

## ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

# Distal humerus nonunions after failed internal fixation – treatment with the Ilizarov external fixator

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**SUMMARY**

**Introduction/Objective** Nonunions of the distal humerus after unsuccessful surgical treatment represents a challenging surgical problem. The complexity of this condition is increased by bone atrophy, scar tissue, poorly vascularized bone fragment, limited elbow mobility, osteomyelitis, and local neurological damage. The advantages of using the Ilizarov external fixation method are stable fixation, adequate fracture reduction, and fragment compression accompanied by minimal soft tissue trauma, with the possibility of early elbow mobilization. This aim of this paper is to present the treatment results of 19 patients with nonunion of distal humerus after internal osteosynthesis managed by the Ilizarov external fixation method.

**Methods** Nineteen consecutive patients were treated with the Ilizarov external fixator. The study group includes 11 male and eight female patients with an average age of 42 years. Surgical technique consisted of approaching the nonunion, removing loose fixation material, making resection and debridement of bone fragments, after which the Ilizarov fixator was placed. Rehabilitation of the elbow started in the early postoperative period. The functional status of the arm was evaluated using the Disabilities of the Arm, Shoulder and Hand (DASH) score.

**Results** All the patients achieved solid bony union after an average of seven months from the application of the external fixator. In 17 patients radiographic analysis indicated the preservation of joint space, while two showed degenerative changes. All the patients showed improvement in elbow range of motion and significantly better DASH score with postoperative value of 21.

**Conclusion** As a treatment of distal humerus nonunion, the Ilizarov external fixation method provides successful healing and increased range of motion in the elbow.

**Keywords:** humerus; nonunion; Ilizarov technique

**INTRODUCTION**

Nonunions of the distal part of the humerus occurring after unsuccessful fracture treatment with open reduction and internal fixation (ORIF) represents a challenging surgical problem [1]. In most cases, this condition is characterized by instability, pain, weakness and reduced range of motion in the elbow joint, which all leads to a high degree of disability of the entire upper extremity [2]. The complex patterns of fracture, low osteogenic potential, damage of soft tissue, if combined with the wrong or inadequate initial fixation, are the main reasons for the development of pseudoarthrosis in this region of the humerus. Other predisposing factors include older age, alcoholism, smoking, obesity, presence of infection, as well as non-operative treatment [3]. The incidence of pseudoarthrosis after treatment of distal humerus fractures is 8–25%, and is most often encountered in the supracondylar region [4]. The complexity of this condition is increased by bone atrophy, scar tissue from previous interventions, small and poorly vascularized bone fragment, limited elbow mobility, and local neurological damage. Bone stock can be seriously compromised by bone absorption, further accelerated with loosening of osteo-fixation material. All this brings numerous obstacles to the successful healing of pseudoarthrosis and achieving good functional results [5].

The most commonly used treatment methods include internal osteosynthesis, the use of bone grafts, arthroplasty, but also elbow arthrodesis. The definitive treatment modality still remains controversial, initiating numerous discussions and disagreements in orthopedic circles [6]. The main reason for disagreement is the assertion of some experts that open surgery carries an increased risk of disrupting vascularity of fragments, as well as the risk of reducing elbow range of motion. Other studies point to satisfactory results after open intervention, which leads to many difficulties in setting operative indications and deciding on the most appropriate treatment option [2, 3]. The presence of infection and poor local soft tissues makes conventional methods of treatment profoundly difficult [7]. At the Banjica Institute for Orthopedic Surgery (Banjica IOS) these conditions are commonly treated by the Ilizarov method of external fixation. The advantages of using external fixation compared to other treatment methods are stable fixation, adequate fracture reduction, and fragment compression accompanied by minimal soft tissue trauma, with the possibility of early elbow mobilization. The basic principle of the Ilizarov method is stimulating ossification process using a compression force, which provides favorable environment for bone fragment healing and biosynthetic processes which increase local resistance to infection occurrence [8].

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The aim of this paper is to present the treatment results of 19 patients with nonunion of the distal humerus after internal osteosynthesis managed at our hospital using the Ilizarov external fixation method.

