Fibular strut allograft influences reduction and outcome after locking plate fixation of comminuted proximal humeral fractures in elderly patients: a retrospective study

Xueliang Cui  
Department of Orthopaedics

Hui chen (✉ chenhui@seu.edu.cn)  
Department of Orthopaedics  https://orcid.org/0000-0002-2462-5852

Binbin Ma  
Department of orthopaedics

Wenbin Fan  
Department of Orthopaedics

He Li  
Department of Orthopaedics

Research article

Keywords: proximal humeral fracture, fibular allograft, locking plate, elderly patients

Posted Date: July 10th, 2019

DOI: https://doi.org/10.21203/rs.2.11169/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Version of Record: A version of this preprint was published on November 3rd, 2019. See the published version at https://doi.org/10.1186/s12891-019-2907-3.
Abstract

Purpose: The purpose of this study was to determine if fibular strut allograft influence reduction and clinical outcomes after locking plate fixation of comminuted proximal humeral fractures (PHFs).

Methods: A retrospective review was performed on sixty 3- and 4-part PHFs treated with either locking plate only or locking plate with a fibular allograft. Fracture reduction was quantitatively determined by humeral head height (HHH) and neck-shaft angle (NSA). Loss of anatomic fixation was defined if the varus malalignment of neck-shaft angle (NSA) was more than 5° or if the change of humeral head height (HHH) was more than 3 mm. Clinical outcome was evaluated by Constant-Murley score (CMS) and American Shoulder and Elbow Surgeons (ASES) score. Result: The average radiological changes were higher in the locking compression plate (LCP) group than in the locking plate with fibular allograft (FA) group (HHH of 4.16 mm versus 1.18 mm [p < 0.001] and NSA of 9.94° versus 3.12° [p < 0.001]). Final average outcome scores were lower in LCP group than in FA group (CMS of 73.00 versus 78.96 [p = 0.024] and ASES score of 72.80 versus 78.64 [p = 0.022]). FA group showed better forward elevation (P=0.010) and abduction (P=0.002), but no significant differences were observed for shoulder external rotation or internal rotation. Conclusion: For comminuted proximal humerus fractures in elderly patients with severe osteoporosis, locking plate fixation with a fibular strut allograft showed satisfactory radiological and clinical outcomes. Key words: proximal humeral fractures; locking compression plate; fibular allograft

Background

Proximal humeral fractures (PHFs) account for 5% of all adult fractures, and they are the third most common occurring fractures in patients over 65 years old[1]. The incidence of PHFs is rapidly increasing because of a larger elderly population[2]. Most of these fractures are non-displaced and thus can be treated with conservative methods. But the optimal surgical treatment of unstable, displaced two-, three- and four-part fractures in geriatric patients remains controversial[3].

Locking plate fixation is currently the most widely used method for the management of unstable PHFs as it provides greater fixation and offers greater load to failure[4]. But it is still difficult to achieve stable fixation and maintain intra-operative reduction in elderly patients with low bone mineral density[5]. Complications including screw perforation and varus malalignment are often reported[6,7]. It is known that the establishment of the medial column support can achieve successful clinical outcome and reduce the complication rate[8,9]. Various techniques have been advocated to reduce and enhance the medical column, such as cement augmentation, inferomedial screws and allograft[10]. Many biomechanical studies have demonstrated that locking compression plate (LCP) combined with fibular allograft could increase the initial stiffness and sustain a higher ultimate failure load[11,12], but few comparative clinical studies were performed.
The purpose of this study was to compare the radiological and clinical outcome between LCP and LCP with fibular allograft in the treatment of comminuted PHFs. We hypothesized that elderly patients treated with LCP and fibular strut allograft would have better outcomes and lower complication rate than those treated with only LCP.

Methods

Institutional review board approval was obtained for this retrospective review of patients’ radiographs and records, and written consent was obtained from all patients. This retrospective study included 65 geriatric patients who underwent a open reduction and internal fixation for comminuted proximal humeral fracture between January 2014 and May 2017. The inclusion criteria were an age of sixty years or older, a minimum of two years of follow-up and a displaced three- and four-part PHFs. The exclusion criteria were pathological fractures, open fractures, fractures that involved articular split of the humeral head and associated never injuries.

