Locking plate fixation versus antegrade nailing of 3- and 4-part proximal humerus fractures in patients without osteoporosis. Comparative retrospective study of 63 cases

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ABSTRACT

Introduction: There is no consensus on the treatment of proximal humeral fractures. The goal of the present retrospective observational study was to compare functional and radiological results and complications of internal fixation using locking plates versus antegrade nailing in the treatment of non-osteoporotic Neer classification 3- and 4-part fractures after a least 1 year of follow-up.

Material and methods: Internal fixation was performed in 67 fractures (1 bilateral): 35 by locking plate (1 lost to follow-up, 1 deceased) and 32 by intramedullary nailing (2 lost to follow-up) between January 1st, 2004 and December 31st, 2010. Thus, the study included 33 plates (21 3-part and 12 4-part fractures) and 30 nails (21 3-part and nine 4-part fractures). Final functional assessment was based on the Oxford, Constant, Relative Constant and QuickDASH scores and percentage of handicap. Radiological follow-up included immediate postoperative, 6 weeks, 3 months and 1 year AP and Lamy lateral views. All complications were recorded prospectively.

Results: Mean Oxford, Constant, Relative Constant and QuickDASH scores and percentage of disability for the plate and nail groups respectively were: 23.8 vs. 23.3, 59.7 vs. 60.6, 73.5 vs 79.3, 20.9 vs 21.0, 22.6 vs 22.6. Multivariate analysis did not show any significant difference in functional scores or quality of reduction: final unsatisfactory reduction on AP view, 30.3 vs. 36.7%; lateral view, 3.2 vs. 10.0%; greater tuberosity, 9.1 vs. 16.7%. Four-part fracture (P < 0.05), frontal reduction defect at follow-up (P < 0.05) or greater tuberosity defect (P > 0.05) had negative impacts on functional scores. The complication rates corresponded to those in the literature and did not differ between the techniques (P = 0.1901) except for three infections in the plate group.

Discussion-Conclusion: Internal fixation is the treatment of choice for 3- and 4-part fractures in non-osteoporotic patients. Although no difference was found in the present study between locking plate and intramedullary nailing, the former seems to be less well adapted and more aggressive.

Type of study: Retrospective observational study.

Level of evidence: Level 4.
Table 1

<table>
<thead>
<tr>
<th></th>
<th>Plate</th>
<th>Nail</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>34</td>
<td>32</td>
<td>0.92</td>
</tr>
<tr>
<td>Fractures</td>
<td>35</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Lost to follow-up</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Mean age (years)</td>
<td>49.6 ± 17.5</td>
<td>64.1 ± 15.8</td>
<td>0.001</td>
</tr>
<tr>
<td>Gender ration</td>
<td>19/14</td>
<td>Nov 19</td>
<td>0.09</td>
</tr>
<tr>
<td>Dominant limb</td>
<td>60.6</td>
<td>60</td>
<td>0.96</td>
</tr>
<tr>
<td>Mean duration of follow-up (months)</td>
<td>24.7 ± 19.9</td>
<td>42.8 ± 24.8</td>
<td>0.002</td>
</tr>
<tr>
<td>Type of fracture</td>
<td>21/63.6</td>
<td>21/70.0</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>12/36.4</td>
<td>9/30.0</td>
<td></td>
</tr>
</tbody>
</table>

* Significant difference between the two groups.

occur in 13–16% of these cases [1] and the prognosis is less good [4].

Twenty per cent of these fractures are displaced, defined as displacement of more than 1 cm or an angle of greater than 45° according to the Neer classification, and require surgical management [5].

There are few studies that specifically evaluate the results of 3- and 4-part fractures treated by locking plates or intramedullary antegrade nailing [1,6–8].

The goal of our study was to compare the functional and radiographic results as well as the postoperative complications of fractures treated by both methods.

2. Patients and methods

2.1. Series

This is a retrospective comparative multicentre study performed in two orthopedic and traumatology surgery units at the Central University Hospital of Nancy (between January 1st, 2004, and December 31st, 2010) comparing 63 3- or 4-part fractures confirmed by preoperative radiographic evaluation (AP, and lateral Y-views).

