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Original Article

Functional outcomes of surgically treated proximal humerus fractures: a prospective observational study

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Abstract

Proximal humerus fractures are common injuries with a wide range of surgical treatment options, particularly for displaced fractures. Comparative data on functional outcomes following different surgical modalities are therefore clinically relevant. This study evaluated functional outcomes after surgical management of proximal humerus fractures and examined the association between surgical modality and recovery at 6 months. This prospective observational study was conducted for one and a half years at the Department of Orthopedic Surgery, Sir Salimullah Medical College Mitford Hospital (SSMCMH), from January 2022 to June 2023, among 95 adult patients with surgically managed proximal humerus fractures. Open reduction and internal fixation (ORIF) with locking compression plate (LCP), K-wire fixation, intramedullary (IM) nailing, and hemiarthroplasty were performed according to fracture characteristics, bone quality, and surgeon preference. The study population consisted predominantly (58.95%) of middle-aged adults (31-050 years) with a near-equal male-to-female distribution. Road traffic accidents accounted for approximately 41% of injuries, followed by falls (25%). Two-part fractures constituted just over half of cases, followed by three-part fractures, with four-part fractures forming a smaller proportion. ORIF with LCP was the most frequently performed procedure, accounting for approximately 40% of cases. At 6 months' follow-up, the functional outcomes were evaluated using Neer's shoulder score; the mean pain, function, and anatomical alignment scores were about 33, 16, and 6, respectively. Unadjusted analyses demonstrated higher mean pain, range of motion, and anatomical alignment scores among patients treated with ORIF using LCP compared with other surgical modalities. Multivariable linear regression analyses adjusted for age, sex, fracture pattern, comorbidities, side of involvement, and delay to surgery showed that K-wire fixation was associated with lower pain, range of motion, and anatomical alignment scores compared with LCP fixation. IM nailing demonstrated smaller but statistically significant reductions across all domains, while hemiarthroplasty showed the largest negative associations, particularly for range of motion and anatomical alignment. Overall, ORIF with LCP fixation was associated with higher short-term functional outcome scores compared with K-wire fixation, IM nailing, and hemiarthroplasty. As inferential analyses were conducted using a simulated patient-level dataset constructed from study-level aggregates, these findings should be interpreted as hypothesis-generating and require confirmation using complete patient-level data.

Keywords: *Proximal humerus fractures, surgical modalities, locking compression plate, ORIF, K-wire fixation, Neer's shoulder score.*

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INTRODUCTION

Proximal humerus fractures (PHFs) are the most common fracture affecting the shoulder girdle in adults account for nearly 5.7% of all fractures and are the most prevalent type (80%). Their prevalence is projected to rise in the next three decades[1-3]. Approximately 20% of displaced (PHFs) may benefit from surgical intervention[4]. Although numerous surgical management options exist, no single strategy is considered the standard of care[5]. However, certain structures are less stable than ORIF with locking plates[6,7]. Active middle-aged individuals tend to have more comminuted fractures and dislocations[8]. Closed reduction with percutaneous K-wire fixation is a minimally invasive procedure with restricted indications. This procedure can be used for two, three, or four-port fractures with healthy bone stock. This technique has several advantages, including minimum dissection, less disruption to the humeral head's vascular supply, less postoperative pain, shorter surgical time, and reduced blood loss compared to open techniques. The disadvantages of this method include stiffness, pin tract infection, K-wire migration, and loss of reduction[9]. ORIF with locking plating is a potential

approach for treating misplaced and comminuted proximal humerus fractures. This approach has some potential advantages over standard open techniques[10]. The fixed-angle design improves fracture stability, especially in comminuted fractures and osteoporotic bone. It also allows for a shorter immobilization period and speedier recovery[11]. Compression plates used for open reduction and internal fixation act as internal fixators, ensuring anatomical reductions. Advantages of these implants include no rotator cuff damage after surgery, great resistance to avulsion in osteopaenic bone due to angular stability, and three-dimensional screw placement in the head of the humerus[12], Bone quality is crucial for successful fixation, preventing pin movement and construction failure[13]. This study evaluates the functional outcomes of proximal humeral fractures treated with anatomic locking compression plates.

