E-ISSN: 3068-3726
Journal of Orthopaedic Science and Research

ATHENAEUM SCIENTIFIC PUBLISHERS

Research Article

Management of Two-Part and Three-Part Proximal Humerus Fractures Using a Novel Mini-External Fixation Technique

Alok Umre[1], Om Wakde[2*], Ritesh Meghare[2], Harshit Khare[2], Sanjay Agrawal[3]

[1]Chairman, Department of Orthopaedics, Arogyam Superspeciality Hospital Nagpur, India

[2]Department of Orthopaedics, Arogyam Superspeciality Hospital, Nagpur, India

[3]Department of Preventive and Social Medicine, Indira Gandhi Government Medical College, Nagpur, India

***Correspondence author:** Om Wakde, MS, DNB (Ortho), Department of Orthopaedics, Arogyam Superspeciality Hospital Nagpur, India; Email: dromwakde@gmail.com

Citation: Umre A, et al. Management of Two-Part and Three-Part Proximal Humerus Fractures Using a Novel Mini-External Fixation Technique. J Ortho Sci Res. 2025;6(2):1-9. https://doi.org/10.46889/JOSR.2025.6207

Received Date: 21-06-2025

Accepted Date: 07-07-2025

Published Date: 14-07-2025

Abstract

Background: The concept of 'biological fixation' which stresses on the preservation of blood supply to the fracture fragments has led to an increased popularity of closed reduction and external fixator application for the management of displaced proximal humerus fractures. In this study, we have described our novel surgical technique of 'mini-fixator' application for 2-part and 3-part displaced proximal humerus fractures, along with their radiological and functional outcomes at 6-months follow-up.

Method: This is a retrospective study involving 119 patients with displaced 2-part or 3-part proximal humerus fractures treated with closed reduction and a novel mini-fixator application technique. Fracture reduction was assessed using Paavolainen criteria. Head-shaft angle (HSA) was calculated on the pre-operative radiographs, immediate post-operative radiographs and 6 months follow-up radiographs. Depending upon the clinical evaluation (pain, ROM, function) and radiological signs of union, the fixator was removed at the end of 6 to 8 weeks. Functional assessment was performed using CONSTANT score at 6 months follow-up.

Results: Mean age of the study population was 61.6 years with 46% males and 54% females. Union was achieved in 116 patients (97.5%) at mean duration of 7.8 weeks (range 6 to 14 weeks). There was statistically significant improvement in the mean HSA in the immediate post-operative and 6 months follow-up radiographs as compared to the pre-operative radiographs with p value < 0.05. As per CONSTANT score, 26.9% patients showed excellent result, 64.7% patients showed good result, 6.7% patients showed fair result and 1.7% patients showed poor result. Complications were seen in 18 cases which included 10 pintract infections, 2 pin-loosening, 2 secondary displacements requiring revision, 1 non-union and 3 shoulder stiffness cases.

Conclusion: Closed reduction and external fixation is a safe and effective option for surgical management of displaced 2-part and 3-part proximal humerus fractures. Our technique of mini-fixator application provides a more compact and cost-effective alternative than conventional external-fixators, without compromising the stability of the construct.

Keywords: Proximal Humerus Fractures; External Fixator; Mini-Fixator; Percutaneous Fixation

Introduction

Different modalities of treatment have been described in the literature for the management of displaced proximal humerus fractures, with no consensus on 'ideal method'. Conservative treatment is usually associated with risk of shoulder stiffness and non-union and should be reserved for patients who are unfit for surgery [1-3]. Open reduction and internal fixation with plate allows for anatomical reduction of fracture and rigid fixation; however, it is associated with decreased residual blood supply to humeral head as well as other risks involved due to exposure such as- blood loss, infection etc. [4-6]. The concept of 'biological fixation' which stresses on the preservation of blood supply to the fracture fragments has led to an increased popularity of closed reduction and external fixator application, particularly Joshi's External Stabilization System (JESS) for the management of

displaced proximal humerus fractures [7-10]. Most of the published articles on the management of proximal humerus fractures with external fixators (JESS or its modifications) have a small study population [7-11]. In this study, we have described our novel surgical technique of 'mini-fixator' application for 2-part and 3-part displaced proximal humerus fractures in a larger cohort, along with their radiological and functional outcomes at 6 months follow-up.

Material and Methods

This is a retrospective study involving the patients with displaced proximal humerus fractures treated with closed reduction and mini-fixator application during January 2018 to December 2023 period.

