Modified Minimally Invasive Reduction and Osteosynthesis System Technique for Fixation of Proximal Humeral Fractures versus Multiple K-Wires Fixation

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ABSTRACT

Background: Fractures of the upper extremity, most commonly the proximal humerus, are commonly treated with the Minimally Invasive Reduction and Osteosynthesis System (MIROS) as well as a modified version of it.

Objective: To compare the radiological and functional outcome of modified MIROS technique and traditional multiple K-wires fixation for the treatment of proximal humeral fractures.

Patients and Methods: At Orthopedic Department of Zagazig University Hospital, we operated upon 18 patients, with a mean age of 53.1 ±9.79, 6 patients had two-part, 7 patients had three-part and 5 patients had four-part fractures, half of them were treated by K-wires and the other by Modified MIROS technique.

Results: The mean Constant score (CS) for the entire series, at the end of the follow-up period, was 74.5±17.40 in the K-wires group, 2 patients had excellent results, 3 patients had good results, 2 patients had fair results and 2 patients had poor results. In the Modified MIROS group, the mean CS was 81.5± 17.62, 3 patients had excellent results, 3 patients had good results, 2 patients had fair results and 1 patient had poor results. 7 patients had complication, 4 patients in the K-wires group as pin tract infection, delayed union, stiffness and nonunion, 3 patients in the modified MIROS group as pin tract infection, shoulder stiffness and inferior subluxation of glenohumeral joint.

Conclusion: Modified MIROS technique can be a very demanding procedure that may fail to provide a satisfactory reduction, particularly in dislocation with four-part injuries.

Keywords: Modified Minimally Invasive Reduction and Osteosynthesis System, Proximal Humeral Fractures.

INTRODUCTION

Among the aged population, proximal humeral fractures rank third in frequency, behind only wrist and hip fractures, that represent 5% of all appendicular bone injuries [1, 2]. High-energy trauma, such as falls from great heights, car accidents, or participation in high-intensity sports, is the most common cause of proximal humerus fractures in children and adolescents[2]. Extreme muscular contraction, such as that which occurs during an electric shock or a seizure, is an uncommon but possible method[3].

Neer's classification is utilized to categorize proximal humeral fractures[4]. Neer categorized fractures of the proximal humerus as either one-, two-, three-, or four-part fractures, fracture-dislocations, or articular-surface fractures. Any section that is more than 1 cm off its original position or has an angulation of more than 45 degrees is considered misplaced, as he defined it[5].

The type of fixation used depends on the patient's age, activity level, bone quality, fracture type, as well as surgical experience. Displaced proximal humerus fractures have a poor functional prognosis if left untreated, according to a number of studies[1].

Because of the possibility of avascular necrosis of the humeral head in displaced three- and four-part fractures, hemiarthroplasty has generally been the treatment of choice. For most three- and even four-part fractures, reduction and internal or external fixation has replaced open surgery in the last two decades as doctors learn more about the vascular supply to the humeral head[6].

Bohler first reported CRPP for proximal humerus fractures in 1962, but it has only recently gained traction in the medical community[7]. Closed reduction and minimal fixation techniques, such as percutaneous pinning fixation, have largely replaced open reduction and massive internal fixation in recent years because they are less invasive and have been shown to reduce soft tissue damage and the risk of avascular necrosis of the humeral head. In individuals with good bone quality, it can be very helpful for unstable 2-part surgical neck fractures and even some 3-part and 4-part fractures [8, 9].

As its name implies, the Minimally Invasive Reduction and Osteosynthesis System (MIROS) is primarily utilized to treat proximal humerus fractures. Elastic K-wires are externally secured in a metal clamp, allowing for decrease of angular displacement and fixing of fracture fragments. Its application is straightforward and requires few specialized tools [10]. In modified MIROS technique intramedullary elastic nails were used for proper reduction and fixation; also original clamp was replaced by Ilizarov cubes.

It was the goal of this study; to compare the radiological and functional outcome of modified MIROS technique and traditional multiple K-wires fixation for the treatment of proximal humeral fractures.

SUBJECTS AND METHODS

At Orthopedic Departments of Zagazig University Hospital, we conducted this clinical trial on 18 patients with displaced proximal humeral fracture.

