Introduction

Approximately 1-3% of all human fractures and 5-10% of all long bone fractures occur in the humeral shaft [1,2]. They account for about 20% of all humeral fractures [1]. The incidence of those fractures in population is 14-20/100,000 per year [1]. Their importance is great because fractures complicated with nonunion and inadequate bone union lead to disability of patients, prolonged absence from work and higher hospital expenses. Fractures with associated injuries of major blood vessels of brachial region and infection can be life threatening.

Humeral shaft fractures are most frequently treated by non-operative means [3] (functional brace or hanging cast), rarely by thoracobrachial immobilization and bone traction. However, the range of indications for operative methods of those fractures have been widened in the last two decades in order to achieve adequate function in the shortest possible time after the injury, better quality of life and decreased period of treating [2, 5]. Improved methods of intramedullary fixation, osteosynthesis with plates and screws and external fixators have contributed to the higher frequency of surgical treatment of these injuries [2,4,5].

Dilemmas regarding humeral shaft management are associated with the absence of universally accepted indications for operations [4] and choice of operative technique. The published results are very controversial and every method has its advantages and weaknesses. Since a wide choice of treating possibilities, operative methods and implants is offered to manage these fractures, but without the absolute agreement of authors, the aim of this study was to compare the functional results of non-operative and different operative techniques of managing humeral shaft fractures.

Material and methods

Forty two patients were operated for humeral shaft fractures at the Clinical Centre of Vojvodina during the period from 2004 to 2007. This study followed 25 of them. We performed 34 operations in the City Hospital of Subotica from 2007 to 2010, and 14 of the operated patients were included in this study as well as 22 non-operatively treated ones. This study is retrospective, multi-centre, with statistic significance of p<0.05 and total specimen of 61 followed patients with united humeral shaft fractures. They were divided into four groups (with sub-groups):

- The first group consisting of 22 non-operatively treated patients with hanging casts included mostly two- part fractures, without a re-dislocation after the closed reduction. The treatment was continued with functional cast in 10 patients because of earlier rehabilitation.
- The second group of 20 patients, treated with intramedullary nail (IMN), had 3 nailing subgroups: locked: anterograde (12), retrograde (4) and small cal-
ibre (Ender) nails (4). The indications were as following: segmental, pathological and secondary dislocated fractures in casts.

The third group consisted of 10 operatively treated patients with dynamic compression plate (DCP), which were mostly used in cases of wedge and associated shaft fractures with metaphyseal and intra-articular components.

The fourth group included 9 patients treated with external fixator (ExFix) (3 Mitković’s and 6 Ilizarov’s). Fixators were indicated for comminuted and open fractures associated with significant damage of soft tissues.

Closed reduction and immobilization were tried as the initial treatment in the first three groups. When the position of fragments was not satisfactory, the choice was operation, so the study included only cases where the first operative method was the definitive one. The average rehabilitation was two weeks (10-30 days) at hospital and afterwards patients performed exercises at home.

In our specimen, 57.4% of patients were males and 42.6% females. Women dominated only in non-operative group. The average age was 40.6 years (16-77). Younger patients were treated mostly operatively. The oldest group was a non-operative one. The patients injured their right arm in 34 cases (55.7%) and left in 27 (44.3%). We did not observe a significant difference considering the side of injured extremity, except in ExFix group, where males most often injured their right arm (Table 1). Sixteen of male patients (45.7%) were injured in the third decade of life in road traffic accidents and 18 females over 50 years of age (69.2%) after simple falls from standing position. Therefore, the most common cause of fracture in older population was fall (26 injured) and traffic accidents (24) in younger patients (Graph 1). Violence caused five fractures, sports activities three (arm wrestling caused two spiral fractures) and three patients had tumour-induced bone destruction.

