Close reduction and percutaneous fixation of unstable fracture proximal humerus: midterm clinical outcome

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Background
Proximal humeral fractures are common injuries and sharply increase in elderly patients, especially those over the age of 60 years. Conservative treatment usually leads to nonsatisfactory results. That is why, open reduction and internal fixations is essential, but it increases the risk of avascular necrosis, infection, and joint stiffness. Minimally invasive techniques, with less disruption of soft tissue attachments, may offer advantages over conventional fixation. Close reduction and percutaneous fixation of proximal humeral reduces risk from soft tissue dissection and may reduce the fracture indirectly, achieving provisional fixation for anatomic healing.

Aim
To evaluate the results of close reduction and percutaneous fixation of unstable fracture proximal humerus with threaded K-wire and cannulated screws.

Patients and methods
A prospective study was conducted over a period of 48 months of 54 patients who presented with unstable fracture proximal humerus (two-part, three-part, and four-part fracture) aiming for close reduction and percutaneous fixation by threaded K-wire and cannulated screws of 4 mm. The mean age was 49 years (29–72 years). The mean follow-up was 20 months (6–30 months). Results were assessed according to the Constant score. Only 50 patients completed their follow-up.

Results
All fractures united within an average of 6 weeks (6–8 weeks). No intraoperative complications occurred. Implant removal was performed after complete radiological union within 8–10 weeks after the initial surgery. In 10 (20%) cases, secondary impaction of the humerus leads to perforation of K-wires through the articular surface requiring premature removal of the entire implant after 4–5 weeks. A total of 35 (70%) patients had a Constant score more than 90, nine (18%) patients had a score more than 85, and the rest six (12%) patients had a score less than 80. In comparison with the normal side, 40 (80%) patients had excellent or good results, seven (14%) patients had fair results, and three (6%) patients had poor results.

Conclusion
Closed reduction and percutaneous fixation of unstable proximal humerus fractures is a useful highly demanding technique in select patients. The rationale of minimizing soft tissue dissection to preserve head vascularity is a very sound reason to select this approach in some three-part and four-part fractures, which is the key to success regarding the functional results of this technique.

Keywords:
cannulated screws, close reduction, percutaneous pinning, proximal humeral fracture, serrated K-wire

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Introduction

Fractures of the proximal humerus are common injuries, accounting for 4–5% of all fractures. The incidence sharply increases in the elderly, with 71% of all proximal humerus fractures occurring in patients older than 60 years. The overall female-to-male ratio has been reported to be 3 : 1 but may reach 7 : 1 in the aging population [1].

Nonoperative treatment of displaced humeral head fractures does not lead to satisfying results, which puts the shoulder at risk of stiffness and malunion [2]. Reduction of the fragments is therefore essential, although there is a danger that reduction by open surgery may increase the risk of avascular necrosis (AVN), especially in four-part fractures and four-part fracture dislocations [3]. Multiple surgical treatment options have been reported. Traditional techniques include open reduction and internal fixation (ORIF) with

plates and screws [4], intramedullary nails [5], tension band wiring, and suture fixation [6]. Arthroscopic assistance has also been reported.

Hagg and Lundberg [7] stated that open reduction doubles the risk of AVN compared with closed treatment. In addition, the risk is increased further by the exposure required for plating compared with that for a lesser procedure.

Increasing attention has been focused on the importance of careful handling of soft tissue and on preservation of the blood supply during the surgical treatment of the fractures. Minimally invasive techniques, with less disruption of soft tissue attachments, may offer advantage over conventional fixation. Percutaneous fixation has been described as a viable treatment option for a multitude of fractures in all age groups. Closed reduction and percutaneous pinning (CRPP) of the proximal humerus is a less-invasive option in selected patients [8].

CRPP (close reduction and percutaneous fixation) of proximal humerus fractures was reported by Bohler [9] but has received more attention in recent literature. The potential advantages compared with ORIF include higher union rates, lower rates of AVN, decreased scar formation at the scapula–humeral interface, and improved cosmoses. The indication varies depending on the fracture type, bone quality, patient factors, and surgeon comfort.