Inclusion Criteria: Displaced (>45 ^{o} angulation or >1 cm displacement) fractures of proximal humerus- Neer's 2-part or 3-part, which were treated with closed reduction and mini-fixator application, with a minimum follow-up of 6 months.
Exclusion Criteria: Open fractures, pathological fractures, fractures with diaphyseal extension.

Surgical Technique

All cases were performed under regional anesthesia (interscalene block). Patients were placed supine on a radiolucent table with a sandbag beneath ipsilateral scapula. Fracture was reduced in near anatomical position by applying traction and performing indirect reduction maneuver, with special care to correct varus angulation and rotational alignment. If required, a 3 mm percutaneous focal pin was inserted in the humeral head and used as a joystick to correct the rotational and angular alignment of the proximal fragment (Fig. 1). In 3-part fractures with a separate Greater Tuberosity (GT) fragment, a percutaneous focal pin was inserted in GT and used as a joystick to reduce the GT fragment over to humeral head fragment. Once reduction was confirmed under image-intensifier, two 9" long 2.5 mm/3 mm percutaneous focal pins were inserted from tip of GT and directed infero-medially across the fracture site to engage the medial cortex of humerus shaft. Another two 12" long 2.5 mm/3 mm percutaneous focal pins were inserted percutaneously from the lateral cortex of humerus shaft (proximal third) and directed supero-medially across the fracture site into humeral head up to the subchondral region. Percutaneous focal pin position and final reduction was confirmed under image intensifier in both the planes (Fig. 2). Outer ends of upper percutaneous focal pins were bent distally twice- first, by approximately 50-60 degrees at 2 cm from the skin surface and again, by 90 degrees at 3-4 cm from the initial bend. Similarly, outer ends of lower percutaneous focal pins were bent proximally twice- first, by approximately 50-60 degrees at 2 cm from the skin surface and again, by 90 degrees at 3-4 cm from the initial bend. These bent outer tips of proximal and distal percutaneous focal pins were connected to each other using two Aesculaps clamps (one for each pair). Clamps were tightened after applying pre-stress to the inserted percutaneous focal pins. Free outer tips of percutaneous focal pins were further bent by 90 degrees close to the clamps and cut. A clinical picture of the final construct is shown in figure 3. Pin-tracts were cleaned using surgical spirit, dressed with betadine soaked guaze pieces and an elastic adhesive dressing was applied over it. A shoulder immobilizer was applied for external support in all the patients.

Rehabilitation Protocol

Pendulum exercises and elbow Range Of Motion (ROM) exercises were started from the next day. Dressing was changed on second post-operative day at the time of discharge and patients were asked to follow-up weekly for pin-tracts dressing and clinical assessment. Passive shoulder ROM exercises were started from the second week. At 3 weeks, radiographs were taken to confirm the alignment and active-assisted shoulder ROM exercises were started, with a target to achieve unrestricted active ROM by 6-8 weeks. Radiographs were repeated at the end of 6-8 weeks to evaluate the alignment and signs of union. Depending upon the clinical evaluation (absence of tenderness/ absence of pain during active ROM) and radiological signs of union (obscuration of fracture line/ callus formation), the fixator was removed at the end of 6 to 8 weeks. Pin-tract infections seen were classified using Checketts-Otterburn classification and managed accordingly [12].

Outcome Measures and Statistics

Fracture reduction was assessed using Paavolainen criteria on immediate post-operative radiographs [13]. Head-Shaft Angle (HSA) was calculated on the pre-operative radiographs, immediate post-operative radiographs and 6 months follow-up radiographs. For the comparison of pre-operative HSA, post-operative HSA and 6 months follow-up HSA, repeated measure ANOVA was used. For pairwise comparison between pre-operative HSA, post-operative HSA and 6 months follow-up HSA, Bonferroni post hoc test was used. Statistical significance was defined at $p < 0.05$. Functional assessment was performed using CONSTANT score [14] at 6 months follow-up. Statistical Package for the Social Sciences (SPSS) version 21.0 was used.

Results

Total 119 patients qualified for the study. 97 patients had 2-part and 22 patients had 3-part proximal humerus fractures. Mean age of the study population was 61.6 years (range- 25 to 88 years) with 55 (46%) males and 64 (54%) females. The mean duration of follow-up was 22 months (range- 7 to 48 months).

As per Paavolainen criteria, the fracture reduction in the immediate post-operative radiographs was good in 110 patients, fair in 9 patients and poor in none of the patients. Union was achieved in 116 patients (97.5%). Mean duration of fixator removal was 7.8 weeks (range 6 to 14 weeks).