Ethical consent:

Research Ethics Council at Zagazig University approved the study (ZU-IRB #9128) as long as all participants provided informed consent forms. Ethics guidelines by the World Medical Association's

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Helsinki Declaration for human experimentation were adhered to.

Inclusion criteria: Patients with post traumatic proximal humeral fractures, and age more than 18 years old.
Exclusion criteria: Patients with open fractures of proximal humerus, pathological fractures, patients not willing to give consent, patients with previous injuries that have already compromised function and movement of shoulder and patients having neurovascular deficit.
Half of patients were treated by **K-wires** and the other by **modified MIROS** technique.

This is what all of the participants in this research had to go through:

1. A thorough review of the patient's medical history and an orthopedic examination.
2. Radiologically by anteroposterior view and axillary view of proximal humerus, shoulder X-ray and computed tomography (CT) in selected cases, then were classified according to Neer's classification,
3. All patients had full preoperative lab investigation before surgery including: Complete blood picture, Random blood sugar, Viral screen, Coagulation studies (PT/PTT) as well as Kidney and liver function tests.

Surgical technique:
1- K-wires group
Anesthesia: All of the study participants were administered general anesthesia. Before inducing anesthesia, a prophylactic broad-spectrum antibiotic was given.

Positioning: The patient was positioned supine, and the afflicted shoulder was kept off the table so that the radiologist could have a good look at it using an image intensifier. Before draping, axillary and anteroposterior (AP) fluoroscopic views were taken to make sure the fracture sites could be seen and the bones could be identified.

Prepping and draping: Anteriorly and posteriorly, the patient's chest was prepared and draped from the midline to the root of the patient's neck.

Reduction and pinning technique:
Hand traction and arm mobilization were used to accomplish the reduction. One 3.5 mm K-wire was utilized as a joystick when reduction of an affected fracture proved challenging. In addition, a blunt elevator could be employed to aid dislodge the head fragments and facilitate reduction.
Once radiographs of the anteromedial and axillary views showed that the fracture had been reduced to an acceptable level (Fig. 1).

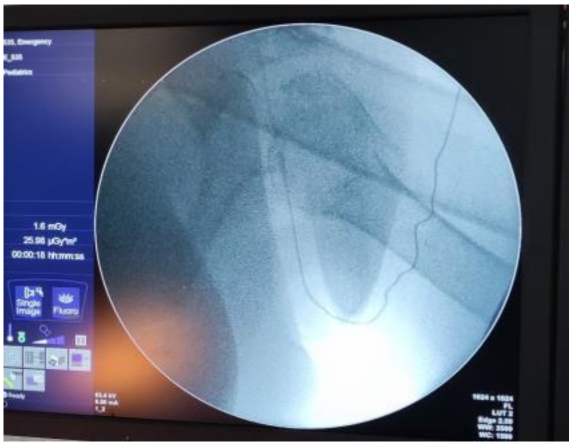


Fig. (1): C-arm view shows reduction of fracture

Fracture fixation was obtained by two methods:
A- Conventional method: fracture of three patients were fixed by conventional method:
A distance of at least 2 cm from the distalmost part of humeral head was required to insert two 2.5-3 mm K-wires through the larger tuberosity and into the medial cortex in order to fix the proximal humerus (Fig. 2).

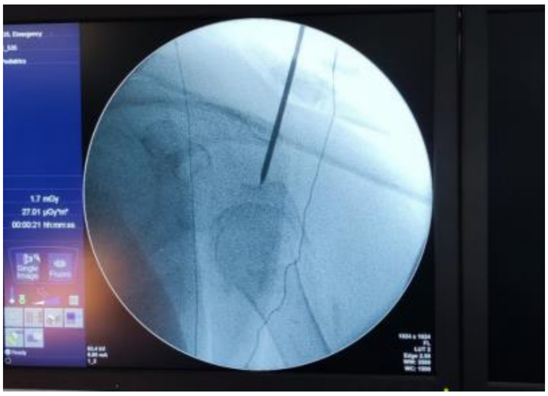


Fig. (2): C- arm view shows insertion of first K-wire

A next K-wire was inserted to enter the lateral cortex of the humeral head and then progressively inclined to the proper angle to engage the inferior aspect of the humeral head. The K-wire was retroverted by 30 degrees and inserted into the bone of the humeral head's inferior portion until the pin was securely lodged in the subchondral bone. The final K-wire was inserted proximally by 0.5-1 cm using the same technique. When necessary, an anteriorly placed K-wire was used to provide further stability.
Both the AP and axillary fluoroscopic views were used to thoroughly inspect the K-wires' location. After making sure the fixation was secure and that there was no chance of the articular surface being penetrated, the range of motion was performed under fluoroscopy (Fig. 3).

