Screw Depth Sounding in Proximal Humerus Fractures to Avoid Iatrogenic Intra-articular Penetration

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Summary: Unstable and displaced proximal humerus fractures remain a treatment challenge. The use of locked plates has improved construct stability, but complication rates remain high. Biomechanical studies have emphasized the importance of anchoring screws in the subchondral bone of the humeral head to improve implant stability. However, the spherical shape of the proximal humerus and the limited tactile sensation of its soft cancellous bone make determining accurate screw length difficult, and reported rates of intraoperative screw penetration are high. Iatrogenic screw penetration, even if recognized and corrected before leaving the operating room, may lead to late failure. We present a simple technique of quickly and safely determining screw length using a blunt-tipped Kirschner wire and instruments found in basic orthopaedic sets.

Key Words: proximal humerus fracture, intra-articular screws, iatrogenic screw penetration, locked plating

INTRODUCTION

Proximal humerus fractures are the third most common fracture of the elderly behind fractures of the hip and distal forearm. The majority of these fractures occur in individuals older than age 65 years and over 75% occur in women. Approximately 80% of proximal humerus fractures are stable, nondisplaced fractures and nonoperative treatment yields predictably good healing and functional outcomes. Achieving successful treatment outcomes in the remaining 20% remains a challenge. When the fracture fragments are displaced and unstable, operative treatment is generally indicated. Historically, achieving stable fixation has been problematic. These fractures most often occur in elderly patients in whom osteopenic bone affords poor implant fixation.

More recently, the use of locked plating systems has led to improved construct stability, potentially allowing earlier motion and decreased complication rates. However, failure rates remain unacceptably high. One area of particular concern involves recent reports of high rates of intraoperative humeral head screw perforation. This is likely the result of several factors, including diverging and converging locking screw vectors, the convex morphology of the humeral head, and the poor bone quality limiting the tactile feedback of the drill bit, among others. Iatrogenic articular screw penetration can lead to early glenoid chondrolysis. This article presents a novel method for assessing screw length when placing screws into the humeral head to avoid inadvertent screw extrusion.

Surgical Technique

The patient is placed supine on a radiolucent operating room table and positioned such that anteroposterior and axillary views of the proximal humerus can be easily obtained using C-arm fluoroscopy. The fracture is exposed through either a deltopectoral or anterolateral acromial approach. Fracture reduction is performed by standard methods, including Kirschner wire joysticks and elevators to control the humeral head fragment and heavy-gauge sutures placed in the supraspinatus, infraspinatus, and subscapularis tendons to provide traction and to mobilize the tuberosities.

The locking plate is applied once the fracture is reduced. Special attention should be paid to the position of the implant, because too proximal a plate placement can lead to subacromial impingement, and too distal plate positioning can preclude placement of the important inferomedial calcar screws.

Once the fracture has been provisionally reduced and the implant temporarily affixed with Kirschner wires, the reduction and implant placement should be verified on C-arm fluoroscopy. Screw placement may begin either proximally or distally depending on the fracture pattern and the implant system being used.

After the locking proximal humeral plate (Synthes, West Chester, PA) has been positioned and provisionally stabilized, the near cortex of the desired locking screw slot is perforated using a 2.8-mm drill bit. A 1.6-mm insert is then placed in the locking drill guide, and the blunt end of a 1.6-mm (0.062-inch) Kirschner wire is then advanced by hand until a firm end point is felt (Fig. 1). Despite the typically poor bone quality, it is still much more difficult to perforate the subchondral plate when manually pushing a blunt Kirschner wire than when inserting a sharp drill on power. Care must be taken to avoid an accidental...
injury from the exposed sharp end of the Kirschner wire. In young patients with healthy bone, the risk of perforation still exists, so this technique is used in these situations as well. In these patients, a small mallet may be needed to advance the Kirschner wire to the subchondral bone.

Once the blunt wire is determined to be abutting the endosteal surface of the subchondral bone, the position of the Kirschner wire can be verified with fluoroscopy. However, the images should be interpreted with caution. The spherical shape of the humeral head, as well as screw vectors that are not perpendicular to the plate, makes verifying the extra-articular position of the tip of a screw or Kirschner wire unreliable on orthogonal views alone (Fig. 2). The tactile feedback of the Kirschner wire against the subchondral bone likely serves as a more accurate assessment of extra-articular position. Confirmatory fluoroscopy can be a useful adjunct as well.

Screw length can then be determined by one of several methods. Most implant manufacturers feature a measuring guide that, when used in conjunction with a threaded locking guide, measures indirectly from the Kirschner wire (Fig. 3). In cases in which an incorporated guide is not available or the clinical situation prevents its use, screw length may be determined by an alternative indirect method. In this method, a second Kirschner wire of the same length is positioned against the plate and the location of the end of the exposed Kirschner wire is marked against the free Kirschner wire. The length of the exposed portion is then subtracted from the overall length of the Kirschner wire to give the desired screw length (Fig. 4). Alternatively, a standard depth gauge has a blunt end that is unlikely to penetrate the subchondral plate, and this can be used in a similar fashion as a blunt Kirschner wire. The downside of using a depth gauge is that the shaft often has a lower flexural rigidity compared with a Kirschner wire, and its path is more likely to deviate with blunt sounding.

