

ORIGINAL ARTICLE

**OPEN VERSUS CLOSED REDUCTION IN HUMERAL SHAFT FRACTURES: COMPARATIVE STUDY BETWEEN INTRAMEDULLARY NAILING AND PLATING**

**OTWARTE A ZAMKNIĘTE ZREDUKOWANIE ZŁAMAŃ TRZONU KOŚCI RAMIENNEJ: BADANIE PORÓWNAWCZE MIĘDZY GWINTOWANIEM ŚRÓDSZPIKOWYM A PŁYTOWANIEM**

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ABSTRACT

**Introduction**

Humerus shaft fractures (HSF) represent 1 to 5% of all fractures in adults. Most HSFs can be managed conservatively. However, there are reports that operative treatment can lead to better outcomes, but with a higher risk of complications.

**Aim**

To evaluate clinical and functional outcomes of Humeral Shaft Fracture (HSF) treatment with intramedullary (IM) nail or locking plate.

**Material and methods**

72 patients were evaluated with a mean follow-up of 38.3 months. Functional results were evaluated using The Disabilities of Arm, Shoulder and Hand scale (DASH), Numeric Pain Rating Scale (NRS) Subjective Shoulder Value (SSV).


**Results**

42 patients were treated with IM nailing and 20 with plating. 18 (29.0%) complications occurred within 30 days and 14 (16.1%) within 6 months. There were significantly more transient neurological complications within 30 days from surgery in patients with plate fixation. Revision surgery was required in 10 (16.1%) and nonunion developed in 2 (2.7%) cases without the significant difference between fixation groups.

**Conclusions**

Fixation of humeral shaft fracture with plate can more often result in transient neurological complications in early postoperative period than nailing. No statistically significant difference in functional results nor other complications were reported.

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**Keywords:** Humerus shaft fractures (HSF), subjective evaluation scales, treatment with intramedullary (IM) nail or locking plate

## STRESZCZENIE

### Wprowadzenie

Złamania trzonu kości ramiennej (HSF) stanowią od 1 do 5% wszystkich złamań u dorosłych. Większość takich złamań można skutecznie leczyć zachowawczo. Niemniej jednak, istnieją doniesienia sugerujące, że leczenie operacyjne może prowadzić do lepszych wyników klinicznych, choć wiąże się z większym ryzykiem powikłań.

### Cel

Ocena wyników klinicznych i funkcjonalnych leczenia złamań trzonu kości ramiennej (HSF) za pomocą gwoździ śródszpikowych (IM) lub płytek blokowanych.

### Materiał i metody

Przeanalizowano dane 72 pacjentów, których średni czas obserwacji wyniósł 38,3 miesiąca. Wyniki funkcjonalne oceniano za pomocą skali Disabilities of Arm, Shoulder and Hand (DASH), Numeric Pain Rating Scale (NRS) oraz Subjective Shoulder Value (SSV).

### Wyniki

42 pacjentów leczono gwoździami śródszpikowymi, a 20 płytkami blokowanymi. W ciągu pierwszych 30 dni po operacji odnotowano 18 (29,0%) powikłań, natomiast w okresie 6 miesięcy wystąpiło ich 14 (16,1%). Znacząco więcej przejściowych powikłań neurologicznych w ciągu 30 dni odnotowano u pacjentów leczonych za pomocą płytek. Konieczność przeprowadzenia rewizji chirurgicznej dotyczyła 10 (16,1%) przypadków, a brak zrostu zaobserwowano w 2 (2,7%) przypadkach, bez istotnej statystycznie różnicy pomiędzy grupami.

### Wnioski

Stabilizacja złamania trzonu kości ramiennej za pomocą płyt blokowanych częściej prowadzi do przejściowych powikłań neurologicznych w początkowym okresie pooperacyjnym w porównaniu z gwoździowaniem. Nie zaobserwowano istotnych statystycznie różnic w wynikach funkcjonalnych ani w występowaniu innych powikłań.

**Słowa kluczowe:** Złamania trzonu kości ramiennej, skale oceny subiektywnej, leczenie za pomocą gwoździ śródszpikowych (IM) lub płytek blokowanych

