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ORIGINAL PAPER

Is distal locking screw necessary for intramedullary nailing in the treatment of humeral shaft fractures? A comparative cohort study

Romain Colombi[1] · Thomas Chauvet[1] · Ludovic Labattut[1] · Brice Viard[1] · Emmanuel Baulot[1,2] · Pierre Martz[1,2,3]

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Abstract

Purpose The gold standard for intramedullary nailing (IMN) in humeral shaft fracture treatment is bipolar interlocking. The aim of this study was to compare clinical and radiographic outcomes in two cohorts of patients treated with IMN with or without distal interlocking. We hypothesized that there was no significant difference between isolated proximal interlocking and bipolar interlocking in terms of consolidation and clinical results.

Methods One hundred twenty-one acute humeral shaft fractures were retrospectively included in group WDI (without distal interlocking screw, $n = 74$) or in group DI (with distal interlocking screw, $n = 47$). One hundred six patients (87.60%) could be verified by an X-ray, and 63 (52.07%) could be examined clinically. Fracture union at 6 months was the primary outcome, and the second was the final clinical outcome for shoulder and elbow after at least 6 months of follow-up. Pain, operating time, and radiation time were also analyzed.

Results The two groups were not significantly different for population, fractures, or immobilization duration. No significant difference was found for bone union (WDI 89.06% vs DI 83.33%, $p = 0.51$), shoulder or elbow functional outcomes, or pain. However, there were significant differences in advantage to the WDI group for operating time (WDI 63.09 ± 21.30 min vs DI 87.96 ± 30.11 min, $p < 0.01$) and fluoroscopy time (WDI 59.06 ± 30.30 s vs DI 100.36 ± 48.98 s, $p < 0.01$).

Conclusions Thus, it seems that there were no significant differences between proximal unipolar and bipolar interlocking for humeral shaft fractures in terms of consolidation and clinical outcomes. WDI avoided the additional operating time and fluoroscopy time and risks linked to DI.

Keywords Humeral fracture · Humeral shaft · Humeral nailing · Distal interlocking

Introduction

The reference technique for intramedullary nailing in humeral shaft fractures, as described by Schellmann [1], requires bipolar locking to counter rotation forces and thus allow bone consolidation. However, the technical difficulties [2] inherent to distal locking increase the risk of iatrogenic damage: longer surgical procedure, longer exposure to intraoperative radiation [3] for the patient and the surgical team, and a greater number of incisions, thus exposing patients to greater neurovascular risk [4, 5]. In 2004, Meyrueis [6] showed that "moderate instability" of the fracture site promoted consolidation during the first 6 weeks after the fracture.

The objective of this study was to evaluate clinical and radiographic outcomes between two groups of humeral shaft fracture treated with antegrade IMN with and without distal interlocking.

Our hypothesis was there was no significant difference between the two groups, concerning bone union or clinical outcomes.

Level of evidence: III, retrospective comparative study, treatment study.

✉ Pierre Martz
martzpierre@neuf.fr

1 Orthopedic and Traumatology Department, Dijon University Hospital, F-21000 Dijon, France

2 INSERM UMR1093-CAPS, Burgundy Franche-Comté university, F-21000 Dijon, France

3 Orthopedic and Traumatology Department, CHU Dijon, 14 rue Paul Gaffarel, 21079 Dijon CEDEX, France

Materials and methods

Study design

We carried out a retrospective analysis of a consecutive non-selected series. Inclusion criteria were all patients > 18 years old with a humeral shaft fracture (all types), between January 1, 2009 and September 31, 2016, treated first by IMN. The following exclusion criteria were applied: follow-up under 6 months, pathological fractures, short IMN, IMN without any interlocking screw, and other first treatments (functional bracing, plate and stable elastic intramedullary nailing). All fractures were classified using the AO/OTA classification system [7]. During the period of inclusion (2009 to 2016), 161 patients were treated for humeral shaft fractures. A total of 120 patients with 121 fractures met the inclusion criteria: 74 in the WDI group and 47 in the DI group. Eight surgeons were concerned without any resident as operator. Characteristics of the included patients are summarized in Table 1.

Surgical technique

Patients were in beach chair position under general anesthesia. An anterior-superior approach was made in all cases. The supraspinatus tendon was open in the line with muscle fiber orientation [8], medial to the greater tuberosity. Then, adequate measurements had been made using fluoroscopy, and a solid humeral nail was inserted. We currently do not ream but when the intraoperative fluoroscopy measurement found an inadequate ratio between the nail and the humeral canal diameters making impossible unreamed nail insertion, the surgeon reamed the humerus 1 mm more than the nail diameter. Then, locking screws were inserted; according to the surgeon for distal locking, from the anterior to the posterior, using fluoroscopy control. The distraction at the fracture site could be prevented during antegrade nailing by pushing or thumping the elbow after proximal locking. And finally, the rotator cuff tendon and deltoid were carefully repaired.

