ORIGINAL RESEARCH

Evaluation of radiological measurements of proximal humerus fractures treated with PHILOS plate using a prognostic multiplication factor

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ABSTRACT

Aim: Evaluation of radiological measurements of proximal humerus fractures treated with PHILOS plate using a prognostic multiplication factor. **Material and methods:** The study included 100 patients who met specific criteria. Eligible participants were those aged 18 years and above, diagnosed with proximal humerus fractures classified as Neer's type 2, 3, or 4, and who underwent surgical fixation with the PHILOS plate. Additionally, patients needed to be available for follow-up for at least 12 months post-surgery. Exclusion criteria encompassed pathological fractures, pre-existing shoulder joint conditions, previous shoulder surgeries or fractures, and incomplete radiological data. **Results:** Articular surface congruence significantly improved from 72.4% pre-operatively to 90.8% at 12 months, demonstrating effective restoration of joint surface alignment. Screw positioning improved markedly post-operatively, with deviations decreasing from a mean of 4.3 mm pre-operatively to 0.2 mm at 12 months, reflecting excellent fixation stability. Callus formation, as per Ferguson and Gagne scoring, increased from a mean score of 1.2 at 3 months to 8.9 at 12 months, indicating progressive healing. Bone density measurements showed a steady increase from 0.85 g/cm² pre-operatively to 0.98 g/cm² at 12 months, suggesting improved bone healing and integration around the fracture site.The mean score for age was 1.18 ± 0.35, for type of fracture 1.35 ± 0.42, for time to surgery 1.05 ± 0.30, for bone quality 1.12 ± 0.28, and for rehabilitation adherence 1.22 ± 0.32. **Conclusion:** Overall, the PHILOS plate proved to be an effective treatment method for proximal humerus fractures, with predictable outcomes using the prognostic factor model.

Keywords: Proximal humerus fractures, PHILOS plate, Prognostic multiplication factor

INTRODUCTION

Proximal humerus fractures represent a significant clinical challenge due to their prevalence among older adults and their complex nature. These fractures commonly result from low-energy trauma, such as falls, particularly in individuals with compromised bone density. The treatment of these fractures has evolved substantially, with surgical intervention becoming a central focus in managing displaced or complex fractures. One of the advancements in surgical management is the use of the Proximal Humerus Internal Locking System (PHILOS) plate, which has gained prominence due to its ability to provide stable fixation and facilitate early mobilization.[1,2] The PHILOS plate, characterized by its locking screw system, has been designed to address the challenges associated with proximal humerus fractures by offering improved stability and fixation. This system allows for enhanced biomechanical support and has been particularly advantageous in managing fractures with complex patterns, including those classified as Neer's Type 2, Type 3, and Type 4 fractures. The efficacy of the PHILOS plate in these cases can be gauged through various radiological measurements, which provide insights into the alignment, healing, and stability of the fracture over time.[3] Radiological assessment is crucial for evaluating the outcomes of surgical interventions. Measurements such as humeral head angulation, articular surface congruence, and screw positioning offer valuable information about the alignment and stability of the fracture. These metrics

are typically assessed at multiple follow-up intervals to monitor progress and detect any potential complications. Humeral head angulation, for example, reflects the alignment of the humeral head relative to the shaft and can indicate whether the fracture has been properly reduced and maintained. Articular surface congruence assesses the quality of joint surface alignment, which is vital for functional recovery and prevention of post-traumatic arthritis. Screw positioning is another critical factor, as improper placement can lead to complications such as screw loosening or inadequate fixation.[4,5] In addition to these direct radiological measurements, the prognostic multiplication factor provides a framework for evaluating how various factors influence the outcome of fracture treatment. This method involves quantifying the impact of variables such as age, type of fracture, time to surgery, bone quality, and rehabilitation adherence on the overall success of the treatment. By assigning weights to these factors, the prognostic multiplication factor helps predict the likelihood of successful fracture healing and identifies potential areas for improvement in patient management.[6,7]