## Introduction

Humerus shaft fractures (HSF) are defined as fractures located between the insertion of pectoralis major tendon proximally and the supracondylar ridge distally and represent 1 to 5% of all fractures in adults (Brinker and O'Connor 2004; Spiguel and Steffner 2018). Their prevalence with age has got two peaks. First in males in their 3rd decade of life and second in females of 60-80 years of age. In the former these are high energy injuries, in latter

low energy injuries (Oliver *et al.*, 2020; Rämö *et al.*, 2020). Fractures of proximal and middle third of humeral shaft are considered fragility fractures (Oliver *et al.*, 2020). Most of HSFs can be managed conservatively. However, there are reports that operative treatment can lead to better outcomes, but with a higher risk of complications (Matsunaga *et al.*, 2017; Westrick *et al.*, 2017). Increasing tendency toward surgical treatment is observed in the

literature, now reaching up to 50% of the cases treated primarily by a surgery (Huttunen *et al.*, 2009; Tzioupis and Giannoudis 2007). Upper limb function remains acceptable if after primary reduction humerus deformity is no more than: 20 degree of angulation in the anterior-posterior plane, less than 30 degree of varus valgus of rotational deformity and 3 cm shortening (Shields *et al.*, 2016). Open fractures and arterial injury are an absolute indications for surgical treatment. Many types of surgical treatment of HSEs are recommended: an ante- or retrograde intramedullary nailing, as well as locking plate fixation in an open or mini-open technique (García-Virto *et al.*, 2021; Lian *et al.*, 2013; Ouyang *et al.*, 2013). Depending on the fracture configuration a wire cerclage can be used with other forms of fixation.

The aim of this study is to present the results of surgical HSF treatment in our Trauma and Orthopedics department from 2013 to 2020. Our hypothesis was that open reduction increases risk of complications compared to closed techniques.

### Materials and methods

Data of 201 patients (117 women and 84 men) with HSF in a period from 2013 to 2020 were reviewed. Patients primarily treated in other medical centers and patients who presented with established nonunion were excluded from the analysis. For plating the fractures antero-lateral or triceps splitting approaches were used depending on fracture location. Locking compression plates (LCP) of two types were used: Stryker Variax (USA, 2825 Airview Blvd. Portage, MI 49002) and LCP Synthes (USA, 1302 Wrights Lane East West Chester, PA 19380). For IM fixation rotator cuff splitting or saving technique was used, with proximal and distal blocking. In cases where cerclage wire was used fracture site was opened and reduced before inserting the IM nail. IM nails of two types were used: Targon H (Germany, Carl-Braun-Straße 1, 34212 Melsungen, Hessen) and CHM Charfix2 (Poland, Lewickie 3b, 16-061 Juchnowiec

Kościelny). Analysis was based on medical documentation, x-rays, outpatient clinic visits and phone calls evaluating results of treatment in a period of up to 30 days and period above six months from the surgery. In the analysis of patients functional scales were used: The Disabilities of Arm, Shoulder and Hand scale (DASH), Numeric Pain Rating scale (NRS) and Subjective Shoulder Value (SSV) (Gilbart and Gerber 2007; Hudak *et al.*, 1996; Williamson and Mbbs). End points of the evaluation were defined as lack of pain, lack of pathological movement and callus formation in the fracture area in the X-Ray evaluation after at least six months after the surgery. Ethical approval was granted by the local Ethics Committee of Medical Center of Postgraduate Studies in view of the retrospective nature of the study and all the procedures being performed were part of the routine care.

### Statistical Analysis

For statistical analysis Microsoft Excel 2019 (Microsoft, Washington, USA) and Statistica 13.1 (Tibco Software Inc., California, USA) software were used. Continuous variables of demographical and clinical data as means and standard deviation ( $\pm$ SD) were presented. Shapiro-Wilk test was performed to determine the normality of data. Statistical differences were calculated with the use of Chi2, Kruskal-Wallis and Mann-Whitney U tests.

### Results

72 patients (35.8%) were treated surgically: 32 (44.4%) women and 40 (56.6%) men. There were 25 cases of 12A1, four 12A2, ten 12A3, four 12B1, seven 12B2, two 12B3, three 12C1, four 12C2 and three 12C3 fractures according to AO-OAT classification. 42 patients (67.7%) were treated with IM nail and 20 (32.3%) with plate fixation. Early evaluation within 30 days, focused on complications evaluation. It was conducted in 62 (83.9%) patients, ten patients were lost for follow-up. Out of these 54 (87.1%) patients were evaluated after six months since the surgery. The average follow-up was 46.5 months – ranging from 13 to 90 months. In 17

(27.4%) patients data was collected from the medical reports, in 37 (59.7%) functional evaluation was conducted using DASH, NRS and SSV scale during clinical control or phone call. Demographic and clinical data, distribution of the fractures localization and methods of treatment are presented in Table 1.

DASH and SSV and lower values of NRS were reported in patients with bone union comparing to patients with complications and revision surgery, however the results were not statistically significant.