Table 1 Patients' characteristics

	Total	WDI group	DI group	*p* value
Number of fractures	121	74	47	
Age at surgery (mean ± SD), years	55.14 ± 21.00	53.61 ± 20.29	57.55 ± 22.07	0.33
Gender, *n* (%)				
Male	60 (49.59%)	40 (54.05%)	20 (42.55%)	0.22
Female	61 (50.41%)	34 (45.95%)	27 (57.45%)	
Lateralization, *n* (%)				
Right-handed	88 (88%)	52 (92.86%)	36 (81.82%)	0.26
Left-handed	7 (7%)	2 (3.57%)	5 (11.36%)	
Ambidextrous	5 (5%)	2 (3.57%)	3 (6.82%)	
Body mass index (mean ± SD)	25.84 ± 5.07	25.49 ± 5.07	26.39 ± 5.08	0.35
Accident at work, *n* (%)	14 (12.17%)	9 (13.24%)	5 (10.63%)	0.68
Trauma mechanism, *n* (%)				
Traffic accident	36 (29.75%)	25 (33.78%)	11 (23.40%)	
Fall	70 (57.85%)	40 (54.05%)	30 (63.83%)	
Fall from height	5 (4.13%)	1 (1.35%)	4 (8.51%)	
Sports	7 (5.79%)	5 (6.76%)	2 (4.26%)	
Others	3 (2.48%)	3 (4.05%)	0	
Comorbidities				
Smoking, *n* (%)	56 (53.84%)	28 (47.46%)	28(62.22%)	0.13
Corticoids, *n* (%)	0	0	0	NA
Alcohol, *n* (%)	26 (25.24%)	12 (20.34%)	14 (31.81%)	0.20
Diabetic, *n* (%)	11 (10.57%)	9 (15.00%)	2 (4.54%)	0.11
ASA PS Classification, *n* (%)				
1	44 (36.36%)	28 (37.84%)	16 (34.04%)	
2	57 (47.11%)	35 (47.30%)	22 (46.81%)	0.62
3	20 (16.53%)	11 (14.86%)	9 (19.15%)	
Mortality	14 (11.57%)	11 (14.86%)	3 (6.38%)	

Continuous data are given as mean ± standard deviation or number of fractures (%)

WDI, without distal interlocking; DI, with distal interlocking; *SD*, standard deviation; *NA*, not applicable; *ASA PS Classification*, American Society of Anesthesiologists Physical Status Classification

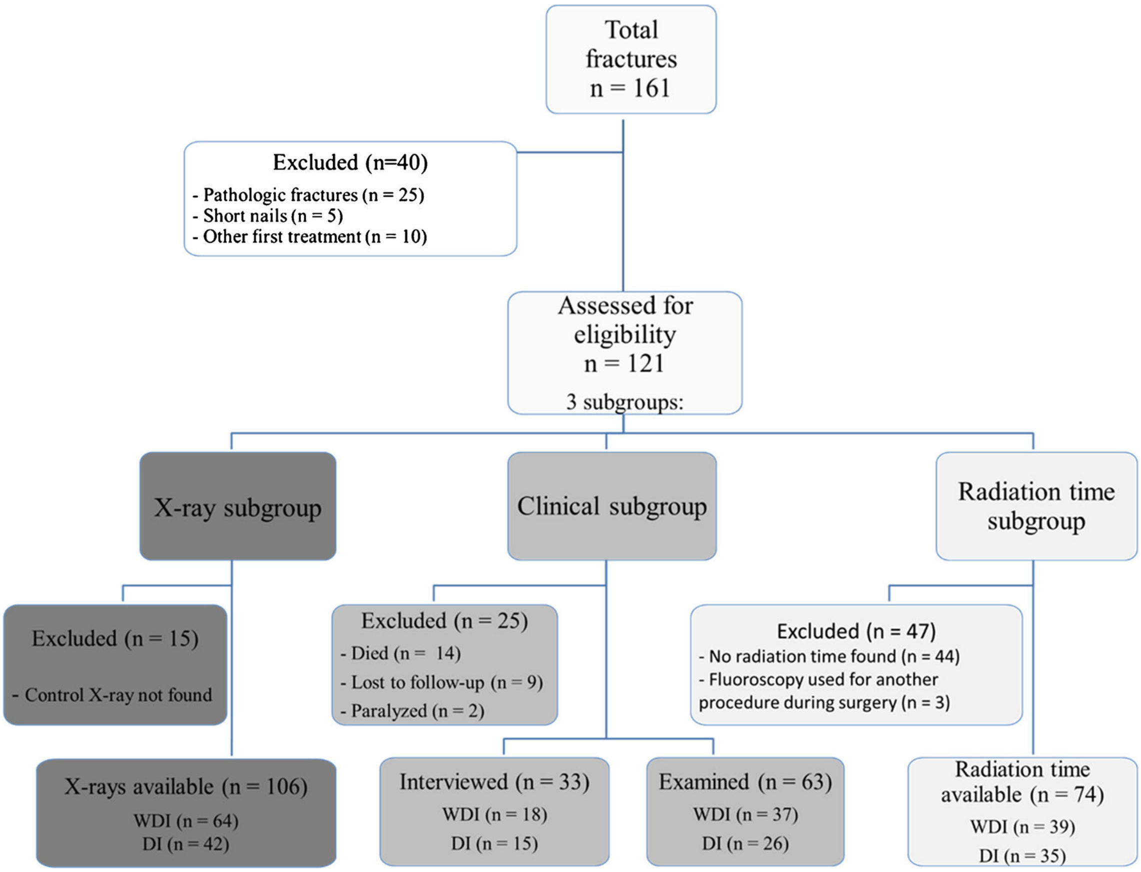

Fig. 1 Participant flow for all patients included in three subgroups (X-ray, clinical, radiation time). n, number; WDI, without distal interlocking group; DI, distal interlocking group

