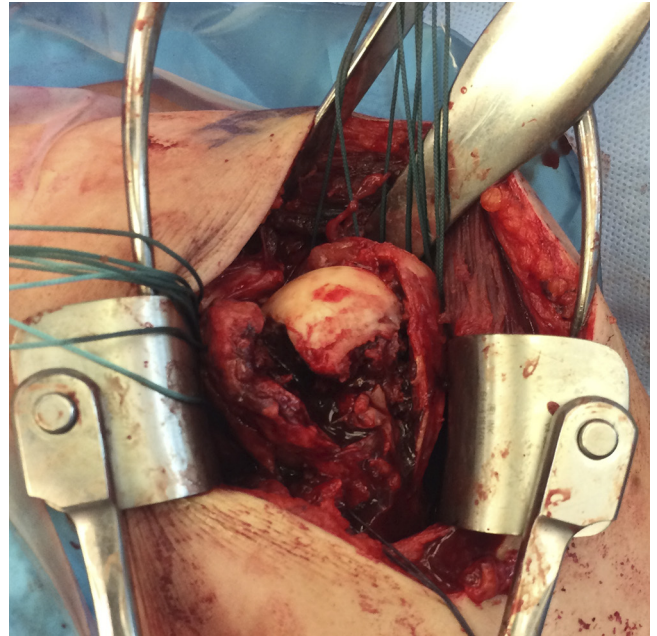


Fig. 7
Heavy stay sutures (number-5 Ethibond) have been placed into the tuberosities for marionette-like reduction control. Full sight into the joint has been achieved by opening the interval and the fracture between the greater and lesser tuberosities (first and second windows).



Fig. 8
Figs. 8-A and 8-B A surgical neck (Neer two-part) fracture in an active sixty-eight-year-old woman with decreased bone quality. **Fig. 8-A** The initial fracture pattern, which was treated nonsurgically in a sling. **Fig. 8-B** Further varus displacement seen after seven days was the indication for ORIF in this active woman.

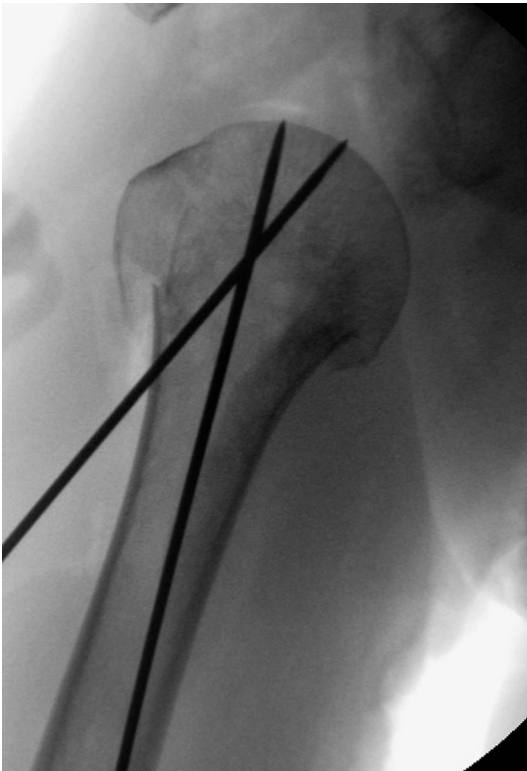


Fig. 9
The reduction can be held temporarily with temporary fixation of the head to the shaft with 1.6-mm Kirschner wires, which should be placed anterior to the final plate position.



Fig. 10
The plate can be positioned with separate Kirschner wires lateral to the Kirschner wires holding the reduction.

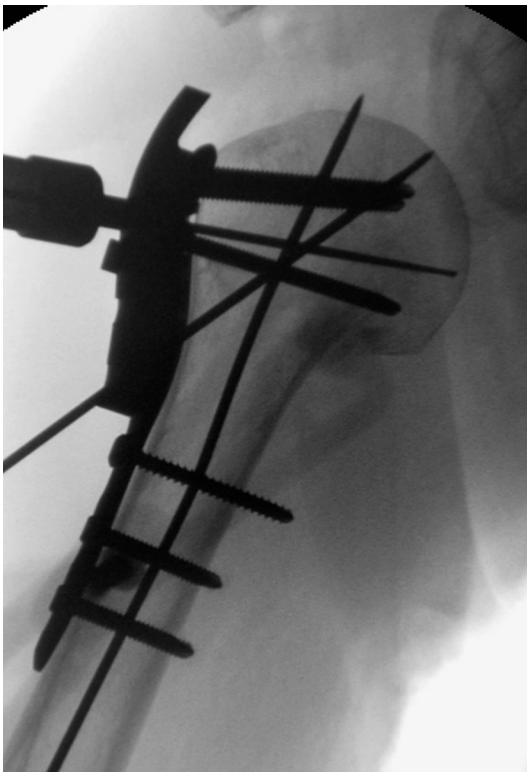


Fig. 11
The cortical screw in the long hole can be used first for final reduction of the plate to the shaft, with the Kirschner wires left in place.

