Open Reduction and Internal Fixation of Proximal Humeral Fractures with Use of the Locking Proximal Humerus Plate

Surgical Technique

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ABSTRACT FROM THE ORIGINAL ARTICLE

BACKGROUND: The treatment of unstable displaced proximal humeral fractures, especially in the elderly, remains controversial. The objective of the present prospective, multicenter, observational study was to evaluate the functional outcome and the complication rate after open reduction and internal fixation of proximal humeral fractures with use of a locking proximal humeral plate.

METHODS: One hundred and eighty-seven patients (mean age, 62.9 ± 15.7 years) with an acute proximal humeral fracture were managed with open reduction and internal fixation with a locking proximal humeral plate. At the three-month, six-month, and one-year follow-up examinations, 165 (88%), 158 (84%), and 155 (83%) of the 187 patients were assessed with regard to pain, shoulder mobility, and strength. The Constant score was determined at each interval, and the Disabilities of the Arm, Shoulder and Hand (DASH) score was determined for the injured and contralateral extremities at the time of the one-year follow-up.

RESULTS: Between three months and one year, the mean range of motion and the mean Constant score for the injured shoulders improved substantially. Twelve months after surgery, the mean Constant score for the injured side was 70.6 ± 13.7 points, corresponding to 85.1% ± 14.0% of the score for the contralateral side. The mean DASH score at the time of the one-year follow-up was 15.2 ± 16.8 points. Sixty-two complications were encountered in fifty-two (34%) of 155 patients at the time of the one-year follow-up. Twenty-five complications (40%) were related to incorrect surgical technique and were present at the end of the operative procedure. The most common complication, noted in twenty-one (14%) of 155 patients, was intraoperative screw perforation of the humeral head. Twenty-nine patients (19%) had an unplanned second operation within twelve months after the fracture.

CONCLUSIONS: Surgical treatment of displaced proximal humeral fractures with use of the locking proximal humeral plate that was evaluated in the present study can lead to a good functional outcome provided that the correct surgical technique is used. Because many of the complications were related to incorrect surgical technique, it behooves the treating surgeon to perform the operation correctly to avoid iatrogenic errors.

LEVEL OF EVIDENCE: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

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INTRODUCTION

Fractures of the proximal part of the humerus are relatively common injuries, accounting for approximately 4% to 5% of all fractures. Whereas stable fractures are generally and successfully treated nonoperatively, the majority of unstable and displaced fractures may benefit from surgical treatment. Open reduction and internal fixation of proximal humeral fractures is still widely preferred, particularly when recently developed fixed-angle implants and the introduction of reduction techniques accommodating to soft tissue are considered.

The Locking Proximal Humerus Plate (LPHP; Synthes, Oberdorf, Switzerland) is now

FIG. 1

The Locking Proximal Humerus Plate is contoured to the anatomy of the lateral aspect of the proximal part of the humerus and works as an internal fixator by securing an anatomical reduction using angular stability. The screw arrangement of the four locking screws in the humeral head is three-dimensional. Additional smaller holes can be used for fixation of sutures or wires, allowing reattachment of the greater or lesser tuberosities in comminuted fractures to neutralize the tension forces of the rotator cuff muscles.

FIG. 2

The patient is placed on a radiolucent operating table in the beach-chair or supine position.

FIG. 3

A deltopectoral approach is used. The cephalic vein is retracted laterally to protect its many deltoid branches.
available for the fixation of these fractures. It is contoured to the anatomy of the lateral aspect of the proximal part of the humerus and ensures stable fixation of the humeral head and its fragments, even in the presence of osteoporosis. This is achieved by the angular stability of screws locking in the plate and their three-dimensional distribution in the humeral head (Fig. 1).

**SURGICAL TECHNIQUE**

The patient is placed on a radiolucent operating table in a beach-chair or supine position (Fig. 2). A deltopectoral approach is used. The cephalic vein is retracted laterally to protect its many deltoid branches (Fig. 3). Blunt dissection through the deltopectoral groove and blunt mobilization of the deltoid muscle are performed. A muscle retractor, preferably a Roux or a deltoid retractor, is inserted. Slight abduction of the arm relaxes the deltoid muscle and eases access to the humeral head (Fig. 4).