Outcomes

Three analyses were carried out in this population according to the subgroup (Fig. 1). The primary outcome was the consolidation at 6 months assessed on all X-rays available (n = 106). Consolidation was defined by the presence of a callus bridging at least three of four cortices, assessed with two orthogonal incidences. Nonunion was defined as failure of radiological union at 6 months [9]. The second criterion was the final clinical outcome, after at least 6 months of follow-up, using usual scores for the shoulder (Constant [10], subjective shoulder value (SSV)) and the elbow (Mayo Elbow Performance Score (MEPS) [11], subjective elbow value (SEV)). On follow-up, all available patients were examined concerning pain (VAS), elbow (MEPS, SEV [12]), and shoulder function (Constant, SSV [13]) and satisfaction. All rotation differences were also clinically measured with a goniometer comparatively with the ipsilateral arm: internal (IR) and external active rotations (ER1, ER2, ER3). Patients who could not attend these examinations were interviewed by phone to collect VAS, SSV, SEV, and satisfaction. We also checked the correlation between SSV/Constant and SEV/MEPS scores with Pearson's correlation coefficient, to validate our telephone interview results. Additional analyses including hospitalization duration, operating time, fluoroscopy time, immobilization duration, and complications were done.

Statistical analysis

Descriptive statistics were reported as means (standard deviations) for continuous variables and numbers (percentages) for discrete variables. A Mann-Whitney U test was used to analyze clinical outcomes (VAS, SSV, Constant absolute and relative, SEV, MEPS, rotations). A Welsh two sample t test was used to analyze age, BMI immobilization duration, operative time, and fluoroscopy time. A Pearson-chi-squared test was used to analyze gender, comorbidities, affected side, and fracture type, and a Fisher exact test was used to compare patient lateralization, open or closed fractures, and fracture localization and consolidation and to compare nail types. Finally, Pearson's correlation test was used to correlate SSV/SEV and CSS/MEPS. Statistics were done with RStudio 1.0.136. A p value < 0.05 was considered statistically significant.

Table 2 Baseline characteristics

	Total	WDI group	DI group	*p* value
Side affected, *n* (%)				
Right	47 (38.84%)	23 (31.08%)	24 (51.06%)	0.03
Left	74 (61.16%)	51 (68.92%)	23 (48.94%)	
Dominant	38 (38%)	18 (32.14%)	20 (45.45%)	0.25
Radial palsy, *n* (%)				
Preoperative	6 (4.96%)	2 (2.70%)	4 (8.51%)	
Postoperative	10 (8.26%)	4 (5.41%)	6 (12.77%)	NA
Spontaneous recovery	10 (100%)	4 (100%)	6 (100%)	
Fractures, *n* (%)				
Open	9 (7.44%)	8 (10.81%)	1 (2.13%)	0.15
Closed	112 (92.56%)	66 (89.19%)	46 (97.87%)	
AO classification, *n* (%)				
Type A	61 (50.41%)	41 (55.41%)	20 (42.55%)	0.27
Type B	28 (23.14%)	17 (22.97%)	11 (23.40%)	
Type C	32 (26.45%)	16 (21.62%)	16 (34.04%)	
Localization on humerus, *n* (%)				
Proximal third	22 (18.18%)	16 (21.62%)	6 (12.77%)	
Proximal and middle third junction	31 (25.62%)	16 (21.62%)	15 (31.91%)	
Middle	54 (44.63%)	33 (44.59%)	21 (44.68%)	
Middle and distal third junction	11 (9.09%)	6 (8.11%)	5 (10.64%)	0.54
Distal third	1 (0.83%)	1 (1.35%)	0	
Bifocal	2 (1.65%)	2 (2.70%)	0	
Time between fracture and surgery, days ± SD	1.93 ± 2.87	1.95 ± 3.46	1.89 ± 1.60	0.91
Days in hospital, days ± SD	8.74 ± 9.94	8.68 ± 9.94	8.85 ± 10.05	0.93
Immobilization duration, weeks ± SD	5.85 ± 2.48	5.85 ± 2.71	5.32 ± 2.02	0.22

Continuous data are given as mean ± standard deviation or number of fractures (%)

WDI, without distal interlocking; *DI*, with distal interlocking; *NA*, not applicable; *SD*, standard deviation

After consulting the local ethics committee (CPP est. 1. Dijon, France), this routine care retrospective study, in accordance with current French legislation at the time of the inclusion, did not require any ethic committee approbation.

