

PERCUTANEOUS ELASTIC STABILITY VS. RIGID FIXATION: EVALUATING FUNCTIONAL OUTCOMES OF THE MODIFIED MIROS TECHNIQUE IN OSTEOPOROTIC HUMERUS FRACTURES

Gopinath K.R¹, S.Paramaguru Rajesh², Hariharan³

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Corresponding Author:

Dr. Hariharan

Email: drdhariharan@gmail.com

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¹Assistant Professor, Department of Orthopedics, Madurai Medical College, Madurai, Tamil Nadu, India.

²Assistant Professor, Department of Orthopedics, Madurai Medical College, Madurai, Tamil Nadu, India.

³Assistant Surgeon, Department of Orthopedics, Government Taluk HQ Hospital, Panruti, Tamil Nadu, India.

ABSTRACT

Background: Proximal humerus fractures are common in elderly osteoporotic patients, where poor bone quality makes stable fixation difficult. This study aimed to compare modified MIROS percutaneous elastic fixation with PHILOS locking plate fixation for perioperative efficiency, healing, functional recovery, and complications. **Materials and Methods:** This comparative non-randomized study included 52 patients treated between January 2022 and December 2024. Of the 52 patients, 27 underwent modified MIROS fixation and 25 underwent PHILOS open reduction and internal fixation. MIROS used closed fluoroscopic reduction, percutaneous Schanz pin or K-wire joystick, multiple 2.5 mm K-wires, and an external modular clamp frame. PHILOS used a deltopectoral approach, anatomical plate, locking and cortical screws. Standard rehabilitation and 12-month follow-up were used. **Results:** Female patients were 20 (74.1%) vs. 18 (72%) ($P=0.865$), males 7 (25.9%) vs. 7 (28%). Two-part fractures were 16 (59.3%) vs. 14 (56%) and 3-part fractures 11 (40.7%) vs. 11 (44%) ($P=0.776$); low-energy falls occurred in 25 (92.6%) vs. 23 (92%) ($P=0.938$). Age was 68.4 ± 6.2 vs. 69.1 ± 5.8 years ($P=0.678$), T-score -3.1 ± 0.4 vs. -3.0 ± 0.5 ($P=0.428$). Operative time, blood loss, union, and hospital stay were lower (all $P<0.001$), while fluoroscopy was longer ($P<0.001$). CMS was higher at 3, 6, and 12 months ($P<0.001$, $P=0.004$, $P=0.046$). Overall complications were 11.1% vs. 36% ($P=0.034$). **Conclusion:** Modified MIROS provided stable fixation, faster recovery, and fewer complications than PHILOS, with less surgical trauma, supporting its use in elderly osteoporotic fractures.

INTRODUCTION

Proximal humerus fractures (PHFs) are an extremely common fracture, especially in older people, and are frequently due to minor trauma in osteoporotic bone. With the rising prevalence of osteoporosis and ageing population, their clinical significance is increasing. The proximal humerus is important for shoulder elevation, rotation and upper-limb function. This can therefore cause malalignment, stiffness, fixation failure, or avascular necrosis, potentially significantly affecting shoulder function and daily activities. Treatment will vary depending on the fracture pattern, degree of displacement, patient-related factors and bone quality. For displaced or unstable fractures that require surgical correction, stability is difficult to obtain and early recovery is still a challenge, particularly in osteoporotic bone.^[1,2]

The treatment of osteoporotic PHFs is challenging due to poor quality bone, which increases the difficulty of purchase and fracture reduction maintenance of implants. With the thinning of the cortex and loss of trabecular bone strength, this can lead to secondary displacement and fixation failure. It is not always the case that it is better to make the fixation stiffer. The fixation should be sufficiently stable and yet be suitable to the biological and mechanical situation of the fracture. Locking plates are currently in common use for unstable PHFs, but issues with screw perforation, varus collapse, avascular necrosis, loss of reduction, and revision surgery have been reported. Bone quality is also a key element in screw failure and loss of stability of fixation.^[2,3]

In spite of these drawbacks, locking plates are proven to be a viable solution for alignment and fixation of

complex fractures due to their anatomic design and multidirectional screw fixation, as well as their angular stability. However, these features do not completely overcome the problems associated with osteoporotic bone. Medial support is still insufficient, varus collapse may still occur, screw migration or perforation and loss of reduction may occur. A number of special techniques have been developed to reinforce the medial column such as additional medial plates and intramedullary strut augmentation. These methods can enhance the stability of the construct and are useful for decreasing mechanical failure in poor quality bones.^[4-7] They continue to primarily enhance the strength of a rigid fixation construct. This has led to interest in alternative approaches which can achieve satisfactory stability with minimal surgical disturbance.