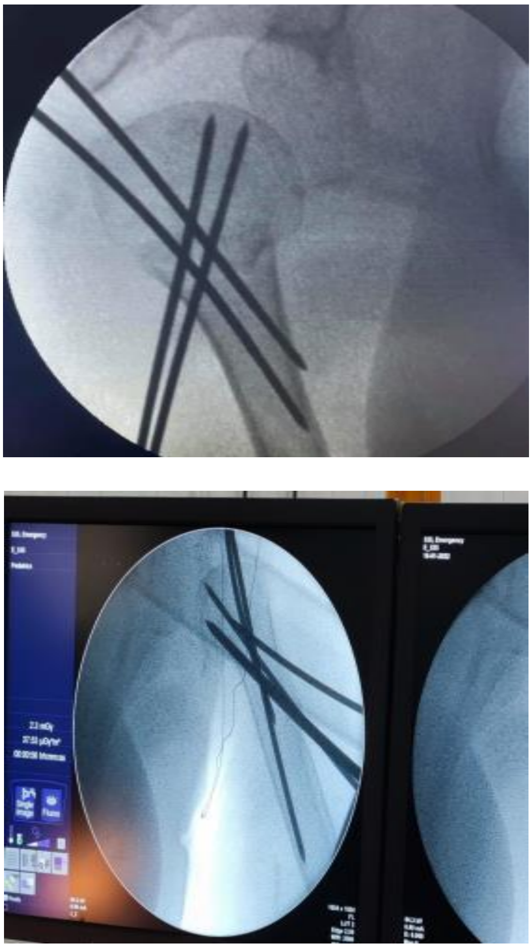


Fig. (3): C- arm views show K-wires fixation by conventional method

B- Modified method: fracture of six patients were fixed by modified method:

K-wire fracture fixation (2.5-3 mm) (also known as pins): A reduction pin, an anti-rotation pin, and a pair of stabilization pins made up the first wire, the second wire, the third wire, and the fourth wire, respectively.

One 2.5-3 mm K-wire was inserted through the proximal fragment and into the humeral shaft. A second, parallel K-wire was used to counteract the reduction achieved by the first. The anti-rotation K-wire was positioned posterolaterally if the reduction K-wire had been inserted anterolaterally, and vice versa.

The fracture location was stabilized using the remaining two K-wires. These K-wires were bored perpendicular to the fracture line into the deep medial cortex and implanted through the greater tuberosity. To further confirm the fixation was secured and to rule out articular surface penetration, range of motion was then performed under fluoroscopy (Fig. 4).

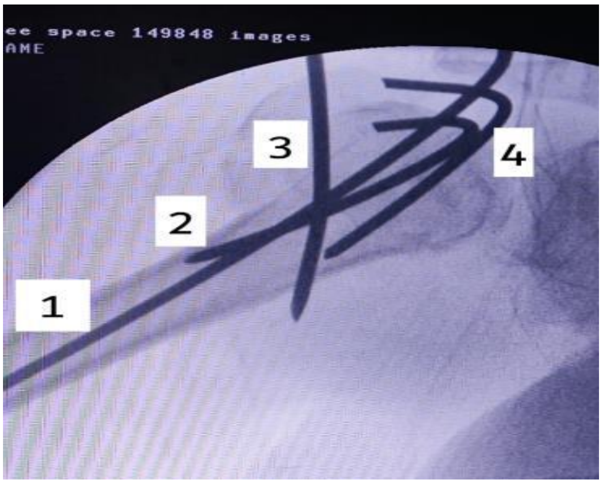


Fig. (4): C-arm view shows intraoperative X-ray with 1. reduction pin, 2. anti-rotation pin, 3,4. stabilizing pins

2- Modified MIROS group

Anesthesia: All of the study participants were administered general anesthesia. Before inducing anesthesia, a prophylactic broad-spectrum antibiotic was given.

