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TREATMENT OF OPEN FRACTURES OF THE HUMERUS USING THE G. A. ILIZAROV METHOD

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Abstract

Background. Open fractures of the humerus are associated with soft-tissue damage, contamination, and a high risk of infection, non-union, and radial nerve injury, which limits the use of internal fixation in the acute period. The transosseous osteosynthesis method of G. A. Ilizarov allows stable fixation away from the zone of injury while leaving the wound accessible for treatment.

Objective. To evaluate the clinical and functional outcomes of treating open humeral fractures with the Ilizarov circular external fixator.

Materials and methods. A retrospective study included 46 patients (32 men, 14 women; mean age 38.6 ± 11.2 years) with open diaphyseal and metadiaphyseal fractures of the humerus (Gustilo–Anderson type I – 12, type II – 21, type IIIA – 10, type IIIB – 3) treated with primary surgical debridement and Ilizarov apparatus fixation. Time to union, complications, and functional outcome (DASH score, Constant–Murley score) were assessed at a minimum follow-up of 12 months.

Results. Bone union was achieved in 44 of 46 patients (95.7%) with a mean fixation period of 14.2 ± 3.1 weeks. Superficial pin-site infection occurred in 9 patients (19.6%) and resolved with local care and oral antibiotics; deep infection was observed in 1 case (2.2%). Two patients developed delayed union requiring compression and bone grafting. The mean DASH score at final follow-up was 14.8 ± 7.9, and the mean Constant–Murley score was 84.3 ± 8.6. Excellent and good results were obtained in 89.1% of patients.

Conclusion. The Ilizarov method is an effective and safe option for open humeral fractures, providing stable fixation, wound access, early mobilisation of adjacent joints, and a high rate of union with a low rate of deep infection.

Keywords: open fracture; humerus; Ilizarov apparatus; transosseous osteosynthesis; external fixation; Gustilo–Anderson classification.

1. Introduction

Fractures of the humeral shaft account for approximately 1–3% of all fractures in adults [1, 2]. Most result from high-energy trauma such as road traffic accidents, falls from height, and industrial injuries, and a considerable proportion of these are open. Open fractures differ fundamentally from closed injuries: the bone communicates with the external environment, the soft-tissue envelope is damaged to a variable extent, and the wound is contaminated by microorganisms [3, 4]. As a result,

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the risks of osteomyelitis, delayed union, non-union, and secondary neurovascular complications are substantially increased.

The anatomical position of the radial nerve in the spiral groove makes the humerus particularly vulnerable to nerve injury, both at the time of trauma and during open surgical procedures. Radial nerve palsy is reported in about 12% of humeral shaft fractures and is more frequent in open injuries [5]. Conservative treatment with functional bracing, which gives good results in closed fractures [6], is often impossible in open fractures because of the wound and the need for repeated dressings.

Internal fixation with plates or intramedullary nails in the presence of a contaminated wound carries a risk of deep infection and implant-related osteomyelitis, especially in Gustilo–Anderson type III injuries. External fixation therefore remains an important method for the management of open fractures [7, 8]. Among the available devices, the circular apparatus developed by G. A. Ilizarov is distinguished by its biomechanical principles: tensioned transosseous wires provide stable yet elastic fixation that allows controlled axial micromotion, stimulating osteogenesis according to the "tension-stress" effect [9, 10]. The apparatus also permits gradual correction of residual deformity and compression or distraction at the fracture site without additional surgery.

Despite these advantages, the Ilizarov method is used less frequently on the upper limb than on the lower limb, and published series on open humeral fractures remain limited [8, 11]. The aim of this study was to evaluate the clinical and functional outcomes of treatment of open humeral fractures using the Ilizarov method.

2. Materials and Methods

Study design and patients. A retrospective analysis was performed of patients with open fractures of the humerus treated at [institution] between [year] and [year]. Inclusion criteria were: age 18 years or older; open diaphyseal or metadiaphyseal fracture of the humerus; primary fixation with the Ilizarov apparatus; and follow-up of at least 12 months. Exclusion criteria were: pathological fractures, intra-articular fractures requiring open reduction, polytrauma with an Injury Severity Score above 25, and incomplete records. The study was approved by the local ethics committee, and written informed consent was obtained from all patients.