Codman first noted that the proximal humerus tends to fracture along the physeal line. Four fragments may be created: the shaft, the articular surface, and the greater and lesser tuberosities. Neer [10] based his classification system on these observations. A fragment is considered displaced if it is separated by more than 1 cm or angulated more than 45°.

Indication

Close reduction and percutaneous fixation of proximal humerus needs less dissection and less disruption of the blood supply than traditional open techniques, which has the advantage of decreased scarring in the scapula–humeral interface and decrease the risk of osteonecrosis with easier and earlier rehabilitation [11].

It is considered as an alternative to ORIF in selected fractures. Fractures amenable to CRPP include two-part fractures of surgical neck, greater tuberosity, and lesser tuberosity; three-part surgical neck fractures with involvement of greater or lesser tuberosity, and valgus-impacted four-parts fractures (Table 1).

Table 1 Fractures amenable to close reduction and percutaneous pinning

Numbers of fracture parts	Type of fracture
Two parts	Surgical neck
	Greater tuberosity
	Lesser tuberosity
Three parts	Surgical neck/greater tuberosity
	Surgical neck/lesser tuberosity
Four parts	Valgus affected

CRPP is a demanding surgical technique. For this technique to be used successfully, several conditions are required: (a) good bone stock, (b) minimal commination particularly involving the tuberosity, (c) an intact medial calcar, (d) a stable closed reduction after pinning, and (e) a cooperative and reliable patient.

Poor bone quality and fracture commination of the medial calcar or tuberosities are contraindications to this technique. Pin loosening and loss of reduction have been attributed to these two factors in several studies.

CRPP depends on limited fixation, thus requiring excellent bone purchase for support. An intact periosteal sleeve along the medial calcar is thought to be important in providing stability to the fracture and for collateral blood flow to the humeral head.

With any humeral head-preserving technique, osteonecrosis is an important postoperative concern; previous studies have suggested minimizing the stripping of the soft tissue. Osteonecrosis rates reported in percutaneous pinning studies have ranged from 4 to 16%, which compares favorably with the 12.5–71% range reported with the use of other techniques [12].

The purpose of this study was to describe a surgical technique and report on the midrange clinical and radiographic outcomes of the patients who were treated for displaced two-part, three-part, and four-part fractures of the proximal part of the humerus with minimally invasive reduction and percutaneous fixation.

Patients and methods

This study was conducted in Suez-Canal University Hospital, Ismailia, between June 2012 and June 2016. The study was approved by ethical committee of Orthopedic Department, Suez-Canal University. All patients were operated upon in Suez-Canal University Hospital, after they have signed an informative consent form. It included 54 patients who presented with

fractures of proximal humerus (two, three, and four parts) treated with closed reduction and percutaneous fixation using threaded K-wire and cannulated screws of 4 mm. There were 32 female and 22 male patients. A total of 33 patients had right humerus fractures and 21 had left humerus fractures. The average age was 49 years (range, between 29 and 72 years). All fractures were attributed to either fall or motor traffic accident. All cases with fracture proximal humerus presented to us within 10 days of trauma and were classified according to Neer's classifications.

In general, fractures were assessed with the use of radiographs (four views: anteroposterior, true anteroposterior, outlet, and axillary). Three-dimensional computed tomography reconstruction is the best for demonstration. Patients with severe osteopenia, severe commination, or tuberosity fragmentation; those with head-splitting fractures; and fractures with marked displacements, such as fracture-dislocation, were not considered candidates for percutaneous fixation and were excluded from this study.

Perioperative planning

The principle of closed reduction depends on understanding the anatomical relationships between the various fragments and the deforming forces around the fracture site, which is not only important for the blood supply but also for the ligamentotaxis effect. Integrity of the periosteum is very important for intact blood supply, which can be detected by the distance between the fragments, that is, the greater the mean distance between fragments (>5 mm), the greater the disruption of the periosteum and blood vessels. The head can be displaced medially or laterally (>45° of angulation). When the head is displaced medially, the periosteum will be stripped off from the shaft fragment but up to a certain amount of displacement and will not be destroyed. When the head is displaced laterally, however, the periosteum then runs over the sharp edge of the shaft fragment and will be destroyed much sooner than with medial displacement.

