International Journal of Research in Orthopaedics
Shreyas BL et al. Int J Res Orthop. 2025 Sep;11(5):1066-1073
http://www.ijoro.org

Original Research Article

DOI: https://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20252631

The study of functional outcome of k-wire fixation with link joints in proximal humerus fractures

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Received: 28 April 2025
Revised: 20 June 2025
Accepted: 22 July 2025

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ABSTRACT

Background: Proximal humeral fractures are the common type of osteoporotic fractures seen in elderly patients. The objective was to evaluate the functional outcome of a novel modification of percutaneous k-wire fixation technique using Neer's classification. In this technique, the transfixing K wires were linked together with a link joint which functions as an external fixator, easily available and cheap compared to MIROS (Minimally invasive reduction and osteosyntesis system) and also has additional advantage of trans fixation.
Methods: The prospective study was conducted in MBS and new medical college, Kota, India over a 24 months period, we treated 25 patients of minimally displaced two-, three- and four-part fractures, 14 patients (56%) were males and 11 patients (44%) were females. Mean age of the patients were 50.52±14.46 years, the mean surgical time was 30.4 min. mean fluoroscopy time was 42.64 seconds, all k wire and link joints removed at 9.5 weeks. mean clinical union was 7.94 weeks.
Results: Final constant score at 18 months was 80.28±4.09. Mean abduction was 129.6±30.6 degrees, the mean anterior forward flexion was 125.5±25degrees. 2 patients developed pin tract infection, 1 patient developed stiffness .4 patients (16%) had fair results, 18 patients (72%) had good results and 3 patients (12%) had excellent results.
Conclusions: The modified novel method that takes advantage of the minimal invasive approach for treating proximal humeral fractures by Kirschner wire mutual linking technique with link joints, providing a great deal of flexibility in the fixation construct's composition which is cost effective and provide even more stability.

Keywords: Proximal humerus fractures, K-wire, Link joint, Constant score, Minimally invasive reduction and osteosyntesis system

INTRODUCTION

Proximal humeral fractures are the commonest type of osteoporotic fractures encountered in trauma bay, accounted for 5% of all appendicular bone injuries, making it the most common injury, second only to wrist and hip fractures. The incidence of this fracture has significantly increased perhaps due to high energy trauma, such as fall from height, road traffic accidents and participation in high intensity sports, which is the most common cause of proximal humerus fractures in children and adolescents.[1] It affects women two to three times more frequently than it does males.[2] A small amount of malunion is both aesthetically and functionally acceptable when fractures are treated conservatively or surgically.

The inability to achieve rigid fixation in the osteoporotic cancellous bone of the proximal humerus, thin cortex of bone and presence of comminution provides weak purchase for the screws offers difficulty in internal fixation, while external fixation works on principle of ligamentotaxis.

With minimally invasive surgery the blood loss can be prevented, percutaneous fixation makes it possible to preserve the vascular supply to bone fragments and perform under regional anaesthesia. Franco Stefano Carbone, Mario Tangari et al studied patients treated with MIROS and traditional percutaneous pinning (TPP), MIROS (Minimally invasive reduction and osteosyntesis system) group had better constant score and outcome, its fixed configuration, construct, limited degree of variability and cost of implant acts as a disadvantage to operate.[3]

Internal fixation has reported to have increased complication rates in these patients due to hardware loosening and pullout of the screws, requirement of significant dissection causes postoperative adhesions which severely restrict range of motion.[6] Many studies show, for majority of proximal humerus fractures, surgical options have changed to methods of reduction and internal or external fixation due to improved understanding of the vascular supply to the humeral head.[7-9]

The purpose of this study was to evaluate the functional outcome of a modification of percutaneous k-wire fixation technique. In this technique, the transfixing k wires were linked together with a link joint. This functions like an external fixator, which is a component of JESS fixator easily available, cheap, multiple degree of variability and also has an additional advantage of transfixation and ligamentotaxis.