**Table 1.** Demographic and clinical data.

	Total	Plate	IM Nail	P
Males/Females	32/30	14/6	18/24	0.72*
Age	52 ( $\pm$ 18.3)	35 ( $\pm$ 15.5)	60 ( $\pm$ 13.5)	<b>&lt; 0.001**</b>
BMI	28 ( $\pm$ 5.0)	28 ( $\pm$ 5.7)	28 ( $\pm$ 4.7)	0.78**
Post surgery neurological complications up to 30 days post-operation	12	8	4	<b>&lt; 0.003*</b>
Neurological complications in six months and above	4	2	2	0.11*
Revision surgeries after primary fixation	10	5	5	0.15*
All complications above six months	15	6	9	0.46*
Proximal fractures	17	1	16	
Mid shaft fractures	27	3	24	
Distal fractures	18	15	3	

\*chi test  
\*\*U Mann-Whitney test

Early complications within 30 days from the surgery were reported in 18 (29.0%) patients (Table 2). Most of them were radial nerve neuropraxia. All five preoperative nerve palsies fully recovered after the surgery. There were statistically significantly more neurological complications in this early postoperative period in patients treated with LCP than IM nail ( $p = 0.0026$ ). In a period over six months fracture union was achieved in 52 out of 54 patients (96.3%) with 15 (27.8%) complications and ten (18.5%) revision surgeries. These are summarized in Table 2. No statistically significant difference in complications rate was observed neither between LCP and IM nail groups ( $p = 0.46$ ) nor between fracture types after six months from surgery ( $p = 0.24$ ).

#### Functional Results

Functional results were clinically evaluated in 37 patients (Table 3). Mean observation period was 38.3 months (from six to 84 months). A tendency for better results in

#### Discussion

Historically HSF non-operative treatment, particularly using functional bracing reported by Sarmiento, used to be a treatment of choice with good results. (Kapil Mani *et al.*, 2013; Sarmiento *et al.*, 1977). Despite this fact there is a tendency to use more aggressive approach with a surgical treatment, which is associated with a lower risk of non-unions. (Huttunen *et al.*, 2012; Schoch *et al.*, 2017). However risk of complications associated with surgical exposure as radial nerve palsy and post-operative infection needs to be weighted in each case. (Gallusser *et al.*, 2021) A tendency to use less invasive techniques such as closed nailing or minimally invasive percutaneous plating (MIPO) leaving fracture site almost intact to prevent extensive soft tissue stripping also seems to be a viable alternative with good preliminary results (García-Virto *et al.*, 2021; Kulkarni *et al.*, 2017).

In this study, we believed that less invasive technique using closed nail fixation would result in lower rate of complications.

**Table 2.** Complications observed.

<b>Complications observed up to 30 days</b>			
	<b>Total</b>	<b>Plate</b>	<b>IM Nail</b>
Radial nerve palsy out of which 5 (8.1%) were reported pre-operatively	15 (24.2%)	7 (1 pre-operatively)	8 (4 pre-operatively)
Ulnar nerve palsy	1 (1.6%)	1	0
Ulnar and radial nerve palsy	1 (1.6%)	1	0
Straight plate destabilization requiring plate reosteosynthesis with wires	1 (1.6%)	1	0
<b>Complications observed above 6 months</b>			
Superficial infection treated with oral antibiotic only	1 (1.9%)	0	1
Allergy to the metal resulted in heavy radial nerve palsy due to callus entrapment. Required implant removal	1 (1.9%)	0	1
Radial nerve paresis after hardware removal	1 (1.9%)	1	0
Radial nerve paresis described in EMG examination – no clinical symptoms	1 (1.9%)	0	1
Radial nerve paresis (one case I–III fingers extension impairment, one sensory deficits, one general partial paresis, one neuralgia)	3 (5.6%)	2	1
Pseudoarthrosis	2 (3.7%)	2	0
Mechanical implant complications (1 acromial hardware conflict, 1 improper method of osteosynthesis to the fracture type required change, hardware break after a fall, 3 hardware destabilisations)	6 (11.1%)	1	5
<b>Revision surgeries</b>			
Destabilisation of internal fixation	3 (4.8%)	2	1
Hardware conflict with acromion	2 (3.2%)	0	2
Inadequate primary stabilization technique chosen for the fracture type	1 (1.6%)	0	1
Allergic reaction to the metal	1 (1.6%)	0	1
Patient intolerance of hardware	3 (4.8%)	3	0