Based on anatomical and biomechanical studies, rupture of the periosteum begins on an average after 9 mm with medial displacement and after 6 mm with lateral displacement [10].

Technique

Principle

Reduction is performed under image intensifier with a percutaneous inserted elevator and pointed of the hook retractor. Maintenance of the reduction is performed with 2.2-mm, threaded-tip Kirschner wires. This avoids displacement of the head in any direction but allows the head segment to glide in the direction K-wires to settle on the shaft fragment, which leads to rapid healing (so-called 'guided sliding' of the head. Screw fixation of the tuberosities is performed with cannulated screw fixation system of 4 mm.

Positioning

The surgical procedure was performed with the patient in modified beach-chair or supine position with sand bag under the scapula, in such a way that the affected shoulder was clear off the table. Fluoroscopy was utilized to obtain orthogonal imaging of the proximal part of the humerus during the fracture reduction and implant placement. Orientation of the humeral head in the cranio-caudal direction is provided by the fluoroscopy, whereas for anteroposterior orientation the humeral head is divided into thirds, with the humeral head into neutral position. The transition between the anterior and middle third corresponds roughly to the intertubercular groove.

Reduction

Reduction was done with the help of a pointed hook retractor and an elevator. A trial of close reduction to confirm the feasibility of reduction and fixation was done before final sterile preparation and draping.

In two-part surgical neck fractures, the major fragments are the humeral shaft and the humeral head. As all the rotator cuff attachments to the head typically are in neutral or slight varus position because of unopposed pull of the supraspinatus. The humeral shaft fragment displaces anteromedially and is rotated internally by the pull of the pectoralis major muscle. The major deforming force is the pectoralis major, and its effects are minimized by flexing, adducting, and internally rotating the humerus. Traction was then applied to the arm, and a posteriorly directed force is applied reducing the apex anterior angulation. Once reduced, the humerus can be externally rotated to neutral.

In two-part greater tuberosity fracture, the greater tuberosity is avulsed by the pull of its tendon superiorly and posterior in the subacromial space. A small incision is made at the limit of the anterior and middle third of the humeral head about 1 cm below the superior border of the tuberosity, and a small sturdy hook retractor is introduced in the direction of the fibers through the deltoid muscle and into the subacromial space. The subacromial

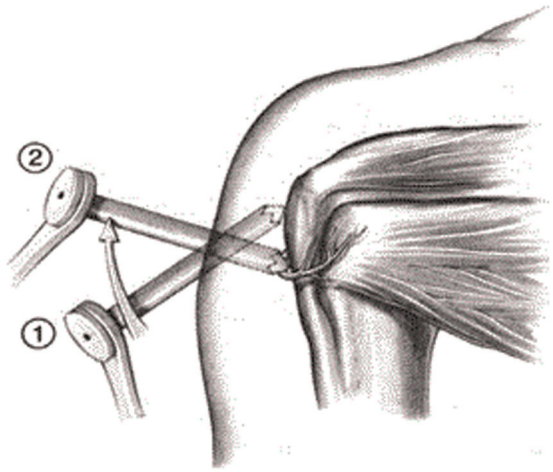
space is enlarged by applying slight traction to the arm. The tuberosity is engaged at the insertion of the supraspinatus tendon and moved anteriorly and caudally until correct position appears to have been reached, that is, the profile of the head is normal. Temporary fixation by K-wire is done, and then rigid fixation by cannulated screw 4 mm. The screw is usually used without a washer to avoid metal impingement on the acromion and possible axillary nerve entrapment (Fig. 1). A washer is used only in cases with a comminuted tuberosity. The same manner done for reduction and fixation of lesser tuberosity as it is displaced medially by the pull of the subscapularis tendon. To avoid damage to the axillary nerve, the cannula and blunt trocar are advanced superomedially and then the bone is followed inferiorly with the sheath deflecting the nerve (Fig. 2)

In surgical neck fractures with avulsion of the greater tuberosity (three-part fracture), the head is rotated internally by the pull of the subscapularis, which in not counteracted by the infraspinatus muscles because of the fracture of greater tuberosity. Additionally, the shaft is displaced anteriorly and medially by the pull of the pectoralis major. The greater tuberosity displaces into the subacromial space and loses its periosteal connection to the shaft. First, the subcapital fracture is reduced with the arm in adduction and internal rotation and then applying traction and counter pressure by the thumb on the posterolateral area of the fracture. Then, the fracture is secure by two 2.5-mm threaded K-wire.

