Fluoroscopic Technique for Open Reduction and Internal Fixation of Proximal Humeral Fracture Using the Proximal Humeral Locking Plate: Proposal of "Plate" and "Screw" Views

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Abstract: Proximal humeral fractures are common injuries with increasing incidence, particularly in the aging population. Nondisplaced or minimally displaced fractures can be treated conservatively whereas surgical fixation is usually indicated in the cases of displaced fractures. Various surgical options have been used for treatment of these fractures. Good outcomes have been reported with use of the Proximal Humeral Internal Locking System (PHILOS plate; Synthes, Zuchwil, Switzerland) as the implant of choice. However many complications have been reported, including varus malalignment, excessive retroversion of the articular part of the humerus, penetration of screws, and avascular necrosis of the humeral head. Therefore, we have hypothesized that an inadequate intraoperative fluoroscopic assessment may be an important factor contributing to these complications. We have described a step-by-step intraoperative fluoroscopic setup, including the proposal of a plate and screw view, focusing on the accuracy of reduction and proper placement of the PHILOS plate to prevent the complications previously described.

Proximal humeral fractures are the third most common fracture following hip and distal radius fractures in patients older than 65 years.[1,2] A majority of these fractures are either nondisplaced or minimally displaced and can be treated conservatively. Surgical fixation is usually indicated for displaced fractures.[3,4] Recently, an angular stable locking plate has been developed to assist with anatomic reduction and stronger anchorage. The Proximal Humeral Internal Locking System (PHILOS; Synthes, Zuchwil, Switzerland) is widely used as it provides a well-fitted precontoured shape and stable locking system, particularly for osteoporotic bone. Various articles have reported good functional outcomes after fixation using the PHILOS plate.[5,6] Nevertheless, many complications have been reported as well with the use of the PHILOS plate, such as varus malalignment, excessive retroversion of the articular part of the humerus, penetration of screws, and avascular necrosis of the humeral head.[7] Surgical technique for open reduction and internal fixation (ORIF) of proximal humeral fractures is usually difficult as it often involves the fixation of comminuted fractures in osteoporotic bone. The shoulder joint consists of complex anatomy that connects the upper extremity to the trunk. The thoracic cage obscures some part of the shoulder joint. We retrospectively reviewed cases that had postoperative complications and hypothesized that inadequate intraoperative fluoroscopic imaging may have been a factor contributing to these complications. To our knowledge, there is limited scientific evidence in the literature regarding fluoroscopic technique for ORIF of proximal humeral fractures. With an increasing incidence of proximal humeral fractures in the aging population, good understanding and proper use of the fluoroscopic techniques for ORIF of the proximal humeral fractures using PHILOS plate should be of great benefit. We have described a step-by-step intraoperative fluoroscopic setup, including the proposal of plate and screw views

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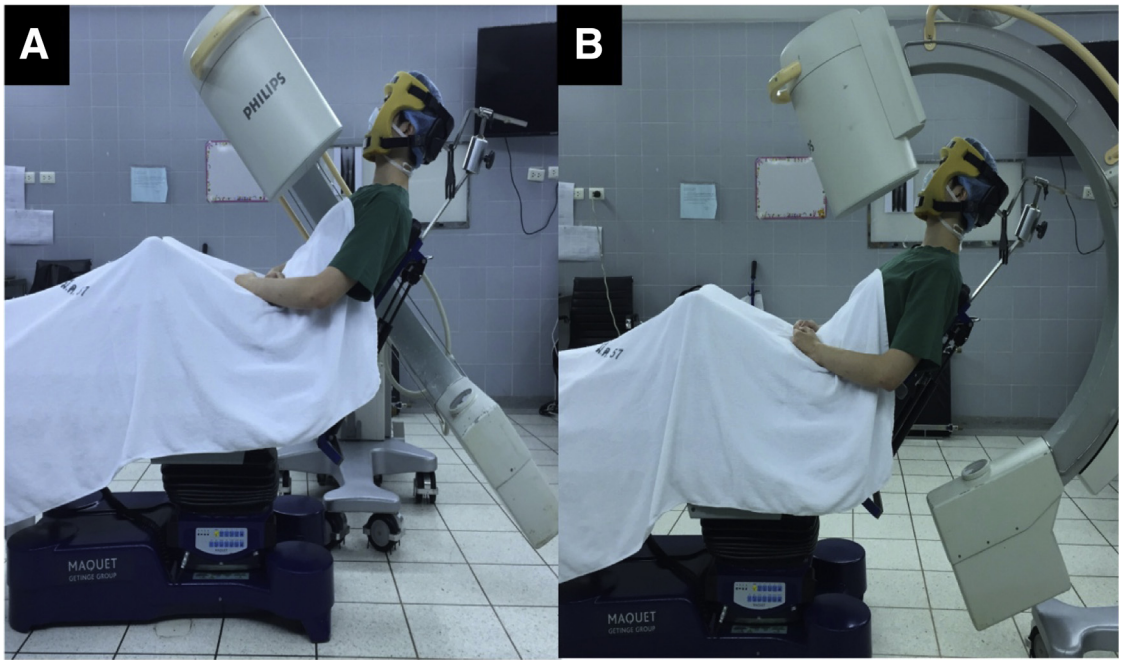