Humeral shaft fractures can be divided according to fracture morphology as: transverse, oblique, spiral, segmental, wedge and comminuted, and all of them as close and open ones. This classification does give enough information for the choice of treatment and indications do not depend on it. AO classification [6] is more preferred. Type A are the simplest two-part fractures, type B have a butterfly fragment and type C consist of comminuted fractures. Every type has three subgroups. Type A1 (spiral fracture) has better chance to heal than other subtypes (transverse and oblique) and it is the most suitable for non-operative treatment. In our study (Graph 2) the simplest fractures were also the most frequent ones. Type A occurred in 44.3% of patients according to the fact that 14 non-operatively treated had this type of fracture. Type B occurred in 19 (31.1%) and type C in 15 (25.0%) cases. The majority of comminuted and all segmental and open fractures were managed operatively (Table 1).

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**Table 1. Demographic data among groups and classification of fractures**

<table>
<thead>
<tr>
<th>Group</th>
<th>Gender/Pohl</th>
<th>Fracture type</th>
<th>Age</th>
<th>Tip preloma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hanging cast/Viceći gips</td>
<td>male/female</td>
<td>transverse</td>
<td>61.4</td>
<td>A B C</td>
</tr>
<tr>
<td>IM nail/Im. klin</td>
<td>male/female</td>
<td>oblique</td>
<td>25.1</td>
<td>4 6</td>
</tr>
<tr>
<td>DC plates/DK ploča</td>
<td>male/female</td>
<td>spiral</td>
<td>29.6</td>
<td>1 9 0</td>
</tr>
<tr>
<td>ExFix/Spolji fiksator</td>
<td>male/female</td>
<td>segmental</td>
<td>36.3</td>
<td>2 1 6</td>
</tr>
<tr>
<td>Total/Uskupno</td>
<td>35 26 27 40 6</td>
<td></td>
<td>27 19 15</td>
<td></td>
</tr>
</tbody>
</table>

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**Abbreviations**

IMN – intramedullary nail
a/g – anterograde
t/r – retrograde
DCP – dynamic-compression plate
ExFix – external fixator
MIPO – minimally invasive plates

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**Graph 1. Etiology of humeral shaft fractures**

**Graph 2. Type of fracture according to fracture line**

We performed the last examination and X-rays one year after the trauma. The evaluation of joints function consisted of Constant score for shoulder [7] and Mayo Clinic elbow scale [8].

This study excluded those patients who had previous operations of humerus, non-united fracture, those who did not undergo rehabilitation, when the initial operative method was changed to another and two death cases.

The results were analyzed, compared and represented in graphs and tables.
**Results**

According to functional scales [7,8], good (71-85 points) total and average results were achieved in all groups, except for insufficient one (under 70) in the hanging cast group and the excellent result (86-100) for the elbow function was achieved only in the nailing group. The best average functional results were recorded in the group IMN, then ExFix, DCP and the hanging casts yielded the worst results (Table 2).

The best results for the shoulder function were achieved in r/g locking nails among the nailing subgroups. The best postoperative function of elbow joint was provided by applying a/g locking nails. Locking nails were superior to Ender nails according to both scales. In addition, Ilizarov ExFix had better results than unilateral fixator (Graph 3).

**Discussion**

Humerus is a very specific bone in comparison to other long bones. This bone was thought to be probably the easiest one for non-operative management, because the union rate was over 90% [3]. But hanging cast treatments have been replaced by other methods because joint exercises are impossible and this inevitably leads to joint stiffness. The choice of treatment nowadays is more often an operative method aimed at achieving the functional arm.

The priority is no longer given to the absolute stability but on the soft tissues and function. According to modern AO principles [5], restoration of length, axis and rotation are more important factors than anatomic reposition of fragments. The acceptable alignment is up to 20 degrees of anterior angulation, up to 30 degrees of varus angulation and up to 3 cm shortening after union of humeral shaft fracture [4].

Those fractures are caused by a direct mechanism during harmless falls in about 60% of cases [1], but in the studies that followed only operated groups [2,9,10], 79-88% of them were caused by high energy injuries, during road traffic accidents and falls from height, those being the main causes among our patients (87%). The incidence of these fractures has been on the rise in the 21st century because of traffic traumatism, particularly those caused by motorcycle accidents among young people and in older population because of prolonged period of life and osteoporosis. The most vulnerable categories are men in the third decade of life and women in their seventies [5], as shown by our surveillance.