The ideal starting point for lateral pinning is twice the distant from the top of the humeral head to the inferior margin of the humeral articular cartilage. This entry point is safe to protect the radial nerve, which is distal to the deltoid tuberosity, and the axillary nerve that is 5 cm from the distal to the acromion (Fig. 3).

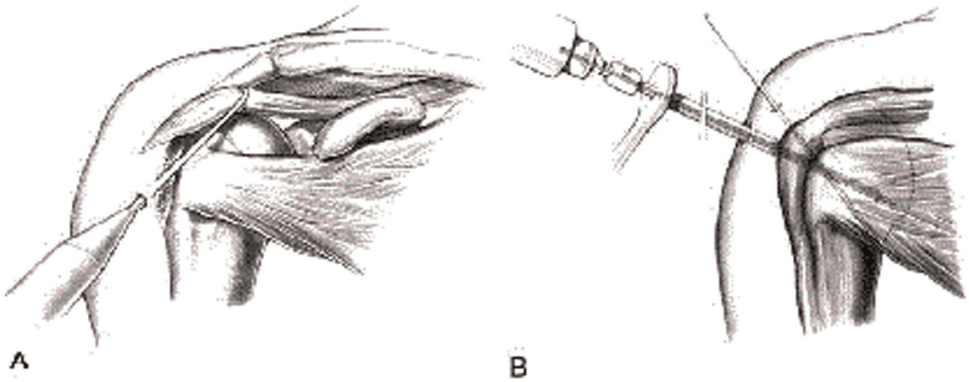
A stable incision was done on the starting point as described before on the lateral side of the arm, soft tissue was retracted, and a 2.5-mm threaded K-wire was place directly over bone with a sleeve under image guidance and advanced into the bone at horizontal angle to prevent sliding of the pin then gradually advanced to the target angle of 40°. The first threaded wire is inserted from the anterior border of the lateral humeral surface and directed posteriorly to the subchondral bone to match the normal retroversion of the humeral head with an angle of 30° (Figs 4 and 5). The second threaded wire is inserted from the posterior

Figure 2



To avoid damage to the axillary nerve, the cannula and blunt trocar are advanced superomedially (a). They then follow the bone inferiorly with the sheath deflecting the nerve (b) [14].

Figure 1

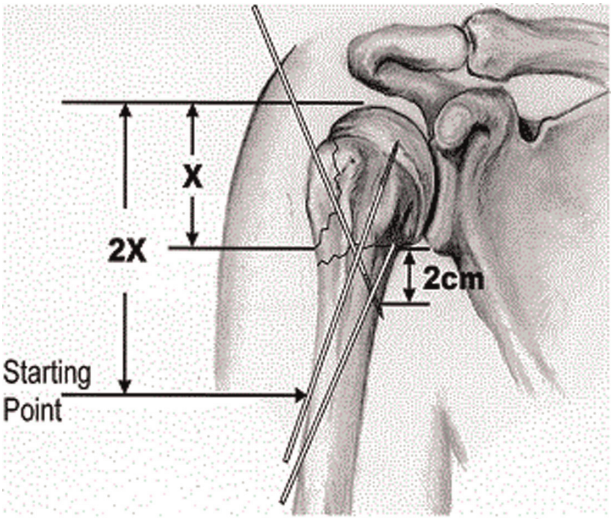


Technique of percutaneous reconstruction of greater tuberosity. (a) The pointed hook retractor is inserted via a stab incision at the transition zone between anterior and medial third and about 1 cm below the original height of the tuberosity. The fragment is grasped at the insertion of the supraspinatus tendon and pulled in a downward and slightly anterior direction. (b) The tuberosity is secured temporarily with either a K-wire or directly with the drill-guide wire combination. Then the arm is rotated internally and externally to check the position of the tuberosity [13].

border of the lateral surface and directed anterior, which result in sufficient fixation formed by two crossing threaded K-wires. The pin placement and reduction were confirmed in both anteroposterior and axillary views with image intensifier.