The mean preoperative HSA was 115.19°, mean post-operative HSA was 131.9° and at 6 months follow up was 129.3°. Pairwise comparison between their values was statistically significant as per Bonferroni post hoc test (Table 1,2).

The mean CONSTANT MURLEY score at the 6 months follow-up was 81 (range 52 to 96). On grading the patients according to CONSTANT score, 32 (26.9%) patients showed excellent result, 77 (64.7%) patients showed good result, 8 (6.7%) patients showed fair result and 2 (1.7%) showed poor results.

In 2 patients, secondary displacement was seen during the 3rd week follow-up, for which they underwent revision surgery. Pin-tract infections were encountered between 2nd and 4th week. It was grade II as per Checketts-Otterburn classification in 10 patients and could be managed with oral antibiotics and daily pin-tract dressing, allowing the fixator to be retained till 6 weeks. However, 2 patients developed loosening of upper percutaneous focal pins (grade IV as per Checketts-Otterburn classification) leading to early removal of fixator. Out of these 2, fracture united in one patient at 10 weeks and the other patient sustained non-union. 3 patients had persistent shoulder stiffness at 3 months follow-up, out of which 2 regained functional ROM by physiotherapy and 1 patient required arthroscopic arthrolysis.

Discussion

There is no "gold standard" treatment for management of displaced proximal humerus fractures. Non-surgical treatment carries the inherent risks of: fracture re-displacement, failure to achieve acceptable reduction thereby leading to non-union or malunion, inability to start early mobilization leading to shoulder stiffness [1-3]. Various surgical options that have been described in the literature are- percutaneous pinning, screw fixation, external fixators, open reduction and internal fixation with plate or transosseous suture fixation and even hemiarthroplasty or reverse shoulder arthroplasty.

Closed Reduction and Percutaneous Pinning (CRPP) has shown to be a viable surgical option for 2-part, 3-part and valgus-impacted 4-part proximal humerus fractures [15]. However, biomechanical studies have demonstrated that fixation with only percutaneous focal pins provides less stable construct as compared with other modes of fixation [16,17]. Intramedullary locking nails can be used in displaced 2-part proximal humerus fractures, however it carries the risk of proximal impingement and potential of rotator cuff injury [18,19]. Open reduction and internal fixation using plate allows anatomical reduction and provides stable construct. Although some studies have shown good outcomes in proximal humerus fractures managed with PHILOS plate, the main disadvantage of open reduction and internal fixation is disruption of the residual vascularity of humeral head and thereby increased risk of avascular necrosis [20,21]. Other drawbacks are- requirement of large exposure, increased blood loss, prolonged operative time and risk of hardware loosening in osteoporotic bones [4-6].

Since last decade, management of proximal humerus fractures (especially 2-part and 3-part) with external fixators has gained popularity. In 4-part displaced proximal humerus fractures, it is difficult to obtain reduction by closed techniques and hence, they are usually managed by open reduction and internal fixation or arthroplasty [22-24]. Many studies have reported good functional outcomes in 2-part and 3-part fractures treated with external fixators [7-11]. The aim while performing closed or indirect reduction is to obtain near-anatomical alignment with particular attention to correct angulation and rotation at the fracture site. As the pins are placed percutaneously, there is minimal soft tissue dissection and the blood supply to humeral head is preserved. It provides stable fixation and allows early mobilization of shoulder joint. Preservation of fracture hematoma retains various cytokines, mesenchymal stem cells and growth factors, thereby contributing to the fracture healing [25]. Major drawbacks of external fixators are pin-tract infections and the bulk of hardware outside the skin causing patient discomfort in daily activities.

Various configurations of external fixators have been described in the literature. Hoffman's fixators used in the past comprised of bulky Steinmann pins which limited their use because of increased risk of soft-tissue injury and inability to apply multiple pins in different planes [26]. Gupta, et al., have described the surgical management of Neer's 2-part, 3-part and valgus impacted 4-part fractures using Joshi's External Stabilization System (JESS) with good outcomes [8]. JESS fixator assembly described in their study was quite bulky, comprising of- three 2.5 mm Schanz pins in humeral head, two 2.5 mm Schanz pins in humerus shaft, three percutaneous focal pins, two connecting rods and 7-8 JESS clamps. Das, et al., have described less bulkier modification of JESS fixator for surgical management of Neer's 2-part and 3-part fractures [11]. It comprises of 4-5 percutaneous focal pins, 4-5 JESS clamps and a separate connecting rod. Ebraheim, et al., have shown good functional outcomes in 64 patients with two-part or three-part proximal humerus fractures using a commercially available mini external fixator, with complications in 16 cases [27]. However, these commercially available mini external fixators are costly. In our technique, we have used even more compact and cheaper version of external fixator without compromising the stability of the construct.