Postoperative radiographs were obtained on the second day, one month, three months, six months, one year, and two years after the surgery. Radiological evaluation was performed by measuring humeral head height (HHH) and by measuring neck shaft angle (NSA) on true anteroposterior (AP) radiographs. As Gardner's description\[13\], HHH was defined as the distance between the superior edge of the humeral head and the top edge of the plate (Figure 1). The NSA was measured on AP radiographs with the shoulder in neutral rotation\[14\]. A line was drawn from the superior to the inferior border of the articular surface. Then a perpendicular line was drawn through the center of the humeral head. The angle between the perpendicular line and the line bisecting the humeral shaft was defined as the NSA (Figure 2). A difference in the HHH > 3 mm or the NSA > 5° on the AP radiograph that was taken two days after the operation and that obtained at the two years follow-up was considered to indicate a loss of reduction\[15\].

Clinical outcomes were evaluated by the American Shoulder and Elbow Society (ASES)\[16\] score and the Constant-Murley score (CMS)\[17\]. Shoulder range of motion including forward elevation, external rotation at the side, abduction and internal rotation at the back was digitally recorded at the first year follow-up examination and the subsequent yearly evaluation. Complications, such as infection, screw penetration and avascular necrosis of the humeral head, were recorded during the follow-up.

Surgical technique

All patients were placed in the beach chair position with the injured arms were hanging over the edge of the radiolucent operating table. The deltopectoral approach was performed to gain access to the proximal humerus. No.2 Ethibond sutures (Ethicon, Somerville, USA) were used to pass through infraspinatus, supraspinatus and subscapularis muscles for easier maneuverability of the fragments and the tuberosity. In the LCP group, anatomical reduction of the fragments was maintained by temporary Kirschner wires and checked under fluoroscopy. After that, a proximal humeral LCP (Synthes,
Oberdorf, Switzerland) was placed on the lateral cortex and fixed with cortical and locking screws. The plate was placed 5mm inferior to the upper end of the greater tuberosity and 1 cm posterior to the bicipital groove\textsuperscript{[18]}.

In the FA group, the fibular allograft was used to indirectly reduce the fracture. A 1.5mm guidewire was placed 1 cm posterior to the intertubercular groove and 1 cm medial to the transition between the head and the greater tuberosity. The fibular allograft was inserted into the cavity, through the fracture site, through the guidewire. By this procedure, the proximal fibular allograft was located at the centre of the head and the distal end was positioned in the humeral shaft. Anatomical reduction of the medial column could be achieved by pushing the fibular allograft upward instead of medial, because the strut could support the humeral head in a proper height and position as in retrograded intramedullary nailing (Figure 3). And then, the greater tuberosity fragments were reduced and temporarily fixed. After confirming the fracture reduction using a c-arm, a LCP was used to fix the fragments. Locking screws were placed through the graft into the humeral head and shaft (Figure 4). Two infer-medial calcar screws were also inserted to provide additional support. Careful irrigation was performed after the fixation and the incision was closed in layers under negative suction, the drain was removed after 48 hours.

A sling was provided to immobilize the arm during the first four weeks after surgery in both groups. Continuous pendulum, passive range-of-motion exercises were started two days post-operatively. Active assisted range-of-motion exercises were followed at four weeks and normal daily activities were resumed according to the patients’ tolerance and the fracture union status on the radiographs.

**Statistical analysis**

Statistical analysis was performed using SPSS software, version 18.0 (Chicago, IL, USA). Continuous data and scores for the LCP and FA groups were evaluated with an independent t test. Differences in proportions were compared with a chi-square test and Fisher’s exact test. The threshold for significance was set at $p < 0.05$.

**Results**

A total of 60 patients (26 men and 34 women) were included in this study. The LCP group comprised 35 patients, 25 patients were three-part fractures and 10 were four-part fractures. The FA group consisted of 25 patients, 17 patients were three-part fractures and 8 were four-part fractures. In the LCP group, 18 patients suffered from medial comminution and the mean follow-up period was 32.23 months (range, 25-40 months). In the FA group, 13 patients suffered from medial comminution and the mean follow-up period was 31.56 months (range, 24-40 months) Table I.