Positioning: The patient was positioned supine, and the afflicted shoulder was kept off the table so that the radiologist could have a good look at it using an image intensifier. Before draping, axillary and anteroposterior (AP) fluoroscopic views were taken to make sure the fracture sites could be seen, and the bones could be identified.

Prepping and draping: All of the patient's upper body was prepared and draped, from the shoulders to the base of the neck and down the middle of the chest on both sides.

Reduction and pinning technique:

Anteroposterior and axillary radiographs indicated the reduction of the fractures after traction and manipulation. When repositioning fracture fragments proved challenging, a Steinman pin was employed to achieve satisfactory results. If displacement was severe and reduction was not obtained, 1 or 2 elastic nails of the same diameter inserted into and advanced beyond fracture site to up to the humerus' proximal metaphysis were used in this procedure. Initially, a K-wire was inserted into the greater tuberosity and pushed deeper until it reached the medial cortex and penetrate it. The second K-wire penetrated the cortex of the distal humerus after being put into the greatest portion of the humeral head. Two further K-wires were placed cranially from the proximal humeral metaphysis distal to the fracture site to the humeral head subchondral bone (Fig. 4 and 5).

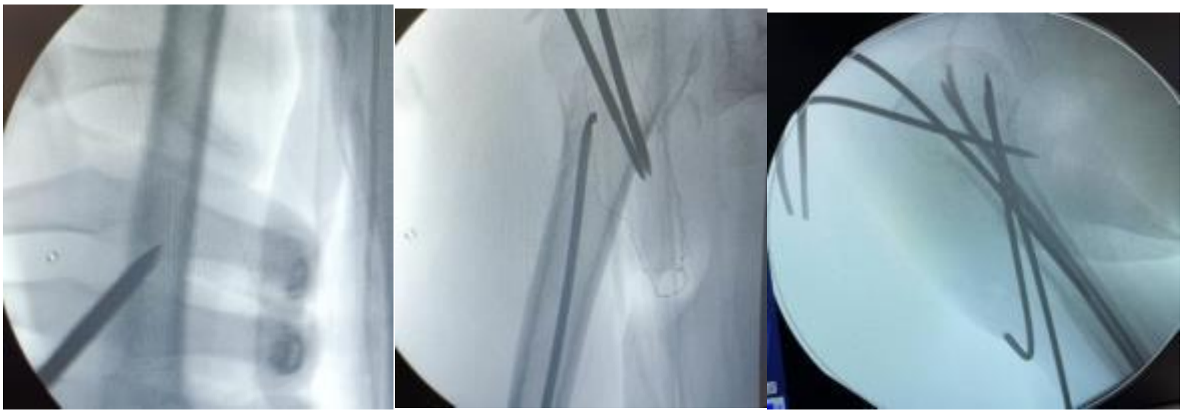


Fig. (5): A, B, C; C- arm views show insertion of K-wires and Nancy nails. The four K-wires were bent in order to be joined with rancho Ilizarov cubes

Fig. (6): Photographs show patient with modified MIROS.

After making sure the fixation was secure and that there was no chance of the articular surface being penetrated, we performed the range of motion under fluoroscopy.

Postoperative regime:

The follow up period was 6 months. Radiological evaluation was done every 2 weeks, until fracture union and pins removal then at 3 months, 6 months. The Constant score (CS), a 100-point score system created by **Constant and Murley**[11] was used to evaluate each patient at the end of the follow-up period.

Statistical analysis

In order to analyze the data acquired, Statistical Package for the Social Sciences version 20 was used to execute it on a computer (SPSS). The quantitative data were presented in the form of the mean, standard deviation, and range. Qualitative data were presented as frequency and percentage.

The student's t test (T) is used to assess the data while dealing with quantitative independent variables. Pearson Chi-Square (X^2) was used to assess qualitatively independent data. The significance of a P value of 0.05 or less was determined.