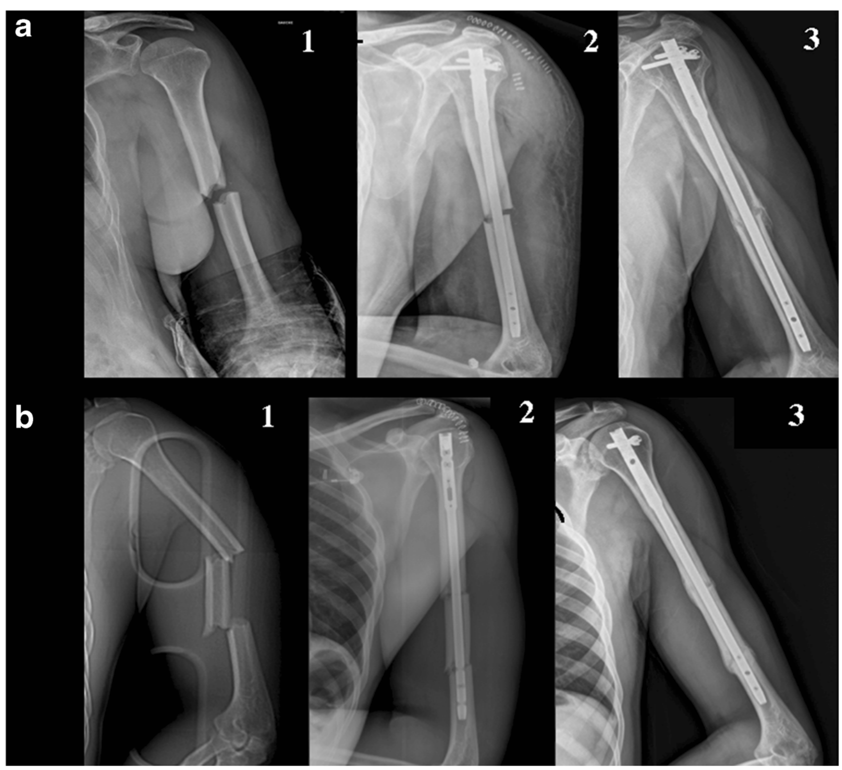

Fig. 2 Left-arm transverse (**a**) and bifocal (**b**) fractures managed by IMN without distal interlocking. 1 X-ray before surgery; 2 X-ray just after surgery; 3 control X-ray at 6 months

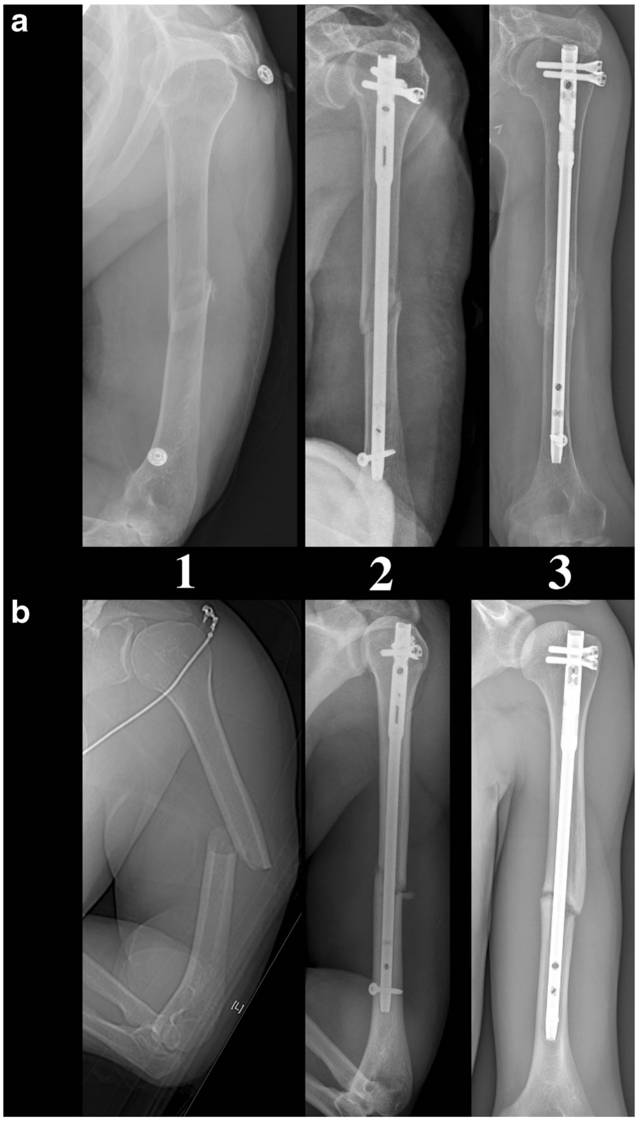

Fig. 3 Left-arm oblique fractures managed by IMN with distal interlocking with a correct bone healing (**a**) and nonunion (**b**). 1 X-ray before surgery; 2 X-ray just after surgery; 3 control X-ray at 1 year

Results

Baseline data

The mean time between the fracture and the surgical treatment was 1.93 ± 2.87 days, ranging from 0 to 18 days in both groups. Four solid humeral nails were used (Multiloc (Depuy-Synthes, Bristol, USA) in 68 cases, T2 (Stryker, Kalamazoo, USA) in 50 cases, Versa (Depuy-Synthes, Bristol, USA) in 2 cases, and Trigen (Smith & Nephew, London, UK) in 1 case), but there was no statistical difference concerning outcomes between the different nails. There were 11 nerve palsies (10 radial palsies and 1 brachial plexus), including four postoperative palsies (2 per group), and all of the radial palsies resolved spontaneously. Other baseline data are summarized in Table 2. No differences were detected between the groups regarding age, sex, BMI, trauma mechanism, AO classification, open or closed fractures, associated lesions, laterality, and radial nerve palsies.