Our "mini-fixator", comprising of four long 2.5 mm percutaneous focal pins and just two Aesculap clamps, has some advantages over the older conventional fixators. Less the number of percutaneous pins, less are the chances of pin-tract infections. Less bulky construct facilitates easier mobilization of shoulder joint/arm and also improves the overall patient satisfaction. The proximal percutaneous focal pins engage the greater tuberosity, humeral head and the medial cortex of humerus shaft. The distal percutaneous focal pins engage the lateral cortex of humerus shaft, dense calcar region and the subchondral bone of humeral head. Engagement of dense calcar region by these distal pins adds more stability to the construct as compared to the conventional JESS fixators. Spanning of the entire humeral head from anterior to posterior as seen in lateral view (Fig. 2) improves the stability of fixation. Additionally, pre-stressing i.e., compressing the proximal and distal bent ends of percutaneous focal pins towards each other while connecting them with clamp improves the back-out strength of those percutaneous focal pins. Another important advantage of our mini-fixator, particularly relevant in a developing country is that it is significantly cheaper as compared to the cost of locking pre-contoured plates or commercially available fixator sets.

The union rate in our study was 97.5% and the mean duration to achieve union was 7.8 weeks. Fig. 4 shows one case of three-part proximal humerus fracture with the pre-operative X-ray (Fig. 4a), the immediate post-operative X-ray (Fig. 4b) and the follow-up X-ray at 6 weeks after fixator removal (Fig. 4c). There was statistically significant improvement in the mean HSA in the immediate post-operative and 6 months follow-up radiographs as compared to the pre-operative radiographs with p value < 0.05 (Table 1).

In 2 patients from our study, secondary displacement at fracture site was observed during the 3rd week. Out of these, one patient had varus collapse with penetration of tips of lower percutaneous focal pins into the shoulder joint and had to undergo revision with PHILOS plate. The other patient gave history of sudden onset pain and difficulty in movement after a vigorous physiotherapy session. She had developed fresh spiral fracture at the site of penetration of proximal pins into the medial cortex of shaft. She underwent revision surgery with intramedullary locking nail. Minor pin-tract infections were seen in 10 patients, which were managed with regular pin-tract dressing and oral antibiotics. Another 2 patients had major (grade IV) pin-tract infection with loosening of percutaneous focal pins. They required early removal of fixator, curettage of pin-tracts and shoulder immobilizer belt. One of these patients was a middle-aged female farm-laborer without any co-morbidities, belonging to a remote village. Major infection in her case could probably be attributed to poor hygiene, non-compliance with weekly pin-tract dressing protocol and failure to review earlier during the initial stage of infection. Nonetheless, her infection healed after fixator removal and curettage of pin-tracts and even her fracture united at 10 weeks follow-up, albeit in mild varus alignment (Fig. 5). The other patient was an elderly male with uncontrolled diabetes and renal impairment. After fixator removal his pin-tracts healed gradually with prolonged treatment by daily dressings and oral antibiotics. Eventually he developed non-union of the proximal humerus fracture. Due to fitness issues and patient's unwillingness for further surgical intervention, he was treated conservatively with physiotherapy and rehabilitation. 3 patients had persistent shoulder stiffness at 3 months follow-up, out of which 2 regained functional ROM by physiotherapy and 1 patient required arthroscopic arthrolysis. Overall, the functional results obtained in our study are comparable to those of other similar studies (Table 3).