Aims and objectives

To study the functional outcome of k-wire fixation with link joint in proximal humerus fractures according to Neer's classification, to assess the functional outcome using constant score and to identify the complications of this procedure.

METHODS

The study design was single arm prospective cohort study conducted at the department of orthopaedics, MBS hospital and NMCH hospital, Kota with a total time duration of 24 months from July 2022 after the approval of ethical committee to July 2024. The total subjects were 30.

Inclusion criteria

Minimally displaced 2, 3, 4 parts fracture proximal humerus more than 18 years of age, with comorbidities (type 2 diabetes and hypertension, etc.,), with ASA (American Society of Anaestesiologists) grade 1 and above, acute (injury less than 2 weeks) displaced proximal humeral fracture.

Exclusion criteria

Existing history of bone disease or pathological fracture, other combined injury like fracture dislocation, previous shoulder injury, previous fracture of the clavicle, scapula, or humerus, and any history of ipsilateral shoulder movement limitation.

After the admission, necessary clinical details were recorded in a trauma sheet comprising of Age, trauma and medical history, time and place of injury, time interval between injury and treatment in our casualty department. This period was less than three days in all cases, Occupation of the patient, associated injuries e.g. neuro-vascular status, tendon injury. Then complete clinical examination comprising of local and systemic examination was recorded on trauma sheet itself. radiologic evaluation of the shoulder were done according to Neer's trauma series which consists of an anteroposterior (AP) view of the scapula and a lateral 'Y-view' of scapula.

All the data was assessed and tabulated using Microsoft excel and statistically analyzed using SPSS version 23 (IBM corp, Armonk, NY, USA). Quantitative variables are reported as means and Qualitative as percentages.

Pre-operative investigations

Routine investigations, C.T. Scan if 3 or more parts involved, fractures were classified according to the Neer's classification and patients were shifted to the ward after initial temporary immobilization with Universal shoulder immobilizer. complete medical and anesthetic fitness of patient for surgery with informed consent and ASA grading done.

Anaesthesia used

General anaesthesia or interscalene block and at least one unit of compatible blood was kept in reserve for all patients who underwent surgery.

Method of treatment

All the patients were operated on either elective or emergency basis; all patients were treated by closed reduction and internal fixation with link joints. Mini open technique was used in displaced greater tuberosity fractures. Implants used were k-wires (2 mm/2.5 mm), Link joints (Medium size), 4 mm CC screws, washer. PHILOS (proximal humerus internal locking system) plate was kept in reserve, in case of change in intraoperative decision. But none of the cases required it.

Surgical procedure

All of the study participants before inducing anesthesia, a prophylactic broad-spectrum antibiotic was given.

Positioning

In order to provide the operator with a clear view of the affected shoulder using an image intensifier, the patient was placed in the supine beach chair posture with the affected shoulder kept off the table and a sandbag being

placed to elevate the shoulder. Axillary and anteroposterior (AP) fluoroscopic views were obtained prior to draping in order to ensure that the fracture sites were visible and the bones could be recognized.

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

Close reduction of the fracture was achieved by manual traction and gentle manipulation; and four to six k-wires (diameter 2–2.5mm), depending on the fragment were needed.

The important structures which are at risk are the axillary nerve, anterior and posterior circumflex humeral artery, cephalic vein, biceps tendon, and musculocutaneous nerve.

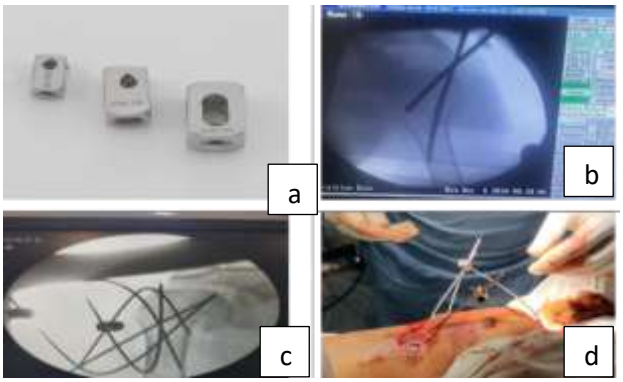

Figure 1 (a-d): From clockwise showing link joints (small, medium, large size), joy sticking of fracture fragments using steinmann pin, the freedom of inserting as many k-wires as needed according to stability and fixing these k-wires mutually by link joints after bending them 90 degrees towards each other respectively.