Consolidation

The analysis of 106 X-rays (87.60% of patients) showed no significant difference between the two groups concerning fracture union. X-rays are presented in Figs. 2 and 3 in order to show the consolidation without distal interlocking. Consolidation at 6 months was 89.06% for the WDI group and 83.33% for the DI group ($p = 0.5081$, Fisher's exact test). At the last follow-up, consolidation was 93.75% for the WDI group and 95.24% for the DI group ($p = 0.6462$, Fisher's exact test) (Fig. 4). Thus, six nonunions were highlighted, with equal distribution between the WDI ($n = 4$) and DI ($n = 2$) group (Fig. 3). All nonunions were eutrophic ($n = 5$) or atrophic ($n = 1$), with all eutrophic nonunions in the WDI group. The results are summarized in Table 3. A statistical power analysis found a good power (> 0.8) for the main criteria.

Clinical outcomes

Ninety-eight patients were either examined or interviewed by phone, with 56 in the WDI group and 42 in the DI group. In each group, one patient was paralyzed (tetraplegic and brachial plexus) and could not be examined; they were thus excluded for the clinical results. Sixty-three (52.07%) were examined and 33 (27.27%) were interviewed (Fig. 1). The mean follow-up time was 32.21 ± 21.88 months. After at least 6 months of follow-up, patients in the WDI group showed no difference in any scores compared with the DI group (Fig. 5). Pain was similar in both groups. All clinical results are summarized in Table 3. This study highlighted a very high correlation (> 0.8) between SEV and MEPS ($r = 0.92$, $p < .001$, Pearson's correlation test), and a high correlation ($0.5 < r < 0.8$) between SSV and CSSabs ($r = 0.72$, $p < .001$, Pearson's correlation test) or SSV and CSSrel ($r = 0.62$, $p < .001$, Pearson's correlation test). The WDI group showed no significant difference in any rotations compared with the DI group (Fig. 6).

Operative time and fluoroscopy use

There was a significant difference between the two groups for the total surgical time, collected for all patients, with a mean of 63.09 ± 21.30 min for the WDI group and 87.96 ± 30.11 min for the DI group ($p < .001$, Welsh test). In the same way, there was also a significant difference for fluoroscopy time during surgery, with a mean of 59.06 ± 30.30 s for the WDI group and 100.36 ± 48.98 s for the DI group ($p < .001$, Welsh test). The results are summarized in Table 3.

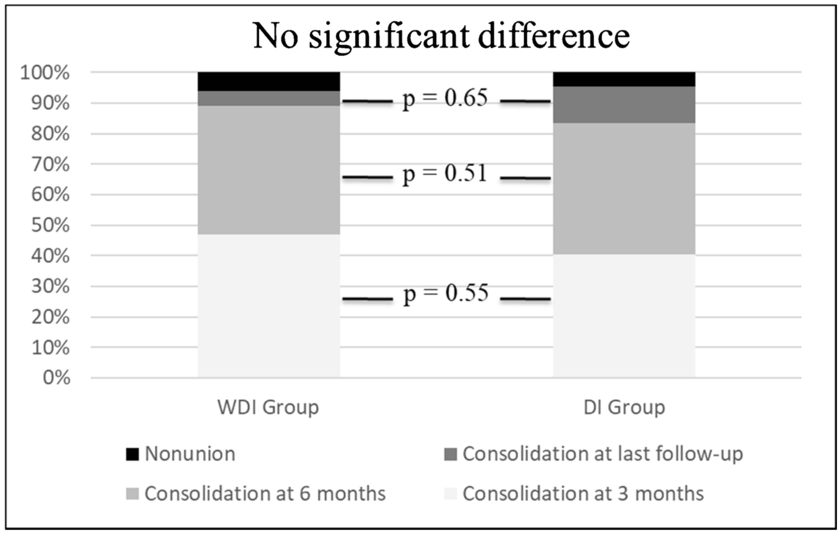

Fig. 4 Comparison of consolidation distribution between the group without and with distal interlocking. WDI, without distal interlocking; DI, distal interlocking