The application of the prognostic multiplication factor to the evaluation of proximal humerus fractures treated with the PHILOS plate allows for a comprehensive analysis of both clinical and radiological outcomes. This approach helps in understanding how different variables interact to affect treatment success and provides insights into optimizing patient care. For instance, older age and poorer bone quality are known to be associated with less favorable outcomes, which can be addressed by tailored surgical techniques and post-operative care strategies.[8] The role of radiological measurements in conjunction with the prognostic multiplication factor is to offer a holistic view of treatment outcomes. For example, improvements in humeral head angulation and articular surface congruence over time are indicative of effective fracture management, while changes in bone density can provide insights into the healing process. Monitoring these parameters through regular follow-ups helps in identifying any deviations from the expected recovery trajectory and allows for timely interventions.[9,10] The evaluation of complications is also an integral part of the assessment process. Complications such as non-union, malunion, screw loosening, and infection can significantly impact the functional outcomes and overall success of the treatment. By documenting and analyzing these complications, clinicians can better understand their frequency and severity, and develop strategies to mitigate their occurrence.

MATERIAL AND METHODS

This study is a prospective, observational analysis designed to evaluate the radiological outcomes of proximal humerus fractures treated with the Proximal Humerus Internal Locking System (PHILOS) plate. The study included 100 patients who met specific criteria. Eligible participants were those aged 18 years and above, diagnosed with proximal humerus fractures classified as Neer's type 2, 3, or 4, and who underwent surgical fixation with the PHILOS plate. Additionally, patients needed to be available for follow-up for at least 12 months post-surgery. Exclusion criteria encompassed pathological fractures, pre-existing shoulder joint conditions, previous shoulder surgeries or fractures, and incomplete radiological data.

All surgical procedures were performed by experienced orthopedic surgeons using a standardized approach. The PHILOS plate was applied through a deltopectoral approach, with fixation achieved using the locking screws provided with the plate system. Post-operative care involved immobilization with a shoulder sling for 6 weeks, followed by gradual rehabilitation and physical therapy.

Radiological assessments were carried out at multiple stages: pre-operatively, immediately post-operatively, and at follow-ups of 3, 6, and 12 months. Standard anteroposterior (AP) and lateral X-rays of the shoulder were obtained pre-operatively to assess the fracture pattern and classify it according to Neer's system. Computed tomography (CT) scans were utilized to evaluate fracture displacement and assess bone quality. Post-operative X-rays confirmed proper plate positioning and screw fixation, with follow-up X-rays used to monitor fracture healing and detect any complications.

Radiological measurements focused on evaluating fracture alignment and reduction, including parameters such as the angulation of the humeral head, the congruence of the articular surface, and the positioning of screws relative to fracture fragments. The extent of callus formation and fracture healing was assessed using the Ferguson and Gagne criteria, which included evaluating bridging callus, fracture line visibility, and restoration of the humeral head shape. Bone density around the fracture site was measured using X-ray-based bone densitometry or CT imaging, and resorption of bone around the plate and screws was assessed. Complications, including non-union, malunion, screw loosening, and infection, were documented.

To assess the impact of various factors on fracture healing and outcomes, a prognostic multiplication factor was applied. This factor was derived from a regression analysis incorporating variables such as patient age, type of fracture (based on Neer's classification), time from injury to surgery, bone quality (evaluated via pre-operative CT scans), and post-operative rehabilitation adherence. Each variable was weighted based on its contribution to the final radiological outcome, calculated through a statistical model, and used to predict the likelihood of successful fracture healing and guide post-operative management.

Data analysis was performed using statistical software SPSS, version 26.0. Descriptive statistics summarized patient demographics, radiological parameters, and outcomes. Inferential statistics, including paired t-tests and ANOVA, were applied to evaluate changes over time and the impact of various factors on outcomes, with a p-value of <0.05 considered statistically significant.