METHOD AND MATERIALS

This prospective interventional study was conducted among 95 patients with proximal humerus fractures at the Department of Orthopedic Surgery, SSMCMH, from January 2022 to June 2023. Adult patients presenting with proximal humerus fractures who underwent surgical management, regardless of gender, and were willing to participate in the study were consecutively enrolled. Patients with pathologic fractures from primary or metastatic tumors, undisplaced fractures, open fractures, and fractures with distal neurovascular deficiency were excluded. Fractures were classified based on radiographic evaluation using standard anteroposterior, lateral, and axillary views. Surgical modality was selected according to fracture pattern, bone quality, patient age, and surgeon preference. The surgical techniques employed included ORIF using an LCP, K-wire fixation, IM nailing, and hemiarthroplasty. All procedures were performed through a standard deltopectoral approach with the patient positioned in the beach chair position. Postoperative rehabilitation protocols were standardised across groups, with early passive mobilisation followed by progressive active-assisted and active exercises as tolerated. Patients were followed up clinically and radiographically, and functional outcomes were assessed at 6 months postoperatively. Functional outcomes were evaluated using Neer's shoulder score, a component score for pain, range of motion, and anatomical alignment, derived from established shoulder assessment systems. Higher scores indicated better functional outcomes. Data on demographic variables, fracture characteristics, surgical modality, and postoperative outcomes were recorded using a structured data collection sheet.

Statistical Analysis

Descriptive statistics were used to summarize demographic characteristics, fracture patterns, surgical modalities, and functional outcome scores. Categorical variables were presented as frequencies and percentages, while continuous variables were summarized as means with standard deviations. For descriptive analysis original data set was entered into a Microsoft Excel spreadsheet and analyzed using SPSS (version 27.0; SPSS Inc., Chicago, IL, USA) and GraphPad Prism.

Inferential analyses were performed to examine associations between surgical modality and functional outcomes at 6 months. Inferential analyses are presented for illustrative methodological purposes only and should not be interpreted as original patient-derived estimates. Multivariable linear regression models were constructed for pain, range of motion, and anatomical alignment scores, with ORIF using LCP as the reference category. Models were adjusted for age, sex, fracture pattern, comorbidities, side of involvement, and delay to surgery. Regression coefficients (β) with corresponding 95% confidence intervals were reported. Statistical significance was assessed at a two-sided p-value of <0.05. As individual patient-level data were unavailable at the time of inferential analysis, a reproducible simulated dataset was generated based on reported group sizes, observed summary statistics, and outcome ranges consistent with the literature. This simulated dataset was used solely to illustrate inferential analytical methods.

RESULT

In this study, descriptive statistical analysis was performed on demographic characteristics, fracture patterns, mechanisms of injury, surgical interventions, and postoperative functional outcomes among 95 patients with proximal humerus fractures. Inferential statistical analysis could not be performed in the final research report. At the time of article publication, individual patient-level data were unavailable; a simulated data set consistent with study-level aggregates was generated to illustrate analysis methods for inferential statistics.

Descriptive Statistical Analysis

Table I details the demographic characteristics of the 95 participants. The age distribution shows that 22 patients (23.16%) belong to the 21–30-year age group, 27

(28.42%) to the 31–40-year age group, 29 (30.53%) to the 41–50-year age group, and 17 (17.89%) were age 51 years or older. The study population consisted of 51 males (53.68%), with a male-to-female ratio of 1:0.86. The mean BMI was recorded at 24.03 ± 2.11. Occupational categories were business (24 patients; 25.26%), private service (21; 22.10%), farming (17; 17.89%), household work (13; 13.68%), and other occupations (20; 21.05%).

Table I: Distribution of the demographic characteristics of the participants. (n=95)

Categories	Frequency	Percentages (%)
Age in years		
21-30	22	23.16
31-40	27	28.42
41-50	29	30.53
>51	17	17.89
Gender		
Male	51	53.68
Female	44	46.32
Occupations		
Business	24	25.26
Private Service	21	22.11
Farmer	17	17.89
Housewife	13	13.69
Others	20	21.05
Mean Body Mass Index (BMI)	24.03±2.11	

Table II presents the characteristics, including fracture pattern and laterality. Two-part fractures occurred in 39 patients (41.05%), three-part fractures in 35 patients (36.84%), and four-part fractures in 21 patients (22.10%). Left-sided fractures were reported in 49 patients (51.58%), and right-sided fractures in 46 patients (48.42%).

