

## Operative treatment of humeral shaft fractures. Comparison of plating and intramedullary nailing

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Plate and screw fixation (PSF) has always been the more common surgical treatment of humeral shaft fractures. However, intramedullary nailing (IMN) of the humerus has gained in popularity over the last two decades. The purpose of this retrospective study was to evaluate the clinical outcome of plate fixation versus intramedullary nailing of midshaft humeral fractures. The study included 91 patients treated at the department of Trauma Surgery of the University hospital of Leuven ; 42 fractures had been treated by plate fixation and 49 by IM nailing. Union, functional outcome, possible complications and the need for additional surgery were compared between the IMN and PSF group.

No significant difference in terms of fracture union and functional recovery was noted between the two groups. There were four cases of postoperative radial nerve palsy in the PSF group, versus two in the IMN group (non significant difference). A significantly larger number of patients with restrictive pain and/or functional hindrance in the shoulder or elbow was noted in the IMN group ( $p = 0.0053$ ). Problems with osteosynthesis material occurred as often in the PSF group as in the IMN group. One patient developed wound infection at the shoulder after antegrade nailing. A significantly larger number of complications was seen in the IMN group than in the PSF group ( $p = 0.05$ ). A reoperation was necessary in 14.3% of the PSF patients and 16.3% of the IMN patients (non significant difference).

In this retrospective study, IMN did not achieve better results than PSF of humeral midshaft fractures and was associated with more postoperative complications. Based on these findings, we suggest that plating of humeral shaft fractures should be considered

as the primary treatment for all surgical indications, except for some open fractures requiring temporary external fixation, pathological fractures, humeral shaft fractures in morbidly obese and osteopenic patients, and large segmental fractures of the humerus.

**Keywords :** humerus shaft ; bone nails ; bone plates ; intramedullary fracture fixation ; open reduction internal fixation.

### INTRODUCTION

Fractures of the shaft of the humerus represent 1 to 3% of all fractures. They can occur at any age but there is an increasing incidence as of the fifth decade, up to almost 60 per 100 000 per year in the ninth decade (8). Most humeral shaft fractures are treated successfully with conservative means

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(22) but there is an indication for surgical treatment in some cases (14). Plate and screw fixation remains the gold standard for surgical treatment (7).

Intramedullary nailing (IMN) of the humerus became more popular over the last two decades, as a result of the rise of minimal invasive treatments, the attractiveness of what appears to be a simple procedure, technological advances and an aggressive marketing. The popularity of IMN has subsequently declined after several reports of shoulder and elbow morbidity, more frequent reoperations and less good union of the fracture. Until now there is no consensus concerning which technique is to be used preferably for the different surgical indications.

We review our recent experience with surgical treatment of humeral shaft fractures within the department of Traumatology of the University Hospital Gasthuisberg, Leuven. Together with a previous publication, we now have a 22 year follow-up of operatively treated humeral shaft fractures in the department (16).

## MATERIAL AND METHODS

Between 2000 and 2007, 105 skeletally mature adult patients were treated operatively at the department of Traumatology of the University hospital of Leuven for a non-pathological humeral shaft fracture.

Sufficient data was available for inclusion of 91 of these 105 patients in this study. Non-cooperative patients, due to a diminished cognitive condition caused by head trauma or with advanced dementia were not included. Patients with insufficient follow-up data and patients with other pathologies of the upper extremities were also excluded. All patients had a minimum follow-up of 24 months.

Of these 91 patients, 42 underwent plate fixation: 25 men with an average age of 45.1 years and 17 women with an average age of 52.8 years. An anterolateral access was used in 11 patients, a posterior access in 31.

The IMN group consisted of 49 patients: 21 male patients with an average age of 47.5 years and 28 female patients with an average age of 56.1 years. Twenty one patients underwent retrograde IM nailing and 28 ante-grade IM nailing.

Fractures were classified according to the AO classification (18) (table I). Operative indications were failure of non-operative treatment, polytrauma patients, radial

Table I. — AO- fracture classification

AO- classification	PSF	IMN	TOTAL
Total	(n= 42)	(n= 49)	(n= 91)
<b>Type A : simple (non comminuted) fractures</b>	<b>23</b>	<b>32</b>	<b>55</b>
A1 : Spiral fractures	8	14	22
A2 : Oblique fractures	5	7	12
A3 : Transverse fractures	10	11	21
<b>Type B : Fractures with butterfly fragment</b>	<b>15</b>	<b>14</b>	<b>29</b>
B1 : Spiral fractures	5	9	14
B2 : Bending wedge fractures	7	4	11
B3 : Wedgefractures with more than one fragment	3	1	4
<b>Type C : Comminuted fractures</b>	<b>4</b>	<b>3</b>	<b>7</b>
C1 : Double spiral fractures	3	2	5
C2 : Segmental fractures	0	1	1
C3 : Complexe fractures	1	0	1

PSF : plate and screw fixation ; IMN : intramedullary nailing.