## METHODS

In this retrospective study, we analyzed the results of 19 patients treated from 1990 to 2000 at the Banjica IOS with the Ilizarov external fixator for distal humerus nonunion after failed ORIF. The study group includes 11 male and eight female patients with an average age of 42 years (range of 16 to 77 years). The mechanism of injury was fall, motor-vehicle or traffic accident. Five patients had nonunions complicated with osteomyelitis. One patient had ulnar, and one had radial nerve paresthesia, both as a result of an initial injury or previous treatment. Nonunions were diagnosed radiographically at least six months after the initial treatment in terms of failing to develop calluses with loosening of the fixation material. The nonunions were characterized according to Weber and Cech [9] criteria as reactive (present in 10 patients) and non-reactive (present in nine patients) (Table 1).

Pre- and postoperative assessment of the elbow range of motion, neurovascular status, evidence of infection and radiographic evaluation of distal humerus in two planes were carried out. The functional status of the arm was evaluated before and after treatment using the Disabilities of the Arm, Shoulder and Hand (DASH) scores [10, 11].

Surgical technique included the principles for open monolocal compression osteosynthesis using the Ilizarov external fixator. For every patient, surgical treatment was conducted in a single act. After the initial incision, approaching the nonunion was followed by the removal of loose fixation material and by taking of a microbiological swab. The bone

ends were debrided and cleaned of all synovial and fibrous tissue with special attention on sparing soft tissue attachment, thus preserving the fragments vascularization. Avascular bone was resected until punctuate bleeding was seen at the bony ends, after which intramedullary canals were opened proximally and distally. The adapted fragments were provisionally reduced and fixed using Kirschner wires. After closing the surgical wound, the Ilizarov fixator was placed. Two transfixation wires were placed in the proximal third of the humerus and attached to the frame. After that, the humerus was fixed and connected to the frame using two wires 4–5 cm long above the nonunion. Three or four distal crossing wires were passed through the epiphyseal–metaphyseal region. The elbow is being extended when placing wires anteriorly and flexed during insertion of wires posteriorly in order to reduce tensions on the soft tissue. Frames were connected with distractors. Axial compression was established on the operating table in order to achieve stable contact of bone fragments (Figure 1) [8, 12].

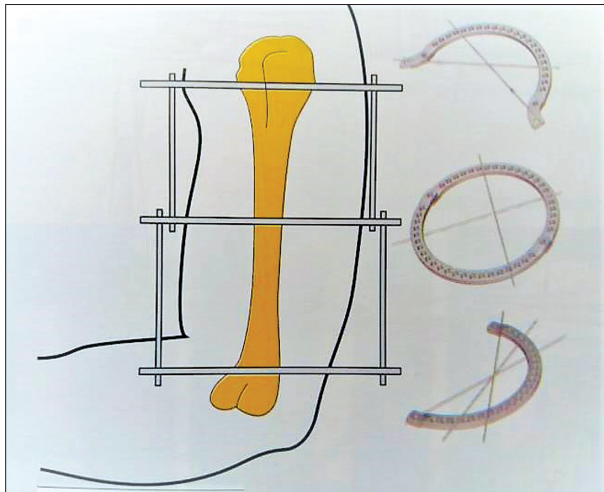
From the second postoperative day axial, compression was applied evenly, 0.5–1 mm per day for three to four weeks. After this, the compression was maintained at the rate of 0.5 mm per week until the removal of the fixator.

The physical rehabilitation of the elbow, in terms of active and passive motion exercises, was carried out in the early postoperative period. The patients were initially allowed to use the treated limb without the use of significant force. The control and dressing of the wound and skin around the wires was done once a day. Osseous healing was defined as the presence of crossing trabecular bone on the lateral and anteroposterior radiographs. Upon establishing the fusion of nonunion, the fixator was removed. Physical rehabilitation was resumed to preserve and increase the range of motion in the elbow, to establish the muscle tone, as well as to train the use of the extremity in everyday