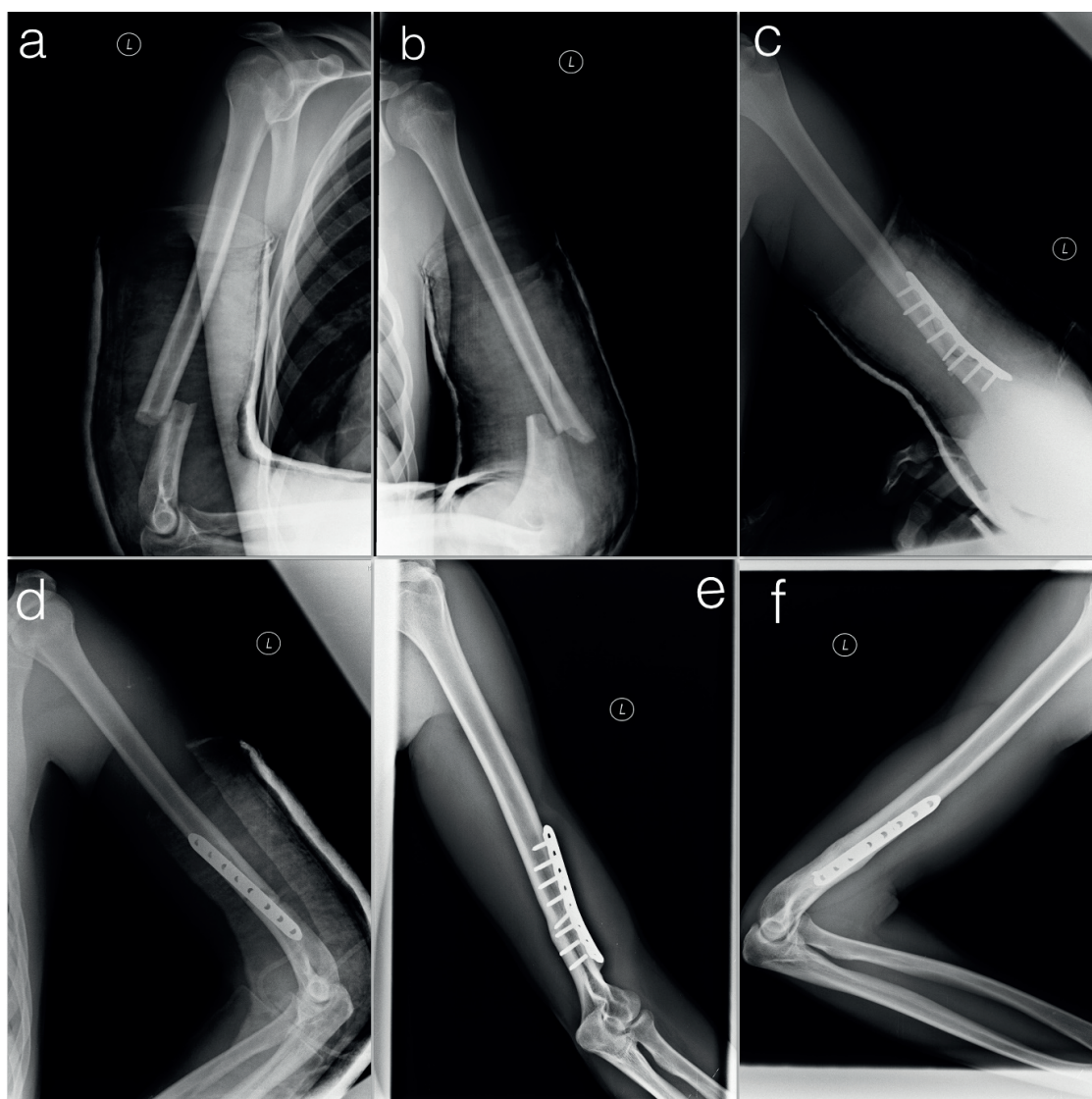
IM – intramedullary; EMG – electromyography

42 (67.7% of all operated patients) of fractures was fixed with IM nail. Only in one patient (2.3% of IM nail fixation and 1.6% of all patients respectively) with a clear technical problem the revision surgery with plate fixation was necessary in early postoperative period (Figure 3).

Non-union rate reported in the literature ranges from 0 to 14% [5–7, 20, 32]. More non-unions seems to be related with nail fixation (Tzioupis and Giannoudis *et al.*, 2007). In our study two non-unions were reported in plate fixation group (10%) and no non-union was reported in IM fixation group. Reasons for such results could be: surgeon experience, type of fracture and patient related factors (Zura *et al.*, 2016). However we did not find any statistically significant differences comparing

these factors. In the literature non-union rates after plate fixation range from 3.5% to 14.0% in an open type fixation and 4% to 10% in MIPO techniques (Akalin *et al.*, 2020; Benegas *et al.*, 2019; Changulani *et al.*, 2007; Daglar *et al.*, 2007; Singiseti and Ambedkar 2010).