Table 3 Results

	Total	WDI group	DI group	*p* value
Consolidation (X-ray analysis), *n* (%)				
Number of patients	106	64	42	
At 3 months	47 (44.34%)	30 (46.87%)	17 (40.47%)	0.55
At 6 months	92 (86.79%)	57 (89.06%)	35 (83.33%)	0.51
At the last follow-up	100 (94.34%)	60 (93.75%)	40 (95.24%)	0.65
Nonunion	6 (5.66%)	4 (6.25%)	2 (4.76%)	NA
Eutrophic	5 (83.33%)	4 (100%)	1 (50%)	NA
Atrophic	1 (16.67%)	0	1 (50%)	NA
Operative time				
Number of patients, *n*	121	74	47	
Duration, min ± SD	72.75 ± 27.78	63.09 ± 21.30	87.96 ± 30.11	< 0.001
Fluoroscopy use				
Number of patients, *n*	74	39	35	
Duration, sec ± SD	80.17	59.06 ± 30.30	100.36 ± 48.98	< 0.001
Interview subgroup, mean ± SD				
Number of patients	96	55	41	
VAS	1.98 ± 2.06	2.20 ± 2.10	1.68 ± 1.99	0.15
SSV	80.67 ± 16.83	78.98 ± 17.63	82.93 ± 15.61	0.26
SEV	92.80 ± 13.97	90.80 ± 15.88	95.49 ± 10.48	0.21
No. of patients with good or excellent result	78 (81.25%)	44 (80.00%)	34 (82.93%)	0.93
Examination subgroup, mean ± SD				
Number of patients	63	37	26	
Constant shoulder score				
Absolute (CSSabs)	69.37 ± 19.34	66.89 ± 20.35	72.88 ± 17.59	0.34
Relative (CSSrel)	85.80 ± 21.80	80.73 ± 22.83	91.81 ± 18.81	0.06
MEPS	89.84 ± 15.29	87.70 ± 16.73	92.88 ± 12.66	0.34
Correlation				
SSV/CSSabs	0.72			< 0.001
SSV/CSSrel	0.62			< 0.001
SEV/MEPS	0.92			< 0.001
Rotation differences with ipsilateral, mean ± SD				
IR	− 0.8 ± 0.99	− 0.8 ± 1.15	− 0.8 ± 0.72	0.93
ER1	− 3 ± 19.51	− 5 ± 20.80	1 ± 17.40	0.66
ER2	− 7 ± 23.95	− 11 ± 28.90	− 1 ± 12.60	0.12
ER3	− 2 ± 15.95	− 3 ± 19.17	− 1 ± 10.35	0.34

Continuous data are given as mean ± standard deviation or number of fractures (%)

WDI, without distal; *DI*, with distal interlocking; *NA*, not applicable; *SD*, standard deviation; *VAS*, visual analogic scale; *SSV*, subjective shoulder value; *SEV*, subjective elbow value; *CSSabs*, absolute Constant score; *CSSrel*, relative Constant score; *MEPS*, Mayo Elbow Performance Score; *IR*, internal rotation; *ER1*, external rotation 1; *ER2*, external rotation 2; *ER3*, external rotation 3

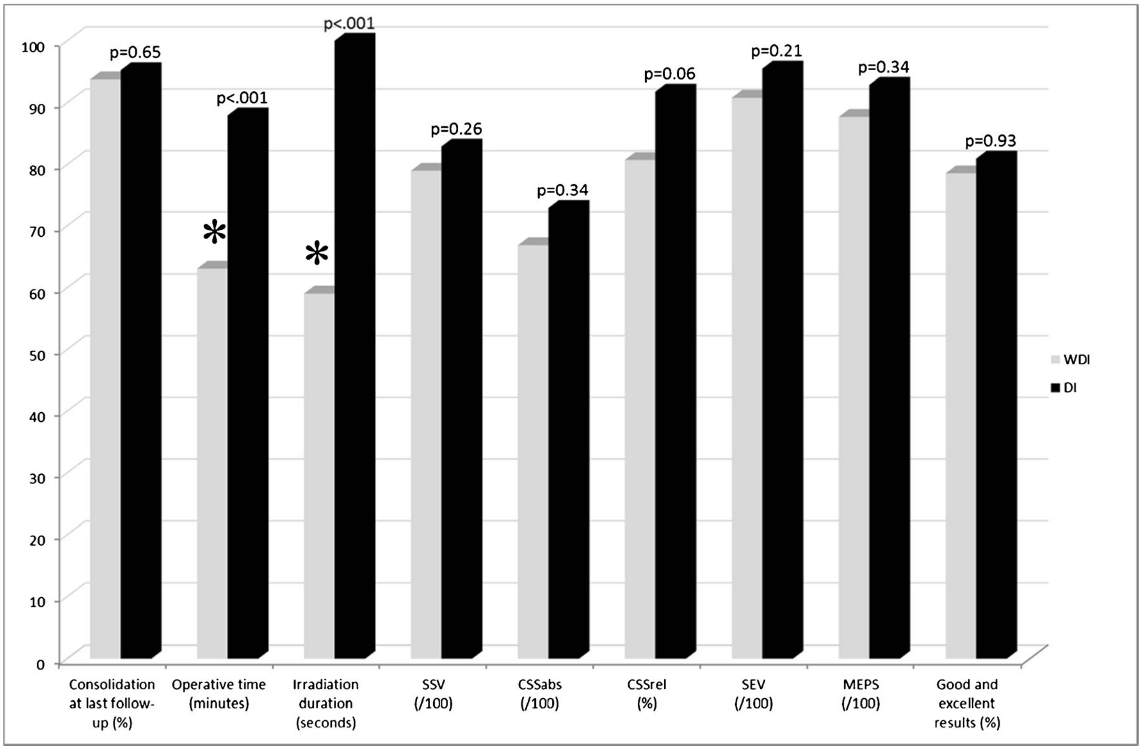

Fig. 5 Comparison of 6-month follow-up results between the two groups. WDI, without distal interlocking group; DI, distal interlocking group; SSV, subjective shoulder value; CSSabs, absolute Constant score; CSSrel, relative Constant score; SEV, subjective elbow value; MEPS, Mayo Elbow Performance Score

Discussion

Many studies [14–17] compared IMN and other treatments, but no previous study has compared IMN with and without distal interlocking for humeral shaft fractures. This study showed no differences between IMN with proximal interlocking alone and IMN with bipolar interlocking for bone union, shoulder function, elbow function, and pain.