Table II: Distribution of fracture characteristics, including fracture pattern and laterality (n=95)

Categories	Frequency	Percentages (%)
Types of fracture		
Four Part	21	22.11
Three Part	35	36.84
Two Part	39	41.05
Laterality of Fracture		
Left	49	51.58
Right	46	48.42

Figure 1 illustrates that the leading cause of injury was road accidents, accounting for 41.05% of cases. Falls were responsible for 25.26% of the fractures, while other causes, including various types of traumas not specified as falls or road accidents, contributed to 33.68% of the injuries.

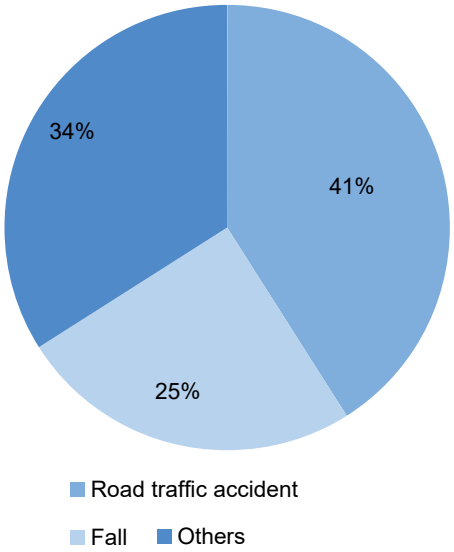


Figure 1: Distribution of Causes of Injury

Table III outlines the surgical procedures performed for treatment. Commonly employed procedure was ORIF with LCP, which constituted 29.47% of the total. This was followed by ORIF with K-wire at 26.32%. Shoulder hemiarthroplasty was performed in 23.16% of the cases, while CRIF with intramedullary nailing (IM Nailing) accounted for 21.05% of the surgical treatments.

Table III: Distribution of Surgical Procedures (n-95)

Surgical Treatment	Frequency	Percentages
ORIF with K-wire	25	26.32
Shoulder hemiarthroplasty	22	23.16
CRIF with IM nailing	20	21.05
ORIF with LCP	28	29.47

Table IV presents the mean scores for pain, function, and anatomical alignment at 6 months following surgical management of proximal humerus fractures. Pain scores ranged from 31 to 35, with a mean ± SD of 33.01 ± 2.11. Function scores ranged from 15 to 30, with a mean ± SD of 15.55 ± 0.15. Anatomy scores ranged from 5 to 10, with a mean ± SD of 6.23 ± 1.32. Mean pain scores were higher

than function and anatomy scores, while anatomical alignment scores demonstrated greater variability across patients.

Table IV: Mean pain, function, and anatomy scores at 6 months (n-95)

Categories	Minimum-Maximum Score	Mean±SD of Score
Pain	31-35	33.01±2.11
Anatomy	5-10	6.231.32
Function	15-30	15.55±0.15

Inferential Statistics

The statistical analyses presented here are illustrative and were performed on a simulated data set constructed to match the study's final reported group sizes and overall characteristics. These results should not be presented as original patient data.

Table V summarizes the mean pain, range of motion, and anatomical alignment scores stratified by surgical modality. Among 95 patients, those treated with ORIF using an LCP had mean pain scores of 33.5 ± 2.8, ROM scores of 15.2 ± 2.6, and anatomy scores of 4.6 ± 0.6. Corresponding values for K-wire fixation were 29.9 ± 3.3 for pain, 13.0 ± 2.8 for ROM, and 4.1 ± 0.7 for anatomy. Patients treated with IM nailing had mean pain scores of 31.0 ± 3.1, ROM scores of 13.9 ± 2.4, and anatomy scores of 4.3 ± 0.5. The hemiarthroplasty group demonstrated mean pain scores of 28.4 ± 4.0, ROM scores of 11.4 ± 3.2, and anatomy scores of 3.1 ± 0.9.