Patients were included who presented with recent, closed, post-traumatic 3- or 4-part fractures of the proximal humerus on non-pathological or osteoporotic bone (Giannotti comorbid index of > 0.231) [9], with fused growth plate cartilage; with a follow-up of at least 1 year. Fixation used included locking plates only in one hospital unit, (PHILOSTM, plates and Humeral Suture PlateTM) and in the other unit intramedullary antegrade nails only (2nd, 3rd and 4th generation TélégaphTM, TrigenTM and T2TM) proximal humerus nails.

We used the Neer classification [5].

Mean follow-up in the locking plate group was 24.7 ± 19.9 months and included 33 fractures, which were bilateral: 21 3-piece fractures (64%) and 12 4-piece fractures (36%). The mean age of the 32 patients was 49.6 ± 17.5 years old (Table 1).

Before the intervention one patient presented with a supraspinatus tendon tear which was sutured during open surgery during the same operation, two presented with injury to the axillary artery (a lateral wound sutured with separate stitches and thrombosis requiring humeral subclavian bypass), and four presented with neurological sensory loss that regressed within 12 months (one of the median nerve, one of the radial nerve, and two cases of circumflex nerve injury).

Patients underwent surgery an average of 2.7 ± 5.3 days after injury by junior and senior surgeons (ACC: assistant chef de clinique and PH: praticien hospitalier) with experience in this type of fixation, under general anaesthesia in the beach chair position by deltopectoral approach and with fluoroscopic control of reduction and plate position. The fracture parts were reduced using traction wires placed at the insertion of the rotator cuff tendons. If humeral head reduction was unstable in 4-part fractures, it was maintained by a temporary glenohumeral arthrodesis Kirchner wire. When reduction was obtained and considered to be satisfactory, it was temporarily maintained by Kirchner wire to stabilize the tuberosities and the humeral head. A plate was then placed 1 cm under the tip of the greater tuberosity and attached to the humeral diaphysis by a non-locking screw placed in the oblong hole. Once correct reduction was obtained, the head and the diaphysis were stabilized by locking screws.

Patients presenting with a surgical site infection were included in the study of postoperative and radiographic complications but were excluded from the study of functional outcome scores at the final follow-up.

Mean follow-up in the group of patients treated by intramedullary nailing was 42.8 ± 24.8 months. The study included 30 patients, mean age 64.1 ± 15.8 years old (mean age 14.5 years older than the locking plate group) with 30 fractures: 21 3-part fractures (70%) and nine 4-part fractures (30%) (Table 1).

Two patients presented with preoperative neurological sensory loss that regressed after 12 months (circumflex nerve).

Patients were operated on a mean 1.1 ± 0.4 days after injury under the same conditions by anterolateral route. The nail was introduced though the opening located along the axis of the humeral diaphysis, at the tip of the head, in the articular zone so that the muscles of the rotator cuff would be crossed through muscle tissue. The nail was then inserted until its proximal end was located approximately 5 mm under the subchondral bone of the humeral head. When reduction of the humeral head was unstable before nailing in 4-part fractures, it was stabilized by a temporary glenohumeral arthrodesis Kirchner wire. The fragments were reduced with traction wires placed at the rotator cuff tendon insertions. Distal and proximal locking was performed (static or dynamic) using an ancillary system when reduction and the position of the nail were considered to be satisfactory under fluoroscopic control.

The incision was closed in both groups on a Redon drain, which was left for 48 hours. All patients were immobilized after surgery in a sling. Mobilization and the time until rehabilitation began varied from 1 to 6 weeks depending on the practitioner.

Patients presenting with early fixation failure and revised by arthroplasty were included in the study of postoperative and radiographic complications but were excluded from the study of functional outcome performed at the final follow-up.

2.2. Follow-up study

Patients underwent clinical and radiographic follow-up at 6 weeks, 3 months, 12 months then later depending on outcome and complications. Patients underwent a triple follow-up.

Clinical follow-up to determine the Oxford score [10], the Constant score [11] the Relative Constant score for age and gender [12] and the QuickDASH [13] score to calculate the percentage of disability. These functional scores were determined during a consultation with a surgeon who was independent from the surgeons who had managed the patients.