Table II. — Radial nerve palsy

	Preoperative n (%)	Postoperative n (%)
<b>PSF</b>	10 (23.8)	1 (2.0)
<b>IMN</b>	2 (4.8)	0 (0)
<b>Total</b>	12 (28.6)	1 (2.0)

PSF : plate and screw fixation ; IMN : intramedullary nailing.

nerve palsy, open fractures, floating elbow and fractures with vascular injury.

Radial nerve palsy was present preoperatively in 10 patients in the PSF group and in 2 in the IMN group. One year postoperatively, all had recovered, except one in the PSF group (table II). Preoperative radial nerve palsies were mainly seen in association with high-energy trauma, open fractures and Holstein-Lewis fractures.

Two patients in the PSF and one patient in the IMN group were temporarily treated with external fixation for a maximum of ten days before proceeding with a definitive treatment.

All procedures were performed by or under direct supervision of a staff surgeon.

The choice of the operative technique was based on the general recommendations at the time of treatment. Generally, fractures with vascular injury, open fractures and fractures with radial nerve palsy were treated with plate fixation, which allowed for exploration of the lesion.

In the IMN group, Unreamed Humeral Nails (Synthes, USA) and Expert Humeral Nails (Synthes, USA) were used. In the PSF group Dynamic Compression Plates, Low Contact Dynamic Compression Plates and Waldemar Link plates were used.

Union, functional outcome, possible complications and the need for additional surgery were compared between the IMN and PSF group. "Union" was defined as fracture healing within a period of six months. "Delayed union" was defined as healing between six months and one year. "Non-union" referred to fractures that were not healed within one year and needing reosteosynthesis.

Functional outcome was graded as excellent, good, fair or poor. Excellent healing meant that complete functional recovery was achieved. The outcome was rated as good if there was a suboptimal recovery without an impact on work and everyday activity. The functional outcome was rated as fair when patients experienced functional impairment with daily activities and work. Poor recovery meant that daily or work activities had to be abandoned because of functional impairment.

Complications that were compared included: the occurrence of iatrogenic fractures, hardware failure, morbidity of shoulder or elbow, radial nerve palsy, the occurrence of infections and compartment syndrome. We also compared the need for additional surgery. The results were statistically evaluated with Fisher's Exact test.

## RESULTS

Union was obtained within six months in 70.3% of all fractures, delayed union was noted in 20.9% and non-union in 8.8%. Patients with delayed union were followed for at least another six months after which the possibility of secondary treatment was considered. There was no significant difference in union rates between the PSF and the IMN group (table III). In the PSF group, non-union after one year was noted in three cases, all with hardware failures (broken screws in 2, broken plate in one) Reoperation on these three patients was successful-

Table III. — Time to union

	TOTAL		PSF		IMN	
	n	%	n	%	n	%
<b>Union</b>	64	70.3	30	71.4	34	69.4
<b>Delayed Union</b>	19	20.9	9	21.4	10	20.4
<b>Non Union</b>	8	8.8	3	7.1	5	10.2

PSF : plate and screw fixation ; IMN : intramedullary nailing.

ly performed with a new PSF, combined with bone grafting in two patients.

In the IMN group five patients presented non-union after one year. Two showed loosening of distal locking screws and one migration of the nail. Two of these underwent revision with PSF, of which one with bone grafts.

A third patient denied any further surgery, as he had no functional limitation and presented no complaints.

In the two patients who had nonunion after IMN without loosening of screws or hardware migration, the unreamed humeral nail (UHN) was replaced by an Expert humeral nail.

No significant difference in functional recovery was seen between the two groups (table IV). Overall, the functional recovery was excellent in 71.4%, good in 20.9%, fair in 3.3% and poor in 4.4% of patients.