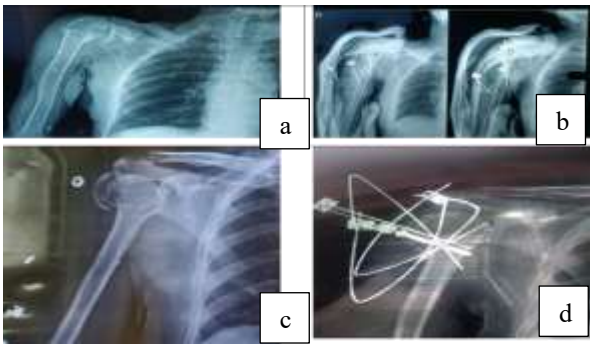

Figure 2 (a-d): Preoperative radiographs on the left-hand side and postoperative radiographs on the right-hand side, with mini open CC screw technique done is shown in right lower radiograph.

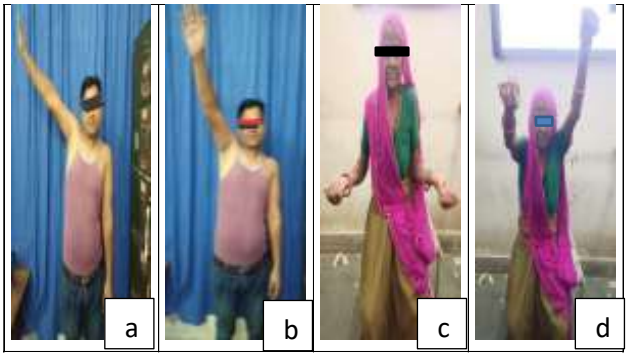

Figure 3 (a-d): The final functional outcome of the patients.

In two-part surgical neck fractures, the head was in the neutral position as both the tuberosities were attached to it, and the shaft was pulled medially due to the pull of the pectoralis major. Longitudinal traction, with flexion and some abduction was required to reduce the fracture .humerus shaft was anteriorly angulated most of the times, it is reduced by lifting the elbow upwards or applying posterior pressure over the shaft at fracture site, A Steinman pin can be inserted through the largest part and joysticking (Figure 1) can be done to achieve reduction, varus angulation is corrected by joystick and longitudinal traction, the aim of reduction is to achieve the fragment in acceptable position that is less than 45 degree of angulation and less than 1 cm of displacement. Once reduction obtained two 2.5 mm k-wires being inserted from greater tuberosity and engaged in medial cortex of shaft, also 2 k-wires inserted from the lateral side of the humeral shaft and anchored to the subchondral bone of the humeral head after stab incision and clearing the soft tissue, the number of k-wires need to be inserted is decided by the stability of the reduction achieved, minimum 4 k-wires were needed for achieving acceptable reduction in 2 part fractures , as the number of parts increased the number of k-wires also increased proportionately, multiple k-wires in multiple directions and planes gives rotational stability to the reduced fracture fragment. Two additional parallel wires were inserted from the lateral cortex of the humeral shaft to the calcar area to provide additional stabilization. Several intramedullary wires could also be applied in cases where the reduction is difficult to maintain. After k-wire application, all wires were bent towards each other at 90 degree at a position about 1cm above the skin to prevent skin irritation, and then mutually hooked with a link joints, Again the number and site of Link joint placement depends upon the number of k-wire, usually 2 k-wires need 1 link joint, and for 6 k-wires we need 3 link joints, the direction and site of placement of link joints depends on the reduction achieved and the valgus force needed to sustain.

The same technique is applied on 3 part and 4-part fractures.