The final cohort comprised 46 patients: 32 men (69.6%) and 14 women (30.4%), with a mean age of 38.6 ± 11.2 years (range 19–67). The mechanisms of injury were road traffic accidents (n = 24; 52.2%), falls from height (n = 11; 23.9%), industrial injuries (n = 7; 15.2%), and gunshot wounds (n = 4; 8.7%). Open fractures were classified according to Gustilo and Anderson [3, 4]: type I – 12 (26.1%), type II – 21 (45.6%), type IIIA – 10 (21.7%), and type IIIB – 3 (6.5%). According to location, 9 fractures involved the proximal third, 25 the middle third, and 12 the distal third of the humerus. Primary radial nerve palsy was present in 7 patients (15.2%).

Surgical technique. All patients received intravenous antibiotic prophylaxis (a first-generation cephalosporin, with an aminoglycoside added for type III injuries) on admission. Surgery was performed within 6 hours of injury in 38 patients (82.6%). Treatment began with thorough surgical debridement: excision of non-viable skin, fascia, and muscle, removal of foreign bodies and free devitalised bone fragments, and copious irrigation with normal saline.

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Closed or minimally open reduction was then performed, and the Ilizarov apparatus was applied. The standard assembly consisted of two or three rings or arches (proximal arch, middle ring, distal ring) connected by threaded rods. In each fragment, two crossed Kirschner wires (1.8 mm) tensioned to 90–110 kgf and/or one or two half-pins (5 mm) were inserted, observing the safe corridors to avoid injury to the radial, median, ulnar, and axillary nerves and to the brachial artery. Wires and half-pins were inserted at least 2–3 cm away from the wound. After fixation, axial compression of 1–2 mm was applied at the fracture site in transverse and short oblique fractures. In comminuted fractures, the fragments were held in neutralisation mode. In patients with primary radial nerve palsy and a wound in the projection of the nerve, the nerve was explored through the wound.

Wounds were closed primarily in type I and II fractures after adequate debridement. In type IIIA injuries, delayed primary closure was performed at 3–5 days, and in type IIIB injuries, soft-tissue defects were covered with split-thickness skin grafts or local flaps; access to the wound through the frame was unrestricted.

Postoperative management. Active and passive exercises of the shoulder, elbow, and wrist joints were started on the second postoperative day. Pin sites were cleaned daily with antiseptic solution. Pin-site infections were graded according to Checketts et al. [12]. Radiographs in two planes were taken immediately after surgery, every 4 weeks, and before removal of the apparatus. The apparatus was dismantled after clinical and radiological signs of union (absence of pain and mobility at the fracture site, bridging callus on at least three of four cortices) and a negative clinical stability test after loosening of the connecting rods.

Outcome assessment. The primary outcome was the rate of bone union and the time to union. Secondary outcomes were complications and function of the upper limb. Function was assessed at the final follow-up with the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire [13] and the Constant–Murley score [14]. Overall results were graded as excellent (DASH 0–10), good (11–25), satisfactory (26–40), and poor (> 40).

Statistical analysis. Data were analysed using [SPSS version / software]. Continuous variables are presented as mean ± standard deviation and categorical variables as numbers and percentages. Differences between groups were tested with Student's t-test or the Mann–Whitney U test for continuous data and Fisher's exact test for categorical data. A p-value < 0.05 was considered statistically significant.

3. Results

The mean follow-up was 18.4 ± 5.3 months (range 12–32). The mean duration of surgery, including debridement, was 74 ± 18 minutes. Postoperative radiographs demonstrated satisfactory alignment (angulation < 10° in both planes and shortening < 1 cm) in all patients.

Bone union. Union was achieved in 44 of 46 patients (95.7%) without additional procedures. The mean duration of fixation in the apparatus was 14.2 ± 3.1 weeks (range 10–22). The time to union increased with the severity of the injury: 11.8 ± 1.6 weeks in type I, 13.6 ± 2.2 weeks in type II, and 17.9 ± 2.8 weeks in type III fractures ($p < 0.001$ for type III versus types I–II). Comminuted fractures required a longer fixation period than simple fractures (16.3 ± 3.0 vs 12.9 ± 2.4 weeks; $p < 0.01$). Two

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patients (4.3%) with type IIIA and IIIB fractures developed delayed union; they were treated with additional compression in the apparatus and autologous bone grafting, and union was achieved at 24 and 27 weeks, respectively.