There were 6 cases of postoperative radial nerve palsy: four in the PSF group and two in the IMN group. Secondary exploration of the nerve was done in one patient in each group. In the PSF patient, the nerve was found to be trapped underneath the plate. This was repaired with an interposed sural nerve graft but the palsy had not recovered one year later. In the IMN patient, the radial nerve was found to be trapped under a Dall-Miles cable used for reduction of the fracture before nailing. After release of the nerve, there was incomplete recovery of the palsy after one year. Three iatrogenic fractures occurred, all in the IMN group: one at the distal tip of an antegrade nail in the distal humerus, two at the entrance site of a retrograde nail. One of these fractures was a supracondylar fracture for which revision with extended PSF was needed (fig 1).

Table IV. — Functional recovery

	TOTAL		PSF		IMN	
	n	%	n	%	n	%
<b>Excellent</b>	65	71.4	32	76.2	33	67.3
<b>Good</b>	19	20.9	8	19.0	11	22.4
<b>Fair</b>	3	3.3	1	2.4	2	4.1
<b>Poor</b>	4	4.4	1	2.4	3	6.1

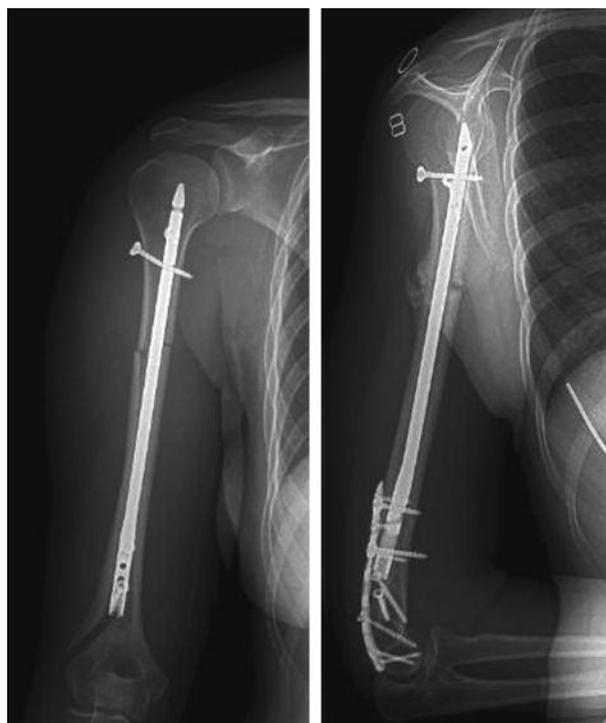
PSF : plate and screw fixation ; IMN : intramedullary nailing.

There were significantly more patients with restrictive pain and/or functional hindrance in the shoulder or elbow in the IMN group ( $p = 0.0053$ ). Eight patients reported persisting pain in the shoulder or elbow one year after the operation, all in the IMN group. After retrograde nailing, two out of 21 patients (9.5%) reported persisting elbow pain at the nail insertion place. After antegrade nailing, 6 of 28 patients (21.4%) reported shoulder complaints related with impingement ; one patient developed a frozen shoulder (table V).

Problems with osteosynthesis material occurred as often in the PSF group (9.5%) as in the IMN group (8.8%) (table V). One broken plate and one bended plate were seen in follow-up, as well as screw breakage in two cases. Following bending or breakage of the plate, a new plate fixation was done, ending up in union with an excellent functional outcome. In the IMN group migration of the nail was noted twice, in each case with impingement in the shoulder ; non-union of the fracture occurred in one case. Breakage of the distal locking screws was seen twice in the IMN group.

One patient had a wound infection at the shoulder after antegrade nailing with an unreamed humeral nail. The infection with coagulase negative staphylococci was treated with antibiotics and the wound was temporary treated with a vacuum-assisted closing device. Twenty-six days later, the wound was secondarily closed (table V). No compartment syndrome occurred among the 91 patients.

Overall, a significantly larger number of complications was seen in the IMN group (36.7%) than in the PSF group (19.0%) ( $p = 0.05$ ) (table V).



**Fig. 1.** — Additional plate and screw fixation for an iatrogenic supracondylar humeral fracture after retrograde intramedullary nailing.

A reoperation was necessary in 14.3% of the PSF patients and 16.3% of the IMN patients (non-significant difference) (table VI).

## DISCUSSION

Conservative treatment of humeral shaft fractures is credited with union rates of more than 90% (5, 21). Although complete anatomical reduction is rarely achieved, there is usually a good functional outcome (23). Shortening up to 3 cm, rotation less than 30° and angulation up to 20° are considered acceptable (12).