**Table 1.** Preoperative parameters

Case	Age/ Sex	Injury	Type	Complication of fracture	Elbow ROM		Nonunion type	DASH score
					Flex./Ext.	Pro./Sup.		
1	41/M	MVA	open	infection	60/-30	50/40	non-reactive	81.7
2	35/M	MVA	open	infection	80/-30	60/40	reactive	76.7
3	41/F	Fall	closed	radial nerve paresis	50/-30	60/60	reactive	95.8
4	42/M	TA	open		70/-40	90/75	reactive	79.2
5	16/F	TA	open	ulnar nerve paresis	60/-30	90/90	non-reactive	84.2
6	20/M	TA	closed	infection	70/-20	90/90	non-reactive	79.3
7	41/M	Fall	open		60/-40	90/90	reactive	89.2
8	43/M	TA	closed		90/-20	90/90	non-reactive	95.0
9	33/M	TA	closed		60/-80	70/80	reactive	85.8
10	40/M	TA	closed		90/-10	90/90	reactive	89.2
11	33/F	Fall	closed		70/-40	90/90	reactive	83.3
12	25/M	TA	closed		60/-30	90/90	non-reactive	81.7
13	53/F	Fall	closed		90/-20	90/90	non-reactive	90.8
14	26/M	MVA	open	infection	70/-40	90/90	reactive	85.5
15	60/F	Fall	closed		60/-30	90/90	reactive	81.1
16	54/F	Fall	closed		100/-20	90/90	reactive	84.2
17	51/F	Fall	closed		70/-40	70/80	non-reactive	89.2
18	77/F	Fall	closed		40/-20	90/90	non-reactive	80.8
19	73/M	Fall	closed	infection	80/-30	90/90	non-reactive	95.8

MVA – motor vehicle accident; TA – traffic accident; ROM – range of motion; DASH – Disabilities of the Arm, Shoulder and Hand



**Figure 1.** Schematic view of application of the Ilizarov external fixator on the humerus (taken from Tomić [8])

activities. The mean follow-up period was 71 months postoperatively (range of 34 to 144 months) (Table 1).

## RESULTS

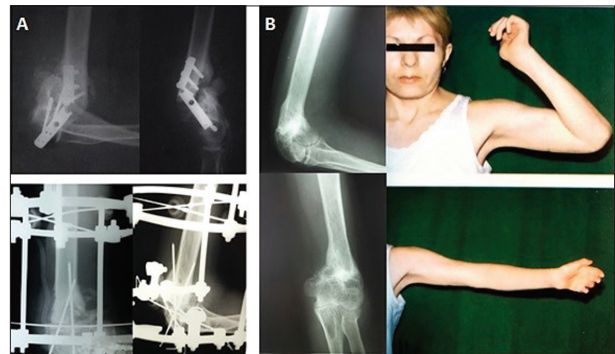
All patients achieved solid bony union. The average time for application of external fixator was seven months (range of five to nine months).

At the last follow-up, the mean range of flexion/extension was 94° to -13°, and pronation/supination 89° to 87°. In all the cases, the elbow range of motion was increased after treatment without clinical signs of instability or significant deviation from the anatomical axis. Radiographic analysis indicated the preservation of joint space in 17 patients, while the other two showed degenerative changes. No elbow instability was encountered for any patient.

There were shortening of the arm, as a result of previous surgeries, bone resorption, debridement, and compression at the nonunion site. An average shortening measured at the last follow-up was  $3 \pm 1.5$  cm, which did not affect the functionality of the limb and was well tolerated by the patients.

All the patients exhibited improvements in shoulder and elbow motion after treatment. The mean value of the DASH score before surgery was 86, whereas the mean score after complete recovery was 21. This showed a significant recovery in the function of the entire upper extremity (Figure 2). Postoperatively, nine patients had no pain in the elbow, eight had moderate pain, while the two had severe pain. Ten patients showed almost complete recovery with minimal disability, while seven had moderate residual disability, and two had severe elbow function impairment. Complete soft-tissue recovery was achieved in all the patients.

There were eight postoperative infections. Five patients had superficial pin-tract infection, successfully treated with oral antibiotics and antiseptic solutions applied locally. The other three had infections of deep structures resolved with debridement, irrigation, intravenous administration of antibiotic and reassembly of external fixator. Two patients had ulnar nerve paresthesia and were treated conserva-



**Figure 2.** (A) Radiographs of a 33-year-old female patient treated with the Ilizarov method eight months after failed initial osteosynthesis; (B) radiographs and clinical photographs after the application of the Ilizarov fixator for nine months, showing complete union, with elbow motion restoration

tively, with complete recovery after two months. All postoperative parameters are shown in Table 2.

## DISCUSSION

Nonunions of the distal humerus are uncommon and are usually associated with instability, reduced elbow mobility, strength loss, pain, and functional loss [3].