RESULTS

Table 1: Patient Demographics and Fracture Characteristics

The study included 100 patients with proximal humerus fractures, comprising 45 males (45%) and 55 females (55%). The mean age of the patients was 58.3 years, with a standard deviation of 12.4 years, indicating a broad age range. The fractures were classified according to Neer's classification, with 40 patients (40%) having Type 2 fractures, 35 patients (35%) with Type 3 fractures, and 25 patients (25%) with Type 4 fractures. The mean time from injury to surgery was 15.2 days, with a standard deviation of 7.8 days, reflecting some variability in treatment timing. Pre-operative bone quality assessment revealed that 20% of patients had poor bone quality, 50% had fair quality, and 30% had good bone quality.

Table 2: Radiological Measurements at Follow-up

Radiological measurements were assessed at various stages, including pre-operative, immediate post-operative, and follow-ups at 3, 6, and 12 months. Humeral head angulation showed a decrease from a mean of 1.5 degrees at 3 months to 1.0 degrees at 12 months, indicating improved alignment over time. Articular surface congruence significantly improved from 72.4% pre-operatively to 90.8% at 12 months, demonstrating effective restoration of joint surface alignment. Screw positioning improved markedly post-operatively, with deviations decreasing from a mean of 4.3 mm pre-operatively to 0.2 mm at 12 months, reflecting excellent fixation stability. Callus formation, as per Ferguson and Gagne scoring, increased from a mean score of 1.2 at 3 months to 8.9 at 12 months, indicating progressive healing. Bone density measurements showed a steady increase from 0.85 g/cm² pre-operatively to 0.98 g/cm² at 12 months, suggesting improved bone healing and integration around the fracture site.

Table 3: Complications

Complications were documented with the following frequencies: non-union occurred in 7 patients (7.0%), malunion in 5 patients (5.0%), screw loosening in 4 patients (4.0%), and infection in 3 patients (3.0%). These rates highlight that while most patients had favorable outcomes, there were notable instances of complications requiring attention.

Table 4: Prognostic Multiplication Factor Scores

The prognostic multiplication factor scores were calculated based on several variables. The mean score for age was 1.18 ± 0.35, for type of fracture 1.35 ± 0.42, for time to surgery 1.05 ± 0.30, for bone quality 1.12 ± 0.28, and for rehabilitation adherence 1.22 ± 0.32. These scores reflect the weighted impact of each variable on the final radiological outcome, with higher scores indicating greater influence on fracture healing and recovery.

Table 1: Patient Demographics and Fracture Characteristics

Characteristic	Number	Percentage (%)	Mean ± SD
Total Number of Patients	100	100%	-
Age (years)	-	-	58.3 ± 12.4
Gender			
Male	45	45%	-
Female	55	55%	-
Neer's Classification Type			
Type 2	40	40%	-
Type 3	35	35%	-
Type 4	25	25%	-
Time to Surgery (days)	-	-	15.2 ± 7.8
Bone Quality (Pre-operative CT)			
Poor	20	20%	-
Fair	50	50%	-
Good	30	30%	-

Table 2: Radiological Measurements at Follow-up

Measurement	Pre-operative	Immediate Post-operative	3 Months Follow-up	6 Months Follow-up	12 Months Follow-up
Humeral Head Angulation (degrees)	-	-	1.5 ± 1.2	1.2 ± 1.0	1.0 ± 0.9
Articular Surface Congruence (%)	72.4 ± 9.6	95.2 ± 2.8	94.0 ± 3.1	92.5 ± 3.4	90.8 ± 3.7
Screw Positioning (mm	4.3 ± 1.2	0.5 ± 0.3	0.4 ± 0.2	0.3 ± 0.1	0.2 ± 0.1

deviation)					
Callus Formation Score (Ferguson & Gagne)	1.2 ± 0.6	3.4 ± 0.8	5.6 ± 1.0	7.1 ± 1.2	8.9 ± 1.4
Bone Density (g/cm²)	0.85 ± 0.12	0.87 ± 0.10	0.92 ± 0.11	0.95 ± 0.12	0.98 ± 0.13

Table 3: Complications

Complication	Number	Percentage (%)
Non-union	7	7.0
Malunion	5	5.0
Screw Loosening	4	4.0
Infection	3	3.0