If there is displaced greater tuberosity fractures, in slender patients with, manipulative reduction achieved by threaded pin after a stab incision pressing of GT with

thumb the GT is reduced manually, if this is unlikely to succeed under image intensifier often works. If not a small incision of 2-3cm was applied over the lateral aspect of greater tuberosity fragment, spread the deltoid muscle gently and insert a small elevator over the upper border and push GT onto its bed , temporary fixation achieved by k-wires confirmation of reduction under image intensifier and fixed using 4mm partially threaded cannulated-cancellous lag screws with or without washer based on quality of bone, then k-wires are inserted as described above (Figure 2).

Link joints

They are the components of JESS fixator. They are available in different sizes and also called by the name of JESS CLAMP with sizes of small, medium, large small size accommodates a k-wire of size upto1.5mm, medium size accommodates a k-wire of size from 1.2 to 3 mm. Large size can accommodate up to 4 mm. there is also Universal link joint - independent locking system for each connecting rod or k-wire and can accommodate up to 4mm diameter (Figure 1).

Figure 1 from clockwise showing link joints (small, medium, large size), joy sticking of fracture fragments using Steinmann pin, the freedom of inserting as many k-wires as needed according to stability and fixing these k-wires mutually by Link joints after bending them 90 degrees towards each other respectively

Figure 2 showing preoperative radiographs on the left-hand side and postoperative radiographs on the right-hand side, with mini open CC screw technique done is shown in right lower radiograph

Post-operative care

Post-operatively limb is immobilized in U slab, pin dressings done on post operative day 2, day 5, and day 12, mobilization was started from first week with shoulder wheel exercises as per patient's pain tolerance, intravenous antibiotics continued for 5 days and oral analgesics were given. Immediate post-op radiographs were done routine A-P and scapular view to assess the reduction of fracture and stability of fixation. If the bone was severely osteoporotic and fixation was less than rigid, motion was delayed; otherwise, re-displacement of the fracture fragments could have occurred. patients were discharged usually on post operative day 3-5, patients discharged with oral analgesics, vitamin D3 supplements and bisphosphonates were given if there was severe osteoporosis.

Rehabilitation

Following is the recommended rehabilitation programme under the supervision of physiotherapist.[12-15] Gentle passive exercises consisting mainly of forward flexion and external rotation are begun. Pendulum type exercises permitted at 10 days. Gentle passive and active exercises progress according to the patient's pain tolerance.[12]

Phases

Phase I: Passive range of motion begins on the second or third post operative day after pain has subsided, consists of passive forward elevation and external rotation of involved shoulder. Later internal rotation is added.

Phase II: Starts at 4-6 weeks consists of active range of motion exercises with terminal stretching, begins once early union has been achieved and confirmed by radiographs.

Phase III: It begins after the 8th post operative week consists of resistive strengthening and terminal stretching program when union is ensured and adequate motion has been obtained.

Realistically 6-12 months of aggressive post-operative rehabilitation is needed for a satisfactory return of function.[13]

Outcome evaluation

Constant murley score used a system based on 100 units: 15 units were assigned for pain, 20 units for activities of daily living, 40 units for range of motion, and 25 units for power.[16] A score of 85 or higher represents an excellent result; 75 to 85 units is good result; 70 to 75 units is a fair result; and 65 to 70 units represent a satisfactory result, less than 65 represent poor result. Each assessment method places varying importance in the areas of pain, range of motion, and function.

RESULTS

The study comprised of 30 patients, out of 30 patients 5 patients had lost to follow-up, all were operated on for Neer's type 2-part, 3 part and 4-part fractures with follow up to 18 months.