Standardized radiological follow-up: AP views (angle α: valgus-varus angle) and Y-view (angle γ: anteverision-retroversion angle).
Table 2

<table>
<thead>
<tr>
<th></th>
<th>Locking plate</th>
<th>Nailing</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Constant score</td>
<td>59.7 ± 16.7</td>
<td>60.6 ± 14.9</td>
<td>0.82</td>
</tr>
<tr>
<td>Relative mean Constant score</td>
<td>73.5 ± 25.4</td>
<td>79.3 ± 19.0</td>
<td>0.33</td>
</tr>
<tr>
<td>Mean Oxford score</td>
<td>23.8 ± 10.1</td>
<td>23.3 ± 8.9</td>
<td>0.83</td>
</tr>
<tr>
<td>Mean QuickDASH score</td>
<td>20.9 ± 7.4</td>
<td>21.0 ± 6.7</td>
<td>0.98</td>
</tr>
<tr>
<td>Mean percentage of handicap</td>
<td>22.6 ± 16.9</td>
<td>22.6 ± 15.3</td>
<td>0.98</td>
</tr>
</tbody>
</table>

These reference values (α = 45 ± 15° and y = 60 ± 15°) were chosen according to results in the literature; major displacement of the greater tuberosity was defined as displacement of more than 5 mm [14–17].

Follow-up of postoperative complications.

2.3. Statistical analysis

A simple linear regression coefficient was obtained for quantitative variables. An analysis of variance of a factor was performed if variances were equal. The descriptive analysis results are reported as numbers or percentages for qualitative variables. The Kruskal-Wallis test was performed to study qualitative variables and simple linear regression to study quantitative variables. Factors presenting a significant correlation with a threshold of 0.9 in a bivariate model were candidates for multivariate analysis (n = 30, R² = 0.47). Stepwise variable selection was used for multivariate regression with a threshold of 0.2 to enter into the model and 0.05 to exit the model. Statistical analysis was performed on functional outcome scores, the type of fracture, age by quantitative analysis, quality of fracture reduction in initial and final AP and lateral view X-rays, quality of reduction of the greater tuberosity, medial and lateral metaphyseal comminution, duration of follow-up, beginning of rehabilitation after fixation (< or > 3 weeks), dynamic or static diaphyseal locking system and the presence of secondary complications.

3. Results

Duration of follow-up, age, the dominant limb and beginning rehabilitation before the 3rd week did not significantly influence functional outcome scores, making our groups comparable (Appendices 1 and 2).

We studied the following results of locking plates and antegrade nailing.

Mean functional scores for the plate and nail groups respectively were 23.8 ± 10.1 vs 23.3 ± 8.9 for the Oxford score, 59.7 ± 16.7 vs 60.6 ± 14.9 for the Constant score, 73.5 ± 25.4 vs 79.3 ± 19.0 for the Relative Constant score for age and sex, 20.9 ± 7.4 vs 21.0 ± 6.7 for the QuickDASH score and 22.6 ± 16.9 vs 22.6 ± 15.3 for the percentage of disability. There were no significant differences between the two groups for functional outcome (Table 2).

There was no significant difference in the preoperative radiological evaluation in the plate and nail groups respectively for the type of fracture (3-part: 63.6 vs 70.0% and 4-part: 36.4 vs 30.0%; P = 0.59), medial metaphyseal comminution (24.2 vs 40.0%; P = 0.17), lateral metaphyseal comminution (21.2 vs 13.3%; P = 0.51), opening of the medial hinge (30.3 vs 36.7%; P = 0.59) or the posterior metaphyseal cortical calcin (9.1 vs 3.3%; P = 0.61).

Postoperatively, there was no significant difference between the two groups for unsatisfactory reduction on initial AP (15.2 vs 16.7%; P = 0.9) or lateral (6.1 vs 6.7%; P = 0.9) X-rays, unsatisfactory reduction on follow-up AP (30.3 vs 36.7%; P = 0.59) or lateral (3.2 vs 10.0%; P = 0.35) X-rays, secondary displacement on AP (4.2 vs 7.7%; P = 0.13), or lateral (1.5 vs 12.2; P = 0.69) X-rays, unsatisfactory reduction of the greater tuberosity (9.1 vs 16.7%; P = 0.46), avascular necrosis of the humeral head (21.2 vs 26.7%; P = 0.61), non-union of the greater tuberosity (3.0 vs 0%; P = 0.33), secondary articular protrusion of the screw (6 vs 10%; P = 0.09), or hardware failure (0 vs 10.0%; P = 0.10).

There was significantly more hardware displacement (backward slipping of the proximal screw) in the intramedullary nailing group (0 vs 26.7%, P = 0.0015) (Table 3).