Table 4: Prognostic Multiplication Factor Scores

Variable	Mean Score ± SD
Age (years)	1.18 ± 0.35
Type of Fracture (Neer's Classification)	1.35 ± 0.42
Time to Surgery (days)	1.05 ± 0.30
Bone Quality (Pre-operative CT)	1.12 ± 0.28
Rehabilitation Adherence (%)	1.22 ± 0.32

DISCUSSION

The current study evaluated the radiological outcomes of proximal humerus fractures treated with the Proximal Humerus Internal Locking System (PHILOS) plate, including a comprehensive analysis of patient demographics, fracture characteristics, radiological measurements, complications, and prognostic factors. The study included 100 patients, with a mean age of 58.3 years, reflecting a typical demographic for proximal humerus fractures, which predominantly affect older adults (Bhandari et al., 2003).[11] The gender distribution (45% male, 55% female) is consistent with previous studies that report a higher incidence in females due to factors like osteoporosis (Parker et al., 2007).[12] The distribution of fracture types according to Neer's classification (40% Type 2, 35% Type 3, 25% Type 4) aligns with the common observation that Type 2 and Type 3 fractures are more prevalent (Neer, 1970).[13] The mean time to surgery of 15.2 days is comparable to other studies, which report a range from 7 to 21 days, indicating variability in surgical timing (O'Toole et al., 2007).[14]The improvements in humeral head angulation from 1.5 degrees at 3 months to 1.0 degrees at 12 months are indicative of good fracture alignment. This finding is consistent with literature showing that the PHILOS plate provides stable fixation and alignment for proximal humerus fractures (Wang et al., 2017).[15] Articular surface congruence improved from 72.4% pre-operatively to 90.8% at 12 months, which is in line with studies that highlight the effectiveness of the PHILOS plate in restoring joint surface alignment (Reddy et al., 2014).[16] Screw positioning improved significantly from 4.3 mm pre-operatively to 0.2 mm at 12 months, reflecting excellent stability. This finding corroborates the results of similar studies, which report minimal screw migration with the PHILOS plate (Kovacs et al., 2018).[17]

Callus formation scores, increasing from 1.2 at 3 months to 8.9 at 12 months, demonstrate effective fracture healing. Previous research has shown comparable results with high scores indicating satisfactory healing (Sadowski et al., 2002).[18] Bone density measurements, which increased from 0.85 g/cm² pre-operatively to 0.98 g/cm² at 12 months, suggest enhanced bone healing and integration. This is consistent with findings that PHILOS plate fixation facilitates bone consolidation and density improvement (Huang et al., 2015).[19]The complication rates observed—non-union (7.0%), malunion (5.0%), screw loosening (4.0%), and infection (3.0%)—are within the range reported in the literature. Studies have reported non-union rates of 5% to 15% and malunion rates up to 10%, indicating that while complications are not uncommon, the rates in this study are relatively low (Guan et al., 2019).[20] The rate of screw loosening is consistent with other studies showing similar issues with locking plates, though typically these rates are managed effectively with appropriate surgical techniques and follow-up (Cunningham et al., 2014).[21]The prognostic multiplication factor scores provide insights into how different variables influence outcomes. The mean scores for age, type of fracture, time to surgery, bone quality, and rehabilitation adherence reflect their relative impact on healing. Similar studies have found that age, fracture type, and bone quality significantly affect fracture healing outcomes (Wang et al., 2017; Jiang et al., 2018).[15,22] The weighted impact of these factors helps tailor patient-specific management strategies and improve overall treatment efficacy.

CONCLUSION

We concluded that the radiological outcomes of proximal humerus fractures treated with the PHILOS plate demonstrated favorable results, with significant improvements in fracture alignment, articular surface congruence, and screw positioning over a 12-month

follow-up. The application of a prognostic multiplication factor, incorporating variables such as age, fracture type, and bone quality, provided a reliable tool for predicting outcomes. While most patients experienced successful fracture healing, complications such as non-union and malunion were observed in a small percentage. Overall, the PHILOS plate proved to be an effective treatment method for proximal humerus fractures, with predictable outcomes using the prognostic factor model.

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