RESULTS

Sociodemographic factors did not differ significantly between the two groups in our study **(Table 1).**

Table (1): Demographics of the studied patients

Variable		The K-wire group		The Modified MIROS group		p-value
		No.	%	No.	%	
Age		55.8±11.2		54.4±10.5		0.79
Gender	Male	3	(33.3%)	3	(33.3%)	1
	Female	6	(66.7%)	6	(66.7%)	
Chronic illness	Yes	5	55.6%	3	33.3%	0.34
	No	4	44.4%	6	66.7%	
Smoking	Yes	1	11.1%	3	33.3%	0.26
	No	8	88.9%	6	66.7%	

We found that intraoperative data from the two groups did not differ significantly in our study **(Table 2).**

Table (2): Operative data of study groups

Variable		The K-wire group	The Modified MIROS group	P-value
		No. = 9	No. = 9	
Interval between trauma and intervention in days	Mean ± SD	3.33 ± 1.80	3.22 ± 1.39	0.88
	Range	1 – 6	1 – 5	
Time of surgery in minutes	Mean ± SD	56.4 ± 10.5	62.7 ± 12.5	0.26
	Range	45 – 75	45 – 80	
Neer's classification	Two-part fracture	3 (33.3%)	3 (33.3%)	0.84
	Three-part fracture	4 (44.4%)	3 (33.3%)	
	Four-part fracture	2 (22.2%)	3 (33.3%)	

There was no significant difference between the two groups regarding radiological union and implant removal **(Table 3).**

Table (3): Comparison of radiological union and implant removal time (weeks) between studied groups

	The K-wire group (N=9)	The Modified MIROS group (N=9)	P
Time of radiological union and implant removal	10.9 ± 6.56	8.2 ± 1.06	0.24

In our study there was no significant difference between the two groups in according to Constant score, or range of motion **(Table 4).**

Table (4): Differences in Constant score, mean range of motion according to study groups

Constant score	The K-wire group (N=9)	The Modified MIROS group (N=9)	p-value
Pain	8.3 ±5 (5-15)	11.1±3.33(5-15)	0.21
Range of motion	30.6± 7.32 (14-40)	32.4± 8.12 (14-40)	0.65
Power	20.4±2.65 (14-23)	21.1±3.55 (13-25)	0.64
Activities of daily living	14.6±2.82 (8-18)	16.6±3.74 (8-18)	0.21
Total	74.5±17.40 (36-94)	81.5± 17.62 (40-98)	0.40
Direction			
Flexion	124.4±28.13 (40-160)	131.6±31.61(55-170)	0.69
Abduction	127.7±29.51 (45-180)	135.5 ± 32.31 (45-175)	0.70
Internal rotation	8±1.32 (6-10)	8.6 ± 1.91 (6-10)	0.47
External rotation	7.7±1.11 (4-10)	8.2 ± 1.63 (6-10)	0.57

Data are presented as mean±standard deviation and range

None of major complications occurred intraoperatively in both groups. The overall complication rate was insignificantly higher in K-wire group than the **Modified MIROS group**.

There were two patients had pin tract infection (PTI), one of them had stiffness and the other patient had pin migration both treated by oral antibiotics, daily dressing, pin removal, and physiotherapy for patient with a stiff shoulder. One patient had delayed union and stiffness of shoulder treated by physiotherapy. While the other patient had nonunion was treated using plate and bone graft.

However, in **Modified MIROS group**, there were two patients had pin tract infection (PTI), one of them had shoulder stiffness both treated by oral antibiotics and daily dressing and physiotherapy for patient with a stiff shoulder. One patient had postoperative inferior subluxation of glenohumeral joint, which was treated by open reduction, plate fixation and anchor **(Table 5)**.