Fig 1. C-arm position. From the contralateral side (A), from over the head and parallel to the operating table (B).

focusing on the accuracy of reduction and proper placement of the PHILOS plate to prevent complications that are related to inadequate intraoperative fluoroscopic assessment. These complications include varus malalignment, excessive retroversion, and screw penetration.

The Fluoroscopic Technique

Under general anesthesia, the patient is placed in the beach chair position (at 60°) with the entire limb prepped for free mobilization. The C-arm could be addressed in 2 positions, with the first position being from the contralateral side (Fig 1A) and the second position being over the head and parallel to the operating table (Fig 1B). Intraoperatively, we prefer to mobilize the patient's limb rather than reposition the C-arm for an adequate assessment (Video 1). Regarding basic anatomy, the articular surface of the humerus is retroverted approximately 20° to 30° relative to the humeral shaft (Fig 2A). Most surgeons acknowledge that the PHILOS plate has been designed for placement lateral to the bicipital groove. More importantly, the PHILOS plate must be placed opposite to the articular surface, which will allow the divergent locking screws to achieve maximum purchase at the humeral head (Fig 2B). The anteroposterior and lateral imaging views of the reduced fracture obtained intraoperatively should be in reference to the plate

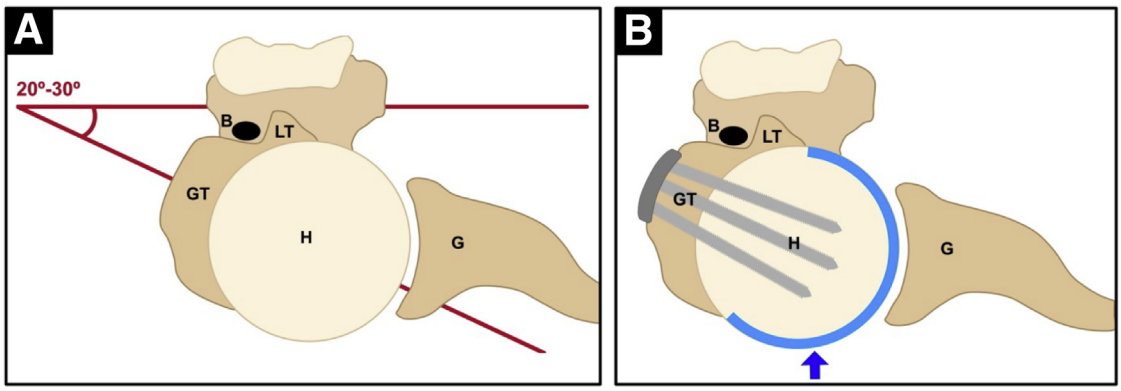

Fig 2. The articular surface of the humerus is retroverted approximately 20°-30° relative to the humeral shaft (A). The proper position of the PHILOS plate should be opposite to the articular surface that allows the divergent locking screws to achieve the maximum purchase at the humeral head (B). (B, long head biceps tendon; G, glenoid; GT, greater tuberosity; H, humeral head; LT, lesser tuberosity; PHILOS, Proximal Humeral Internal Locking System [Synthes].)