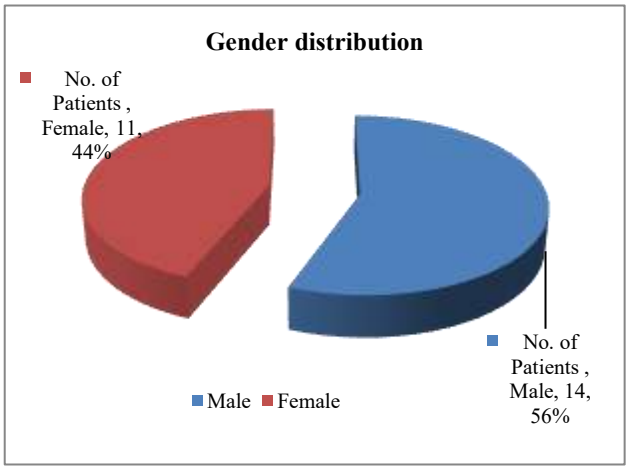

Figure 4: Describing gender distribution.

14 patients (56%) were males and 11 patients (44%) were females (Figure 4) Mean age of the patients were 50.52±14.46 years (Figure 5). Right shoulder was operated on 16 patients (64%) and left was 9 patients (36%), 16 patients had their injury on their dominant side and remaining 9 patients on their non-dominant side.

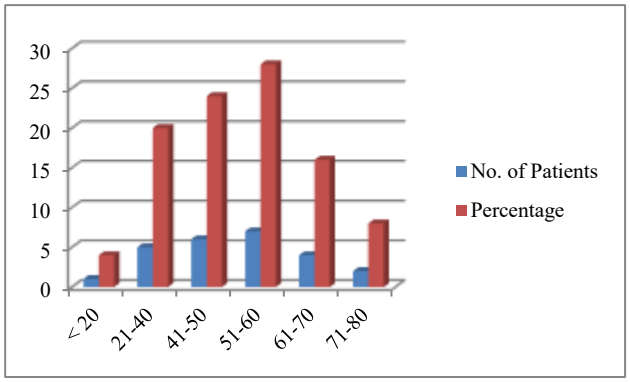

Figure 5: Age distribution in our study.

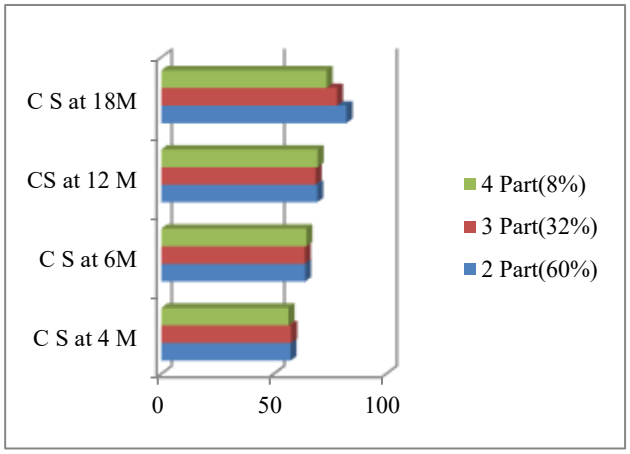

Figure 6: Trend of constant score.

Most common mechanism of injury was Road traffic accident in 11 patients (44%) and fall on ground in 14 patients (56%). Neer's type 2-part fracture was diagnosed in 15 patients (60%), 3-part fracture in 8 patients (32%), 4-part fractures in 2 patients (8%). All patients were initially managed by U slab, one patient had grade 1 Open fracture according to Gustilo- Anderson classification remaining 24 patients (96%) had closed fractures.7 patients (28%) had ASA grade 1,11 patients (44%) had ASA grade 2 (44%), 7 patients (28%) had ASA grade 3.