Table (5): Characteristics of study groups as regards complications

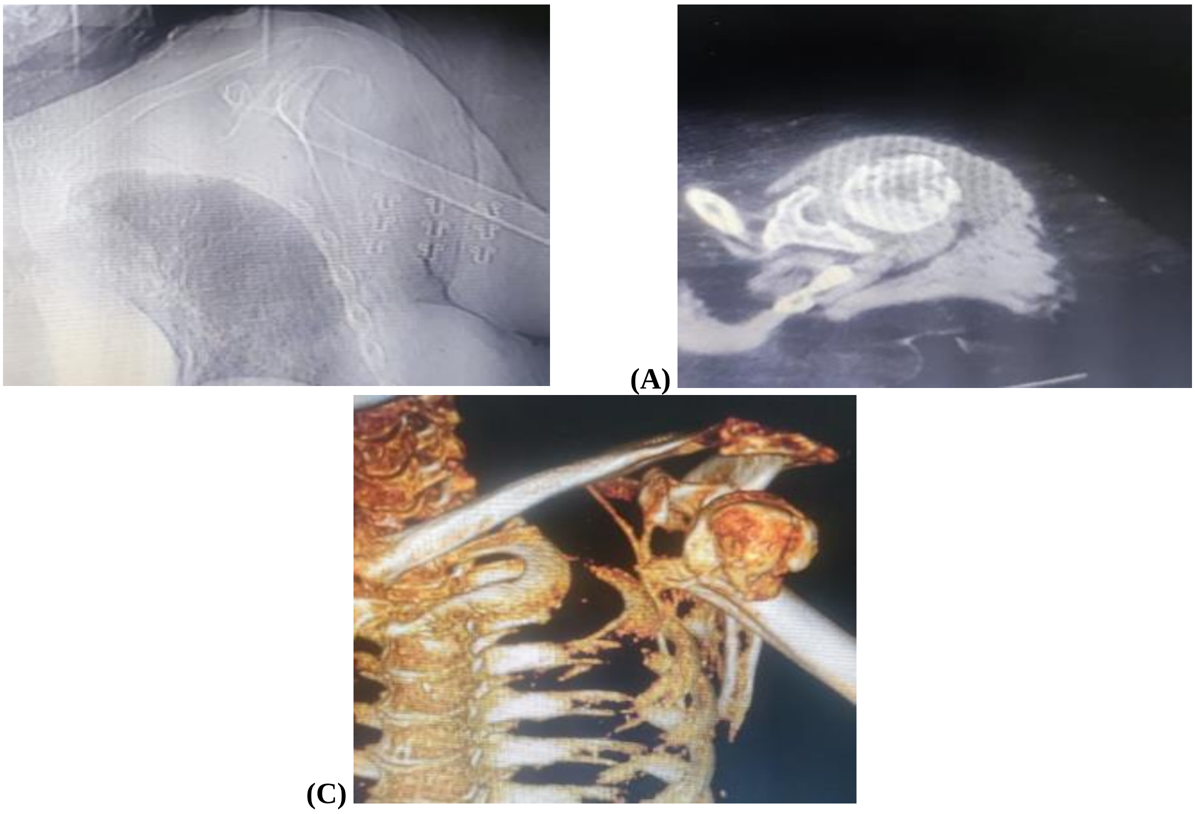
Variable	The K-wire group	The Modified MIROS group	P-value
	N=9	N=9	
COMPLICATION			
Present	4 (44.4%)	3 (33.3%)	**0.63**
Absent	5 (55.6%)	6 (66.7%)	
TYPE OF COMPLICATION			
Pin tract infection	2	2	
Stiffness	2	1	
Delayed union	1	------	
Pin migration+ GT displacement	1	------	
Nonunion	1	------	
Inferior Subluxation of glenohumeral joint	------	1	

As regard Constant score, the difference between both groups was not significant (**Table 6).**

Table (6): Relation between Constant score and study groups

Result	The K-wire group (N=9)		The Modified MIROS group (N=9)	
	No.	%	No.	%
Excellent	2	22.3%	3	33.3%
Good	3	33.3%	3	33.3%
Fair	2	22.2%	2	22.2%
Poor	2	22.2%	1	11.1%
Chi-square test	0.53			
P-value	0.91			

Figures 7-10 show pre- and postoperative management by Modified MIROS of one case of 4-part proximal humerus fracture.



(A) (A)

(C)

Fig. (7): Preoperative (A, B, C) CT showing 4-part proximal humerus fracture. 49 years, fall from height, Diagnosis: Left side 4-part fracture proximal humerus. The patient was admitted to Zagazig University Hospital, Orthopedic ER Department. As for preoperative clinical examination, the patient was neurovascular intact. The patient was operated upon after 2 days by Modified MIROS under C-arm imaging. Postoperative clinical examination showed that the patient was neurovascular intact. Radiological follow up was done until fracture union and pins removal at 8 weeks. Clinical evaluation was done using the CS. The patient was graded as good result