Neurological complications were observed in 15 cases (24.2%) in an early postoperative period. In case of plate fixation there was a significantly higher risk of neurological complications than in nail fixation ( $p = 0.0026$ ). They occurred in eight patients (19.0%) treated with IM nail and seven (35.0%) with plate. In six (30.0%) plate cases and four (9.5%) IM cases neurological complications appeared post-operatively. In all cases of IM nail fixation it was radial nerve palsy. In plate group the most

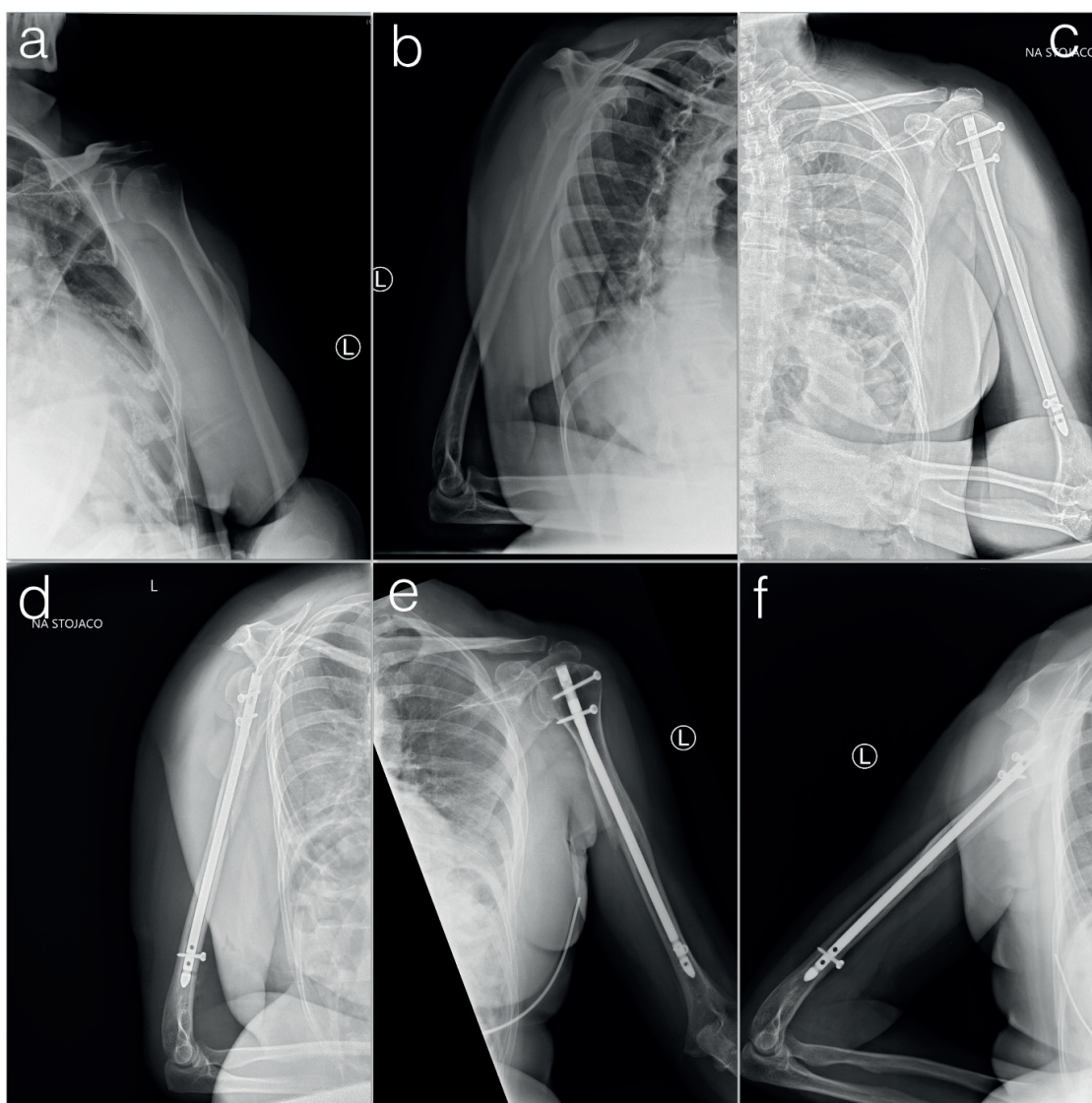


**Figure 1.** X-ray of distal 1/3 humerus fracture. Pre-operative (a, b), post-operative (c, d) and after eight months from the surgery (d, e)

common was radial nerve palsy observed in seven (35.0%) cases but there was also one (5.0%) case of radial and ulnar nerve palsy and one case (5.0%) of isolated ulnar nerve palsy. In the literature prevalence of the radial nerve palsy is less common after nailing compared to plating (2.6% and 15% respectively) (Belayneh *et al.*, 2009; Chaugulani *et al.*, 2007; Chapman *et al.*, 2000; Schwab *et al.*, 2018; Singiseti and Ambedkar 2010). In a period over six months from the surgery neurological symptoms persisted equally in three cases of plate fixation (15.0%) and IM fixation (7.1%), but this difference did not reach any statistical significance. All preoperative

nerve palsies recovered after surgery (Table 2). These results suggest that there was probably inadequate surgical technique causing higher than in comparable studies iatrogenic radial nerve injuries in plate fixation group. It seems to be confirmed by really high number of radial nerve palsies in about 1/3 of patients in plate fixation group (Akalin *et al.*, 2020; RG *et al.*, 2000).