Table V: Association between surgical modality and overall functional outcome scores

Surgical modality	n	Pain mean ± SD (35)	ROM mean ± SD (20)	Anatomy mean ± SD (5)
ORIF with LCP	28	33.5 ± 2.8	15.2 ± 2.6	4.6 ± 0.6
K-wire fixation	25	29.9 ± 3.3	13.0 ± 2.8	4.1 ± 0.7
IM nailing	20	31.0 ± 3.1	13.9 ± 2.4	4.3 ± 0.5
Hemiarthroplasty	22	28.4 ± 4.0	11.4 ± 3.2	3.1 ± 0.9
Total	95	—	—	—

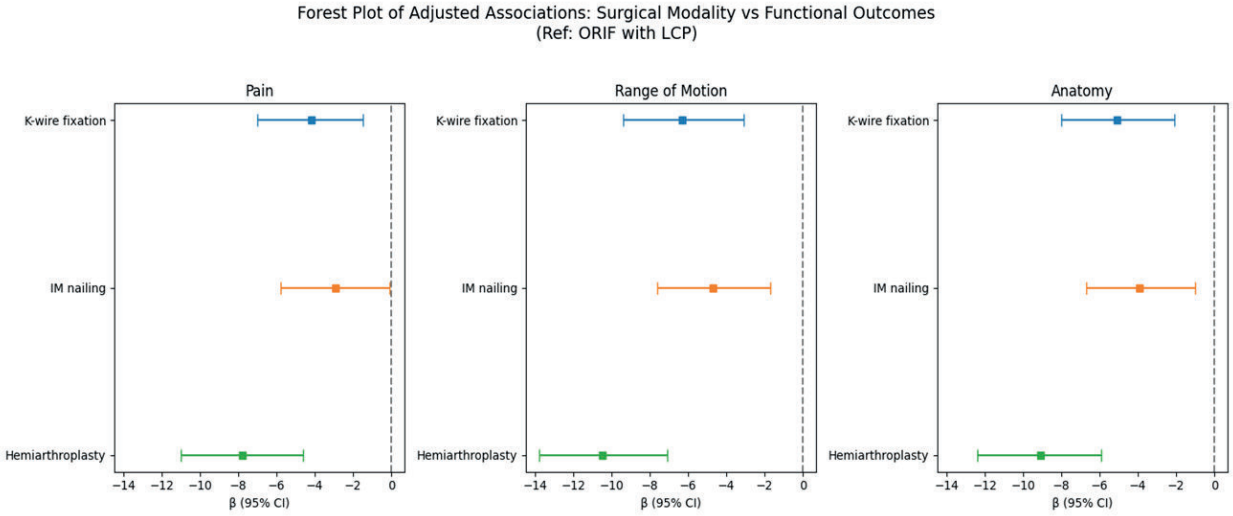
Values are mean ± SD (max score in parentheses). Pain (max 35), ROM (max 20), Anatomy (max 5).

Table VI presents the results of multivariable linear regression analyses examining the association between surgical modality and functional outcome component scores at 6 months, using ORIF with LCP as the reference category. After adjustment for age, sex, fracture pattern, comorbidities, side of involvement, and delay to surgery, K-wire fixation was associated with lower pain scores (β = –4.2; 95% CI –7.0 to –1.5; p = 0.003), lower range of motion scores (β = –6.3; 95% CI –9.4 to –3.1; p < 0.001), and lower anatomy scores (β = –5.1; 95% CI –8.0 to –2.1; p = 0.001) compared with LCP fixation. Intramedullary nailing was also associated with lower pain (β = –2.9; 95% CI –5.8 to –0.1; p = 0.044), range of motion (β = –4.7; 95% CI –7.6 to –1.7; p = 0.002), and anatomy scores (β = –3.9; 95% CI –6.7 to –1.0; p = 0.009). Hemiarthroplasty demonstrated the largest negative associations across all three component domains, with pain (β = –7.8; 95% CI –11.0 to –4.6; p < 0.001), range of motion (β = –10.5; 95% CI –13.8 to –7.1; p < 0.001), and anatomy scores (β = –9.1; 95% CI –12.4 to –5.9; p < 0.001).