An important factor in the development of nonunion of the distal humerus is inadequate choice of surgical techniques or implants during the primary fracture operation [13]. The treatment of nonunions of this region, after previously unsuccessful surgeries is very difficult and complex [14]. Repeated procedures in the area above the elbow usually result in elbow contractures, articular cartilage deterioration, and, in most cases, ulnar nerve lesions [15]. Each of these conditions should be taken into consideration during preoperative evaluation and treatment selection. Although such operations are difficult and complicated, detailed preoperative planning with adequate fixation methods and early postoperative rehabilitation ensures healing and good functional results [6]. These nonunions present with wide range of different characteristics, consequently surgical treatment must be individualized for each patient [3].

Because of the complexity of this problem, decision making in the management of these nonunions is difficult and not well clarified in the literature [6]. The type of treatment depends on several factors, including functional requirements of the patient, the condition of soft tissues and articular cartilage, the range of motion in the elbow, and bone quality [16]. Many treatment options have been described, including open reduction – internal fixation with plates and screws, intramedullary nailing with interfragmentary wiring, elbow arthroplasty, and free vascularized bone grafting [17–20].

This paper describes treatment of patients with nonunion of the distal part of the humerus with the Ilizarov external fixator. The advantages of this method are the ability to achieve adequate fracture reduction and stable fixation, to provide a gradual or intermittent compression of fragments, and to allow early rehabilitation, as well as the opportunity to treat transitional infected nonunions [8].

**Table 2.** Postoperative parameters

Case	Follow-up (months)	EFT (months)	Pain	Disability	Elbow ROM		Compl.	Shortening (cm)	DASH score
					Flex./Ext.	Pro./Sup.			
1	96	9	none	minimal	80/-20	90/50	DI	2.0	25.0
2	116	9	none	moderate	100/-10	90/90	DI	4.5	20.0
3	84	6	none	moderate	100/-20	90/90	PTI	3.5	24.2
4	36	7	none	moderate	110/-10	80/90		4.0	14.2
5	38	6	none	minimal	90/-10	90/90		3.0	25.0
6	112	9	moderate	moderate	90/-20	90/90	PTI	2.0	15.8
7	96	8	moderate	minimal	90/-30	90/90		1.5	20.0
8	100	8	moderate	moderate	110/-10	90/90		2.0	27.5
9	144	7	moderate	minimal	90/-10	90/90	PTI	2.0	20.5
10	120	6	moderate	moderate	110/-0	90/90		4.0	20.8
11	60	5	none	minimal	90/-20	90/90		2.0	14.2
12	37	8	none	minimal	90/-10	90/90	UNP	4.0	20.0
13	39	9	moderate	moderate	110/-10	90/90	UNP	2.0	24.2
14	94	8	moderate	minimal	90/-10	90/90	PTI	3.0	20.8
15	36	7	none	minimal	80/-10	90/90		2.0	17.5
16	34	6	none	minimal	110/-10	90/90		3.5	14.2
17	39	6	moderate	minimal	90/-20	80/80		4.0	18.3
18	36	9	severe	severe	60/-10	90/90	PTI	3.5	29.2
19	34	8	severe	severe	90/-10	90/90	DI	2.5	27.5

EFT – external fixator time; PTI – pin-track infection; DI – deep infection; UNP – ulnar nerve paraesthesia; Compl. – complications; ROM – range of motion; DASH – Disabilities of the Arm, Shoulder and Hand

The clinical and radiographic results of this study correlate with the findings of Brinker et al. [15] by the range of motion and the rate of healing nonunions this part of the humerus. We consider that the success of the procedure is determined by standardizing surgical techniques in terms of complete and thorough debridement of nonunions exposing fresh bleeding bone ends; adjustment of fragments for appropriate contact; application of the adequate structure of the fixator; direct and intermittent compression; implementation of early physical rehabilitation and removal of the fixator only after verification of complete healing.

Infected nonunions are associated with marked osteopenia, a significant articular contracture, focal bone defects, and avascular or necrotic parts of bones that make reconstruction even more challenging. Studies show significantly worse results than those obtained in aseptic nonunions [7]. Success of this method in septic pseudoarthrosis is confirmed by the results of Brinker et al. [15], who applied on their patients a surgical technique similar to the one used in this study.