Calculation of the Constant score and MEPS score required the examination of patients, which was not possible when the patient was unavailable (living far away, deceased, refusal), and is why the SSV and SEV were used for all patients contacted by phone. In this study, only 63 patients (52.07%) could be examined clinically.

Gilbart [13] and Schneeberger [12], respectively, showed a very high correlation ($r = 0.80$) between the SSV and the Constant score, and a high correlation ($r = 0.67$) between the SEV and MEPS. In this study, a high correlation ($r = 0.72$ and 0.62) was found between the SSV and CSSabs and CSSrel, respectively, and a very high correlation ($r = 0.92$) was found between the SEV and MEPS (Table 3). These correlations allowed us to extrapolate clinical results for all patients, even those who had the SSV and SEV but not the CSS or MEPS.

As the nailing technique is the same for isolated proximal locking and bipolar locking, it was obvious to obtain equivalent clinical outcomes in this study. In addition, the clinical results concerning the Constant score were similar to those reported by Cuny et al. in 2007 [18]. However, as the subjective SSV and SEV scores have not yet been assessed after humerus nailing, our results cannot be compared with the literature.

Locking the nails exposes patients to a risk of neurovascular damage, as reported by Rupp et al. [4]. Numerous studies [4] have shown the risks concerning the brachial artery and the radial, median, and ulnar nerves associated with distal lateromedial locking, or concerning the musculocutaneous nerve during anteroposterior locking. In our series, there were no such complications in either group. Nonetheless, the use of isolated proximal locking avoids these risks.

The use of nailing without locking goes back to the basic principles of nailing described in 1945 by Kuntscher [19]. This approach was then developed, notably by Klemm and Schellmann [1], with the introduction of locking to neutralize rotary constraints. Other studies have confirmed this advantage [3, 20, 21], and since then, it is recognized that nailing must be locked to ensure the stability necessary for satisfactory consolidation of the humeral shaft.

Only three recent studies have reported nailing with isolated proximal locking. Cuny et al. [18] were the first to describe the use of nailing without distal locking in their study

