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**Distal humerus nonunions after failed internal fixation:
Treatment with Ilizarov external fixator**

Псеудоартрозе дисталног хумеруса након неуспеле унутрашње
остеосинтезе: Лечење методом Илизарова

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Distal humerus nonunions after failed internal fixation: Treatment with Ilizarov external fixator

Псеудоартрозе дисталног хумеруса након неуспеле унутрашње остеосинтезе:
Лечење методом Илизарова

SUMMARY

Introduction/Objective Nonunions of distal humerus after unsuccessful surgical treatment represents 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 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 Ilizarov external fixation method.

Methods nineteen consecutive patients were treated with the Ilizarov external fixator. The study group includes 11 male and 8 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 Ilizarov fixator was placed. Rehabilitation of the elbow started in early postoperative period. The functional status of the arm was evaluated using the DASH score (Disabilities of the Arm, Shoulder and Head).

Results All patients achieved solid bony union after average 7 months from application of external fixator. In 17 patients radiographic analysis indicated the preservation of joint space, while two showed degenerative changes. All patients showed improvement in elbow range of motion and significantly better DASH score with postoperative value of 21.

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

Keywords: humerus; nonunion; Ilizarov technique

САЖЕТАК

Увод/Циљ Псеудоартрозе дисталног дела хумеруса после неуспелог оперативног лечења су изазован хируршки проблем. Комплексности стања доприносе коштана атрфија, ожиљно 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.

Метод Методом Илизарова лечено је 19 пацијената, 11 мушкараца и 8 жена просечне старости 42 године. Хируршка техника је била: отварање псеудоартрозе, уклањање остеофиксационог материјала, ресекција и дебридман коштаних фрагмената и постављање 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 радиографски је потврђен очуван зглобни простор, док су се код два развили знаци дегенеративног обољења лакта. Код свих је повећан обима покрета у лакту уз значајно бољи *DASH* скор након операције (просечно 21).

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

Кључне речи: хумерус; псеудоартроза; метод Илизарова

INTRODUCTION

Nonunions of 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 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 between 8% and 25%, and is most often encountered in 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 in successful healing of pseudoarthrosis and achieving good functional results [5].

The most commonly used treatment methods include internal osteosynthesis, 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 to reduction of 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 Institute for Orthopedic Surgery "Banjica" (IOS "Banjica") 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 Ilizarov method is stimulating ossification process using a compression force which provides favorable environment for bone fragment healing and biosynthetic processes with increase local resistance to infection occurrence [8].

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

METHODS

In this retrospective study, we analyzed the results of 19 patients treated from 1990 to 2000 at IOS "Banjica" with Ilizarov external fixator for distal humerus nonunion after failed ORIF. The study group includes 11 male and 8 female patients with an average age of 42 years (range 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 patient had radial nerve paraesthesia, both as a result of an initial injury or previous treatment. Nonunions were diagnosed radiographically at least 6 months after the initial treatment in terms of failing to develop calluses with loosening of fixation material. The nonunions were characterized according to Weber and Cech criteria as reactive (present in ten patients) and non-reactive (present in nine patients) (Table 1) [9].

Table 1. Preoperative parameters.

Case	Age/ Gender	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

Pre and postoperative assessment of 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 DASH scores (Disabilities of the Arm, Shoulder and Head) [10, 11].

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

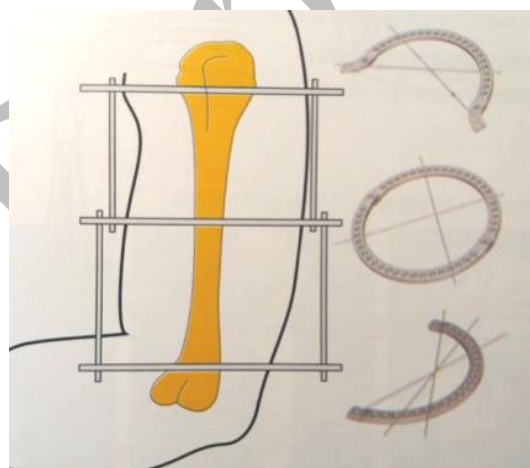


Figure 1. Schematic view of application of Ilizarov external fixator on humerus (taken from Tomić [8]).

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 Ilizarov fixator was placed. Two transfixation wires were placed in proximal third of humerus and attached to frame. After that, humerus was fixed and connected to frame using two wires 4-5cm above the nonunion. Distal crossing wires, 3 or 4, were passed through 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 soft tissue. Frames were connected with distractors. Axial compression was established at the operating table in order to achieve stabile 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 3 to 4 weeks. After that compression was maintained in rate of 0.5 mm per week until the removal of fixator.

The physical rehabilitation of the elbow, in terms of active and passive motion exercises, was carried out in the early postoperative period. Patients were initially allowed to use the operated 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 fusion of nonunion, the fixator was removed. Physical rehabilitation was resumed to preserve and increase range of motion in the elbow, to establish the muscle tone, as well as to train the use of the extremity in everyday activities. The mean follow-up period was 71 months postoperatively (range 34 to 144 months) (Table 1).

RESULTS

All patients achieved solid bony union. The average time for application of external fixator was 7 months (range 5 to 9 months).

At last follow-up, the mean range of flexion/extension was 94° to -13°, and pronation/supination 89° to 87°. In all cases elbow range of motion was increased after treatment without clinical signs of neither instability nor significant deviation from the anatomical axis. In 17 patients radiographic analysis indicated the preservation of joint space, 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. Average shortening measured at last follow-up was 3±1.5 cm which did not affect the functionality of the limb and was well tolerated by patients.

All patients had improvement 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, 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 patients.

There were eight postoperative infections. Five patients had a superficial pin-tract that were 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 paraesthesia and were



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

treated conservatively with complete recovery after two months. All postoperative parameters are shown in table 2.

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.

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 or ulnar nerve lesions [15]. Each of these conditions should be taken in 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]. Type of treatment depends on several factors, including functional requirements of the patient, the condition of soft tissue and articular cartilage, 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 [17], intramedullary nailing with interfragmentary wiring [18], elbow arthroplasty [19] and free vascularized bone grafting [20].

This paper describes treatment of patients with nonunion of the distal part of the humerus with Ilizarov external fixator. The advantages of this method are 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].

The clinical and radiographic results of this study correlates with the findings of Brinker et al. by range of motion and the rate of healing nonunions this part of the humerus [15]. We consider that the success of the procedure is determined by standardizing surgical techniques in terms of a complete and thorough debridement of the nonunions exposing fresh bleeding bone ends; adjustment of the fragments for appropriate contact; applying adequate structure of the fixator; direct and intermittent compression; implementation of early physical rehabilitation and removal of 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. who have applied similar surgical technique used in this study on their patients [15].

In a study conducted by Mitsunaga et al. priority was given to achieving osseous healing versus mobility as a secondary objective. Their results showed union in 80% of patients with only 9° improvement in elbow range of motion [21]. Capsular release and arthrolysis in patients with distal humerus non-union and motion limitation due to articular causes improve elbow mobility and reduce stress on 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 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 treatment Ilizarov method. [15]. Although it is uncomfortable for some patients external fixator provides stable fixation of 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 consider 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 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. were treating fifteen 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 [2].

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

The treatment of distal humerus nonunions after failed internal osteosynthesis with Ilizarov external fixator 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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