16 patients (64%) needed X-ray alone for diagnosis and planning the management, whereas 9 patients (36%) needed CT scan for accurate diagnosis and management plan. 3 patients (12%) had associated upper limb injury and 2 patients (8%) had associated lower limb injury. Mean time after injury and surgery was 38.8 hours (range; 24-48 hours). All patients were operated by skillful experienced surgeons; The mean surgical time was 30.4 minutes (range; 23-40 minutes). Mean fluoroscopy time was 42.64 seconds (range; 35-52 seconds). 15 patients needed 4 k-wires for stabilization, 2 patients needed 5 k-wires and 6 patients needed 6 k-wires for stabilization of fracture. 2 patients were operated by mini open CC screw fixation. Mean clinical union was 7.94 weeks (range; 7-9 weeks). Mean radiological union was 9.46 weeks (range; 8.5 -10 weeks) the mean implant removal time was 9.5 weeks (range; 9-10 weeks) mean constant score at 4 months was 57.4, at 6 months was 63.9, at 12 months was 69.1and final constant score at 18 months was 80.28±4.09 (range; 73-88) (graph-3). 3 patients (12%) developed complications, 2 patients developed pin tract infection, 1 patient developed stiffness. 4 patients (16%) had fair results, 18 patients (72%) had good results and 3 patients (12%) had excellent results.

DISCUSSION

Marco et al results of three treatments for displaced proximal humerus fractures were compared: percutaneous pin fixation, open reduction and fixation, and hemiarthroplasty.[17] 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.

Internal fixation has been reported to have increased complication rates in osteoporotic patients due to hardware loosening and pullout of the screws.[18-20] Additionally, the use of internal fixation device prolongs the operative time, increases intraoperative bleeding, and increases the risk of avascular necrosis of humeral head because of the disruption of the residual vascularity.[18,19] Several studies have shown that less anatomical reduction of bone fragments is not a major drawback in most of the fractures of proximal humerus ,because the clinical results can be satisfactory even in presence of non-anatomical reduction of fracture, similar results were obtained in our study.[6,21,22]

By using a locking device on the pins, certain efforts have been made to improve the stability of the pinning fixation and reduce the wire-migration rate. The "Humerus block" is one such locking mechanism that holds two crossed k-wires at the fracture site at a predetermined angle using a locking screw and block locking device, the disadvantage of this is need skin incision and need of implant removal.

A different approach known as the "Hybrid technique" involves applying K-wires and securing them with an external fixator after performing open reduction, open reduction again has its own disadvantages and many researchers also performed closed reduction and external fixation using JESS fixator Monga et al, Gupta et al fixing with a bulky external apparatus is a concern to the patients, some of the patients even deemed that bulky fixator is socially unacceptable and developed psychological intolerance, for which antianxiety drugs too prescribed.[10,11,24]

Another device, "MIROS" by Stephenocarbone et al and its modified MIROS method by Salem et al.[1,3] All these instruments produce good clinical and radiographic outcomes, and generally have lower complication rates, lower revision rates, and lower rates of pin migration than the percutaneous pinning alone.[3] Furthermore, the purpose of these methods is to increase structural strength and pin stability by the use of an external locking device.

But the humerus block and MIROS devices can only employ a certain amount of k-wires two wires for the humerus block and four wires for the MIROS device and modified MIROS method. The locking device's set direction of k-wire anchoring is another drawback. Regretfully, insufficient fragment fixation could result from these restrictions.

Chang et al justified all these concerns to a great extent but mutual linking rubber bands questions the stability of the construct and all k-wires linked to the same site causes fragments to move.[4] Kelkar et al addressed all issues but using clamps without mutual bending the k- wires resulted in pin migration and failure of the construct in one case.[2]

On the other hand, our modified method offers the benefit of sufficient k-wires that can be freely positioned and oriented to connect multiple parts which can be mutually bent and locked using a link joint, we can use as many link joints as needed according to stability, direction of fixation, plane of fixation and number of k wires used. Comparing the construct to earlier devices, it is more affordable and smaller, but in addition, the bending and mutual linking of the wires can offer extra valgus force to resist the deforming stress from the deltoid and supraspinatus muscles.

Constant score and range of motion

There was steady improvement in constant score (Table 1 and 2) over a period of 18 months The elderly patients had limited improvement of constant score from 6 month to 1 year as most of these patients were unwilling to undergo rigorous rehabilitation programme. The range of motion (ROM) was adequate to carry out day to day activities (Table 3).