In the LCP group, eighteen patients showed a change in the HHH of more than 3 mm, with the average of 4.16mm (range, 0-13mm). Twenty patients had a change of NSA of more than 5° , with an average of 9.94° (range, 0-30°). In the FA group, three patients showed a change of HHH of more than 3mm, with the
average of 1.18mm (range, 0-4mm). Four patients had a change of NSA of more than 5°, with an average of 3.12° (range, 0-8°) (Figure 5).

The CMS, ASES scores, shoulder range of motion for all the patients are presented in Table II. In comparison with the LCP group, the FA group had significantly better mean CMS (78.96 versus 73.00; p=0.024) and ASES scores (78.64 versus 72.80; p = 0.022). At two years, the active forward elevation, abduction, external rotation, and internal rotation of the shoulder were 128.49 ± 22.81°, 122.37 ± 22.31°, 55.09 ± 8.63°, and L1, respectively, in the LCP group compared with 144.04 ± 21.37°, 140.64 ± 20.34°, 58.96 ± 8.49°, and T12 in the FA group (Figure 6). Significant difference between the two groups was found regarding active forward elevation (p = 0.010) and abduction (p = 0.002) of the shoulder. There was no significant difference between the groups with respect to mean external rotation values (p = 0.090) and internal rotation values (p = 0.438). There were 12 complications in 10 of 35 patients (28.57%) in the LCP group, including varus malunion in 5, screw penetration in 5, and avascular necrosis in 2. In the FA group, one patient presented screw penetration and two patients developed avascular necrosis of the humeral head.

**Discussion**

A clinical comparison was conducted between the LCP group and the FA group involving three- and four-part PHFs in patients aged 60 years or older. We aimed to evaluate the influence of fibular allograft on the radiological and clinical outcomes. In this retrospective study, PHFs treated by LCP and fibular allograft showed significantly better clinical outcomes, and a lower complication rate. The FA group also showed superior radiological results regardless of the fracture type.

The treatment of unstable and displaced PHFs in elderly patients remains a challenge\[19]. Anatomical reduction is difficult to maintain because the poor quality of the humeral head, many surgeons believe that LCP is a promising treatment to deal with this problem\[20]. Compared to standard nonlocking plate, the LCP can provide a screw fixation angle in multidirection and the locking screw provide stable fixation maintenance\[21]. However, many studies have show variable outcomes, with high rate of complications including screw penetration, varus collapse and avascular necrosis of the humeral head, especially in older patients with osteoporosis or medial column comminution\[22,23]. Ockert et al.\[24] reported the 10 years’ outcomes after operative treatment with LCP for unstable and displaced PHFs, the majority of the patients obtained good or excellent outcomes. But poor outcomes and complications appeared in patients of higher age and of female gender. In recent years, many effects have made to overcome these problems. Clinical and biomechanical studies have paid more attention to use allograft augmentation to increase the stability of locking plate fixation of PHFs. Gardner et al.\[25\] were the first to introduce this technique using fibular strut allograft to indirectly reduce the fracture and maintain the fixation, all of the seven fractures got union completely without any loss of reduction.

Mathison et al.\[12\] first made a biomechanical comparison between locking plate alone and locking plate with fibular allograft. They created a 10-mm wedge-shaped osteotomy at the lever of the surgical neck to
simulate the comminution of the medial column. Load-displacement curve was used to test failure load and stiffness of the constructs. This study demonstrated that the bone peg increased the failure load and the initial stiffness of the constructs. Relative to locking plate fixation alone, failure load was increased by 1.72 times and the initial stiffness was increased by 3.84 times. Chow et al.\cite{11} performed a similar study to evaluate the effect of fibular allograft. No augmented construct collapsed prior to 25,000 cycles, while six of the eight specimens in the non-augmented locking compression group failed at an average of 6,604 cycles. Neviaser et al.\cite{26} retrospectively reviewed 38 patients treated by locking plate with endosteal strut augment, they reported high clinical outcome scores and a low rate of reduction loss (2.6%), screw cut-out (0%), and avascular necrosis (2.6%). Recently, Panchal et al.\cite{27} assessed the effect of an intramedially fibular allograft on clinical and radiological outcome in unstable PHFs with medial column disruption. According to the clinical rating scale, 26 patients had excellent or good outcomes, six patients showed fair outcomes and only four cases experienced poor outcomes. In regard to the restoration of the humeral NSA, the result was good in 31, fair in three and poor in two cases. When calculating the HHH, the mean loss of reduction was measured as 1.6 mm. Only one case experienced varus collapse of the humeral head and osteonecrosis was noted in one patient. Cha et al.\cite{15} compared the radiological outcome of fixation using only LCP with fixation using LCP with an fibular allograft in the treatment of comminuted PHFs. In the LCP group, 22 of 32 patients had a change in the NSA of more than 5°, with the average of 10.2°. Twenty patients obtained a change of HHH of more than 3 mm, with an average of 4 mm. While in the LCP with fibular allograft group, the average NSA and HHH change was 3° and 1 mm, respectively. In our study, the FA group group had significantly better CMS and ASES scores, as well as shoulder range of motion, than the LCP group. The change of the NSA and HHH in the LCP group was also obvious higher than the FA group.