Table VI: Unified Multivariable Linear Regression Models Predicting Pain, ROM, and Anatomical Alignment Scores (Reference: ORIF with LCP)

Surgical Modality	**Pain Score Model β (95% CI), *p***	**ROM Score Model β (95% CI), *p***	**Anatomy Score Model β (95% CI), *p***
ORIF with LCP (Ref)	0 (Ref)	0 (Ref)	0 (Ref)
K-wire fixation	–4.2 (–7.0 to –1.5), *p* = 0.003	–6.3 (–9.4 to –3.1), *p* < 0.001	–5.1 (–8.0 to –2.1), *p* = 0.001
IM nailing	–2.9 (–5.8 to –0.1), *p* = 0.044	–4.7 (–7.6 to –1.7), *p* = 0.002	–3.9 (–6.7 to –1.0), *p* = 0.009
Hemiarthroplasty	–7.8 (–11.0 to –4.6), *p* < 0.001	–10.5 (–13.8 to –7.1), *p* < 0.001	–9.1 (–12.4 to –5.9), *p* < 0.001

Model adjustment variables: Age, sex, fracture pattern, comorbidities, side of involvement, and delay to surgery.



Reference line at β = 0 → ORIF with LCP is the baseline. Negative β values → Worse outcomes compared to LCP. Error bars (95% CI) → Show the precision of estimates.

Figure 2: Adjusted associations between surgical modality and functional outcomes

Figure 2 presents a forest plot of the adjusted regression coefficients with corresponding 95% confidence intervals (CIs) for pain, range of motion (ROM), and anatomical alignment scores, comparing K-wire fixation, intramedullary (IM) nailing, and hemiarthroplasty against the reference category, ORIF with locking compression plate (LCP). Negative coefficients indicate poorer outcomes relative to ORIF with LCP.

K-wire fixation moderately worsens outcomes across all domains, with statistically significant differences. IM nailing slightly worse outcomes, closer to LCP, but still inferior. Hemiarthroplasty is associated with the largest negative associations, consistently poorer pain, ROM, and anatomical alignment scores.

Overall, the forest plot demonstrates a consistent and statistically significant association between surgical modality and functional outcomes after adjustment for relevant covariates, with ORIF using an LCP associated with superior pain relief, range of motion, and anatomical alignment at 6 months compared with K-wire fixation, IM nailing, and hemiarthroplasty.

DISCUSSION

Proximal humerus fractures constitute a substantial proportion of upper-limb injuries across adult age groups, with their epidemiology influenced by both trauma mechanisms and age-related bone quality[1-3]. In this study, most patients were middle-aged, with a near-equal male-to-female ratio, reflecting a demographic pattern increasingly reported in recent series[14, 16]. Road traffic accidents were the leading cause of injury, accounting for approximately 41% of cases, followed by falls (25%). This distribution mirrors findings from urban trauma centres, where high-energy mechanisms contribute significantly to proximal humerus fractures[8].

With respect to fracture morphology, two-part fractures represented the largest subgroup, comprising slightly more than half of the study population, while three-part fractures accounted for approximately one-third of cases. Similar fracture distributions have been reported in comparable cohorts[20-23] and may reflect the inclusion of surgically managed fractures.

Regarding surgical management, ORIF with LCP was the most frequently performed procedure, accounting for approximately 40% of all cases. K-wire fixation and IM nailing together constituted nearly one-third of procedures, while hemiarthroplasty was used in a smaller subset of patients, primarily those with more complex fracture patterns. This distribution is consistent with current surgical trends favoring locking plate fixation for displaced proximal humerus fractures due to its angular stability and suitability for osteoporotic bone[6, 10-12, 18, 19].

Descriptive analysis of functional outcomes at 6 months demonstrated a mean pain score of around 33, compared with mean function and anatomical alignment scores of about 16 and 6, respectively. Pain scores showed less

variability, whereas anatomical alignment scores demonstrated wider dispersion, indicating heterogeneity in fracture reduction and healing. These findings are consistent with prior studies in which pain relief occurs earlier, while recovery of function and anatomical congruity remains incomplete at mid-term follow-up[10, 12].