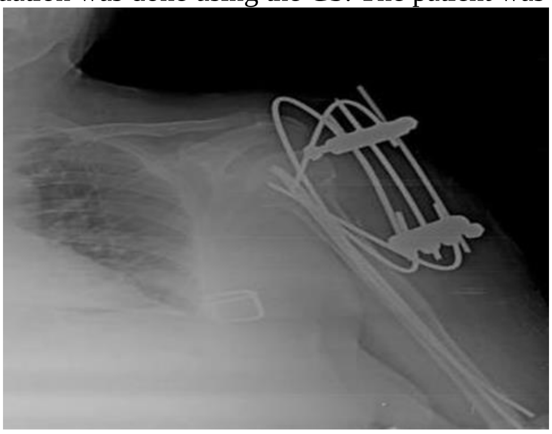


Fig. (8): Postoperative AP X-ray view at 2 weeks showing stable fixation

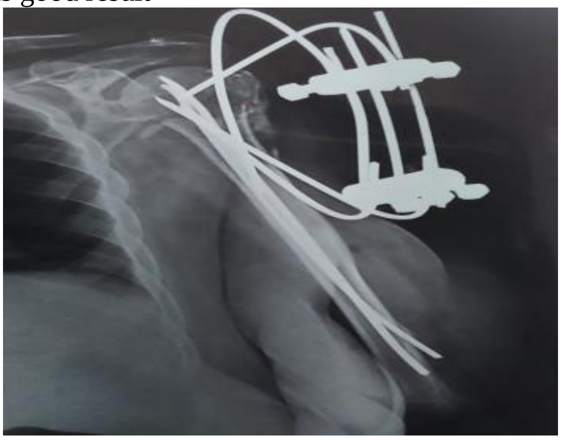


Fig. (9): Postoperative AP X -ray at 6 weeks showing stable fixation and callus formation

Fig. (10): Postoperative AP X -ray at 8 weeks after pin removal and fracture union

DISCUSSION

Most shoulder fractures are found in the proximal humerus. The distal radius is the most commonly broken upper extremity bone; however, this is a close second. Non-operative, open reduction and internal fixation (ORIF), percutaneous screw/pin fixation, hemiarthroplasty, and external fixation are just few of the methods used to treat these fractures. High-energy traumas in people of all ages and even minor falls in the elderly with osteoporosis are both major causes of fractures in this area. Fragility of bone further complicates the pattern of fracture in elderly people [(12)].

Marco *et al.* [(13)] results of three treatments for displaced proximal humerus fractures were compared: percutaneous pin fixation, open reduction and fixation, and hemi-arthroplasty. The average percentages for each Constant were 68, 57, and 74%. It was found that percutaneous pin fixation is a viable surgical approach on par with open reduction and hemiarthroplasty.

In this clinical trial study 18 patients were included, 9 patients treated by **modified MIROS** technique and the others 9 patients by multiple **K-wires**. The mean age of the patients was 53.1± 9.79 years with minimum age patient of 29 years and maximum of 66 years, the mean age was 55.8±11.2 years in **K-wire group** and 54.4±10.5 years in **Modified MIROS group**, 12 of them were females (66.7%) and 6 were males (33.3%), and the affection side was right in 11 patients and 7 patients with left. Falling down was the most common cause of injury (50 percent) followed by road traffic accident (33.3%), fall from height (16.7%). The majority of fractures in the present study were Neer's type 3 part (38.8 %), followed by 2 part (33.4%), 4 part (27.8%). This was comparable with **Elashmawy** [(10)] as patients' ages ranged from 50 to 75, with the mean age recorded was 62.5 of that range. The majority of the patients were men (60%) and women (40%), and the majority of the injuries were the result of car accidents (60%), with the remaining 40% being the result of falls. Half of the fractures were classified as Neer's type 3 (50%), followed by type 2 (30%), and type 4 (10%) (20 percent).

We assessed the shoulder functions between two groups according to Constant score and found superior functional outcomes in the **Modified MIROS group** than the **K-wire group**, but the difference was nonsignificant. Many published studies have shown significant differences between both methods; however, most of them compare the **percutaneous pinning** and **MIROS** techniques [(10-12)].

In our study the mean Constant score in **Modified MIROS group** was 81.5±17.6 and the score in K**-wire group** 74.5±17.4. This is in agreement with the study of **Bhavsar *et al.***[(14)]. The average constant score was 78.6 in **K-wire group**, while it was 89.1 in **percutaneous pinning and external fixation (MIROS) group** and with **Elashmawy** [(10)] The mean Constant score was 76.45± 9.4 in **K-wire group**, while in **MIROS group** the mean Constant score was 88.54 ± 4.5, and in comparison to **Anshuman and Patnaik *et al.*** [(15)] where the score was 80.8 in percutaneous K-wire.