In an observation period above 30 days six (11.1%) revisions were performed in a group of 42 patients fixed with IM nail. In one (2.4%) case it was due to improper fixation technique, in three (7.14%) patients due to fixation failure. In one (2.4%) patient due to allergic reaction



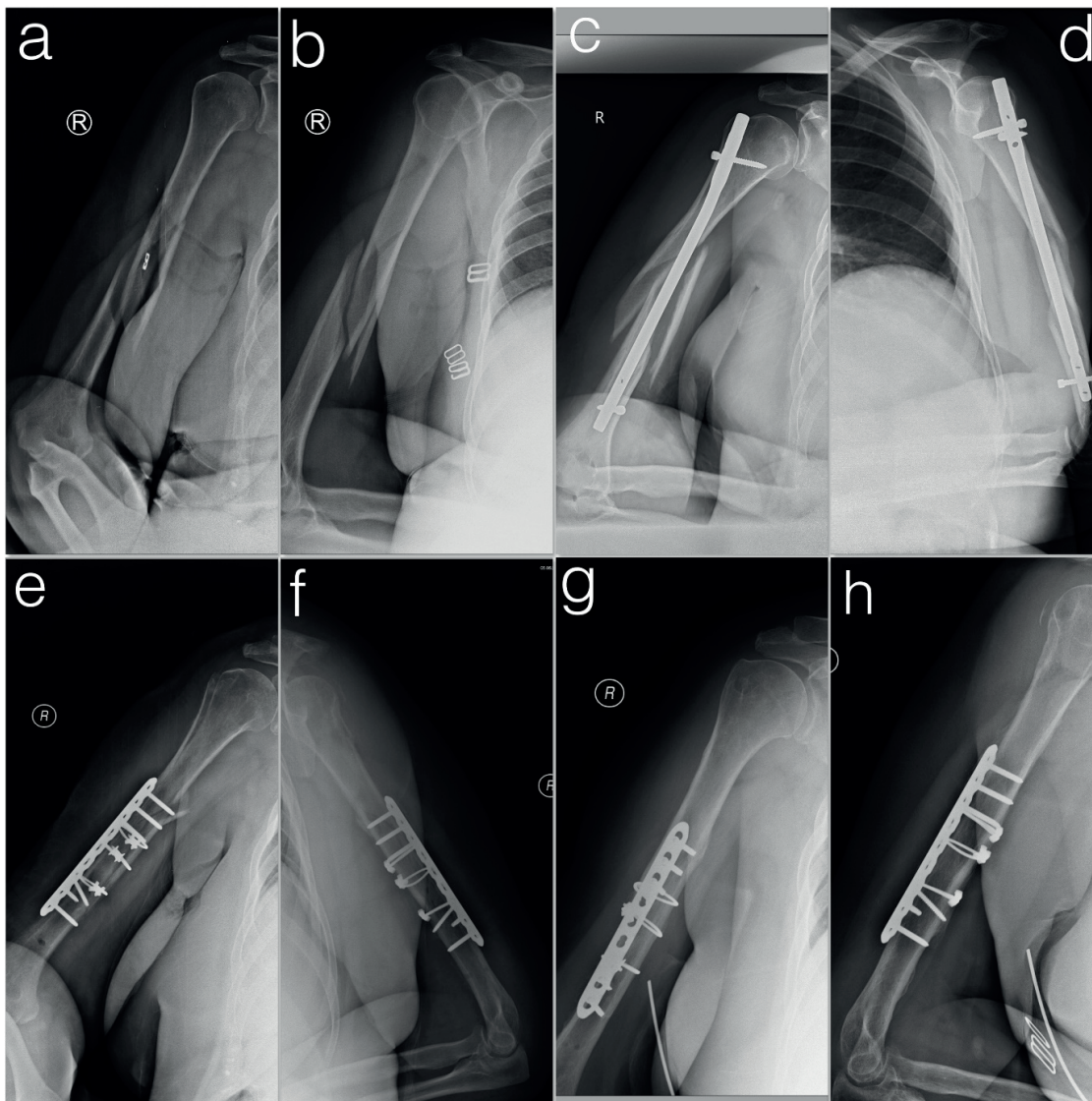
**Figure 2.** X-ray of middle 1/3 humerus fracture. Pre-operative (a, b), post-operative (c, d) and after 13 months from the surgery (d, e)

to implant it was necessary to remove it and in one (2.4%) case due to hardware protrusion and conflict with acromion. In literature reoperation rate after IM nailing ranges from 5.5% to 17.4% (Changulani *et al.*, 2007; Chapman *et al.*, 2000; Daglar *et al.*, 2007) and hardware protrusion rate reaches around 6% in comparable studies (Belayneh *et al.*, 2019; Putti *et al.*, 2009). Nevertheless, five cases of revision in our study were related to a technical error.