The tendon of the long head of the biceps is identified at the upper border of the pectoralis muscle, and its course is followed cranially. One fracture line usually runs close to the intertubercular sulcus; it separates the fragment of the greater tuberosity from that of the lesser tuberosity. If the intertubercular sulcus cannot be reconstructed or if the tendon of the long head of the biceps is damaged, a tenodesis is done after completion of the osteosynthesis.

The indirect reduction maneuver can be achieved without force by longitudinal traction on the arm, with abduction or adduction, rotation, and lateralization of the humeral shaft while pulling simultaneously on the sutures.
To achieve an exact reduction, the plate is positioned laterally, and the shaft, which lies slightly medially, is pulled laterally with a 3.5-mm cortical screw introduced into the first hole distal to the fracture.
For fracture reduction, the rotator cuff tendons are tagged with nonabsorbable suture, whether as part of a tuberosity fragment or in continuity with the head fragment. With these tagging sutures, the tuberosity fragments can be brought in continuity with the lateral cortex of the shaft fragment. Care must be taken to ensure that the sutures lie directly at the tendon-
Figs. 7-A and 7-B In the presence of multiple fragments and after looping of the cuff tendons, the head fragment can be gently manipulated under direct vision with a periosteal elevator introduced into the fracture gap.
bone junction to prevent their cutting through the tendinous tissue, particularly in elderly patients. The indirect reduction maneuver can be achieved without force by applying longitudinal traction on the arm, with abduction or adduction, rotation, and lateralization of the humeral shaft while pulling simultaneously on the sutures (Fig. 5).

The pull of the pectoralis muscle often causes medial displacement of the humeral shaft in instances of subcapital fractures. Its partial reduction is achieved by applying longitudinal traction and lateral pull, and the exact reduction is accomplished by careful approximation of the shaft to the plate. To achieve this, the plate is positioned laterally on the humeral head, and the shaft, which still lies slightly medially, is pulled laterally with a 3.5-mm cortical screw introduced into the first hole distal to the fracture (Figs. 6-A through 6-F). If a varus tilt of the head fragment is present, its malposition can be corrected by a simultaneous pull on the cranial suture loop. When the above technique is used, the proper placement of the plate is important. Reduction of the medially displaced shaft achieved by tightening of the 3.5-mm cortical screw may lead to a slight upward migration of the plate on the greater tuberosity. Therefore, it may be necessary to start by placing the plate in a slightly distal position on the greater tuberosity to anticipate this movement. If the plate has been inserted too far cranially, repositioning may be necessary.

If the head fragment is impacted onto the shaft, a periosteal elevator can be inserted into the fracture site to disimpact the head and restore the medial portion of the calcar (Fig. 7-A). Once the head fragment has been reduced, the tuberosities are pulled with the suture loops and fitted by digital manipulation (Fig. 7-B). These indirect reduction techniques are important since the placement of large clamps or extensive stripping of the soft tissues can exacerbate vascular injury to the already compromised humeral head. In instances of comminuted fractures, the reduction can be provisionally stabilized with threaded Kirschner wires. Care must be taken to ensure that these wires do not interfere with subsequent plate positioning.

The Locking Proximal Humerus Plate should be positioned with the help of a mounted aiming device at least 5 to 8 mm distal to the upper end of the greater tuberosity and 2 to 4 mm lateral to the bicipital groove, ensuring that a sufficient gap is maintained between the plate and the tendon of the long head of the biceps. The insertion of the deltoid muscle should not be detached during plate placement. The correct plate position and the result of reduction are checked with the image intensifier. To avoid impingement, care

FIG. 8
The insertion of the angular stable screws into the humeral head is facilitated by the use of a drill guide. After drilling with the 2.8-mm drill-bit and determining the correct screw length, the locking screws can be inserted.
must be taken not to insert the plate too far cranially. The first screw to be placed is usually a 3.5-mm cortical screw, inserted close to the fracture with use of the standard technique. This neutralizes the pull of the pectoralis on the shaft fragment. During tightening of the screw, care must be taken to ensure that the distal part of the plate is properly centered on the humeral shaft.