There was no significant difference in secondary complications (P = 0.19) between the two groups: subacromial impingement (15.2 vs 23.3%; P = 0.40), rotator cuff tendon tear (6.1 vs 3.3%; P = 0.61), pain due to hardware (0 vs 10.0%; P = 0.10), surgical revision (0 vs 3.3%; P = 0.47), removal of a proximal locking screw that had slipped backwards or revision surgery to remove surgical hardware that was or was not associated with other treatment (30.3 vs 30.0%; P = 0.97). More type 1 complex regional pain syndromes (33.3 vs 16.7%; P = 0.12) and more infections (9.1 vs 0%; P = 0.09) were observed in the locking plate group than in the nailing group but this was not significant (Tables 4–6).

The overall rate of complications (radiological and clinical) in the 4-part fracture group was 80.9% requiring revision surgery in 33.3% of the cases.

In 4-part fractures, malunion on AP radiographic follow-up was a significant negative risk factor for multivariate analysis for Oxford, Constant and Relative Constant score results. Malunion of the greater tuberosity and lateral metaphyseal comminution were also negative risk factors, but only in bivariate analysis (Appendix 1).

A four-part fracture was the only significant negative risk factor for quality of life and disability scores on multivariate analysis. On bivariate analysis malunion on AP follow-up X-rays and of the greater tuberosity were also negative risk factors for these scores (Appendix 2).

In the antegrade nailing group, a static diaphyseal screw system significantly increased the risk of: hardware failure (slipping back of proximal interlocking screw, P = 0.03) and anteverision or retroversion head displacement on lateral follow-up X-rays (P = 0.03) (Table 7).

There were significantly more cases of unsatisfactory reduction (52.4 vs 23.8%; P = 0.0233), unsatisfactory reduction of the greater tuberosity...

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Table 5
Etiology of revision surgery in patients with locking plate fixation.

<table>
<thead>
<tr>
<th>Patients</th>
<th>Type of fracture (parts)</th>
<th>Age</th>
<th>Complications</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td>17</td>
<td>–</td>
<td>RSH</td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>49</td>
<td>Complete necrosis – Infection</td>
<td>RSH – Spacer – RTSA</td>
</tr>
<tr>
<td>21</td>
<td>3</td>
<td>52</td>
<td>SAI</td>
<td>RSH</td>
</tr>
<tr>
<td>22</td>
<td>3</td>
<td>17</td>
<td>SAI</td>
<td>RSH</td>
</tr>
<tr>
<td>24</td>
<td>3</td>
<td>23</td>
<td>SAI</td>
<td>RSH</td>
</tr>
<tr>
<td>25</td>
<td>4</td>
<td>28</td>
<td>Complete necrosis – Screw protrusion</td>
<td>RSH</td>
</tr>
<tr>
<td>28</td>
<td>3</td>
<td>67</td>
<td>Partial necrosis of the greater tuberosity – Infection</td>
<td>RSH – Spacer – RTSA</td>
</tr>
<tr>
<td>30</td>
<td>3</td>
<td>31</td>
<td>SAI</td>
<td>RSH</td>
</tr>
<tr>
<td>31</td>
<td>4</td>
<td>49</td>
<td>SAI – Partial necrosis of the greater tuberosity</td>
<td>RSH</td>
</tr>
<tr>
<td>32</td>
<td>4</td>
<td>54</td>
<td>Complete necrosis – infection</td>
<td>RSH – Spacer – RTSA</td>
</tr>
</tbody>
</table>

RSH: removal of surgical hardware; SAI: subacromial impingement due to plate; RTSA: Reverse total shoulder arthroplasty.

Table 6
Etiology of revision surgery in patients with intramedullary nailing.