In plate fixation group five (25.0%) patients required revision surgery: one (5.0%) due to nonunion, one due to fixation failure and three (15.0%) due to poor implant tolerance

by the patient. Metal removal in Chapman *et al.* work was estimated to 2% and fixation failure in McCormac's *et al.* was estimated as 4.5% (Chapman *et al.*, 2000; RG *et al.*, 2000). These values were significantly lower than in our study, which can also confirm some technical problems. Statistical analysis of complications rate depending on fracture level and fixation used did not show any statistical significance and to our knowledge there is no study describing such relationship.

Functional results can be compared in DASH scale and by extrapolation of NRS scale to VAS (visual analogue scale) as there are no other studies evaluating arm function by NRS scale.



**Figure 3.** X-rays presenting inadequately chosen primary stabilization technique of middle 1/3 of humeral shaft (a, b) with intra medullary nail (c, d). Revision surgery was conducted within 6 weeks from initial surgery with change of IM nail to LCP plate with cerclage wire (e, f). X-ray 7 months after the surgery with bone healed (g, h)

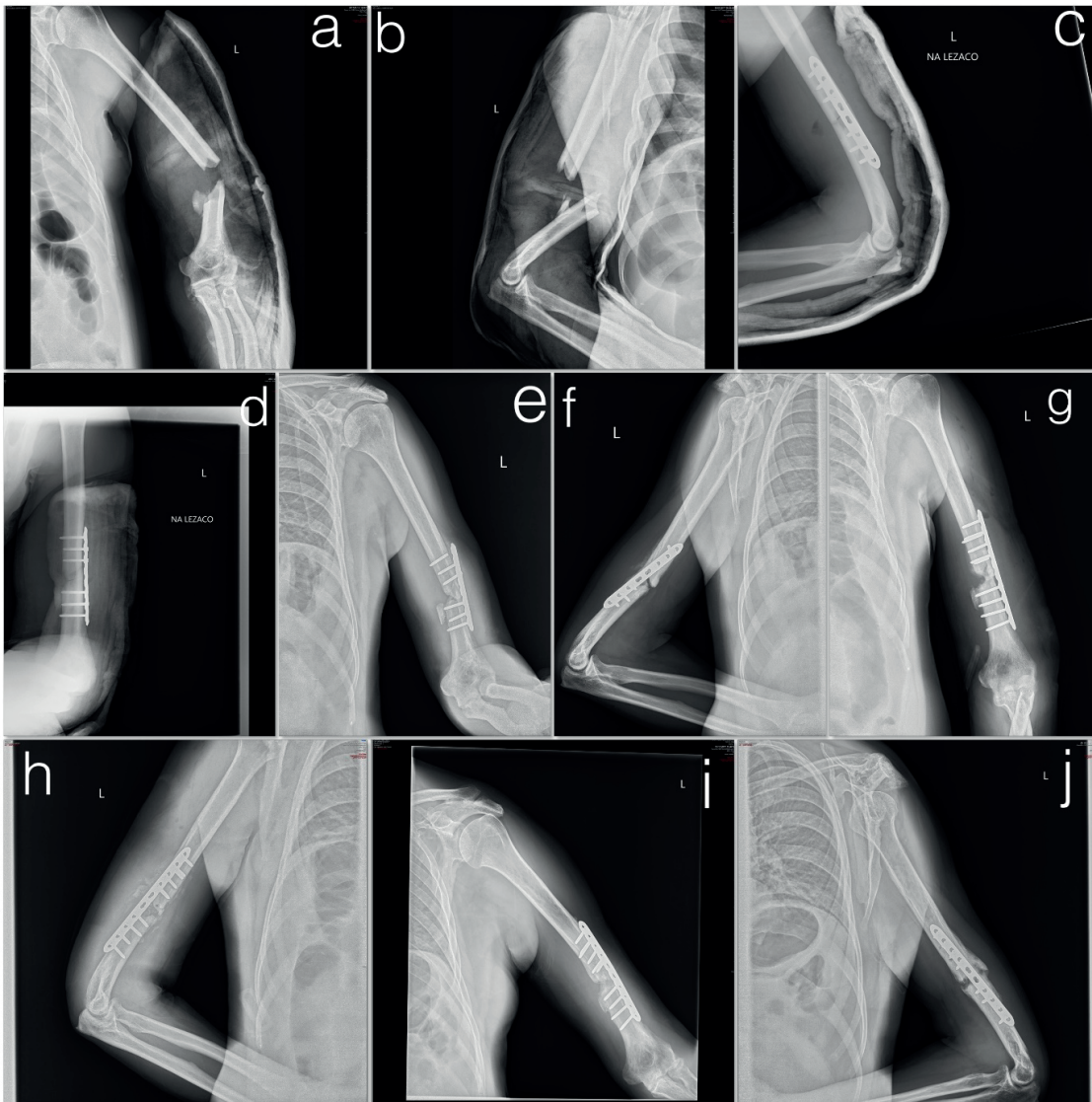
None of comparable works used SSV as a functional result of HSF, however patient self-evaluation of upper extremity seemed to the authors very useful. Patients who did not require revision presented tendency to better functional scale results than patients who required revision. The same tendency was found between patients with healed fractures versus patients with pseudarthrosis. Due to small groups included into functional evaluation no statistical significance was found.