Sometimes however there is a specific indication for surgical treatment. The surgical indications in this study were : unacceptable reduction, associated vascular lesions, open fractures, radial nerve palsy, polytrauma patients, floating elbow and one patient with obesity who was at risk for developing a varus angulation. These indications are in line with the literature (7).

Table V. — Postoperative complications

	Total		PSF		IMN	
	n	%	N	%	n	%
<b>Postoperative complications</b>	<b>26</b>	<b>28.6</b>	<b>8</b>	<b>19.0</b>	<b>18</b>	<b>36.7</b>
<b>Radial nerve palsy</b>	<b>6</b>	<b>6.6</b>	<b>4</b>	<b>9.5</b>	<b>2</b>	<b>4.1</b>
Complete recovery	4	4.4	3	7.1	1	2
Partial recovery	1	1.1	0	0	1	2
No recovery	1	1.1	1	2.4	0	0
<b>Iatrogenic fracture</b>	<b>3</b>	<b>3.3</b>	<b>0</b>	<b>0</b>	<b>3</b>	<b>6.1</b>
<b>Pain/functional restriction</b>	<b>8</b>	<b>8.8</b>	<b>0</b>	<b>0</b>	<b>8</b>	<b>16.3</b>
Elbow	2	2.2	0	0	2	4.1
Shoulder	6	6.6	0	0	6	12.2
<b>Hardware failure</b>	<b>8</b>	<b>8.8</b>	<b>4</b>	<b>9.5</b>	<b>4</b>	<b>8.2</b>
Migration	2	2.2	0	0	2	4.1
Breakage plate	1	1.1	1	2.4	0	0
Bending plate	1	1.1	1	2.4	0	0
Migration/ breakage screws	4	4.4	2	4.8	2	4.1
<b>Infection</b>	<b>1</b>	<b>1.1</b>	<b>0</b>	<b>0.0</b>	<b>1</b>	<b>2.0</b>
<b>Compartment syndrome</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>

Table VI. — Reoperations

	Total		PSF		IMN	
	n	%	N	%	n	%
Total	14	15.3	6	14.3	8	16.3
Non union	7	7.7	3	7.1	4	8.2
Revision for radial nerve palsy	2	2.2	1	2.4	1	2.0
Hardware failure	8	8.8	5*	11.9	3**	6.1
Removal of osteosynthesis material for impingement	1	1.1	0	0.0	1	2.0
Corrective osteotomy for functional hindrance	1	1.1	0	0.0	1	2.0
Correction of perioperative fracture	1	1.1	0	0.0	1	2.0

\* Including 3 cases of non-union.

\*\* All 3 cases presented non-union of the fracture.

Plate and screw fixation has always been the more common surgical treatment (7), but the choice has become more controversial since the rise of intramedullary nailing. Bhandari *et al* (2) carried out a meta-analysis of prospective studies which included 155 patients and could not formulate any conclusive preference.

## UNION

In this study, a union rate of 90% after one year was achieved, without a significant difference between PSF and IMN (table III).

In recent reports, no differences in union rates can be found in some prospective studies (2) whereas

plate fixation shows less non-unions than IM nailing in others (11,16,25). The average union rate for plate fixation is 96% after one year (2,25). The time to eventually achieve union seems to be shorter in the IMN group but plate fixation is more frequently used for more seriously injured patients, patients with open fractures or fractures with vascular injuries, which can slow down the healing process (4). We further note that when non-union occurred after nailing, patients in this study were revised with a plate, as suggested in literature (15). When conservative treatment fails, our policy is to prefer open PSF over IMN. The reduction is generally easier by means of open access since approximating screws can be used for reduction of the fracture. Also any possible pseudoarthrosis can be resected and bone grafts can be placed.

### FUNCTIONAL OUTCOME

This study did not conclude to any significant difference in functional outcome between both groups (table IV). However, there were two patients out of a total of 21 in the IMN group with postoperative pain and hindrance of the elbow after retrograde nailing. After antegrade nailing 6 out of 28 patients reported shoulder problems (table V). These complaints ranged from impingement to frozen shoulder. Similar findings are frequently mentioned in literature (3,4). Thus Mc Cormack *et al* reported no significant difference in functional outcome but they had six patients with impingement in their group of 21 IMN patients (13). Flinkkilä *et al* (10) claim that a correctly placed nail is not responsible for postoperative shoulder problems. This we dispute. Often impingement arises from not positioning the nail distal enough, possibly out of fear to cause a distal iatrogenic fracture in a narrow humerus. Impingement can also arise from migration of unlocked nails.