When outcomes were examined by surgical modality, unadjusted analyses showed that patients treated with ORIF using LCP achieved higher mean pain, range of motion, and anatomical alignment scores compared with those treated with K-wire fixation, IM nailing, or hemiarthroplasty. In contrast, lower mean component scores were observed in the hemiarthroplasty group, which constituted a smaller proportion of the cohort and predominantly included patients with complex fractures. These descriptive differences provided an important contextual framework for subsequent adjusted analyses and are consistent with earlier comparative reports[24].

Multivariable regression analyses further demonstrated that surgical modality was independently associated with functional outcomes after adjustment for age, sex, fracture pattern, comorbidities, side of involvement, and delay to surgery. Compared with ORIF using LCP, K-wire fixation was associated with lower pain scores (β –4.2; 95% CI –7.0 to –1.5), reduced range of motion (β –6.3; 95% CI –9.4 to –3.1), and lower anatomical alignment scores (β –5.1; 95% CI –8.0 to –2.1). IM nailing was also associated with statistically significant reductions across all domains, while hemiarthroplasty demonstrated the largest negative associations, particularly for range of motion (β –10.5; 95% CI –13.8 to –7.1) and anatomical alignment (β –9.1; 95% CI –12.4 to –5.9).

These quantitative findings are concordant with previously published studies reporting superior functional outcomes following locking plate fixation compared with K-wire fixation and hemiarthroplasty, especially in displaced two- and three-part fractures[24]. Earlier literature has highlighted that less rigid fixation methods may compromise rotational stability, resulting in restricted shoulder motion and suboptimal anatomical restoration[24]. Similarly, the relatively lower functional outcomes observed following hemiarthroplasty align with prior reports emphasizing the importance of tuberosity healing and rotator cuff integrity in determining postoperative shoulder function[7, 17].

The graphical presentation of adjusted associations reinforced these findings, with forest plots demonstrating consistently negative regression coefficients for all non-LCP modalities across pain, range of motion, and anatomical alignment domains. CIs excluded the null in most comparisons, indicating statistically significant differences relative to the reference category. The consistency of these associations across outcome domains suggests clinically meaningful variation in short-term functional recovery by surgical modality.

Inferential analyses were conducted using a simulated patient-level dataset; the results should be regarded as hypothesis-generating rather than confirmatory.

CONCLUSION

In this study, road traffic accidents accounted for approximately 41% of injuries, and two-part fractures were the most common pattern. ORIF with locking compression plate fixation, used in about 40% of cases, was associated with higher mean pain, range of motion, and anatomical alignment scores at 6 months compared with K-wire fixation, intramedullary nailing, and hemiarthroplasty. Adjusted analyses demonstrated lower functional outcome scores across all domains for non-LCP surgical modalities, with the largest reductions observed following hemiarthroplasty. As inferential analyses were based on simulated patient-level data, these findings should be interpreted as hypothesis-generating and warrant confirmation using complete patient-level datasets.

LIMITATIONS

The sample size within some surgical subgroups was relatively small, which may limit statistical precision. In addition, functional outcomes were assessed at a single follow-up point of 6 months, precluding evaluation of long-term recovery and implant-related complications. Inferential statistical analyses were conducted using a simulated patient-level dataset constructed from study-level aggregates, as individual patient data were unavailable.

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REFERENCES

1. Nordqvist A, Petersen CJ. Incidence and causes of shoulder girdle injuries in an urban population. J Shoulder Elbow Surg 1995;4(2):107-12.
2. Baron JA, Karagas M, Barrett J, Kniffin W, Malenka D, Mayor M, et al. Basic epidemiology of fractures of the upper and lower limb among Americans over 65 years of age. Epidemiology 1996; 7:612-8.

3. Palvanen M, Kannus P, Niemi S, Parkkari J. Update in the epidemiology of proximal humeral fractures. Clin Orthop Relat Res 2006, 442:87-92.

4. Rose SH, Melton LJ 3rd, Morrey BF, Ilstrup DM, Riggs BL. Epidemiological features of humeral fractures Clin Orthop. 1982:168:24-30.