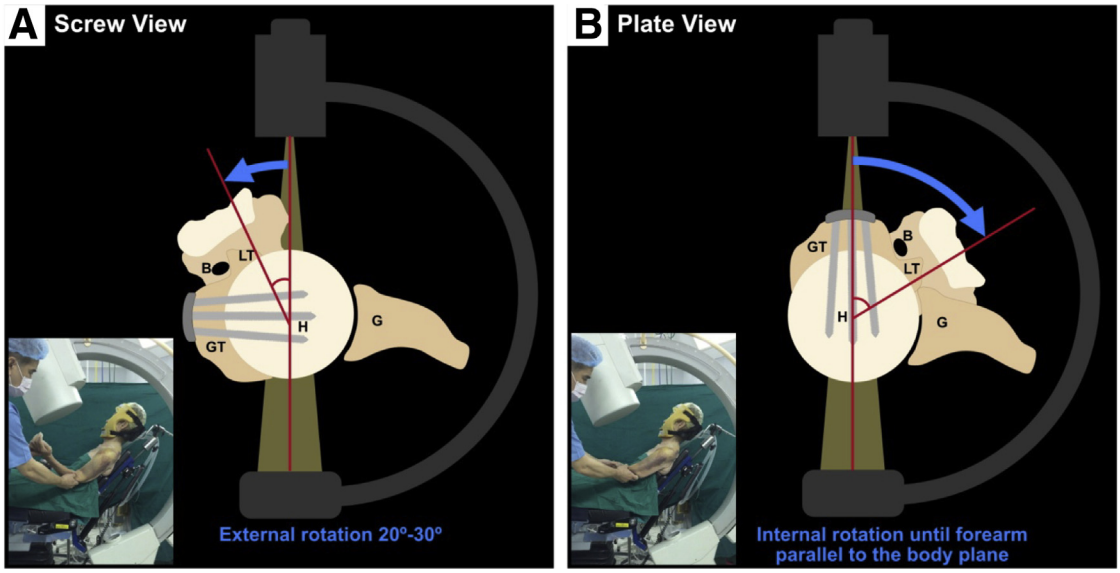

Fig 3. Screw view: The arm is positioned at 20°-30° of external rotation. This view shows the maximum length of the inserted screws, and only the edge of the PHILOS plate can be seen (A). Plate view: The arm is internally rotated until the forearm is parallel to the coronal plane of the body. This view shows the full profile of the PHILOS plate, and only the distal portion of the locking screws spreading to the periphery can be seen (B). (B, long head biceps tendon; G, glenoid; GT, greater tuberosity; H, humeral head; LT, lesser tuberosity; PHILOS, Proximal Humeral Internal Locking System [Synthes].)

position, not according to the limb position as might be misconstrued.

Screw View

In this view, the arm is positioned in 20° to 30° of external rotation (Fig 3A). This allows the articular surface of the humerus to be fully engaged in the glenoid fossa and corresponds with a retroversion of 20° to 30° in relation to the humeral shaft. As the name proposes, this view shows the maximum length of the inserted screws and only the edge of the PHILOS plate can be seen (Video 1). Two major pitfalls can be

