Comparison of calcaneal plate fixation and Philos plate fixation for the treatment of split fractures of the greater tuberosity of the humerus: a retrospective review

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Research Article

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Abstract

Objective To compare the effect of two internal fixation methods of calcaneal plate fixation and Philos plate fixation for the treatment of split fractures of the greater tuberosity of the humerus.

Methods A retrospective analysis was carried out on the data of 37 patients with isolated split fractures of the greater tuberosity of the humerus treated in our hospital from September 2016 to April 2021. There were 24 males and 13 females, with an average of 46.7 (25-67) years old. All patients had fresh split fractures with displacement of >5mm and without other injuries (such as Bankart injury, SLAP injury and Hill-sachs injury). Enrolled patients were divided into two groups according to different internal fixation methods. Patients in group A were treated with calcaneal anatomical locking plate (n=16), and those in group B were given Proximal Humeral Internal Locking System (PHILOS) (n=21). Further comparison was conducted on the interval from injury to operation, length of incision, operation time, bleeding volume, postoperative Constant-Murley shoulder joint function score and complications between the two groups.

Results All the 37 cases had fracture healing during the follow-up period ranging from 10-23 months, with an average of 11.9 months. The average interval from injury to operation was 3.7 days (2-4 days) in group A and 4.1 days (3-6 days) in group B, with no significant difference. The average length of incision was 6.2cm (4.5cm-7.3cm) in group A and 9.1cm (8.2cm-10.7cm) in group B, with significant difference. The average operation time was 61 minutes (51-77 minutes) in group A and 65 minutes (57-79 minutes) in group B, with no significant difference. There was significant difference in the comparison of bleeding volume between group A and group B [47ml (35ml-63ml) vs. 103ml (79ml-125ml)]. During the 6-month follow-up, the average Constant-Murley score was 87.5 points (76-97 points) in group A and 80.3 points (71-91 points) in group B, with significant difference. In addition, shoulder impingement syndrome occurred in 2 cases in group B, but not in group A.

Conclusion Calcaneal anatomical locking plate can achieve satisfactory results in the treatment of adult fractures of the greater tuberosity of the humerus, with the advantages of less surgical trauma and less bleeding. Findings in our study can provide a new choice for the surgical treatment of isolated fractures of the greater tuberosity of the humerus.

Introduction

Isolated greater tuberosity fractures occur typically in young patients with high-energy trauma, especially in males\(^{1-3}\), accounting for only about 20% of proximal humeral fractures. Due to the special anatomical structure and movement characteristics at and around the greater tuberosity of the humerus, there are common reports of internal fixation failure and impingement syndrome caused by insufficient and unreasonable fixation in the past\(^{4-5}\). The key to treatment is to determine the appropriate internal fixation method for anatomic reduction, rigid fixation and reducing the impact on shoulder function. From September 2016 to April 2021, a total of 37 patients with isolated split fractures of the greater tuberosity of the humerus were treated in our hospital, of whom 16 were treated with calcaneal anatomic locking
plate and 21 with Proximal Humeral Internal Locking System (PHILOS) for internal fixation. It is reported as follows.

**Materials And Methods**

This retrospective study was approved by the institutional review board of the People's Hospital of Lishui City and obtained all the participants’ written informed consent before its commencement. We reported this study in accordance with the Helsinki Declaration and following the Strengthening the Reporting of Cohort Studies in Surgery (STROCSS).

**Inclusion and exclusion criteria of eligible patients** Inclusion criteria: patients with split fractures according to the classification of isolated greater tuberosity fracture proposed by Mutch et al.\(^6\) in 2014, showing acute fresh injuries with or without dislocation of glenohumeral joint; adult patients aged >18 years old, and, the displacement of the main bone mass of the greater tuberosity of the humerus >5mm or the angulation >45° according to preoperative CT; and patients with postoperative follow-up of >10 months. Exclusion criteria: patients with old, pathological and open fractures; patients with Bankart injury or Hill-sachs injury as well as ipsilateral nerve and vascular injury; patients with other chronic diseases that affected the function of the ipsilateral shoulder joint; and patients with a previous history of surgery around the ipsilateral shoulder joint.

**General data** A total of 37 patients were included in this study, including 24 males and 13 females, with an average of 46.7 (25-67) years old. In terms of the causes of injury, there were 21 cases of falls and sports injuries, and 16 cases of traffic accident injuries. According to the preoperative CT and MRI results, 22 cases were accompanied by anterior dislocation of the glenohumeral joint, and 17 cases had fresh rotator cuff injury(Table 1). Patients with fracture and dislocation underwent a routine manual reduction in emergency, and were given symptomatic treatment such as limb immobilization, detumescence and analgesia after admission. The interval from injury to operation was 1 to 7 days.