The average age of injured people is about 55 years [1], but younger population is more frequently operatively treated. That is the reason why the average age of our patients was 40.6 years. In the studies with predominantly operated patients in the sample, especially those younger than 40 [2,9], men fractured their humeral shafts around three times more frequently than women because of more active life style and surveillance, men were also 1.3 times more frequently included the patients over 65 years of age [10]. In our surveillance, men were also 1.3 times more frequently injured than women because of more active life style in: sports, industry and traffic accidents [1,2,5]. Some of the authors [2,9] did not record a significant difference of the injured side of arm, while others [10], as we did, recorded more fractures of the right arm.

According to the fracture line, 25-40% of humeral shaft fractures are transversal, 25-28% comminuted, 18-19% oblique, 14-15% spiral and 1-2% segmental [2,18]. We recorded similar results with slightly higher percentage of spiral fractures (25%). According to AO
classification [6], the majority of fractures belong to A type with frequency of 44-63%, then B type with 27-36% and C type with 10-20% [1,2]. A type fractures were the most common among our patients as well (44.3%), but more severe fractures dominated in our operated groups.

The comparison of results among non-operative and operative methods is not easy, especially when more complicated fractures treated operatively are compared, because of more dislocated fragments, more serious soft tissue damage and associated injuries of other bones, nerves and blood vessels [11]. Some authors [3,12] have proved that there is no evidence that operative methods have better chances for union of simple fractures. In our hanging cast group, the majority of patients had A1 type because of its better chance to unite spontaneously. Wearing immobilization for two months is too long, uncomfortable for patients and leads to joints contractures. The functional scales are the lowest in our hanging cast group (Table 2) because of the above reasons.

If the surgeon opts for the operative method, it is necessary to perform preoperative planning of soft tissue damage [5] and treat it primarily. Afterwards, a temporary or permanent ExFix should be implanted [13], as we did in open fractures. In addition, the surgical approach, reduction type and implant should be chosen (Figure 1).

![Figure 1](image.png)

**Figure 1**. Radiographs of humeral shaft fractures treated with: plate, nail, Ilizarov’s and Mitkovic’s fixators

**Table 2**

The majority of humeral fractures, except for those situated 2-3 cm from the shaft, are suitable for IM nails [15]. Contraindications for their use are too thin intramedullary canal and severe infection (Gustilo-Anderson’s types IIIb- IIIc) [16]. Former nails had the main disadvantage of rotational stability and migration [15,17]. That was corrected in new generations of locking nails [12,15,17-20]. In this study we used elastic (Ender’s) and locking (anterograde or retrograde) nails. The main disadvantage of a/g nails is antegrade access to the medullary canal through the rotator cuff tendons, which may cause shoulder joint pain and impairment of function [12,15,17-20]. Retrograde nailing can cause elbow contractures [18]. O’Donnell et al [19] followed 33 patients with a/g IMN by MRI 11 days postoperatively. They found complications in 21 shoulder joints (63.6%): 10 had subacromial bursitis, five partial rupture of rotator cuff, one complete rupture of supraspinatus tendon and four inflammatory changes of acromioclavicular joint. The problem with morbidity of entrance site can be prevented with transversal approach to rotator cuff tendons and their reconstruction after placing the nail [17-20]. The medullary canal can be reamed for using thicker nails or unreamed [12,15]. Reaming stimulates the bone union because the vascular response generates solid periostal callus formation. This fact is better documented for femur and tibia [21] than for humerus. Some authors [22] have recorded higher nonunion rates after reaming while others, like us, have recommended it [21].