The concept of percutaneous elastic stabilization is to provide some flexibility and load sharing, rather than a completely rigid fixation. It can also help to minimize soft-tissue damage and dependence on purchase of cancellous screw. Elastic fixation provides some micromotion of the fracture and may have a more gradual transfer of load across the fracture, as compared to locking plates. Preservation of the local biological environment is likely to be important as well as mechanical stability, especially in osteoporotic bone.^[8,9] Studies have compared minimally invasive intramedullary fixation with locking plates support the investigation of less rigid fixation options. There is a general consensus in these studies concerning the functional results, and perhaps the minimally invasive fixation has benefits with regard to the procedure and exposure.^[9-11] One of these percutaneous elastic fixation methods is the Modified Minimally Invasive Reduction and Osteosynthesis System (MIROS).

MIROS offers minimal disruption of the fracture reduction and acts as a stabilizing elastic fix for the fracture, and may allow for the preservation of surrounding soft tissues and provide adequate fracture stability for healing. It has a lesser reliance on large surface area and cancellous screw purchase, which may be beneficial in osteoporotic PHFs. The feasibility of minimal invasive elastic fixation has been reported early on, but there are no clear advantages to be obtained from modified MIROS compared to more modern locking plate fixation.^{9,12} Thus, a clinical question remains regarding the ability of the modified MIROS procedure to achieve comparable functional recovery with improved peri-operative efficiency and less peri-operative complications without compromising radiographic healing.

Aim: This study aimed to evaluate the perioperative efficiency, functional recovery, radiographic healing, and complication profiles of the modified MIROS technique against rigid locking plate fixation in osteoporotic proximal humerus fractures.

MATERIALS AND METHODS

This comparative, non-randomized study evaluated 52 consecutive elderly osteoporotic patients treated for closed, displaced proximal humerus fractures (Neer 2-part surgical neck and 3-part fractures) between January 2022 and December 2024. Ethical approval was obtained from the Institutional Ethics Committee, and written informed consent was obtained from all participants before study initiation.

Inclusion and Exclusion Criteria: This study included patients aged 60 years or older with confirmed systemic osteoporosis based on Dual-energy X-ray Absorptiometry (DEXA) T-score ≤ -2.5 at the hip or lumbar spine, presenting with closed, acute (<10 days old) Neer 2-part surgical neck or 3-part proximal humerus fractures. Patients had independent pre-injury functional status and a minimum follow-up of 12 months. Patients with pathological fractures secondary to malignancy, open fractures, nerve deficits such as axillary nerve injury, vascular compromise, Neer 4-part displaced fractures, fracture-dislocations requiring primary arthroplasty, severe cognitive impairment, or inability to comply with postoperative rehabilitation protocols were excluded from the study.

Materials: The materials used in the study included a radiolucent operating table, C-arm fluoroscopy, 2.5 mm Schanz pins, heavy K-wires, multiple 2.5 mm K-wires, a modular MIROS clamp system, external frame components, an anatomical proximal humeral locking plate (PHILOS), locking and cortical screws, standard surgical instruments, general anaesthesia equipment, and standard postoperative rehabilitation and radiographic assessment equipment.

Methods: Fifty-two patients were included in the study. The modified MIROS technique was used in 27 patients (Group A), whereas a proximal humeral locking plate (PHILOS) was used in 25 patients (Group B) for open reduction and internal fixation. Treatment method chosen based on surgical risk profile and surgeon's experience of each technique. All the procedures in Group A were conducted with general anaesthetic and interscalene region block. Patients were positioned in the "beach-chair" position on a radiolucent table. Closed reduction was performed using longitudinal traction under fluoroscopic guidance with gentle abduction and rotation, and with gentle rotation. If sagittal and/or coronal apex angulation was present, a percutaneous joystick was performed. A 2.5 mm Schanz pin or heavy K-wire was used to re-align the neck-shaft and re-position the tuberosities in the head fragment. Polyvinylchloride (PVC) 2.5 mm K-wires were then placed percutaneously under C-arm guidance in multiple locations.