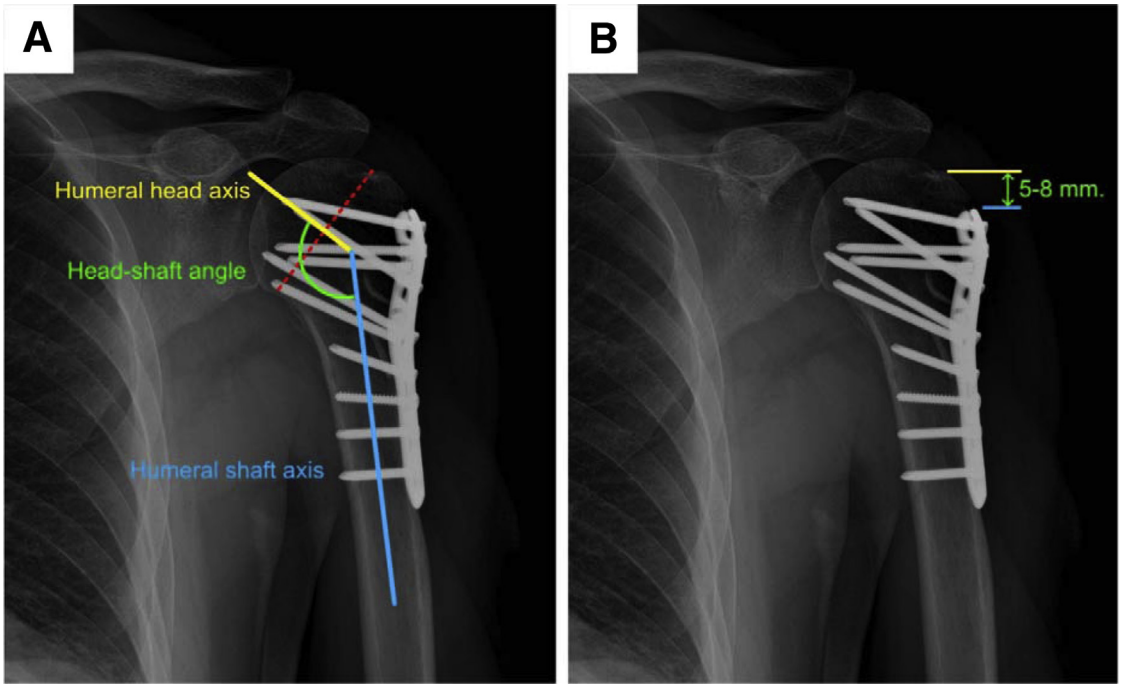

Fig 4. Screw view: The humeral head–shaft angle (A). The appropriate level of the PHILOS plate placement is seen, which ideally should be 5-8 mm below the tip of the greater tuberosity (B). (PHILOS, Proximal Humeral Internal Locking System [Synthes].)

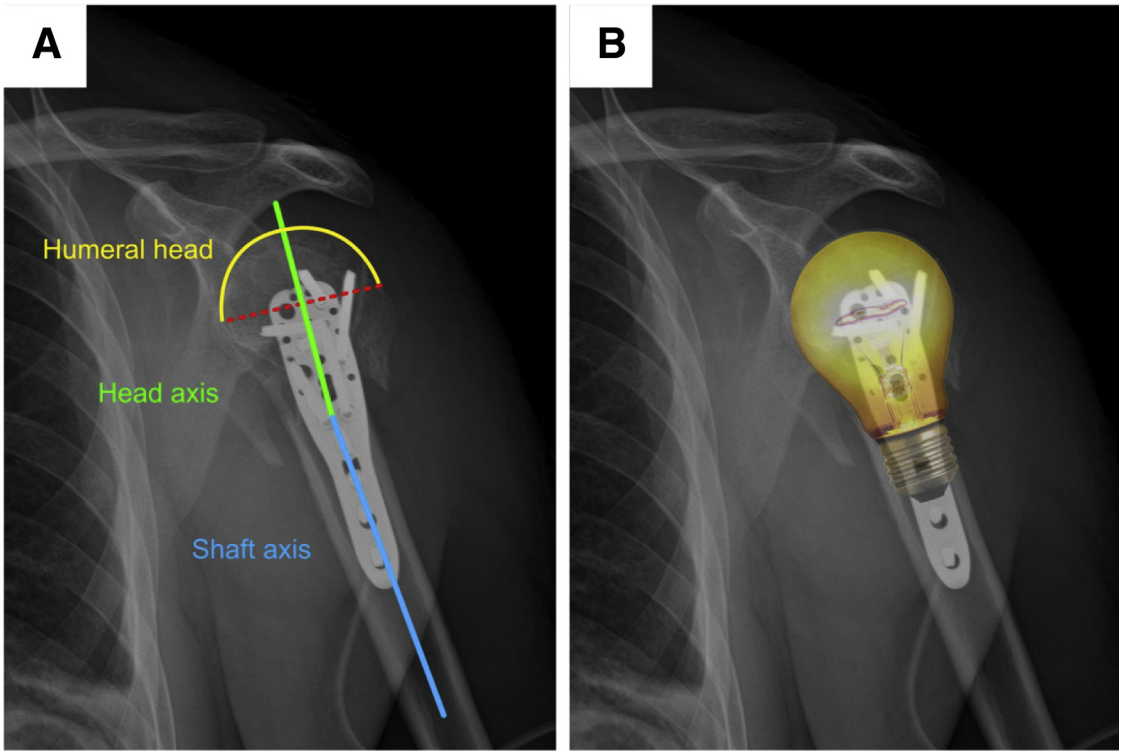

Fig 5. Plate view: This view shows the full profile of the PHILOS plate (A). The articular surface appears as a light bulb centered and over the plate (B). (PHILOS, Proximal Humeral Internal Locking System [Synthes].)