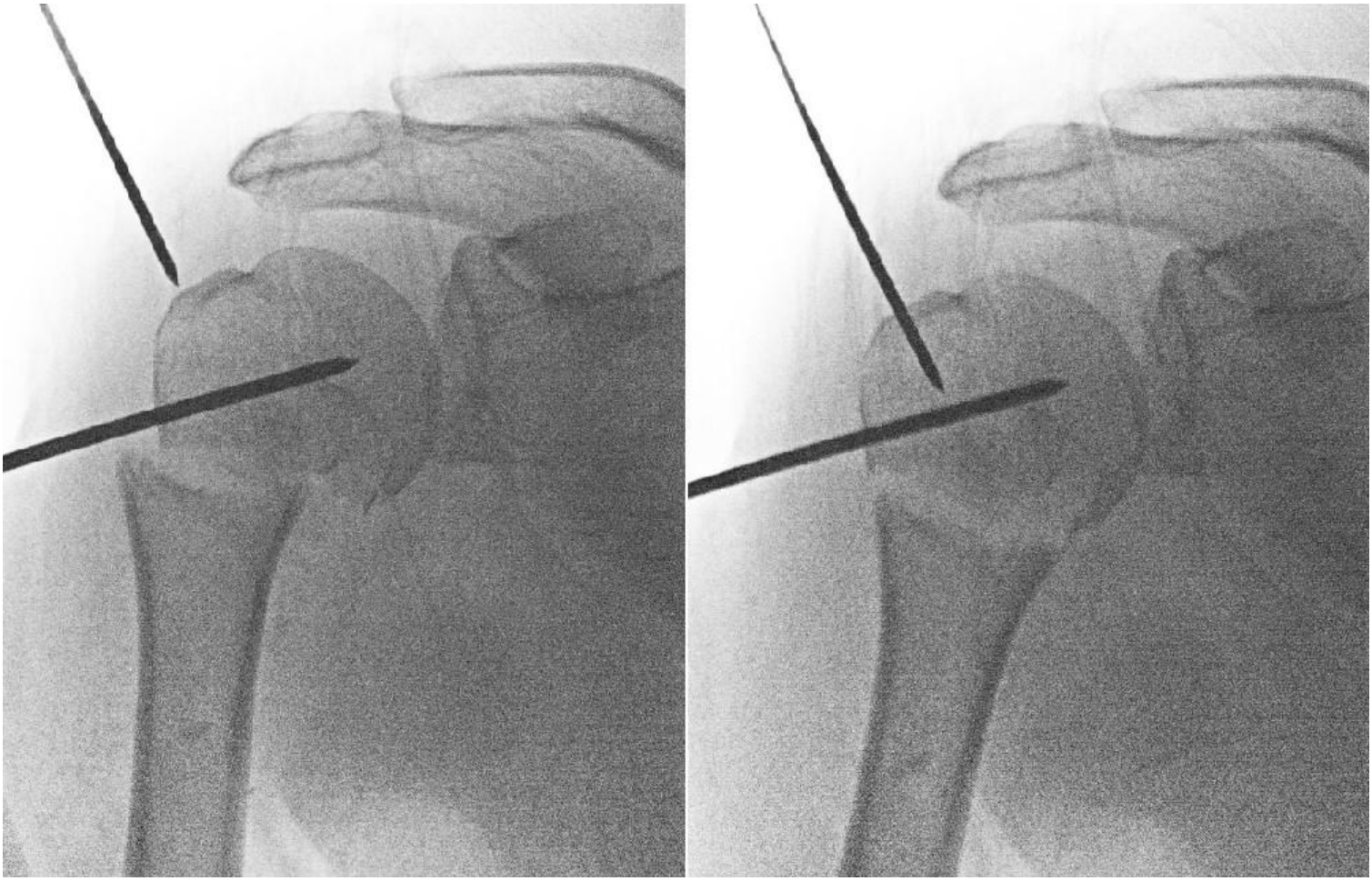

Figure 1: Percutaneous focal pin inserted in the humeral head is used as a joystick to correct the rotational and angular alignment of the proximal fragment.