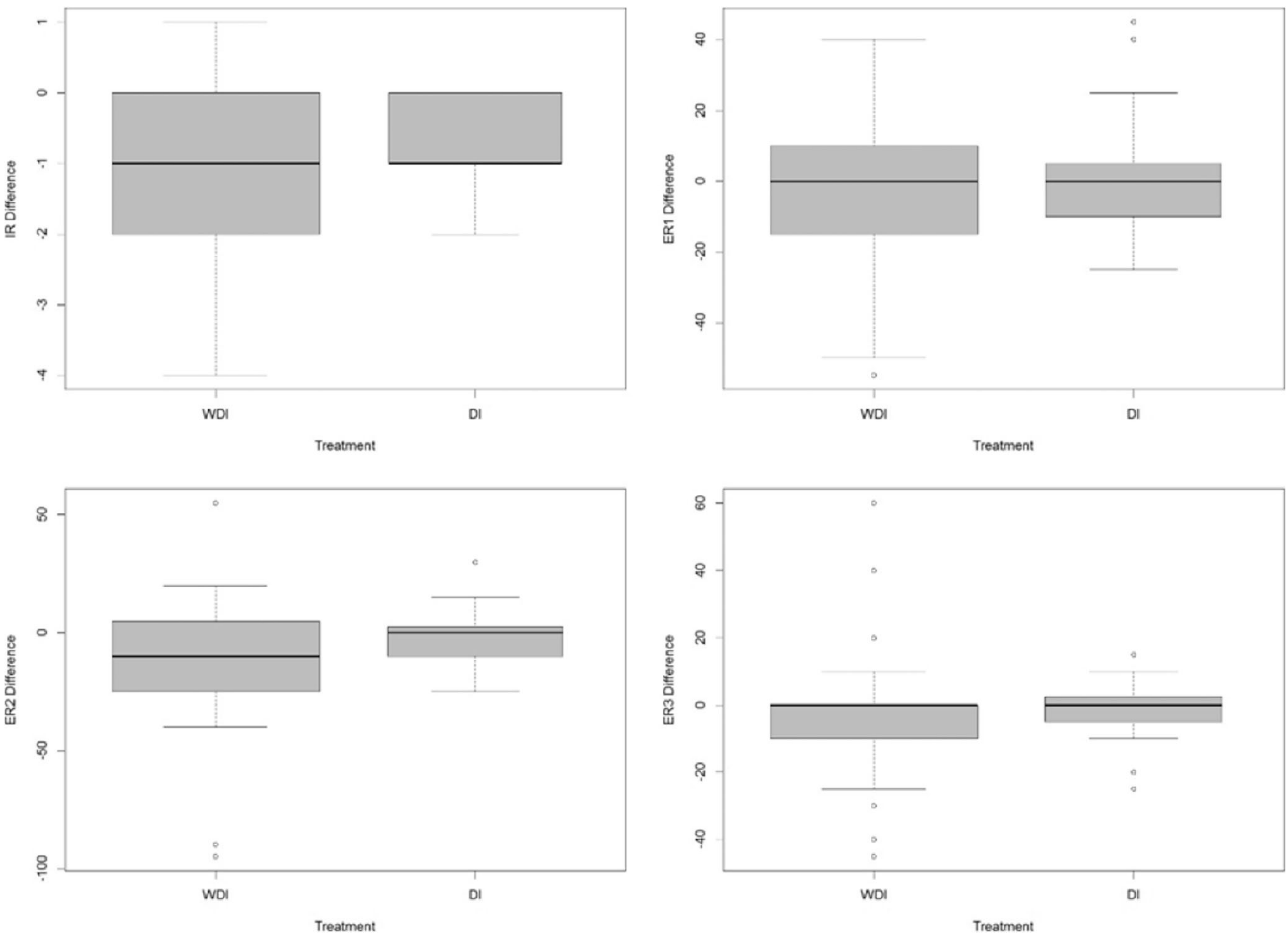

Fig. 6 Comparison of rotations between the two groups. IR, internal rotation; ER1, external rotation 1; ER2, external rotation 2; ER3, external rotation 3; WDI, without distal interlocking group; DI, distal interlocking group

comparing three types of distal locking for their Telegraph nail (static, dynamic, without locking). They concluded that nailing with dynamic locking was better than nailing with isolated proximal locking, which in turn was better than bipolar locking. These conclusions seem to be in keeping with our results. In 2013, Tyllianakis [2] studied a cohort of 64 patients with isolated proximal locking and concluded that this technique, even though in contradiction with biomechanical studies, gave good results for consolidation. The findings from our comparative study are in line with those of the Tyllianakis study. In a case report in 2015 [22] Inal et al. described good results and concluded that this technique could be used in appropriate cases.

This study analyzed 106 X-rays (87.60% of patients) and showed an average rate of consolidation of 94.34% (93.75% for the WDI group and 95.24% for the DI group), which is similar to rates in the literature. Indeed, in the literature [2], the bone union rate for IMN ranges from 82.6% for Passuti et al. in 2004 [23] to 100% for Osman et al. in 1998 [24]. The mean time to consolidation of 16 weeks found in this retrospective study is in keeping with published studies in which times range from around 8 weeks for Osman [24] to 20 weeks for Taglang [25].

Contrarily to other studies [18], which reported that insufficient or absent distal locking was a risk factor for nonunion, our comparative study found no significant difference between the WDI and DI groups. In this study, there were six cases of nonunion (5.66% of fractures), which is too few to draw any significant conclusions. Several studies have reported that smoking [21], transversal fractures [21, 26], fractures in the middle third [21, 27], open fractures [21, 27], or diabetes [6] were risk factors for nonunion. In our nonunion's population, 50% of patients were smokers, 50% of the fractures were transversal, and 83.3% were middle third fracture, which seems to corroborate data in the literature [9]. Other factors described in the literature [6, 9, 21, 27] such as obesity, alcohol abuse, comminution, or distraction of the fracture were not found in this study. This finding needs to be interpreted with caution given the small number of nonunions and the low statistical value of these parameters.

In the three recent studies that have reported nailing with isolated proximal locking, no one conclude for the rotations.

In literature, many studies [18, 20] have shown the distal interlocking for IMN was necessary to obtain union without malrotation. This study showed no significant difference for rotation with ipsilateral arm, in the two groups.

The surgery time for bipolar locking found in this study (87 min) was similar to that in the rare data in the literature, ranging from 70 [2] to 85 min [28].

No studies have investigated the dose of radiation delivered to patients during intramedullary nailing of the humerus and, in particular, for distal locking. Concerning this parameter, our study provided a strong argument in favor of nailing without distal locking as it led to a significant reduction of exposure to radiation for both the patient and the surgical team.

The limitations of this study are commensurate with those inherent to any retrospective study and include the lack of randomization of treatment modalities. In addition, the time between X-rays varied among patients, as some patients had no control X-rays between the post-operative X-ray and the X-ray at the last follow-up. This is why the mean time to consolidation could not be exactly assessed. Therefore, the consolidation time is probably overestimated. Finally, there are various types of nail implants, with different proximal anchoring [29]; nevertheless, each implant is equitably divided between the groups and there was no statistical difference concerning outcomes.

Conclusions

The neutralization of rotation constraints thanks to bipolar locking of intramedullary nails has rarely been questioned. On the basis of biomechanical and clinical studies, bipolar locking is considered essential to counter rotation forces and to ensure satisfactory bone consolidation in fractures of the humeral shaft.

Our study demonstrated that isolated proximal locking of humeral intramedullary nails gives similar results to the reference technique, namely bipolar locking, in terms of consolidation and functional outcomes.

By suppressing distal locking, it is possible to eliminate associated neurovascular risks and to significantly diminish the duration of the surgery and of exposure to the iatrogenic radiation related to image intensification. In clinical practice, exclusive proximal locking reduces the risks for the patient and for the surgeon.

In the light of this study, the benefit-risk ratio of isolated proximal locking appears to be favorable, and bipolar locking no longer seems to be the best strategy, whatever the location, the type of fracture, or the degree of comminution in nonpathological humeral shaft fractures.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

IRB/ethical committee approval After consulting the local ethics committee (CPP est. 1. Dijon, France), this routine care retrospective study, in accordance with current French legislation at the time of the inclusion, did not require any ethic committee approbation.

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