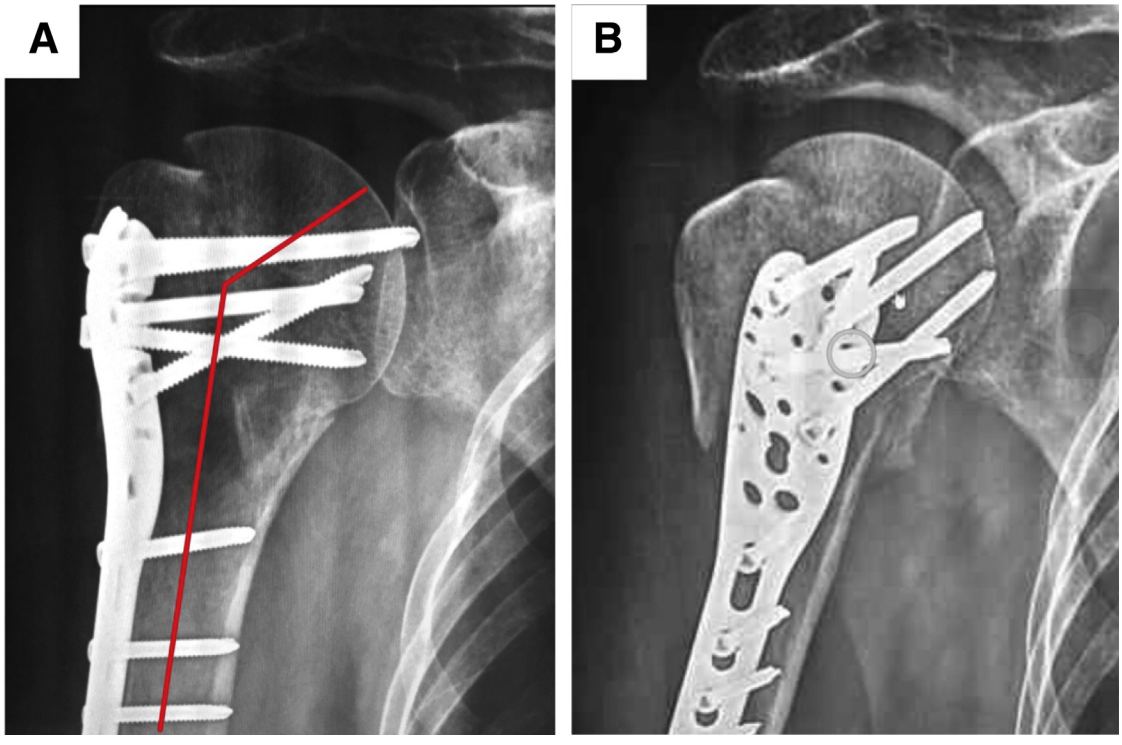

Fig 6. The case where screw penetration could not be detected intraoperatively is shown. A postoperative radiograph of right shoulder, AP view, revealed acceptable head-shaft angle but screw penetration was seen (A). The light bulb location is not centered and over the plate (B), therefore excessive retroversion should be suspected. Incorrect plate placement was observed with screw penetration anteriorly. (AP, anteroposterior.)

Table 1. Crucial Steps of the Fluoroscopic Technique for ORIF of Proximal Humeral Fracture Using the PHILOS Plate

Patient position
Beach chair position (at 60°) with entire limb prepped for free mobilization. The original beach chair provides better fluoroscopic image of the shoulder region as it lacks back support.
C-arm position
Contralateral side or
Over the head and parallel to the operating table
Ipsilateral side: obstructs assessment of the surgical field
Techniques
Mobilize the patient's limb rather than repositioning the C-arm
Use the technique of plate and screw views in reference to the position of the plate, not the patient's position

ORIF, open reduction and internal fixation; PHILOS, Proximal Humeral Internal Locking System (Synthes).

assessed and addressed in this view. First of all, the humeral head–shaft angle can be assessed to prevent varus malalignment (Fig 4A). Second, the appropriate level of the PHILOS plate placement can be assessed, which ideally should be 5 to 8 mm below the tip of the greater tuberosity to avoid secondary impingement (Fig 4B).

Plate View

In this view, the arm is internally rotated until the forearm is parallel to the coronal plane of the body (Fig 3B). As the name states, this view shows the full profile of the PHILOS plate. The PHILOS plate should be positioned opposite to the articular surface, at the center and over the humeral head and the shaft. The articular surface appears as a light bulb that is centered and over the PHILOS plate (Fig 5). Only the distal portion of the screws spreading to the periphery can be seen (Fig 5). However, if the classic light bulb is not seen in the appropriate position after placing the PHILOS plate lateral to the bicipital groove, malrotation of the humeral head should be suspected especially if excessive retroversion is seen. This should be of particular interest given that excessive retroversion often leads to 3-part fractures as a result of pull-out of the subscapularis tendon (Fig 6). When this malrotation occurs, there is risk of screw penetration.