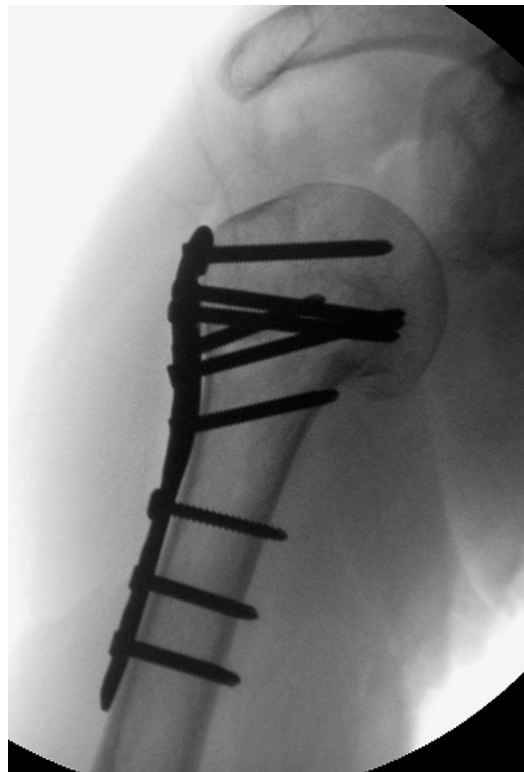


Fig. 12
Final reduction of a varus fracture with the impacted calcar.

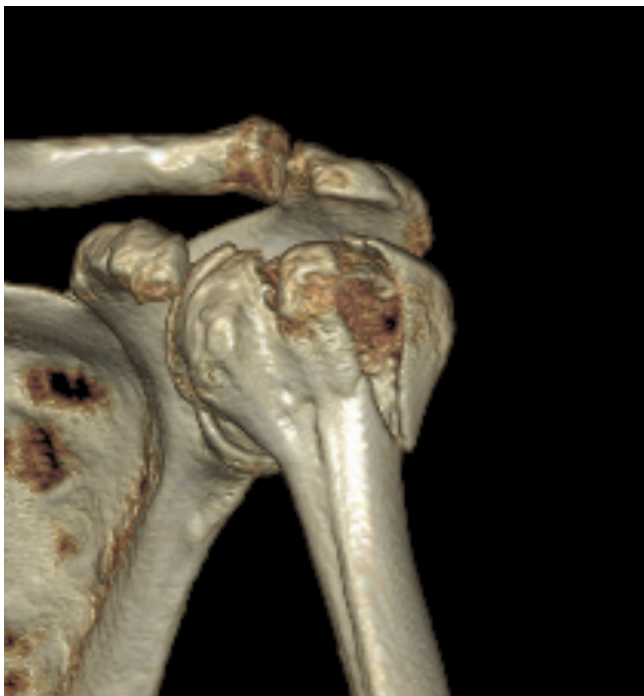


Fig. 13A



Fig. 13B



Fig. 13C



Fig. 13D

Figs. 13-A through 13-F A valgus impacted three-part fracture in a fifty-four-year-old active woman. **Fig. 13-A** 3D reconstruction of a CT scan. **Fig. 13-B** Axial CT scan showing the substantial impaction of the humeral head in relation to the lesser tuberosity fragment. **Fig. 13-C** Intraoperative anteroposterior c-arm image of the fracture. **Fig. 13-D** The Cobb retractor is placed through the fracture between the tuberosities (second window) with its tip aimed at the calcar. The retractor can be lifted up to slowly disimpact the head fragment while the tuberosities are closed with tension on the stay sutures.



Fig. 13E

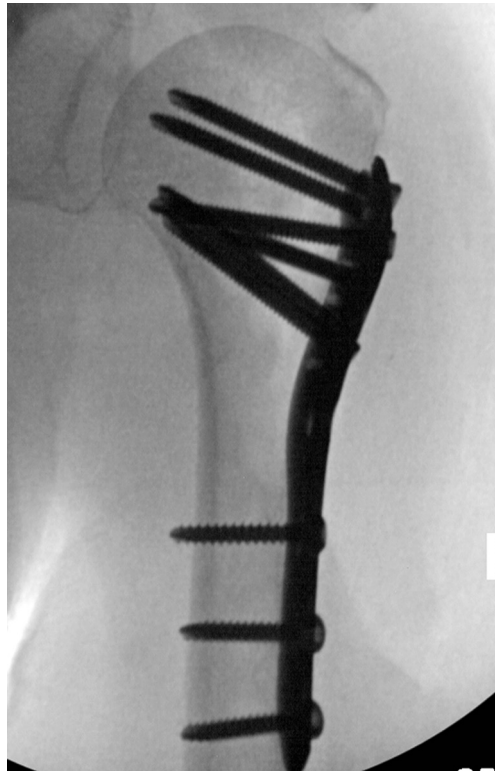


Fig. 13F

Fig. 13-E The plate placed in a position to buttress the greater tuberosity, and the final reduction achieved by compressing the plate to the shaft with use of the long-hole cortical screw. **Fig. 13-F** Final reduction with the plate and screws in place.