The insertion of the angular stable screws into the humeral head is facilitated with the use of a drill guide (Fig. 8). After drilling with the 2.8-mm drill-bit and determining the correct screw length, the locking screws can be inserted. To gain optimal purchase, the screw tip should be brought within a few millimeters of the opposite cortex. At the level of the head, only self-tapping locking screws should be used to reduce the risk of screw penetration if impaction of the fracture occurs. The humeral head is stabilized with five fixed-angle screws aligned in different planes (Fig. 9). At the shaft, a minimum of two bicortical locking screws, or three in osteoporotic bone, should be used to prevent screw avulsion. Depending on the fracture type, previously placed suture loops are then threaded through the provided holes in the plate and are knotted (Fig. 10). The tensional forces of the cuff are neutralized by the loops tied to the plate, further increasing the stability.

Passive mobilization under direct vision to check the stabil-
ity of the construct, followed by image intensification, is then performed. Particular attention should be paid to the result of reduction, plate position, stability, and length of the locking screws. Since the screws are inserted three-dimensionally in the humeral head, it is necessary to check the correct proximal position of every single screw separately by rotating the arm under image intensification and by making an axillary radiograph.

A suction drain is inserted, and wound closure in layers is performed. After surgery, radiographs should be made to document fracture reduction and implant position (Figs. 11-A and 11-B).

**CRITICAL CONCEPTS**

**INDICATIONS:**
- Unstable two, three, and four-part humeral head fractures, with an angulation of the articular surface of >45° or displacement between the major fracture segments of >1 cm, or fractures that are unstable when tested with passive motion with use of an image intensifier
- Fractures of the proximal part of the humerus, classified according to the AO system as types 11-A2, A3, B1, B2, B3, and C1
- Fractures of the proximal part of the humerus, classified according to the AO system as types 11-C2 and C3 in young patients
- Fractures of the proximal part of the humerus classified according to the AO system as types 11-C2 and C3 in older patients, if satisfactory reconstruction can be expected and the patient continues to be physically active
- Subcapital humeral nonunion
- Pathologic fracture

*continued*
RELATIVE CONTRAINDICATIONS:

- Nondisplaced stable fractures and fractures with minimal displacement and adequate stability
- Fractures of the proximal part of the humerus in children
- Fractures of the proximal part of the humerus classified according to the AO system as types 11-C2 and C3 in older patients with absent blood supply to the head fragment, a poor chance of reconstruction, and/or few physical demands
- An acute local infection

PITFALLS:

- Interruption of the blood supply to the fragments because of overly extensive exposure of the fracture and/or insertion of a periosteal elevator, reduction forceps, or Hohmann retractors on the medial side of the humeral neck, destroying the delicate vessel branches supplying the humeral head fragment.
- Inadequate reduction and repositioning of the displaced head fragment, particularly when tilted in varus, risking loss of reduction and subsequent limitation of motion.
- Subacromial impingement during abduction because placement of the plate is too cranial.
- The position of the spoon-shaped end of the plate is too posterior, resulting in a lack of posterior-cranial apposition of the plate to the curved humeral head.
- The placement of the plate is too anterior, impinging on the ascending branch of the anterior circumflex humeral artery and the tendon of the long head of the biceps.
- The displaced tuberosities have not been sufficiently reduced or are inadequately fixed to the plate either with head screws or strong suture loops. This may cause secondary displacement or a subacromial impingement, especially if the displacement is >5 mm.
- A locking screw that was initially chosen is too long or perforates during fragment subsidence. Protrusion into the articular surface causing painful limitation of motion and damage to the glenoid articular surface should be corrected by exchanging the offending screw.
- The locking screws are too short and have insufficient purchase in the head fragment, risking a secondary fragment displacement. The screw should be replaced, or the postoperative treatment protocol must be modified.
- Self-drilling screws are used for locking in the humeral head. The pointed tips of these screws can cut through the head cortex during healing.
- The positioning of the locking screw is incorrect, resulting in poor locking of the screw head in the plate, with distraction of the thread, cold welding, or screw loosening.
- Medial buttressing is not achieved, leading to a secondary loss of reduction or implant breakage.
- Too few bicortical locking screws are used in the shaft area (only 3.5-mm standard cortical screws or monocortical anchorage of locking screws), leading to avulsion of the plate from the shaft.

AUTHOR UPDATE:

No changes in the technique have occurred since the publication of the original report.
REFERENCES