In three-part fractures involving the greater tuberosity, the head is fixed over the head by two wires as described previously. The greater tuberosity is fixed by K-wire after reduction of at least 20 mm distal from the inferior extent of the humeral head to avoid injury of axillary nerve and posterior circumflex humeral artery and then fixed by a cannulated screw of 4 mm with a washer.

Figure 3



The safe starting point for the proximal lateral pins and the end for the greater tuberosity pins. *X*=distance from the superior most aspect of the humeral head to the inferior most aspect of the humeral head. 2*X*=the starting point for the proximal lateral pin. The end for the greater tuberosity pin should be more than 2 cm from the inferior most margin of the humeral head [15].

In four-part fractures involving greater and lesser tuberosities, reduction and fixation is done as described previously. The lesser tuberosity fixation is achieved by K-wire followed by a cannulated screw of 4 mm with a washer (Fig. 6).

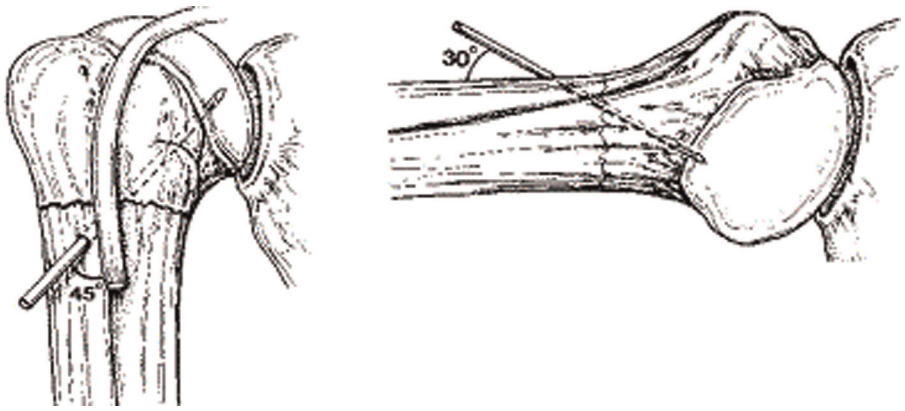
After percutaneous fixation, the wires are cut below the skin and should be cut short enough to be buried entirely even after the initial swelling subsides while still kept long enough for easy removal. Cutting the wire below the skin reduces the change of superficial pin-tract infection. All the incisions are closed with interrupted nylon sutures.

Postoperatively the arm is immobilized in a collar and cuff for 3 weeks. Pendulum exercises started on the second day of operation with active mobilization of the elbow. Four to 6 weeks after surgery, active mobilization of the shoulder is performed with abduction to 90°. Implant removal is required 6–8 weeks postoperatively depending on the appearance of the radiological union. In the case of secondary head impaction followed by perforation of K-wires into the joint, the K-wires are removed earlier as soon as (3 weeks postoperatively) possible to avoid damage of the glenoid articular cartilage.