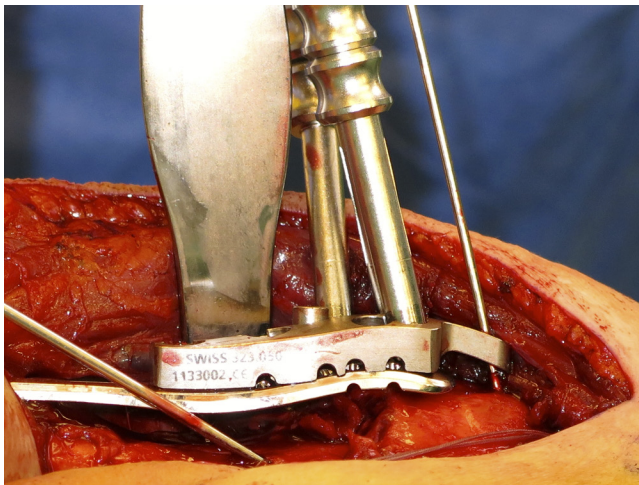


Fig. 14

Aiming jig for the head screws. The correct placement of the screws in relation to the plate is crucial for the final locking mechanism. The jig prevents the screws from aiming in a wrong position in the head (especially in patients with osteoporotic bone).

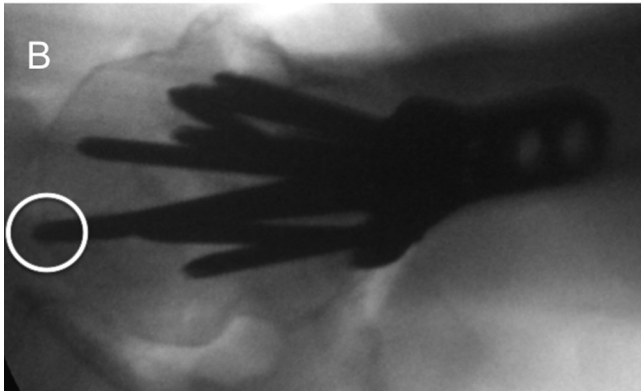
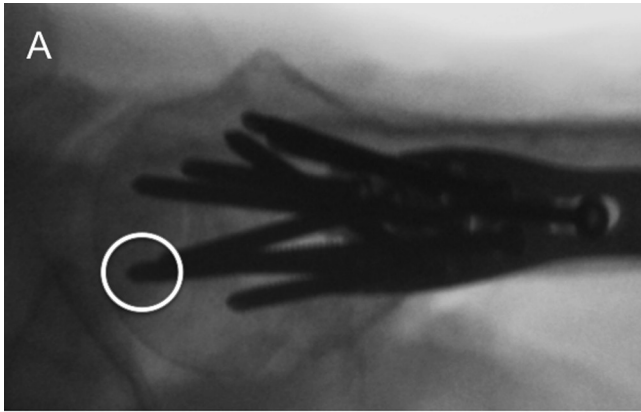


Fig. 15

Figs. 15-A and 15-B Primary screw cutout as seen on two intraoperative axial views of a cadaveric shoulder²². **Fig. 15-A** This axial view, made in the usual manner with the shoulder in 60° of abduction, does not show the screw tip penetrating the joint. **Fig. 15-B** This axial view, made with the shoulder in 30° of abduction, clearly shows the cutout of a screw tip in the inferior humeral hemisphere.

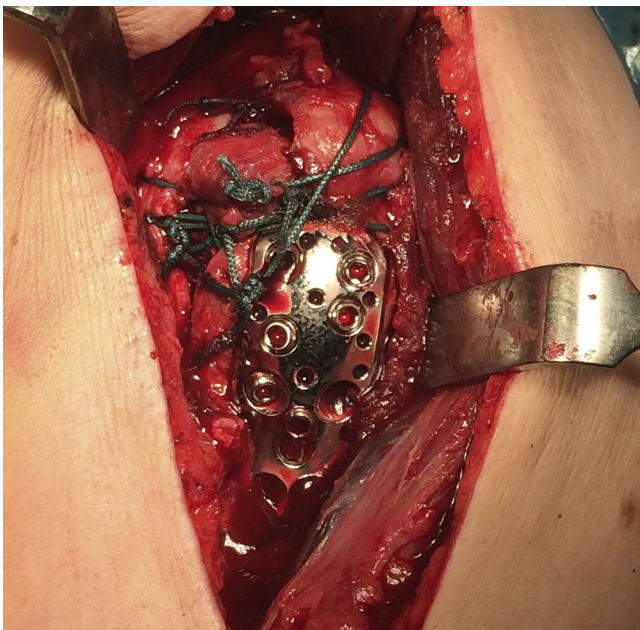


Fig. 16

The stay sutures can be used to fix the tuberosities back to each other and to the plate to restore the anterior-posterior force couple.