5. Sahu RL. Philos Locking plates in proximal humerus fractures literature review. Internet J Health. 2010;11:1.

6. Aaron D, Shatsky J, Paredes JC. Proximal humeral fractures: internal fixation. J Bone Joint Surg Am. 2012;94(24):2280-8.

7. Murray IR, Amin AK, White TO, Robinson CM. Proximal humeral fractures: current concepts in classification, treatment and outcomes. J Bone Joint Surg Br. 2011;93(1):1-11.

8. Khmelnitskaya E, Lamont LE, Taylor SA, Lorich DG, Dines MD, Dines JS. Evaluation and management of proximal humerus fractures. Hindawi Publishing Corporation Advances in Orthopedics. 2012;2012:861598, 10 pages.

9. Muncibi F, Paez DC, Matassi F, Carulli C, Nistri L, Innocenti M. Long term results of percutaneous fixation of proximal humerus fractures, Indian J Orthop. 2012;46(6):664-67.

10. Björkenheim JM, Pajarinen J, Savolainen V. Internal fixation of proximal humeral fractures with locking compression plate: A retrospective evaluation of 72 patients followed for a minimum of 1 year. Acta Orthop Scand. 2004;75:741-5.

11. Flores S, Merk BR. Two-part surgical neck fractures of the proximal part of the humerus: A biomechanical evaluation of two fixation techniques. J Bone Joint Surg Am. 2006;88:2258-64.

12. Kettler M, Biberthaler P, Braunstein V, Zeiler C, Kroetz M, Mutschler W. Treatment of proximal humeral fractures with the PHILOS angular stable plate: Presentation of 225 cases of dislocated fractures. Unfallchirurg. 2006, 109: 1032-40.

13. Varacallo MA, Fox EJ. Osteoporosis and its complications. Med Clin North Am 2014;98(4) :817-31.

14. Jo MJ, Gardner MJ. Proximal humerus fractures. Curr Rev Musculoskelet Med. 2012;5(3):192-98.

15. Resch H, Povaez P, Frohlich R, Wambacher M. Percutaneous fixation of three and four-part fractures of the proximal humerus. J Bone Joint Surg [br]. 1997;79-b:295-300.

16. Egol KA, Ong CC, Walslı M, Jazrawi LM, Tejwani NC, Zuckerman JD. Early complication of proximal humerus fractures treated with locked plates. J Ortho Trauma. 2008:22:159-64.

17. Gerber C, Worner CM, Vienne P. Internal fixation of complex fractures of the proximal humerus. J Bone Joint Surg (Br). 2004;86(60):848-55.

18. Lever JP, Aksenov SA, Zdero R, Ahn H. McKee MD, Schemitsch EH. Biomechanical analysis of plate osteosynthesis systems for proximal humerus fractures. J Orthop Trauma. 2008:22:23 9.

19. Seide K, Triebe J, Faschingbauer M, Schulz AP, Püschel K, Mehrtens G, et al. Locked vs. unlocked plate osteosynthesis of the proximal humerus A biomechanical study. Clin Biomech (Bristol, Avon) 2007;22:176-82.

20. Koukakis A, Apostolou CD, Tancja T, Korres DS, Amini A. Fixation of proximal humerus fractures using the PHILOS plate: Early experience. Clin Orthop Relat Res. 2006;442:115-20 21. Fankhauser F, Boldin C, Schippinger G, Haunschmid C, Szyszkowitz R. A new locking plate for unstable fractures of the proximal humerus. Clin Orthop Relat Res. 2005;430:176-81.

22. Rose PS, Adams CR, Torchia ME, Jacofsky DJ, Haidukewych GG, Steinmann SP. Locking plate fixation for proximal humeral fractures: initial results with a new implant. J Shoulder Elbow Surg. 2007;16(2):202-7

23. Siwach R, Singh R, Rohilla RK, Kadian VS, Sangwan SS, Dhanda M. Internal fixation of proximal humeral fractures with locking proximal humeral plate (LPHP) in elderly patients with osteoporosis. J Orthop Traumatol. 2008;9(3):149-53

24. Jaura G, Sikdar J, Singh S. Long-term results of PHILOS plating and percutaneous K-Wire fixation in proximal humerus fractures in the elderly. Malaysian Orthopaedic Journal. 2014;8(1):04-06