The wires were introduced retrogradely, from the lateral cortex of the shaft, distal to the deltoid insertion, towards the dense subchondral bone of the humeral head. Special attention was given to not entering the glenohumeral joint. The end of the wires

was bent, and the modular MIROS clamp system has been used to connect the wires. This produced a firm but elastic structure of frame, with a good skin clearance. The patients were placed in the beach-chair position and had been anesthetized with general anesthesia for Group B procedures. The standard deltopectoral approach was used. Fracture site was exposed, leaving the soft tissue attachments of the tuberosities intact. The subscapularis and infraspinatus tendons were inserted with traction sutures to help reduce the fracture. A PHILOS anatomical locking plate was placed 1.5-2.0 cm distal to the superolateral border of the greater tuberosity, and 5 mm back to the bicipital groove.

Locking screws were placed in the humeral head under fluoroscopy, paying special attention to the placement of the inferomedial calcar screw, which was done in several passes. Locking and cortical screws were used to fix the shaft. This wound was then closed over a suction drain. All patients underwent the same rehabilitation programme after surgery. Passive pendulum exercises and gentle passive shoulder movements initiated on POD 3-5 as tolerated. Active-assisted shoulder movements were started at 3-4 weeks. Full active movement and resistance exercises were commenced at the time of early bridging callus formation as seen on radiography (typically 6-8 weeks).

A local analgaesic was administered in the outpatient clinic, with the MIROS frame and K-wires being removed at 6-8 weeks following surgery, once radiographic union was confirmed, in Group A. Perioperative outcomes included operative time, estimated intraoperative blood loss, fluoroscopy time, length of hospital stay, and time to radiographic union. Functional outcome was evaluated at 3, 6 and

12 months using the Constant-Murley Score (CMS) focused on pain, activities of daily living, range of motion and isometric power. Throughout the 12 months follow-up period, complication data were recorded. Complications recorded during the 12-month follow-up included screw cutout/joint penetration, avascular necrosis, secondary varus collapse or loss of reduction, pin-tract irritation/infection, subacromial impingement or shoulder stiffness, deep wound infection, and secondary revision surgery.

Statistical Analysis: Data were presented as mean, standard deviation, frequency and percentage. Continuous variables were compared using the independent sample t-test. Categorical variables were compared using the Pearson chi-square test and Fisher's exact test. Significance was defined by P values less than 0.05 using a two-tailed test. Data analysis was performed using IBM-SPSS version 26.0 (IBM Corp., Armonk, NY).

RESULTS

Female patients were common in both groups, with 20 (74.1%) in Group A and 18 (72%) in Group B ($P=0.865$). Male patients accounted for 7 (25.9%) in Group A and 7 (28%) in Group B. Two-part surgical neck fractures were present in 16 (59.3%) patients in Group A and 14 (56%) in Group B, whereas 3-part fractures involving the greater tuberosity were seen in 11 (40.7%) and 11 (44%), respectively ($P=0.776$). Low-energy falls were the most common injury mechanism in both groups, reported in 25 (92.6%) patients in Group A and 23 (92%) in Group B ($P=0.938$) (Table 1).

Table 1: Comparison of Sex Distribution, Neer Fracture Type, and Injury Mechanism Between the Study Groups

		N (%)		P value
		Group A	Group B	
Sex	Female	20 (74.1%)	18 (72%)	0.865
	Male	7 (25.9%)	7 (28%)	
Neer fracture type	2-part surgical neck	16 (59.3%)	14 (56%)	0.776
	3-part (greater tuberosity)	11 (40.7%)	11 (44%)	
Injury mechanism (low-energy fall)		25 (92.6%)	23 (92%)	0.938