Table 1: The constant score comparison between different studies.

Study	Mean constant score	P value
Salem et al[1]	81.5±17.6	0.40
Carbone et al[3]	60	0.02
Kelkar et al[2]	77.2	-
Bhavsar et al[5]	89.18	0.003
Present study	80.28±4.09(range ;73-88)	0.001

Table 2: Describes the improvement in constant score over a period of 18 months.

Neer's type	CS at 4 m	CS at 6m	CS at 12 m	CS at 18m
2 part (60%)	57.46	63.93	69.33	82.33
3 part (32%)	57.75	63.8	68.6	78.12
4 part (8%)	56.5	64.5	69.5	73.5

Table 3: Mean range of motion achieved after 18 months of follow up.

Motion	Maximum ROM (in degrees)	Mean observed ROM (in degrees)
Abduction	180	129.6±30.6(70-160)
Forward flexion	180	125.5±25(80-155)
External rotation	60	7.7±2.7(5-10)
Internal rotation	90	7.2±1.7(6-10)

Complications

In our study we observed 3 patients (12%) developed complications, 2 patients developed pin tract infection, 1 patient developed stiffness, none of them developed Pin migration, pin loosening, unacceptable malunion, non-union, osteonecrosis, nerve injury. We were successful in preventing pin migration by mutually linking by bending the k-wire 90 degree towards each other and giving extra stability to construct by link joints.

Table 4: Results of the study.

	This study	Salem et al[1]	Kelkar et al[2]	Bhavsar et al[5]	Gupta et al[11]	Kristiansen et al[23]
No. of cases	25	9	27	11	16	23
Excellent (%)	12	33.3	26	72.73	18.75	8.69
Good (%)	72	33.3	52	27.27	62.5	43.48
Fair (%)	16	22.2	22	-	18.75	43.38
Poor (%)	-	11.1	-	-		4.35

Pin tract infection was seen in 2 patients, which was classified according to Moore and Dahl classification and treated according to it, both patients had grade 2 infection that is superficial infection with serous discharge and treated with regular pin dressings with half strength hydrogen peroxide and betadine with oral antibiotics for 2 weeks, the infection subsided. None of the patient required pin removal. One patient developed stiffness at shoulder joint this patient was elderly having 4 parts fracture, was

unwilling to undergo rigorous rehabilitation programme and developed stiffness.

In our study 4 patients (16%) had fair results, 18 patients (72%) had good results and 3 patients (12%) had excellent results, the results were comparable to Kelkar et al, Gupta et al, Kristiansen et al (Table 4).[2,11,23]

Limitations of the study

Small sample size of 30 patients, long term follow-up results needed for better conclusions, Prospective single center study with no control group and Usage of unthreaded k-wires.

CONCLUSION

The optimal course of treatment for proximal humerus fractures is still up for debate. This method may be recommended for older patients with good general health who require less anatomical fracture reduction and have great functional outcomes. It is a biological fixation that permits early joint movements, early discharge from hospital and produces positive outcomes. We conclude that the modified method that takes advantage of the minimal invasive approach for treating proximal humeral fractures by percutaneous Kirschner wire mutual linking technique with link joints. This modified novel approach allows for an infinite number of K-wires and link joint fixations to be used throughout the surgical procedure, providing a great deal of flexibility in the fixation construct's composition and it is cost effective. Mutual linking provides even more stability, decreases pin migration and fracture displacement. We think that other fracture situations, like distal radial and ulnar fractures, distal humerus fractures, metatarsal and metacarpal bone fractures, could also benefit from the use of this approach. More examples are necessary to elucidate the clinical effectiveness of our method.

ACKNOWLEDGEMENTS

Special thanks to Dr. Anup Kumar, Dr. Sudeep Kumar and Dr. V. K. Sahni for their support.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Shreyas BL, Meena DK, Burhani AA, Athul M, Bansal A. The study of functional outcome of k-wire fixation with link joints in proximal humerus fractures. Int J Res Orthop 2025;11:1066-73.