This study results should be compared to Akalin *et al.* study who noted better functional results in the University of California at Los Angeles (UCLA) shoulder score

for plate fixation and higher VAS scores in patients treated with IM nail in long-term follow-up. However no statistical difference was found using DASH scale. [1]. DASH scale results in patients who did not required revision are similar as in Zhang *et al.* study – authors did not observe statistically significant difference in DASH and VAS results after different methods of surgical treatment (Zhang *et al.*, 2020).

Absolute values for patients not requiring revision surgery are better than in Zhang's *et al.* study – DASH for our patients operated with IM nail and plate are respectively 23.76 and 22.37 (Zhang *et al.*, 2020).





**Fig. 4** Distal 1/3 humeral shaft fracture x-rays (a,b) fixed primarily with a straight plate c and d are post-operative x-rays. Five months after initial surgery revision was made due to implant failure (e,f). Patient reoperated (g,h) and after 3.5 year since initial surgery pseudarthrosis persists with progressive angular deformation (i,j), patient does not want to reoperate.

Interesting is fact that in Ranstam et. al. study patients treated functionally had DASH score 12.0 which is comparable for all surgically treated group (DASH 13.1) with revisions and pseudarthrosis patients (Rämö et al., 2020). In our study range of motion of the ipsilateral shoulder was: flexion  $169.0^{\circ} (\pm 25.6)$ , abduction  $165.9^{\circ} (\pm 27.7)$ , external rotation  $56.2^{\circ} (\pm 11.0)$  and in revision group  $153.3^{\circ} (\pm 46.8)$ ;  $150.0^{\circ} (\pm 45.5)$ ;  $60.0^{\circ} (\pm 14.1)$  respectively. These are better results than in Park et. al. study who used the same method of functional evaluation of HSF (Park et al., 2008).

This study has some very important limitations. First limitation could be heterogeneity of compared groups. Age of patients who were operated with plate is twice lower than patients operated with IM nail thus all observed differences can be assigned not only to the mode of treatment but also to the age of patients. However it is still hard to ascribe more neurological complications in period of 30 days from the surgery in group of patients operated with plate to the age difference between two groups. Second limitation is small group of patients controlled after more than six months from

**Table 3.** Functional results.

	All operated patients with functional scales evaluation n = 37	Patients healed without any revision surgery n = 27	Patients who developed pseudoarthrosis n = 2	Patients who required reoperation n = 10	p value *
NRS scale	0.92 (STD 1.60)	0.59 (STD 1.06)	3.00 (STD N/A)	1.88 (STD 2.57)	0.64
Subjective function evaluation	83.71% (STD 21.88)	89.00% (STD 9.66)	60.00% (STD N/A)	68.13% (STD 29.78)	0.38
DASH score	13.09 (STD 19.26)	8.1 (STD 8.74)	40.5 (STD N/A)	31.19 (STD 31.96)	0.21

\*Kruskall Wallis test

Table 3 NRS and functional results of SSV and DASH scale with mean value and standard deviation. NRS-numeric rating scale; SSV subjective shoulder value; DASH The Disabilities of the Arm Shoulder and Hand score; SD-standard deviation.

surgery – 40% of patients were lost to follow-up. Possible reason for this situation is long period taken to analysis (seven years) and fact that patients operated in our center come from remote parts of whole country which makes follow-up more difficult. Another limitation of this study is lack of comparison to functionally treated patients, which arises from different aim and methodology of this paper. The advantage of this study is honest and meticulous description of all technical complications reported by relatively experienced team of surgeons operating in a reference center. This study despite all its limitations confirm our hypothesis, that open surgery with plate fixation can create more complications, particularly concerning early neurological problems. However, less invasive IM fixation requires very meticulous technique, as need for hardware removal is related with technical problems.

### Conclusion

Functional and radiological results of surgical treatment of HSF are satisfactory, however complications in patients treated with plate fixation were found more often than in comparable studies in the literature. Also, in patients treated with plate fixation significantly more neurological complications were reported in early postoperative period. There is a tendency toward better functional results in patients after primary surgery compared to patients who required revision surgery or developed nonunion. Open reduction with

plate fixation can create more complications, particularly concerning early neurological complications. However, less invasive IM fixation requires very meticulous technique, as potential hardware removal is related with technical problems.

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