The mean age was similar between Group A and Group B (68.4 ± 6.2 vs. 69.1 ± 5.8 years; $P=0.678$). Bone mineral density was also similar between the groups (-3.1 ± 0.4 vs. -3.0 ± 0.5 ; $P=0.428$). Group A had a shorter mean operative time than Group B (48.3 ± 8.6 vs. 92.5 ± 14.2 minutes; $P<0.001$). Blood loss was also lower in Group A (35.2 ± 12.1 vs. $185.4 \pm$

42.5 mL; $P<0.001$). However, fluoroscopy was used for a longer duration in Group A (42.1 ± 9.5 vs. 21.3 ± 6.1 seconds; $P<0.001$). Radiographic union occurred earlier in Group A (8.4 ± 1.2 vs. 10.1 ± 1.8 weeks; $P<0.001$), and the mean hospital stay was shorter (1.4 ± 0.6 vs. 3.8 ± 1.1 days; $P<0.001$) (Table 2).

Table 2: Comparison of Baseline Variables and Perioperative and Radiographic Outcomes Between the Study Groups

		Mean $\pm$ SD		P value
		Group A	Group B	
Age (years)		68.4 ± 6.2	69.1 ± 5.8	0.678
Bone mineral density (T-score)		-3.1 ± 0.4	-3.0 ± 0.5	0.428
Outcome	Operative time (minutes)	48.3 ± 8.6	92.5 ± 14.2	<0.001
	Estimated blood loss (mL)	35.2 ± 12.1	185.4 ± 42.5	<0.001
	Fluoroscopy duration (seconds)	42.1 ± 9.5	21.3 ± 6.1	<0.001
	Time to radiographic union (weeks)	8.4 ± 1.2	10.1 ± 1.8	<0.001
	Length of hospital stay (days)	1.4 ± 0.6	3.8 ± 1.1	<0.001

Functional recovery was better in Group A throughout follow-up. The mean Constant-Murley Score was higher at 3 months (66.8 ± 7.1 vs. $58.4 \pm$

8.3 ; $P<0.001$), 6 months (75.1 ± 6.4 vs. 69.2 ± 7.8 ; $P=0.004$), and 12 months (79.4 ± 6.8 vs. 75.2 ± 8.1 ; $P=0.046$) (Table 3).

Table 3: Comparison of Constant-Murley Scores at Different Follow-up Intervals Between the Study Groups

		Mean $\pm$ SD		P value
		Group A	Group B	
Follow-up interval (in months)	3	66.8 ± 7.1	58.4 ± 8.3	<0.001
	6	75.1 ± 6.4	69.2 ± 7.8	0.004
	12	79.4 ± 6.8	75.2 ± 8.1	0.046

Regarding complications, screw cutout or joint penetration occurred in 4 (16%) patients in Group B and none in Group A ($P=0.046$). Avascular necrosis was seen in 3 (12%) patients in Group B and none in Group A ($P=0.104$). Secondary varus collapse occurred in 1 (3.7%) patient in Group A and 3 (12%) in Group B ($P=0.341$). Pin-tract irritation or infection occurred in 2 (7.4%) patients in Group A and none in Group B ($P=0.491$). Subacromial impingement or

stiffness occurred in 4 (16%) patients in Group B and none in Group A ($P=0.046$). Deep wound infection was reported in 1 (4%) patient in Group B and none in Group A ($P=0.481$). Overall, complications occurred in 3 (11.1%) patients in Group A compared with 9 (36%) in Group B ($P=0.034$). Secondary revision surgery was required in 3 (12%) patients in Group B and none in Group A ($P=0.104$) (Table 4).

Table 4: Comparison of Postoperative Complications and Secondary Revision Surgery Between the Study Groups

		N (%)		P value
		Group A	Group B	
Complication	Screw cutout / joint penetration	0	4 (16%)	0.046
	Avascular necrosis (AVN)	0	3 (12%)	0.104
	Secondary varus collapse	1 (3.7%)	3 (12%)	0.341
	Pin-tract irritation / infection	2 (7.4%)	0	0.491
	Subacromial impingement / stiffness	0	4 (16%)	0.046
	Deep wound infection	0	1 (4%)	0.481
	Total patients with complications	3 (11.1%)	9 (36%)	0.034
	Secondary revision surgery	0	3 (12%)	0.104



Figure 1: Preoperative AP and lateral radiographs demonstrating a displaced surgical neck proximal humerus fracture in an osteoporotic bone.