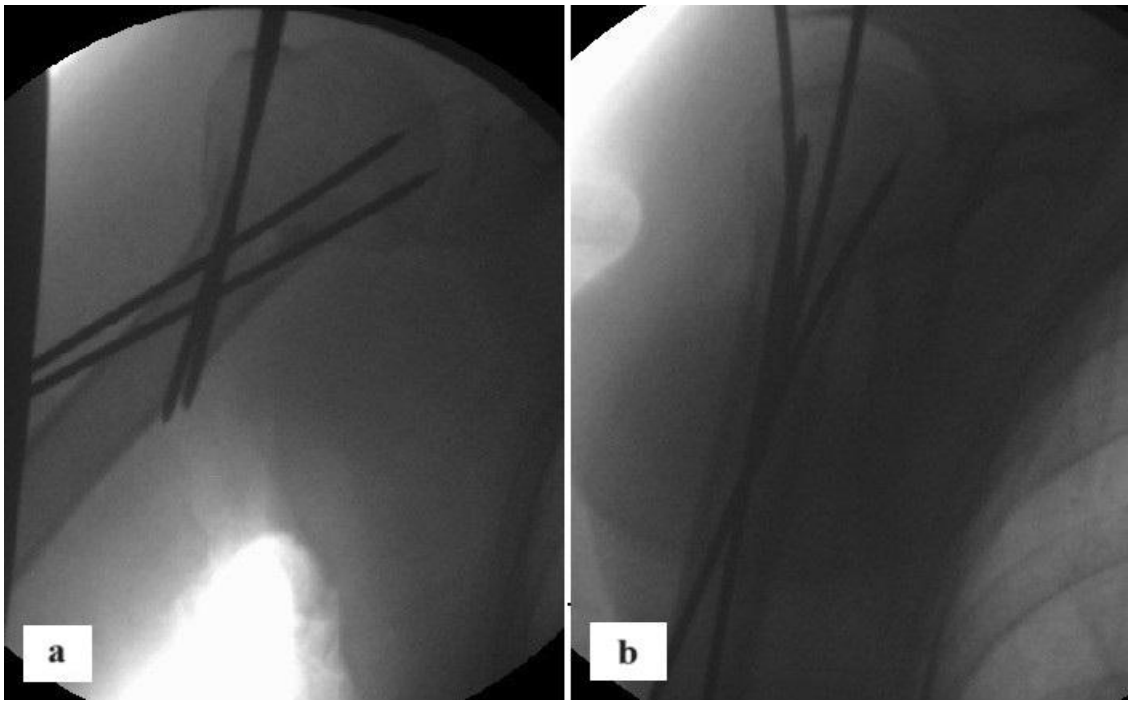

Figure 2: a: Antero-posterior view under image intensifier showing the positions of percutaneous focal pins; b: Lateral view under image intensifier showing the positions of percutaneous focal pins.

Figure 3: Clinical photograph of the mini-external fixator.