Results

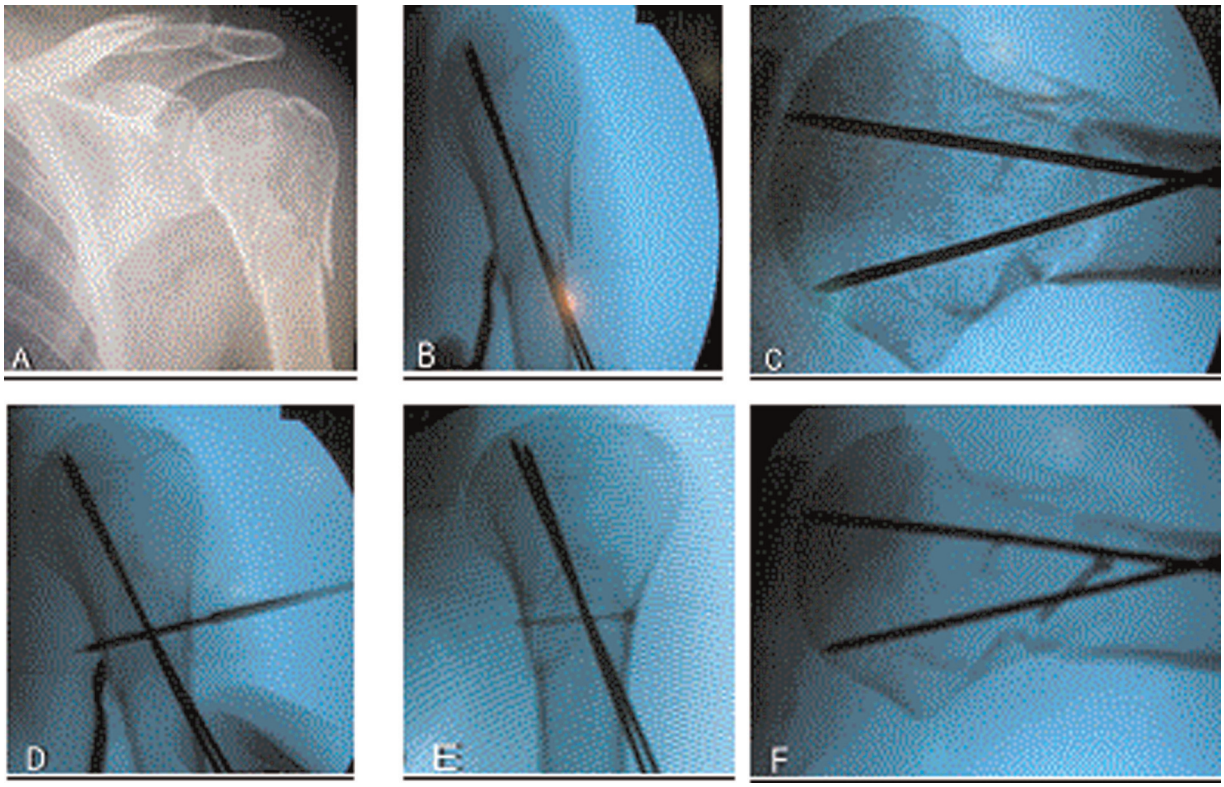
The operation time from induction of general anesthesia to extubation averaged 75 min, with a range of 25–125 min, with no intraarticular complications. A total of 50 patients of the 54 patients were available for follow-up for an average of 20 months (range, 6–30 months) postoperatively. Overall, 19 (38%) patients had two-part fractures (including eight greater tuberosity fractures, eight surgical neck fractures, and three with anatomical

Figure 4



Angle of entry of K-wire in the neck humerus in coronal and axil plane.

Figure 5



(a) A 52-year-old male patient presented after RTA with three-part fracture proximal left humerus. (b, c) Intraoperative AP and lateral views under image show reduction of the surgical neck and fixation by two crossing threaded K-wires. (d) Intraoperative AP under image shows reduction of the greater tuberosity and fixation by cannulated screw. (e, f) Intraoperative AP and lateral views show postreduction three-part fracture of proximal humerus fixed by two crossing threaded K-wires and cannulated screw. AP, anteroposterior.

neck fractures); three patients of the greater tuberosity fracture were associated with anterior shoulder dislocation. Moreover, 18 (36%) patients had three-part fractures, and 13 (26%) patients had four-part fractures. Four patients were lost to follow-up: two of them were cases of four-part fractures that died owing to non-associated reason within 3 months after surgery, and the last two patients experienced a second trauma caused by falling after the operation, which resulted in metaphyseal comminution and screw and wire loosening because of osteoporosis. They refused a further operation; therefore, no revision surgery was performed, but bracing was undertaken.