Figure 2: Preoperative AP and axial/lateral radiographs of a left proximal humerus fracture in an elderly patient.



Figure 3: Clinical photo of a patient with the assembled modified MIROS external elastic frame maintaining skin clearance on the shoulder



Figure 4: Post-op plain anteroposterior radiograph demonstrating the modified MIROS construct securing the proximal humerus alignment

DISCUSSION

Our study compared modified MIROS percutaneous elastic fixation with PHILOS locking plate fixation in osteoporotic proximal humerus fractures. Women were more common in both groups, ($P=0.865$); men were 7/27 (25.9%) and 7/25 (28.0%), respectively. Two-part fractures were seen in 16/27 (59.3%) and 14/25 (56.0%), while 3-part fractures occurred in 11/27 (40.7%) and 11/25 (44.0%) ($P=0.776$). Low-energy falls were reported in 25/27 (92.6%) and 23/25 (92.0%) patients ($P=0.938$). Mean age was 68.4 ± 6.2 and 69.1 ± 5.8 years ($P=0.678$), and mean T-score was -3.1 ± 0.4 and -3.0 ± 0.5 ($P=0.428$). Hemal et al. studied 51 patients, including 33 with pre-existing osteoporosis, with a male-to-female ratio of 0.46:1, mean age of 39.70 ± 12.77 years, and 19/51 Neer type III fractures.¹³ Salem et al. reported a mean age of 53.1 ± 9.79 years in 18 patients, including

6 two-part, 7 three-part, and 5 four-part fractures.¹⁴ Metwally et al. also studied elderly patients with Neer 2-part and 3-part fractures, although specific age, sex, and bone-density values were not reported.¹⁵

Our study showed clear perioperative differences between the two methods. Operative time was shorter with MIROS, 48.3 ± 8.6 versus 92.5 ± 14.2 minutes ($P<0.001$), as was blood loss, 35.2 ± 12.1 versus 185.4 ± 42.5 mL ($P<0.001$), and hospital stay, 1.4 ± 0.6 versus 3.8 ± 1.1 days ($P<0.001$). Fluoroscopy time was longer with MIROS, 42.1 ± 9.5 versus 21.3 ± 6.1 seconds ($P<0.001$). Shi et al., in 38 studies involving 2,699 patients, reported shorter operative time, less blood loss, faster healing, and fewer complications and infections with intramedullary nails than locking plates.¹⁶ Ouhadi et al. studied 97 patients and reported complication rates of 62.7% with nails and 67.4% with plates.¹⁷ Wang et al. compared 36 minimally invasive nail patients with 25 locking-plate patients among 61 patients and reported better results with nailing for operative time, blood loss, hospital stay, and complications; $P=0.001$ for operative time, incision length, and blood loss, $P=0.006$ for hospital stay, and $P=0.03$ for complications.¹⁸ These findings support the advantage of limited surgical exposure, although the greater fluoroscopy requirement with MIROS remains a practical concern.

Our study showed earlier radiographic union with MIROS, at 8.4 ± 1.2 versus 10.1 ± 1.8 weeks ($P<0.001$). Shi et al. similarly reported shorter fracture-healing time with intramedullary nails than locking plates.¹⁶ Palco et al. found that both MIROS and intramedullary nail groups achieved healing within three months, although one MIROS patient required reoperation for hardware failure.¹⁹ These results suggest that minimally invasive fixation can provide satisfactory healing, although differences in fracture type and assessment methods may influence the reported healing time.