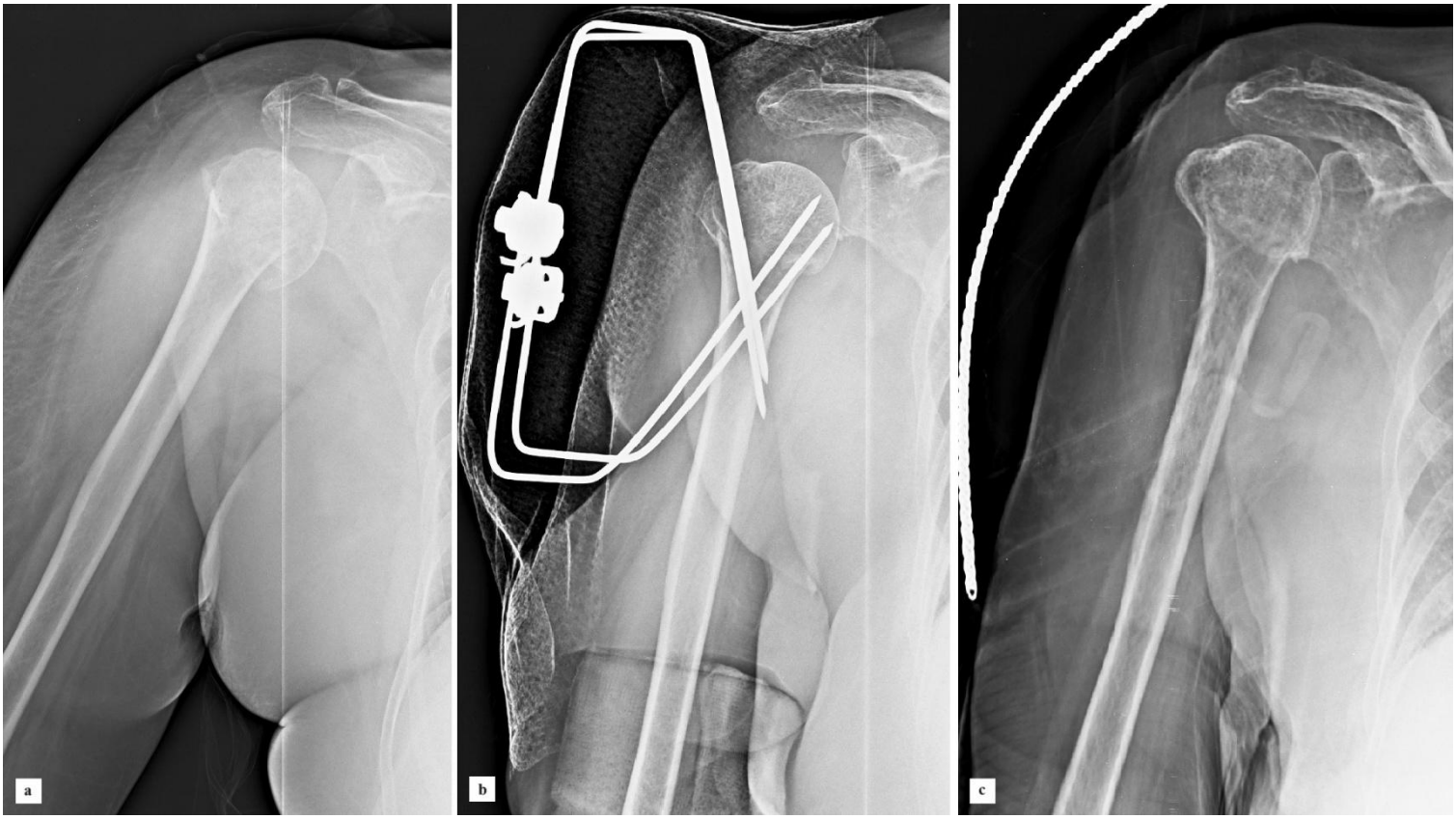

Figure 4: a: Pre-operative X-ray of a three-part displaced proximal humerus fracture; b: Immediate post-operative X-ray after closed reduction and mini-fixator application; c: Follow-up X-ray at 6 weeks, after fixator removal.

Figure 5: Fracture united in mild varus alignment at 10 weeks, in a patient who underwent early removal of external fixator due to major pin-tract infection.

Time Period	Mean HSA	Std. Error	95% Confidence Interval		P-value
			Lower bound	Upper bound	
Pre-operative	115.193	2.168	110.900	119.487	0.000
Post-operative	131.916	0.779	130.374	133.458	
6 months follow-up	129.361	0.865	127.648	131.075	
HSA: Head Shaft Angle					

Table 1: Comparison of pre-operative HSA, post-operative HSA and 6 months follow-up HSA using repeated measure ANOVA.

P-value	Pre-Operative	Post-Operative	6 Months Follow-Up
Pre-operative	--	0.000	0.000
Post-operative	0.000	--	0.004
6 months follow-up	0.000	0.004	--

Table 2: Pairwise comparison of pre-operative HSA, post-operative HSA and 6 months follow-up HSA using Bonferroni post hoc test.

Results	Our Study	Das, et al., [11] (2019)	Gupta OP, et al., [9] (2016)	Gupta AK, et al., [7] (2012)	Ebraheim, et al., [27] (2007)
No. of cases	119	15	18	16	64
Mean duration of union/ fixator removal (weeks)	7.8	6.8	9.33	6.5	9.43
Functional Outcomes (%)					
Excellent	26.9	20	22.22	18.75	63.4
Good	64.7	60	44.44	62.5	18.8
Fair	6.7	13.3	22.22	18.75	12.7
Poor	1.7	6.7	11.11	-	5.1
Total Complications	18	5	3	2	16
Pin tract infections	10	4	2	1	4
Pin loosening	2	1	-	1	-

Non-union	1	-	-	-	2
AVN* humeral head	-	-	-	-	-
Neurovascular injury	-	-	-	-	-
Shoulder stiffness	3	-	1	-	-
Secondary displacement requiring revision	2	-	-	-	4
Bicipital tendinitis	-	-	-	-	5
RSD#	-	-	-	-	1
AVN: Avascular Necrosis; RSD: Reflex Sympathetic Dystrophy					

Table 3: Comparison of our study with other studies.

Limitations of our study are- its retrospective nature and the possibility of a bias, as it is a single-centre study. Strengths of our study are- large study population, uniformity of surgical technique and good follow-up period. Prospective comparative studies (randomized control trials) involving multiple centres will further determine the effectiveness of this surgical technique for displaced 2-part and 3-part proximal humerus fractures.

Conclusion

Closed reduction and external fixation is a safe and effective option for surgical management of displaced 2-part and 3-part proximal humerus fractures. Our technique of mini-fixator application provides a more compact and cost-effective alternative than conventional external-fixators, without compromising the stability of the construct.

Conflict of Interests

The authors declare no conflict of interest.