The crucial steps of the fluoroscopic technique for ORIF proximal humeral fracture using the PHILOS plate is presented in Table 1. Summaries of the plate and screw views, their advantages/disadvantages, and pearls/pitfalls are presented in Tables 2, 3, and 4, respectively. The rehabilitation protocol following ORIF of proximal humeral fracture using the PHILOS plate is presented in Table 5.

Table 2. Summary of Plate and Screw Views

Screw view
Shows the maximum length of the screws being inserted
Articular surface of the humerus is fully engaged to the glenoid fossa
Arm position externally rotated 20°-30°
Only the edge of the PHILOS plate can be seen
Assessment of the head-shaft angle and proper level of the PHILOS plate
Plate view
Shows the full profile of the PHILOS plate
Articular surface of the humerus overlaps with the PHILOS plate and appears as a light bulb centered and over the plate
Arm position is internally rotated until the forearm is parallel to the coronal plane of the body
Only the distal portion of the screws spreading to periphery can be seen
Assessment of malrotation and screw penetration particularly if there is incorrect placement of the PHILOS plate

PHILOS, Proximal Humeral Internal Locking System (Synthes).

Table 3. The Advantages and Disadvantages

Advantages
Beach chair position allows better fluoroscopic image.
The plate and screw views are 2 orthogonal views that provide adequate details of fixation.
Forearm reposition for different fluoroscopic views is easier
Disadvantages
Supine position makes it difficult for fluoroscopic assessment.
Two orthogonal views in reference to patient's position provide inadequate details of fixation.
Reposition of the C-arm for different fluoroscopic views is difficult and takes more time.

Table 4. Pearls and Pitfalls of the Fluoroscopic Technique Using Plate and Screw Views

Pearls
• The use of an original beach chair provides better fluoroscopic image intensification of the shoulder region as it lacks back support
• The intraoperative fluoroscopic images taken should be referenced from the position of the PHILOS plate rather than the position of the patient
• The C-arm should be positioned contralateral to the surgical field or over the head of the operating table parallel to the patient to assess the surgical field more efficiently
• The screw view detects malalignment of the reduction (particularly varus)
• The plate view detects screw penetration, especially when there is excessive retroversion of the humeral head
• Forearm repositioning without disruption of the C-arm position for different fluoroscopic views results in quick assessment
Pitfalls
• The use of a standard operating table set up in beach chair position may not provide adequate fluoroscopic image of the shoulder region as usually there are still radiopaque side bars present
• Imaging of the anteroposterior and lateral views that is referenced from the position of the patient rather than the position of the PHILOS plate can result in undetected complications such as screw penetration or malalignment
• The C-arm positioned ipsilateral to the surgical field obstructs assessment the surgical field
• Repositioning of the C-arm for different fluoroscopic views results in a prolonged operation time

PHILOS, Proximal Humeral Internal Locking System (Synthes).

Table 5. Rehabilitation Protocol Following ORIF of Proximal Humeral Fracture Using PHILOS

1. Arm sling for 4-6 weeks
2. Passive ROM exercise is allowed 48-72 hours postoperation
3. Active assisted ROM exercise is allowed 3-4 weeks postoperation

ORIF, open reduction and internal fixation; PHILOS, Proximal Humeral Internal Locking System (Synthes); ROM, range of motion.

Discussion

When an unstable displaced proximal humeral fracture is encountered, an angular stable locking plate, known as the PHILOS plate, is a widely preferred implant. It allows stable fixation of the fracture, particularly in osteoporotic bone. Various articles have reported successful outcomes using this angular stable device. Nevertheless, Sudkamp et al.[8] reported a relatively high complication rate of 34% in a prospective, multicenter, observational study. These complications included screw penetration, malreduction, loss of reduction, and avascular necrosis. The greater number of complications were associated with incorrect surgical technique, with 40% of complications already presented at the end of the procedure.[9]

Therefore, this indicates that correct surgical technique as well as an adequate intraoperative fluoroscopic assessment will lead to stable fixation and allow the surgeon to avoid these particular complications. This article describes a step-by-step fluoroscopic technique for ORIF of proximal humeral fracture, including the use of plate and screw views. It focuses on the accuracy of reduction and the precise placement of the PHILOS plate, which has rarely been mentioned in the existing literature. This technique is of great value to achieve successful outcomes.

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