Complications. Superficial pin-site infection (Checketts grades 1–3) occurred in 9 patients (19.6%) and was managed successfully with intensified local care and oral antibiotics; in 2 of these cases one wire was replaced. Deep infection developed in 1 patient (2.2%) with a type IIIB fracture; it was resolved by repeated debridement and targeted antibiotic therapy without loss of fixation. No iatrogenic nerve or vascular injuries related to wire or half-pin insertion were observed. Of the 7 patients with primary radial nerve palsy, spontaneous recovery occurred in 6 within 3–6 months; one patient with a nerve defect underwent nerve repair. Elbow stiffness (flexion–extension arc < 100°) was found in 3 patients (6.5%) at final follow-up, all with distal-third fractures. There was no refracture after removal of the apparatus.

Functional outcome. At the final follow-up, the mean DASH score was 14.8 ± 7.9 and the mean Constant–Murley score was 84.3 ± 8.6. Results were excellent in 23 patients (50.0%), good in 18 (39.1%), satisfactory in 4 (8.7%), and poor in 1 (2.2%). Thus, excellent and good outcomes were obtained in 41 patients (89.1%). Functional results were significantly better in type I–II fractures than in type III fractures (DASH 11.9 ± 5.8 vs 22.1 ± 8.4; $p < 0.001$). All patients returned to daily activities, and 39 of 43 employed patients (90.7%) returned to their previous work at a mean of 5.1 ± 1.4 months after injury.

4. Discussion

The management of open humeral fractures requires simultaneous solution of several problems: control of infection, preservation of the soft tissues and blood supply of the fragments, stable fixation, and early restoration of joint function. Our results show that the Ilizarov method meets these requirements, with a union rate of 95.7%, a deep infection rate of 2.2%, and 89.1% excellent and good functional results.

The union rate in our series is comparable to that reported for external fixation of humeral shaft fractures by Catagni et al., who achieved union in 97.6% of 84 patients treated with a circular fixator [8], and is higher than the rates often reported for monolateral external fixators, in which delayed union and malalignment are more common [7, 11]. The biomechanical advantage of the Ilizarov apparatus lies in the use of tensioned thin wires, which provide multiplanar stability while allowing controlled axial micromotion. According to Ilizarov's tension-stress concept, such micromotion stimulates osteogenesis and angiogenesis [9, 10].

Infection is the most feared complication of open fractures. The incidence of deep infection after plate fixation of open humeral fractures, particularly type III, may exceed 10% [3, 4]. In our study, transosseous fixation away from the wound zone, combined with radical debridement and antibiotic prophylaxis, kept the rate of deep infection low. Pin-site infection remains the most frequent complication of the Ilizarov method, reported in 10–30% of cases [12, 15]; in our series its rate (19.6%) fell within this range, and all cases were minor and resolved without frame removal.

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The risk of iatrogenic nerve injury is a frequently cited argument against the use of transosseous wires in the arm. Strict adherence to known safe corridors and the use of half-pins in the most dangerous zones allowed us to avoid this complication entirely, which agrees with the experience of other authors [8, 15]. An additional advantage of the method is that the radial nerve is not exposed during fixation, in contrast to open plating, where secondary radial nerve palsy has been reported in up to 10% of cases [5].

The functional results in our study were good, with a mean DASH score of 14.8, which is comparable to the outcomes reported after internal fixation of closed fractures [6]. We attribute this to early active mobilisation of the shoulder and elbow, which was possible owing to stable fixation. Poorer results were associated with type III injuries and distal-third fractures, in which elbow stiffness was more common. This underlines the importance of careful positioning of the distal ring so as not to restrict elbow motion.

The limitations of the method include patient discomfort, the need for daily pin-site care, the relatively long period of fixation, and the requirement for surgeon training. The present study also has limitations: its retrospective design, the relatively small number of patients, and the absence of a control group treated with other fixation methods. Prospective comparative studies are required to define the place of the Ilizarov method relative to internal fixation and conversion strategies.

5. Conclusion

Transosseous osteosynthesis with the G. A. Ilizarov apparatus is an effective and safe method for the treatment of open fractures of the humerus. It provides stable fixation outside the zone of injury, unrestricted access to the wound, the possibility of correcting the position of fragments and applying compression without repeat surgery, and early functional rehabilitation. In our series, the method achieved a union rate of 95.7% with a low rate of deep infection and a high proportion of excellent and good functional outcomes. The Ilizarov method can be recommended as a method of choice for open humeral fractures, particularly Gustilo–Anderson type II and III injuries.

Conflict of interest. The authors declare no conflict of interest.

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