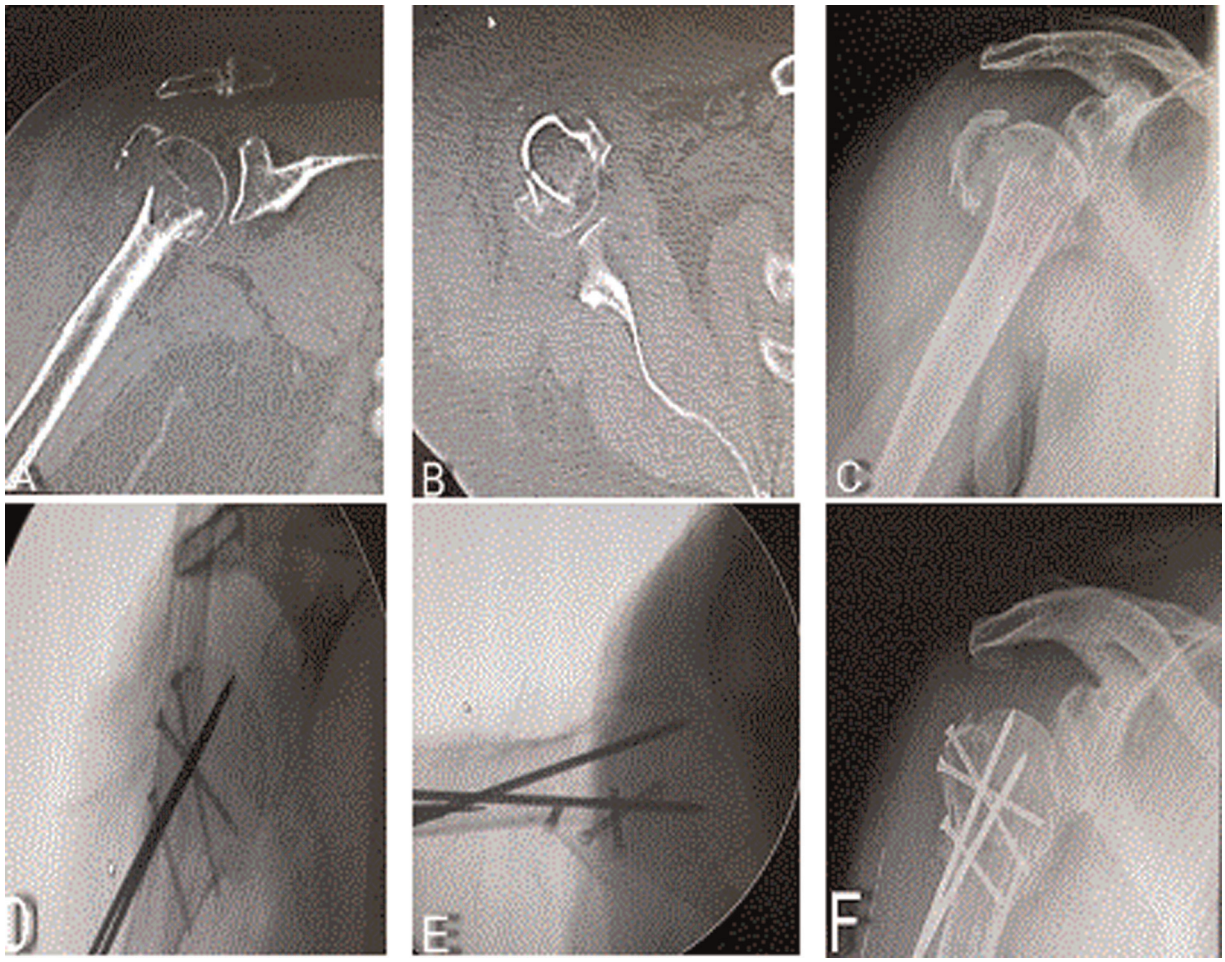
All fractures united within 4–8 weeks, with an average of 6 weeks, which depended on the degree of comminutions and age of the patient. A total of 10 (20%) patients had screw and K-wires perforation of the humeral head, which were removed after 4–5 weeks. Moreover, 14 (28%) patients had malunion, which did not require any treatment as the range of movement was acceptable.