In a study conducted by Mitsunaga et al. [21], priority was given to achieving osseous healing over mobility, as the secondary objective. Their results showed union in 80% of patients with only 9° improvement in the elbow range of motion. Capsular release and arthrolysis in patients with distal humerus nonunion and motion limitation due to articular causes improve elbow mobility and reduce stress on the healing site during postoperative mobilization [3]. Many of the patients in the published ORIF studies underwent multiple contracture releases, sometimes in staged procedures, to attain their final range of motion [15]. In our series of patients, there was no need for subsequent loosening of soft tissue to improve the range of motion in the elbow. We believe that a stable fixation and early

mobilization are equally important factors in the treatment of these conditions.

Significant DASH score improvement is consistent with other studies that analyzed the results of the Ilizarov method treatment [15]. Although it is uncomfortable for some patients, an external fixator provides stable fixation of the nonunion site which allows greater freedom of movement in the shoulder and elbow, by which the whole arm becomes more functional [22]. The relatively small amount of shortening in our series was well tolerated by the patients and did not affect their functional outcome.

In our research, the ulnar neuropathy occurred in two patients, which were successfully treated non-operatively. Some authors state that anterior transposition of the ulnar nerve should be a routine part of the surgical procedure in the treatment of such nonunions [3].

ORIF is generally a recommended type of treatment of uninfected nonunions in younger, more active patients who have good bone stock at the injury site [16]. Ring et al. [2] treated 15 unstable nonunion of the distal humerus with contracture release, ORIF, and bone grafting. The functional results in their study were excellent in two patients, good in nine, and fair in one case.

Total elbow arthroplasty can be useful in older patients with osteoarthritis, but its application in younger patients remains controversial [19]. It is considered to be a technically demanding salvage procedure and should be done only when other operative procedures are unsatisfactory [23].

Elbow arthrodesis is reserved only for patients with infected nonunion. The procedure does not provide good results, since it affects the essential function of the elbow, thus limiting the movement in the joint. Resection or distraction arthroplasty and the use of joint allograft have yielded disappointing results [24].

## CONCLUSION

Treatment of distal humerus nonunions with the Ilizarov external fixator after failed internal osteosynthesis provides

successful healing and increased range of motion in the elbow. This method should be considered as the primary choice of treatment of distal humerus nonunion.

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## Псеудоартрозе дисталног хумеруса после неуспеле унутрашње остеосинтезе – лечење методом Илизарова

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### САЖЕТАК

**Увод/Циљ** Псеудоартрозе дисталног дела хумеруса после неуспелог оперативног лечења су изазован хируршки проблем. Комплексности стања доприносе коштана атрфија, оживљено ткиво, инсуфицијентна васкуларизација фрагмената, контрактура лакта, остеомијелитис и неуролошке лезије. Предности коришћења спољашњег фиксатора огледају се у могућности стабилне фиксације, адекватне репозиције и компресије праћене минималном траумом меких ткива уз могућност ране мобилизације лакта.

Циљ овог рада је био анализа резултата код 19 болесника са псеудоартрозом дисталног дела хумеруса лечених методом Илизарова после неуспеле унутрашње остеосинтезе.

**Материјал** Методом Илизарова лечено је 19 болесника – 11 мушкараца и 8 жена просечне старости 42 године. Хируршка техника састојала се у отварању псеудоартрозе, уклањању

остеофиксационог материјала, ресекцији и дебридману коштаних фрагмената и постављању Илизаровљевог апарата. Непосредно после операције започета је физикална рехабилитација покрета у лакту. Функционални статус руке евалуиран је помоћу *DASH* скор.

**Резултати** Код свих испитиваних констатовано је потпуно коштано зарастање псеудоартрозе после просечног ношења апарата од седам месеци. Код 17 болесника радиографски је потврђен очуван зглобни простор, док су се код два развили знаци дегенеративног обољења лакта. Код свих је повећан обим покрета у лакту уз значајно бољи *DASH* скор после операције (просечно 21).

**Закључак** Лечење псеудоартрозе дисталног хумеруса методом Илизарова обезбеђује успешно зарастање и повећање обима покрета у лакту.

**Кључне речи:** хумерус; псеудоартроза; метод Илизарова