We considered that the fibular allograft was an reasonable option to maintain the anatomical reduction in the treatment of comminuted PHFs in the elderly patients. The fibular allograft could be used as tool to indirectly reduce the fracture. Gardner et al.\cite{25} first introduced the use of screw to push the fibular allograft medially for the reduction of medial column. Instead of using pushing screw, we placed a guide pin at the apex of the humeral head. Then, the fibular allograft was pushed upward in the intramedullary cavity through the guide pin to support the height of the humeral head an neck, and the reduction of the medial column was subsequently obtained. Especially in cases with medial cortex disruption, using the fibular allograft as a pillar to support the humeral head from intramedullary cavity was more helpful in maintaining reduction. The added stability provided by the fibular allograft permitted an early rehabilitation program and reduced the complication rate. In our study, the FA group showed significant lower rates of varus malunion and screw penetration. The fibular allograft also had disadvantages, such as risk of infection, disease transmission and high cost. The fibular allograft had cortical bone, so it might get fractured while inserting the screws.

This study has several limitations. First, it was limited by its retrospective design, the number of patients was relatively small, further study with a greater number of patients was needed. Second, the duration of the follow-up was rather short, the difference in NSA and HHH might change with longer monitoring.
Third, the Neer classification is the most widely used grading system for PHFs, but some studies have shown the Neer classification to have only fair to good reliability.

**Conclusion**

In conclusion, the elderly patients treated with locking compression plate and fibular allograft obtained better radiological outcomes, clinical outcomes, and a lower rate of complications compared with those who had LCP alone for the treatment of a three- or four-part PHFs. Using the fibular allograft is a reasonable option to help the reduction, provide additional support to the humeral head, improve outcomes and minimize complications.

**Declarations**

**Competing**

On behalf of all authors, the corresponding author states that there is no conflict of interest.

**Acknowledgments**

The authors thank Dr. Hui Chen, He Li, Wenbin Fan, and Dr. Xueliang Cui for their contributions to the operations.

**Authors’ contributions**

Dr. Binbin Ma and Dr. Wenbin Fan participated in the recruitment, data collection, and analysis. Dr. Xueliang Cui wrote the manuscript. Dr. Hui Chen and Dr. He Li performed the surgery as main operators. Dr. Xueliang Cui contributed to the study design and conception. All authors read and approved the final manuscript.

**Funding**

No funding.

**Availability of data and materials**

Our data used to support the findings of this study are included within the article.

**Ethics approval and consent to participate**

The Institutional Review Board of Zhongda Hospital affiliated to Southeast University reviewed and approved this study. Each author certifies that all investigations were conducted in conformity with ethical principles. Written consent was obtained from all individual participants included in the study.

**Consent for publication**

The authors have received written consent from participants to publish individual patient data.
Reference


Tables

Table 1: Demographic characteristics data for patients included in this study.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>LCP Group (n=35)</th>
<th>FA Group (n=25)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age (year)</td>
<td>72.46</td>
<td>73.16</td>
<td>0.566</td>
</tr>
<tr>
<td>Sex distribution (male : female)</td>
<td>11:24</td>
<td>7:18</td>
<td>0.775</td>
</tr>
<tr>
<td>Dominant arm involvement</td>
<td>17:18</td>
<td>13:12</td>
<td>0.793</td>
</tr>
<tr>
<td>The mean time from injury to surgery (day)</td>
<td>4.69</td>
<td>4.48</td>
<td>0.237</td>
</tr>
<tr>
<td>The mechanism of injury (F: TA)</td>
<td>27:8</td>
<td>20:5</td>
<td>0.791</td>
</tr>
<tr>
<td>Classification of Neer (3 part : 4 part)</td>
<td>25:10</td>
<td>17:8</td>
<td>0.775</td>
</tr>
<tr>
<td>Medial comminution</td>
<td>18:17</td>
<td>13:12</td>
<td>0.965</td>
</tr>
<tr>
<td>The mean follow-up period (months)</td>
<td>32.23</td>
<td>31.56</td>
<td>0.898</td>
</tr>
</tbody>
</table>

LCP, locking compression plate; FA, fibular allograft.