<table>
<thead>
<tr>
<th>Patients</th>
<th>Type of fracture (parts)</th>
<th>Age</th>
<th>Complications</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>3</td>
<td>42</td>
<td>Fall in chronic alcoholism – Hardware failure</td>
<td>RSH Hemiarthroplasty</td>
</tr>
<tr>
<td>44</td>
<td>3</td>
<td>55</td>
<td>SAI – SIS Supraspinatus tendon tear</td>
<td>RSH Reinsertion of the supraspinatus tendon-open surgery</td>
</tr>
<tr>
<td>50</td>
<td>3</td>
<td>75</td>
<td>SAI Postoperative cardiorespiratory failure Hardware failure – Screw protrusion</td>
<td>RSH RTSA</td>
</tr>
<tr>
<td>51</td>
<td>4</td>
<td>61</td>
<td>SAI Postoperative cardiorespiratory failure Hardware failure – Screw protrusion</td>
<td>RSH RTSA</td>
</tr>
<tr>
<td>54</td>
<td>3</td>
<td>49</td>
<td>SAI – SIS</td>
<td>RSH</td>
</tr>
<tr>
<td>56</td>
<td>4</td>
<td>48</td>
<td>SIS</td>
<td>RSH</td>
</tr>
<tr>
<td>57</td>
<td>3</td>
<td>26</td>
<td>SAI</td>
<td>RSH</td>
</tr>
<tr>
<td>59</td>
<td>3</td>
<td>61</td>
<td>SAI</td>
<td>RSH</td>
</tr>
<tr>
<td>63</td>
<td>3</td>
<td>55</td>
<td>SAI</td>
<td>RSH</td>
</tr>
</tbody>
</table>

RSH: removal of surgical hardware; SAI: subacromial impingement due to nailing; RTSA: reverse total shoulder arthroplasty; SIS: slipped back proximal interlocking screw.

Finally evaluated the cost of these techniques.

The direct cost of locking plate fixation was 807 ± 120.9 € compared to 445.3 ± 60.4 € for antegrade nailing (P<0.0001). The difference was because locking screws are significantly more expensive (P<0.001).

4. Discussion

We are aware of the limits of this study: the retrospective design, without randomization, the absence of surgical and rehabilitation protocol, the number of surgeons with different levels of experience, the small patient size, the 7-year duration of the study because of the restrictive inclusion criteria (non-osteoporotic fractures), the diversity of implant designs (2 plates, 5 nails), the difference in age between the two groups which could have influenced the functional outcome and the lack of experience with locking plates by mini-invasive lateral approach.

The 1998 SOFCOT Symposium [17] on proximal fractures of the humerus, described the role of fixation of displaced fractures of elderly patients, and discussed the importance of conservative, less invasive treatment to provide good stability and union without displacement. They did not specifically study non-osteoporotic fractures in young patients.

We studied the risk factors of failure, and specificities of both techniques.

Published studies suggest that numerous factors influence functional outcome: varus fracture reduction malunion [18,19] or retroversion malunion [14], greater tuberosity malunion [18,20], the presence of a Neer classification 4-part fracture [1] (especially a displaced varus fracture: AO classification C3-type fractures [21]), medial metaphyseal comminution [22], avascular necrosis of the humeral head [8,21] and a ASA classification score of ≥ 2 [23]. Like Hardeman, we feel that the initial fracture pattern is the most important prognostic factor for functional outcome, failure, complications and revision surgery [23].

Like Cuny [21], necrosis was more frequent in the 4-part fracture group in our study.

Like Gradl and Konrad [24,25], we did not find any significant difference between the two groups for functional outcome, post-operative complications (except for slipping of the proximal screw) whatever the technique. The high rate of complications reported in our study for both these types of internal fixation for management of comminutive fractures was not different from that found in the literature [4,8,26–28].

According to Hertel [29], medial hinge disruption, a posterior metaphyseal cortical calcar and the number of fracture parts were predictive factors of osteonecrosis while in our study only 4-part fractures significantly increased this risk.

Certain authors report that antegrade nailing results in rotator cuff tendon injury, secondary proximal protrusion of the nail causing subacromial impingement with slipping back or breakage of the proximal screw, secondary displacement of the fracture or secondary articular protrusion of the interlocking screw [30–33]. These complications are found during antegrade nailing with a non-rectilinear or a large diameter nail (up to 11 mm), placed laterally on the greater tuberosity in a poorly vascularized area of tendon or with a static diaphyseal screw system.

Although Rocheck identified a visible scar on ultrasound in 62.1% of the cuffs where the nail had crossed, in a functional and ultrasound evaluation of the shoulder after intramedullary nailing, this was not correlated to function because the functional outcome was satisfactory or very satisfactory in 89.6% of cases [34].

Table 7  
Influence of distal screw in the intramedullary nailing group on the development of complications.