Funding/Sponsorship

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

References

1. Hodgson SA, Mawson SJ, Stanley D. Rehabilitation after two-part fracture of the neck of the humerus. J Bone Joint Surg Br. 2003;85(3):419-22.
2. Jakob RP, Miniaci A, Anson PS, Jaberg H, Osterwalder A, Ganz R. Four-part valgus impacted fracture of the proximal humerus. J Bone Joint Surg Br. 1991;73(2):295-8.
3. Zyto K, Kronberg M, Brostrom LA. Shoulder function after displaced fractures of the proximal humerus. J Shoulder Elbow Surg. 1995;4(5):331-6.
4. Siegel J, Dines D. Proximal humerus malunions. Orthop Clin North Am. 2000;31(1):35-49.
5. Wijgman AJ, Roolker W, Pall TW, Raaymakers EL, Marti RK. Open reduction and internal fixation of three and four-part fracture of the proximal part of the humerus. J Bone Joint Surg Am. 2002;84(11):1919-25.
6. Clavert P, Adam P, Bevort A, Bonnomet F, Kempf JF. Pitfalls and complications with locking plate for proximal humerus fracture. J Shoulder Elbow Surg. 2010 Jun;19(4):489-94.
7. Gupta AK, Gupta M, Sengar G, Nath R. Functional outcome of closed fractures of proximal humerus managed by Joshi's external stabilizing system. Indian J Orthop. 2012;46(2):216-20.
8. Gupta U, Chaudhary S, Aggrawal G, Khan A, Pathania VP, Gandotra A. Surgical management of proximal humerus fracture by Joshi's external stabilizing system. J Evol Med Dent Sci. 2014;3(18):5032-41.
9. Gupta OP, Vashisht A, Rastogi A, Gupta N, Shahi U, Goyal G. Functional outcome following external fixator (JESS) application for proximal humeral fractures. Int J Res Orthop. 2016;2(4):303-6.
10. Ghosh S, Ghosh D, Datta S, Chaudhuri A, Roy DS, Chowdhury A. External fixation by Joshi's external stabilizing system in cases of proximal humerus fractures in elderly subjects. J Sci Soc. 2013;40(2):99-102.
11. Das H, Laskar AH. Results of modified JESS augmentation for fracture proximal humerus stabilized with percutaneous K-wires. Int J Orthop Traumatol Surg Sci. 2019;5(1):32-5.

12. Checketts RG, MacEachern AG, Otterburn M. Pin track infection and the principles of pin site care. In: De Bastiani A, Apley AG, Goldberg A, editors. Orthofix external fixation in trauma and orthopedics. Berlin: Springer; 2000;97-103.
13. Paavolainen P, Björkenheim JM, Slätis P, Paukku P. Operative treatment of severe proximal humeral fractures. Acta Orthop Scand. 1983;54(3):374-9.
14. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res. 1987;(214):160-4.
15. Magovern B, Ramsey ML. Percutaneous fixation of proximal humerus fractures. Orthop Clin North Am. 2008;39(4):405-16.
16. Wheeler DL, Colville MR. Biomechanical comparison of intramedullary and percutaneous pin fixation for proximal humeral fracture fixation. J Orthop Trauma. 1997;11(5):363-7.
17. Koval KJ, Blair B, Takei R, Kummer FJ, Zuckerman JD. Surgical neck fractures of the proximal humerus: A laboratory evaluation of ten fixation techniques. J Trauma. 1996;40(5):778-83.
18. Young AA, Hughes JS. Locked intramedullary nailing for treatment of displaced proximal humerus fractures. Orthop Clin North Am. 2008;39(4):417-28.
19. Gracitelli MEC, Malavolta EA, Assunção JH, Matsumura BA, Kojima KE, Ferreira Neto AA. Ultrasound evaluation of the rotator cuff after osteosynthesis of proximal humeral fractures with locking intramedullary nail. Rev Bras Ortop. 2017;52(5):601-7.
20. Hirschmann MT, Fallegger B, Amsler F, Regazzoni P, Gross T. Clinical longer-term results after internal fixation of proximal humerus fractures with a locking compression plate (PHILOS). J Orthop Trauma. 2011;25(5):286-93.
21. Olerud P, Ahrengart L, Ponzer S, Saving J, Tidermark J. Internal fixation versus nonoperative treatment of displaced 3-part proximal humeral fractures in elderly patients: a randomized controlled trial. J Shoulder Elbow Surg. 2011;20(5):747-55.
22. Boileau P, Pennington SD, Alami G. Proximal humeral fractures in younger patients: fixation techniques and arthroplasty. J Shoulder Elbow Surg. 2011;20(2 Suppl):S47-60.
23. 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.
24. Resch H. Proximal humeral fractures: current controversies. J Shoulder Elbow Surg. 2011;20(5):827-32.
25. Schell H, Duda GN, Peters A, Tsitsilonis S, Johnson KA, Schmidt-Bleek K. The haematoma and its role in bone healing. J Exp Orthop. 2017;4(1):5.
26. Kristiansen B. Treatment of displaced fractures of the proximal humerus: transcutaneous reduction and Hoffmann's external fixation. Injury. 1989;20(4):195-9.
27. Ebraheim NA, Patil V, Husain A. Mini-external fixation of two- and three-part proximal humerus fractures. Acta Orthop Belg. 2007;73(4):437-42.