Our study also showed better functional recovery with MIROS. Constant-Murley Scores were 66.8 ± 7.1 versus 58.4 ± 8.3 at 3 months ($P<0.001$), 75.1 ± 6.4 versus 69.2 ± 7.8 at 6 months ($P=0.004$), and 79.4 ± 6.8 versus 75.2 ± 8.1 at 12 months ($P=0.046$). Salem et al. reported a final Constant score of 81.5 ± 17.62 with modified MIROS versus 74.5 ± 17.40 with K-wire fixation.¹⁴ Metwally et al. reported significant improvement in Constant score and forward flexion with MIROS compared with nonoperative treatment ($P=0.0001$).¹⁵ In contrast, Shi et al. found no significant difference in Constant scores between nails and plates.¹⁶ Ouhadi et al. reported relative Constant scores of $72.7 \pm 0.3\%$ versus $65.4 \pm 0.3\%$ and SST scores of 6.7 ± 3.9 versus 6.0 ± 3.6 for nails and plates, respectively.¹⁷ Palco et al. found no significant difference in DASH scores between MIROS and nails, although VAS pain was 45 ± 25.7 versus 58.1 ± 12.5 .¹⁹ The differences may be due to the patient groups, fracture patterns, rehabilitation, and outcome measures used. The smaller difference

at 12 months in our study may indicate that the main benefit of MIROS is faster early recovery.

Our study showed fewer selected implant-related complications with MIROS. Screw cutout or joint penetration occurred in 4 (16%) PHILOS patients versus 0 MIROS patients ($P=0.046$); avascular necrosis occurred in 3 (12%) versus 0 ($P=0.104$); varus collapse in 1 (3.7%) versus 3 (12%) ($P=0.341$); stiffness or subacromial impingement in 4 (16%) versus 0 ($P=0.046$); and deep infection in 1 (4%) versus 0 ($P=0.481$). Revision surgery was required in 3 (12%) versus 0 patients ($P=0.104$). Hemal et al. reported infection in 1/51 (1.96%), stiffness in 3/51 (5.88%), necrosis in 2/51 (3.92%), and nonunion in 1/51 (1.96%), while 45/51 (88.24%) patients had no postoperative complications.^[13] Palco et al. reported complications in 22.2% of MIROS patients versus 8.8% of nail patients, with K-wire migration and superficial infection being the main MIROS problems; one MIROS patient required reoperation for hardware failure.^[19] Shi et al. found no significant difference between nails and plates for osteonecrosis, additional surgery, impingement, delayed union, screw penetration, or screw back-out, although overall complications and infection favored nails.^[16]

Our study reported pin-tract irritation or infection in 2 (7.4%) MIROS patients and none with PHILOS ($P=0.491$). Hemal et al. reported infection in 1/51 (1.96%), while Salem et al. reported three complications with modified MIROS, including pin-tract infection and stiffness, compared with four with K-wire fixation.^[13,14] Palco et al. also reported K-wire migration and superficial infection as common MIROS-related problems.¹⁹ Overall complications in our study were 3 (11.1%) with MIROS versus 9 (36%) with PHILOS ($P=0.034$). Metwally et al. reported complication rates of 14.3% with modified MIROS and 52.3% with nonoperative treatment.¹⁵ Ouhadi et al. reported 62.7% with nails versus 67.4% with plates, while Palco et al. reported 22.2% with MIROS versus 8.8% with nails.^[17,19] Taken together, these findings suggest that MIROS can reduce some plate-related problems, although pin-related complications remain a limitation. Overall, our study supports modified MIROS as a useful option for selected elderly patients with osteoporotic 2-part and 3-part proximal humerus fractures, especially when less surgical trauma, lower blood loss, and earlier recovery are desired.

Limitations: The non-randomized design and relatively small sample size of 52 patients may introduce selection bias and limit the generalizability of the findings. MIROS required longer fluoroscopy exposure, which represents an important practical consideration for the surgical team. The study included only Neer 2-part and 3-part proximal humerus fractures; therefore, the findings may not be applicable to more complex fracture patterns such as 4-part or head-split fractures.

CONCLUSION

Modified MIROS percutaneous elastic fixation was associated with shorter operative time, lower blood loss, earlier radiographic union, shorter hospital stay, better Constant-Murley scores during follow-up, and fewer overall complications compared with PHILOS fixation. Fluoroscopy time was longer, but functional recovery was better at 3, 6, and 12 months. The overall complication rate was also lower. Pin-tract irritation/infection occurred in 7.4% of patients, and varus collapse in 3.7%. Modified MIROS provided stable fixation with less surgical trauma and appears to be a useful option for elderly patients with osteoporotic proximal humerus fractures.

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