External fixators also have their place in humeral shaft treatment [13,23-27], especially in open fractures (grades III b, c), which was our main indication for their use. The incidence of open fractures is about 5.6% [1], but it is higher among operated patients (14%) [2], as recorded by us (12%). Open fractures with less soft tissue damage (types: I, II and IIIa) are treated non-operatively or operatively with internal fixation, after adequate management of soft tissues [13,27]. The same group of authors think that the initial treatment with ExFix leads to soft tissues healing 2-14 days after the trauma and other implants are more suitable afterwards. Almost every bone fracture can be initially stabilized with Ilizarov’s ExFix [26], but this method has not become popular for closed humeral fractures. Some authors [23,25,26] disagree with that fact. There are many types of external fixators. We used Ilizarov’s with rings [26] and unilateral, domestic, Mitkovic’s fixator [23]. According to some authors [23,24], unilateral ExFix has comparable results to plates. The advantages of this method are connected with minimally invasive surgery, operation time is shorter, blood loss minimal, hospitalization time shorter and removal of hardware is easy [23]. We have achieved

[14] achieved excellent results with these techniques by positioning plates through two minimal incisions over and under the site of fracture. Our experience with new generations of plates is limited because of small specimen and the price of implants, so the study did not follow MIPO and Bridge Plating groups.

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good results with unilateral ExFix, but better with ExFix with rings (Graph 3). Ilizarov’s fixator provides stable fixation in osteoporotic bones as well. By controlled compression and distraction, it stimulates local blood supply, callus production and bone union even in cases of infected pseudarthrosis, which are the most difficult to treat [12,23-27]. This technique corrects deformity in all planes, bone defects and restores the length of extremity with proper soft tissues preservation, allowing early rehabilitation [25,26]. The main disadvantages of ExFix are: difficulty to achieve anatomic reposition [13], pin tract infection [23,25] and weight of implant. Unilateral ExFix is cheaper and not so heavy but our functional results of Ilizarov’s ExFix were superior, because of the secondary opportunity to correct the position of dislocated fragments.

There are many disagreements in literature about the choice of operative method. According to indications, some authors [5,11-14] suggest using DC plates because of potential nailing shoulder joint problems. Others think that locking nails are the most suitable solution [17,18,20-22,28], especially for comminuted, pathological and segmental humeral shaft fractures. We also used the last mentioned indications for nails.

The results of treating humeral shaft fractures can be evaluated by many different scoring systems. We compared ours with the results of those who used Constant [7] and Neer’s scores [29] for the shoulder function (with maximum of 100 points); and for the elbow function, we used the Mayo Clinic scale [8], which took the following into consideration: pain, patient’s everyday activities, range of motion and stability. Our results were similar to the majority of other studies according to the shoulder joint function [10,21,30,31]. Considering the elbow function, our results were very good because we estimated that more than 75% of our patients had excellent or very good results, as some other authors had [10,18,33]. By comparing results among the groups we found that the nailing group had the best results. This evaluation is similar to the conclusion of some other studies [10,21,31].

Finkella et al [31] also compared different groups by Constant score and they recorded the average score in nailing group of 66 points. We achieved similar results only in Ender’s subgroup (68.7) but much better in locking IMN (74.8 and 71.2) (Graph 3). The same authors [31] had average score of 82 in the plating group that was better than ours (72) and in ExFix Ilizarov group only 53.7, while we had 75.2. Even better results than those which we achieved in ExFix group were observed by Tomić et al [25], who did not record any insufficient results. Micić, Mitković et al [23] had average score of 74.3 points, that being similar to ours (71.5).

Some consequences for shoulder and elbow joint can be found in 0-38% of non-operatively treated patients [1,3,31]. In our hanging cast group, 32% of patients had symptoms of shoulder impairment and 38% of elbow joint. Ciernik et al [32] recorded 74% of joint stiffness and pain. The results of treating those fractures with functional orthosis are much better than with hanging casts. Some authors [3,9] did not record any statistically significant differences in the range of motion between non-operatively treated patients with functional braces and operated groups.

The results between nailing and plating groups in treating humeral shaft fractures were compared by large number of worldwide studies, which did not find a significant difference in function of joints [18,31,33,34]. Neither did we record this difference in shoulder joint but we did in the range of motion of elbow (92.6 points for a/g IMN vs. 77.5 DCP).