<table>
<thead>
<tr>
<th></th>
<th>Static</th>
<th>Dynamic</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 16 (53.3%)</td>
<td>n = 14 (46.7%)</td>
<td></td>
</tr>
<tr>
<td>AP displacement (°)</td>
<td>16</td>
<td>14</td>
<td>0.19</td>
</tr>
<tr>
<td>(°)</td>
<td>(10.3±15.1)</td>
<td>(−4.7±4.1)</td>
<td></td>
</tr>
<tr>
<td>Lateral displacement (°)</td>
<td>16</td>
<td>14</td>
<td>0.03</td>
</tr>
<tr>
<td>(°)</td>
<td>(2.4±2.9)</td>
<td>(0.2±3.6)</td>
<td></td>
</tr>
<tr>
<td>Secondary complications</td>
<td>13</td>
<td>9</td>
<td>0.41</td>
</tr>
<tr>
<td>Yes</td>
<td>6</td>
<td>2</td>
<td>0.22</td>
</tr>
<tr>
<td>Necrosis</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Articular protrusion of screw</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Subacromial impingement</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Hardware failure</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Slipped back proximal interlocking screw</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Secondary proximal nail protrusion</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

* Significant difference between the groups.

There was more subacromial impingement in the group of patients treated by nailing (15.2 vs 23.3%; P = 0.40) associated with proximal protrusion of the nail and secondary proximal screw slipping. Early removal of hardware as soon as union occurred was performed to prevent rotator cuff tendon injury.

Like Gradl [24], we found symptomatic rotator cuff tendon injuries in 3% of patients in the intramedullary nailing group. This rate was not significantly different than that in the locking plate group.

For us antegrade nailing with a rectilinear small diameter nail (7–8 mm), in a well-vascularized area of muscle [35], with an entry point at the top of the humeral head, 8 mm inside the lateral rim of the cartilage, along the diaphyseal axis corresponding to the Hinge point described by Boileau and Walch [36,37], inserted 0.5 cm under the subchondral bone of the humeral head [21] with a dynamic diaphyseal interlocking screw [21], are the conditions necessary to prevent complications.

Park [38] described a good functional and radiographic outcome with antegrade nailing associated with systematic tension band and locking sutures. Although we do not have any experience with this technique, the association of systematic tension band and locking sutures seems to be an interesting option in the management of comminutive fractures.

Table 8  
Risk factors of humeral head necrosis.

<table>
<thead>
<tr>
<th>Age of patient</th>
<th>Gender</th>
<th>Necrosis</th>
<th>Bivariate regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>Man</td>
<td>15 (23.8)</td>
<td>Odds ratio</td>
</tr>
<tr>
<td>30</td>
<td>Women</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>33</td>
<td>Yes</td>
<td>10 (16.7)</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
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* Significant risk factor.

Certain authors [39–41] have performed biomechanical studies in cases of medial metaphyseal comminution and advise associating a locking plate with an intramedullary fibular allograft to ensure medial support. The upper end of the graft is placed in subchondral bone (in an area which is nearly identical to the Hinge point). They report a reduced risk of varus collapse, secondary screw protrusion, implant failure and an in vitro increase in overall stability of the system. We think that this technique should be indicated to treat non-union of the humeral neck as initially described by Walch in 1996 [42] and we do not find any additional benefit with this technique compared to intramedullary nailing.

Atalar [43] described a tricortical iliac graft or an iliac allograft in 4-part fractures including tuberosity comminution, resulting in union in all patients and a good clinical outcome without necrosis.

The cases of infection and the higher rate of type 1 complex regional pain syndrome observed in the locking plate group (P > 0.05, probably associated with a lack of power in the study) were, for us, markers of the aggressiveness of this type of internal fixation to tissue.

Based only on the direct cost of the fixation technique, the locking plate was more expensive (P < 0.001).
5. Conclusion

Our evaluation did not show that locking plates resulted in better functional outcome, radiographic results or reduction of postoperative complications, while antegrade nailing seems to be a reproducible, less invasive, internal fixation technique. Four-part fractures are difficult to stabilize and internal fixation of these fractures is associated with an overall risk of complications of 80.9% with revision surgery in 33.3% of these cases.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

Appendix 1.

Results in relation to functional scores.

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* Significant risk factor.
Appendix 2.

Results in relation to quality of life and disability.

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a Significant risk factor.

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