### RADIAL NERVE PALSY

The overall incidence of radial nerve palsy in humeral shaft fractures is approximately 11% ; spontaneous recovery can be expected in 70% of cases (24).

In the PSF and IMN performed in this study, respectively 10 and 2 patients with preoperative radial nerve palsy or 28.6% were seen. One year postoperatively, there were respectively one and no more patients remaining with radial nerve palsy (table II). Most fractures (83.3%) with preoperative radial nerve palsy were treated with plate fixation, following our policy, in line with the literature.

Radial nerve palsy is the most frequent complication noted after plating of the humerus. In this study, postoperative radial nerve palsy was seen in 6 cases (9.5%) : four in the PSOS group and two in the IMN group (table V). In the PSF group the radial nerve was stuck underneath the plate in one case. This is a frequently documented complication of PSF. With every open reduction treated with PSF one must make sure that the radial nerve is above the plate.

In the IMN group the radial nerve was once stuck under a Dall-Miles cable. This is a disadvantage when using intramedullar nails : in order to obtain a good reduction of the fracture, the fragments sometimes need to be reduced blindly with a cerclage wire or a cable. This is done so the minimal invasive feature of the operation is not compromised. Yet, by blindly cabling the humeral shaft, there is a chance that the radial nerve is being squeezed under the cable. After release of the nerve by removing the Dall-Miles cable, the palsy recovered partially.

### INFECTION

Infections after humeral fractures are rare, even with open fractures (1-2%). When infection occurs, there is frequently a secondary reason such as diabetes or serious traumatic vascular lesions. More infections are described after plating (4). In this group of patients one patient in the IMN group was seen with a wound infection at the shoulder with coagulase negative staphylococcus, following antegrade nailing. Antibiotic treatment was necessary combined with wound care with a vacuum-assisted closure device.

### COMPARTMENT SYNDROME

Compartment syndrome is rare after humeral shaft fractures ; there was no instance in this study.

## REOPERATION

No significant difference was seen between the need for reoperation in the PSF and the IMN group (table VI). However recent literature shows that IMN is more likely to require revision surgery. Bhandari *et al* (2) calculated that if one treats ten patients with plate fixation instead of nailing, one reoperation can be avoided (NNT = 10).

Specific problems with IMN, in this study, were the need for removing antegrade nails owing to impingement complaints and the implementation of corrective osteotomy in a 34-year-old male patient with a physically demanding occupation, to correct a 45° external rotation after IMN. This was done with plate fixation (fig 2). Rotational malalignments are best treated with plate fixation (1). When using IMN, we prefer using locked humeral nails since these guarantee better compressive and rotational stability. The use of Ender nails, Steinman pins or Hackethal nails is avoided. Also iatrogenic supracondylar humeral fractures were seen at the retrograde introduction site of the IMN. These were corrected with additional plate fixation (fig 1).

This study is limited in its value by its retrospective nature. We are aware that by including both ante- and retrograde nailing, additional variables are introduced which hamper a direct comparison with plate fixation. It is very difficult to conduct a scientific study based on clinical findings. This may be why a lot of qualitatively good articles on this subject had difficulties reaching a conclusion or formulated contradictory conclusions. This may be obviated by carrying out large randomised prospective, preferably multi-centric, studies.

We must note that more plates were used in this study for the more complex fractures such as open fractures and fractures caused by high-energy trauma with radial nerve palsy. The study results showed that the union rate, the functional outcome and the occurrence of postoperative radial nerve palsy was equivalent in the IMN and the PSF group. However, more postoperative pain and limitation of the shoulder in antegrade nailing and of the elbow in retrograde nailing was seen. This is a morbidity of the insertion site which is also described in literature (6). The complications were more frequent in



**Fig. 2.** — Corrective osteotomy with PSOS to correct a 45° external rotation after IMN.

antegrade than in retrograde nailing, but the difference was not significant. Complications requiring reoperation were however significantly more frequent and more serious in the IMN group in comparison with the PSF group.

Bearing this in mind we think that plate fixation must be considered as the primary option for operative treatment of humeral shaft fractures, for the majority of the indications and most certainly for fractures with accompanying radial nerve palsy. Open fractures (Gustilo 2 and higher) or fractures with major soft tissue damage, sometimes need to be treated with primary external fixation (17). Segmental humeral shaft fractures, humeral shaft fractures in morbidly obese patients, very osteopenic patients and pathological fractures are preferably treated with IMN (19,20). For all other surgical indications our preference goes to plate fixation.

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