Table 2: Radiographic Evaluation, Outcome Scores and Range-of-Motion Data for the Study Population.

<table>
<thead>
<tr>
<th>Variable</th>
<th>LCP Group (n=35)</th>
<th>FA Group (n=25)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHH (mm)*</td>
<td>4.16±4.2</td>
<td>1.18±1.08</td>
<td>0.001</td>
</tr>
<tr>
<td>NSA *</td>
<td>9.94±9.92°</td>
<td>3.12±3.13°</td>
<td>0.001</td>
</tr>
<tr>
<td>CMS*</td>
<td>73.00±9.94</td>
<td>78.96±9.71</td>
<td>0.024</td>
</tr>
<tr>
<td>ASES*</td>
<td>72.80±9.73</td>
<td>78.64±9.18</td>
<td>0.022</td>
</tr>
<tr>
<td>Forward elevation*</td>
<td>128.49±22.81°</td>
<td>144.04±21.37°</td>
<td>0.010</td>
</tr>
<tr>
<td>Abduction*</td>
<td>122.37±22.31°</td>
<td>140.64±20.34°</td>
<td>0.002</td>
</tr>
<tr>
<td>Internal rotation†</td>
<td>L1 (buttock-T5)</td>
<td>T12 level (L5-T5)</td>
<td>0.438</td>
</tr>
<tr>
<td>External rotation*</td>
<td>55.09±8.63°</td>
<td>58.96±8.49°</td>
<td>0.090</td>
</tr>
</tbody>
</table>

LCP, locking compression plate; FA, fibular allograft; HHH, humeral head height; NSA, neck shaft angle; ASES, American Shoulder and Elbow Society score. CMS Constant-Murley score.

*The values are given as the mean and standard deviation. †The values are given as the mean with the range in parentheses.

Figures
Figure 1

Calculation of the humeral head height. The two lines drawn running perpendicular to the shaft of the plate; one was placed at the top edge of the plate, and the other was placed at the superior edge of the humeral head. The distance between these two lines was measured and designated as the head height.
Figure 2

The head-shaft alignment (angle $\alpha$) was determined as follows: a first line (dashed line) was drawn from the superior border to the inferior border of the articular surface and a second line was drawn perpendicular to the first line through the center of the humeral head. A third line bisected the humeral shaft, and the angle between the second and third line was defined as the head-shaft angle $\alpha$. 
The reduction and fixation process with a fibular strut allograft. (a) A 1.5mm guidewire was placed 1 cm posterior to the intertubercular groove and 1 cm medial to the transition between the head and the greater tuberosity. (b) The fibular allograft was inserted into the cavity, through the fracture site, through the guidewire. And then, it was pushed upwards to support the humeral head in a proper height. (c) After confirming the fracture reduction, a LCP was used to fix the fragments. Locking screws were placed
through the graft into the humeral head and shaft. (d) Post-operative radiograph showing good anatomical reduction.

**Figure 4**

surgical procedure (a, b) Holes were drilled on the fibular allograft to make the fibula easily maneuvered into position. (c) The fibular allograft was inserted into the cavity through the bone defect. (d) Without the exposure of medial calcar, the medial column could be indirectly reduced to pushing the fibular allograft upwards. (e) A proximal locking plate was used to fix the greater tuberosity to the humeral head. (f) Multiple non-absorbable sutures were passed to compress comminuted fragments to the bony defect of the proximal humerus.
Figure 5

A case of a 3-part fracture with severe metaphyseal comminution. (a) Radiograph of a displaced 3-part humeral fracture in the left shoulder of a 73-year-old woman. (b) CT scan, 3-D reconstruction view. (c,d) Radiograph 1 year after surgery.
Figure 6

Clinical function 2 years after surgery.