Self-tapping locking screws can typically be inserted without additional drilling. However, in some younger

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**FIGURE 1.** Sawbones model demonstrating the “sounding” technique using a Synthes 3.5-mm LCP Proximal Humeral Locking Plate. Note the blunt tip of a Kirschner wire abutting the endosteal surface of the subchondral bone (arrow).

**FIGURE 2.** Intraoperative fluoroscopic image of a Kirschner wire being used to determine screw depth (arrow). Although this wire is resting against the subchondral bone, note that it appears to be short as a result of the convexity of the humeral head.

**FIGURE 3.** Example of an implant-specific measuring device that incorporates the locking-guide and wire-guide insert so that the screw length can be read indirectly from a depth gauge.
patients, it may be necessary to carefully predrill an additional length of the screw tract. After all desired screws have been placed, the shoulder should be taken through a full range of motion to assess for intra-articular screw penetration. Live fluoroscopy taken during passive range of motion likely increases the sensitivity of detecting screw penetration. The posterosuperior portion of the humeral head is particularly at risk for iatrogenic screw penetration. Placing the arm in 20° to 30° of flexion and 80° to 90° of internal rotation can aid in visualizing this difficult-to-assess region of the humeral head. However, the repeated and indiscriminate use of live fluoroscopy unnecessarily exposes both the surgeon and patient to increased radiation and is discouraged.

Clinical Experience

After approval by the Institutional Review Board, a retrospective review was conducted of all proximal humerus fractures treated with open reduction and internal fixation by the senior author (M.J.G.). Between September 2009 and November 2010, 23 patients were treated surgically using the anterolateral acromial approach in 21. Based on the Orthopedic Trauma Association fracture classification system, there were three 11 A3-type fractures, five 11 B1-type fractures, and one each of 11-B2, -C1, -C2, and -C3-type fractures.

All fractures were treated with locked plates and suture reinforcement of the tuberosity fragments. Humeral head screw lengths were determined using the intraoperative Kirschner wire “sounding” technique as described previously. A palpable change in resistance was felt in all cases when the wire reached the increased density of the subchondral bone. None experienced intraoperative screw penetration. Extra-articular screw position was verified with live fluoroscopy at the end of each procedure as well as postoperative plain radiographs.

DISCUSSION

Surgical intervention for unstable proximal humerus fractures is a common procedure in orthopaedics. Despite an abundance of research, there is no single agreed-on algorithm for the treatment of these difficult fractures. Based on promising results from biomechanical studies, locked plating systems have recently become increasingly used. However, they have not proved to be a clinical panacea and complication rates remain high. A meta-analysis of 12 locked plating studies conducted in 2009 reported a 12% loss of reduction and an 11.6% screw cutout rate. Similarly, a five-center, retrospective analysis of 153 patients found an overall loss of fixation of 13.7%. In their analysis, initial varus malreduction (head-shaft angle less than 120°) was found to significantly increase the failure rate from 11% to 30%. Other authors have noted similar late failure rates. Intra-operative complications are common as well. Kettler et al reported on 176 patients treated with locked plating and noted an 11% incidence of intra-articular screw penetration. Two other large series have reported intraoperative screw penetration rates of 11% and 14%, respectively. These complications lead to poorer patient outcomes, delayed functional recovery, and increase the overall cost of care.

A strong correlation exists between the incidence of proximal humerus fractures and advancing age. Higher incidences of osteoporosis and susceptibility to falls in the elderly likely play significant roles. The relatively osteopenic quality of the bone in the humeral head makes achieving stable fixation a challenge. Biomechanical studies have attempted to quantify the bone density profile of the humeral head to guide screw placement. In a cadaveric proximal humerus model, Liew et al found that subchondral screw-tip abutment significantly increased screw pullout force when compared with screws placed 5 mm short of the subchondral bone. They, and other authors, found the bone in the superior–anterior quadrant to have the poorest pullout strength and caution against relying on screws in this location. Histomorphometric and bone strength distribution analysis demonstrated that trabecular thickness and bone strength are greatest in the central and medial region of the humeral head, a finding consistent with other biomechanical studies.

The importance of subchondral screw placement and high reported rates of intraoperative screw penetration risk suggest a need for more accurate assessment of screw tip location. Orthogonal radiographs play a role in identifying screw penetration. However, the spherical shape of the humeral head imposes limitations on its accuracy. Live, intraoperative fluoroscopy likely improves detection of screw penetration. However, neither modality addresses the challenge of placing screws against, but not through, the subchondral bone. Accidental perforation, even when recognized and remedied, may compromise the overall integrity of the humeral head. In this case, the subchondral bone has already been violated, eliminating the mechanical buttress and the effectiveness of the screws. Accidental perforation may compromise the ability of the implant–bone construct to resist the varus moment created by the rotator cuff, ultimately leading to cutout and varus collapse.

In conclusion, the technique of “sounding” the humeral head using a blunt-tipped Kirschner wire can minimize the risk of intraoperative screw or drill-tip penetration. The quality of the subchondral bone in the humeral head, especially in geriatric patients, is typically poor. Thus, there is limited tactile...
feedback during drilling to aid in differentiating between cancellous bone and the thin shell of subchondral bone. Because of this, the traditional method of advancing the drill bit until the tactile resistance of the subchondral bone is indirectly palpated carries a high risk of unintentional humeral head perforation. The present technique takes advantage of the relatively porous cancellous bone of the humeral head to manually advance a blunt Kirschner wire for measurement, and it can be performed with instruments contained in standard orthopaedic trays.

REFERENCES