A total of 35 (70%) patients had a constant score more than 90, nine (18%) patients had a score more than 85, and the rest six (12%) patients had a score less than 80. In comparison with the normal side, 40 (80%) patients had excellent or good results, seven (14%) patients had fair results, and three (6%) patients had poor results. Patients who have poor results had a low constant score of 64, 62, and 60, mainly owing to limited strength of abduction, external rotation, and subjective decrease in the level of activities. The patients with fair results had decrease range of motion than normal, with four of them having mild to moderate shoulder pain. Fracture dislocations had better results than expected. Surgical neck fractures had good excellent to good results, which were better than anatomical neck fractures.

Discussion

According to the recommendation of Neer, operative approaches with minimal dissection and rigid fixation have been emphasized with the objective of preservation of vascularity to the articular segment. The method of closed reduction and percutaneous fixation bears the inherent advantage of minimizing tissue destruction that, hence, preserves vascularity to the humeral head and facilitates early tissue healing and early mobilization.

Figure 6



(a, b) Coronal and axial CT and AP view of a 60-year-old male patient who presents after falling on his right shoulder with four-part valgus fracture of proximal right humerus. (d, e) Intraoperative AP and lateral views under image show reduction of the surgical neck and fixation by two crossing threaded K-wires and three cannulated screws in greater and lesser tuberosities after reduction. (f) Postoperative AP view shows good reduction and fixation of four-part proximal humeral fracture. AP, anteroposterior.

Percutaneous reduction and fixation of proximal humeral fractures requires careful study of the radiographs, which must be in two planes, and three-dimensional computed tomography if needed. They demonstrate the direction of displacement fracture parts, which identify the deforming muscle force around the fracture, which are benefit for ligamentotaxis.

Many studies [16–18] reported that there is no correlation between fracture type and postoperative range of motion after ORIF of proximal humerus fractures and have considered the severity of soft tissue injury as the main factor affecting function outcome. In this study, patients with two-part fractures showed significantly better results than those with three-part and four-part fractures. Similar results have been reported for proximal humeral fractures treated conservatively [19–21], which indicates that the degree of soft tissue injury may be insignificant during this procedure. Many authors [22] found that the rates of nonunion and AVN are between 12 and 14% and rates of osteoarthritis are between 12 and 28% 2–10 years after conservative treatment of comparable fractures. In the present study, none of the patients showed signs of osteoarthritis after a mean follow-up of 20 months. Furthermore, in the present study, a significant number of cases (20%) showed secondary impaction of the humerus head, leading to perforation of K-wires through the articular surface and requiring early removal of the entire implant. No significant difference in the functional outcome (Constant–Murley score) was reported between patients with and without K-wire perforation in the short-term follow-up, but this complication may lead to premature development of osteoarthritis in the long-term follow-up.

Resch and Hubner [13] reported many important features about the percutaneous technique, which

are: as follows (a) the important factor for the success of percutaneous reconstruction is the presence of soft tissue bridging the various fragments, thus offering support in the form of ligamentotaxis; (b) in the case of three-part fractures and four-part fractures, the percutaneous reduction technique usually produces good to very good functional results; (c) because of the reduced availability of soft tissue bridges between the fragments, four-part fractures with pronounced lateral displacement of the articular segment are clearly less suitable for the percutaneous technique than those without significant lateral displacement; (d) the necrosis rate is not increased by this technique; and (e) in the absence of fracture exposure, adhesion within the surrounding gliding surface is reduced and the rehabilitation period is shorter than following open surgery.

Conclusion

Closed reduction and percutaneous fixation of unstable proximal humerus fractures is a useful highly demanding technique in select patients. It has very good results if meticulous attention is taken in reduction and fixation steps. In addition, the biologic rationale of minimizing soft tissue dissection to preserve head vascularity is a very sound reason to select this approach in some three-part and four-part fractures, which is the key of success of the functional results of this procedure. The surgeon should develop skill and confidence with the technique with two-part fractures and then move to the more difficult three-part and four-part fractures as his or her skills improve. The keys to success are proper setup to understand the fracture biomechanics, a careful reduction to restore the anatomy, a biomechanically sound pin configuration to maximize fixation, appropriate aftercare to achieve healing, and avoidance of complications.

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Conflicts of interest

There are no conflicts of interest.

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