In **K-wire group** mean flexion was 124±40, the mean abduction was 127.7±40, the mean external rotation 7.7 point and the mean internal rotation was 8 point. In **Modified MIROS group** mean flexion was 131.6±35.5, the mean abduction was 135.5±44.7, the mean external rotation 8.2 point and the mean internal rotation was 8.6 point.

In our study, three patients in the Modified MIROS group and 2 patients in the K-wire group got excellent results after six months. However, three patients in the Modified MIROS group and three patients in the K-wire group achieved good results, 2 patients in the modified MIROS group and 2 patients in the K-wire group both had fair results, and one patient in the Modified MIROS group and two patients in the K-wire group had poor outcomes. Compared to that of **Bhavsar *et al.***[(14)], when comparing the K-wire and MIROS groups, the outcomes were as follows: excellent for one patient (9%) and good for seven patients (64%) in the K-wire group; fair for two patients (18%) and poor for one patient (9%) in the MIROS group (36 percent), and compared to **Elashmawy** [(10)] there was one patient with outstanding outcomes (10%), six patients with good results (60%), two patients with fair results (20%), and one patient with poor results (10%). In the MIROS group, six patients with excellent results (60%) and four patients with good results (40%) were found.

The results of our **Modified MIROS group** were compared to the results of **Ambulgekar and Shewale** [(16)]. In the study 33 patients were treated by close reduction and multiple K-wires, the results were excellent in 10 (37.03%), good in 6 (22.22%), fair in 6 (22.22%) and poor in 5 (18.51%). While the results of our **K-wire group** compared to **Kelkar and Mundra** [(17)] results for 27 patients, treated with the modified approach for percutaneous K-wire fixation employing fixator micro clamps and rods, ranged from excellent (26% of cases) to good (52% of cases) to fair overall (22 percent).

None of major complications occurred intraoperative in both groups, four patients in the K-wire group and three in the Modified MIROS group experienced postoperative complications. The overall complication rate was higher in k-wire group (44.4%) than the Modified MIROS group (33.3%). In **K-wire group** two patients had pin tract infection (22.2%) one of them had pin migration with slight GT displacement and the other patient had shoulder stiffness, one patient had delayed union and shoulder stiffness (11.1%) and last patient had non-union (11.1%), while in **Modified MIROS group** of our study one patient had inferior glenohumeral subluxation (11.1%), two patients had pin tract infection (22.2%) one of them had stiff shoulder.

Carbone *et al.* [(6)] reported seven out of twenty-seven patients who underwent repeated percutaneous K-wire fixation experienced pin migration. Also,

Ambulgekar and Shewale [16] found that there were two incidences of pin migration in 33 patients who had had repeated percutaneous K-wire fixation. The K-wires technique had one occurrence of pin mobilization (migration), while the Modified MIROS group had none. According to **Kelkar and Mundra** [17], it has been widely observed that loosened K wires and wire penetration into joints are common issues. Clamping the wires to a fixator rod is a good way to reduce this.

We encountered 3 cases with shoulder stiffness one of them with the K-wires technique and one case with Modified MIROS technique. These cases mobilized their shoulders lately and were treated by physiotherapy. The higher number of restricted range of motion (ROM) patients in **K-wires** group than **Modified MIROS group** shows the benefit of early mobilization among **Modified MIROS group** patients due to more stable construct. **Vijay *et al.*** [18] reported in 6 cases, several K-wires were used to relieve stiffness in the shoulder.

Also, we found 1 case, 63 years old female, in the **Modified MIROS group** with inferior subluxation of glenohumeral joint 7 weeks postoperatively. The X-rays which were done before discharging patient till 3 weeks postoperatively didn't detect the inferior subluxation of joint. This complication was not reported by previous studies using MIROS technique [6]**.**

CONCLUSION

Percutaneous pinning is a good treatment option in high operative risk patients. Modified MIROS technique can be a very demanding procedure that may fail to provide a satisfactory reduction, particularly in dislocation with four-part injuries.

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Author contribution: Authors contributed equally in the study.

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