Some authors [20-22] have suggested that shoulder impairment is more frequent in nailing than in plating groups. This fact stands only for our Ender nailing subgroup. Chapman et al [35], as well as the authors of this study, have concluded that pain and limited motions of shoulder are more frequent in nailing groups while plating groups have more elbow joint impairment. Like others, we also found among our nailing subgroups that a/g nails influenced some limited motions of shoulder because of rotator cuff damage although we did not find a significant difference between a/g and r/g locking nails [18,31,36] (Graph 3).

The rehabilitation of patients after humeral shaft fractures is very important because 50% of limited range of motion of elbow joint can produce even 80% disability of arm function [37]. Jandrić and Bošković [37] recorded and treated 35.5% of posttraumatic elbow contractures which decreased to only 8.8% after adequate rehabilitation. Our rehabilitation results were not so good, probably because our patients were much older.

The limitations of this study are connected with no possibility of using modern functional orthosis and new generation of plates and because we indicated External Fixators for the most complicated cases which could potentially lead to insufficient results of this group of patients. This study is comparable to few ones which followed all four groups of patients with subgroups. The comparison of different methods creates conditions for developing new techniques of humeral fractures management. Every one of them should be aimed at achieving better function of the arm in the shortest possible period.

Conclusion

Humeral shaft fractures can be treated with different methods and every one of them has its advantages and disadvantages. Closed reduction and immobilization with hanging cast is the cheapest and easiest way but reserved only for the fractures with good union prognosis. It often produces limited range of motion. We achieved the best functional results with locking intramedullary nails because this method provides rigid fixation, solid callus formation, preserves soft tissues, and there is no need for extraction of implant. It is a minimally invasive procedure that allows early postoperative rehabilitation, so patients return to everyday activities in shorter
period in comparison to other methods. Dynamic compression plates also offer rigid fixation and early rehabilitation but we recorded better results in nailing group. External fixators are easy to implant and enable proper treatment of soft tissues, but it is hard to achieve anatomic reduction and rehabilitation lasts longer than in other methods.

The most important factors for successful treatment of humeral shaft fractures are: proper indication, adequate choice of method, precise surgical technique, rigid fixation and adequate rehabilitation. These choices should be individual for each patient.

References

Sažetak

Cilj studije je bio da upoređi funkcionalne rezultate neoperativne i različitih operativnih tehnika, prosečno godinu dana nakon traume, kod 61 pacijenta sa zaraslim prelomom tela nadlakatne kosti kod kojih je početni način lečenja bio i definitivan. Pacijenti su podeljeni u četiri grupe: 22 lečena visećom gipsnom imobilizacijom, 20 intramedularnim klinovima, 10 dinamičko-kompresivnom pločom sa zavrtnjima i 9 spoljašnjim fiksatorima. Zarastanje preloma procenjeno je na osnovu radiografskih snimaka, kliničkog pregleda i poređenja rezultata pomoću Constant i Mayo bodovnih skala. Uzroci povređivanja u 87% slučajeva bili su pad i saobraćajni traumatizam. Grupa neoperativno le-čenih imala je najviše kontrakture lakta i nezadovoljavajuće re-zultate funkcionalnih skala. U grupi lečenih pločom zabeleženi su lošiji rezultati od grupe klinova, posebno u funkciji lakta. Među podgrupama, znatno bolji rezultati zabeleženi su kod zaključavajućih u odnosu na elastične klinove. Najkomplikovaniiji slučajevi, lečeni spoljašnjim fiksatorima po Mitkoviću i Ilizarovu, imali su zadovoljavajuće rezultate, posebno otvorenih prelo-ma, ali i dužu rehabilitaciju. Najbolji prosečni funkcionalni re-zultati lečenja zabeleženi su u grupi lečenih zaključavajućim in-tramedularnim klinovima zbog stabilne fiksacije, formiranja so-lidnog kalusa i najranijeg povratka svakodnevnim aktivnostima.

Ključne reči: Frakture humerusa; Ishod lečenja; Fiksacija fraktura; Spoljašnji fiksatori; Pločice; Šrafovi; Intramedularna fiksacija preloma; Ilizarova tehnika

Rad je primljen 18. III 2011.
Prihvaćen za štampu 1. IV 2011.