**Table 1** Comparison of demographics and injury-related data between group A and group B
### Groups Classifications

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=16)</th>
<th>Group B (n=21)</th>
<th>$\chi^2$/$t$/$Z$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>11</td>
<td>13</td>
<td>0.187</td>
<td>0.666</td>
</tr>
<tr>
<td>Females</td>
<td>5</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>50.51±12.28</td>
<td>48.35±12.71</td>
<td>0.520</td>
<td>0.606</td>
</tr>
<tr>
<td>Causes of injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sports injury</td>
<td>10</td>
<td>11</td>
<td>0.379</td>
<td>0.538</td>
</tr>
<tr>
<td>Traffic accident</td>
<td>6</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative CT and MRI results 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior dislocation of glenohumeral joint</td>
<td>8</td>
<td>14</td>
<td>1.046</td>
<td>0.306</td>
</tr>
<tr>
<td>Without</td>
<td>8</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative CT and MRI results 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh rotator cuff injury</td>
<td>7</td>
<td>10</td>
<td>0.055</td>
<td>0.815</td>
</tr>
<tr>
<td>Without</td>
<td>9</td>
<td>11</td>
<td></td>
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</tbody>
</table>

**Surgical methods** After successful general anesthesia, patients were adjusted to keep their beach chair position with the shoulder of the affected side padded. In group A, the longitudinal incision was made from the inferoanterior part of the acromion (deltoid space approach), and the standard thoracic deltoid approach was used in group B. Attention was paid to careful separation during the operation to avoid damaging the axillary nerve and the feeding vessels of the humeral head. The fracture end of the greater tuberosity of the humerus was explored and cleaned to avoid soft tissue embedding, followed by the exposure and exploration of the rotator cuff insertion by rotating the shoulder joint. Rotator cuff suture traction combined with bone tenaculum can be used to reduce the fracture end in the process. After that, 1-2 1.5mm Kirschner wires were utilized to temporarily fix the fracture ends. After the identification of the good position of the fracture end under C-arm fluoroscopy, the calcaneal plate (Changzhou Kanghui Medical Instrument Co., Ltd.) was trimmed to cut off the excess part according to the size of the fracture fragments in group A, followed by plastic processing and then implantation; while the plate was implanted through the pectoralis major and deltoid sulcus in group B. The implantation position of the plate was that the upper edge should not exceed 3mm below the apex of the greater tuberosity, and the leading edge should be about 5mm outside the intertubercular sulcus. Screwing was performed in according to the shape and position of the fracture. According to the rotator cuff injury by preoperative MRI, B-ultrasound and intraoperative exploration, the injury was repaired with a non-absorbable suture, which can be sutured on the edge of the plate or screw hole through the bone-plate gap (Figs. 1-2). In the final step, the fracture reduction, internal fixation position and length were confirmed to be satisfactory under fluoroscopy. The shoulder joint was moved to avoid subacromial impingement, followed by routine placement of the drainage rubber and suture of the incision layer by layer.

**Postoperative rehabilitation** After the operation, the patients were informed to use the forearm sling for 4-6 weeks initially, with elbow/wrist joint/finger activities within the allowable range. The shoulder joint can
carry out a pendulum movement with no internal rotation permitted to protect the fracture fragments. Patients were permitted to have passive activities 1-2 weeks after operation. According to the imaging examination 4 weeks after operation, active assistance and active activities could be started gradually based on the condition of fracture healing. Weight-bearing activities could be performed 10-12 weeks after operation. In addition, patients could choose to take out the implant 12 months after operation.

**Statistical analysis**

Separate counting was conducted on the interval from injury to operation, incision length, operation time, bleeding volume and postoperative Constant-Murley shoulder joint function score of the patients in the two groups. SPSS 22 software was used for statistical analysis, and inter-group comparison adopted an independent sample t-test. P<0.05 meant that the difference was statistically significant.

**Results**

All 37 cases had fracture healing during the follow-up period ranging from 10-23 months, with an average of 11.9 months. According to the statistical analysis results, the average interval from injury to operation was 3.7 days (2-4 days) in group A and 4.1 days (3-6 days) in group B, with no significant difference. The average length of incision was 6.2cm (4.5cm-7.3cm) in group A and 9.1cm (8.2cm-10.7cm) in group B, with a significant difference. The average operation time was 61 minutes (51-77 minutes) in group A and 65 minutes (57-79 minutes) in group B, with no significant difference. There was a significant difference in the comparison of bleeding volume between group A and group B [47ml (35ml-63ml) vs. 103ml (79ml-125ml)]. At the last follow-up, the average Constant-Murley score was 87.5 points (76-97 points) in group A and 80.3 points (71-91 points) in group B, with a significant difference; besides, the Constant-Murley score was excellent in 10 cases (62.5%), good in 5 cases (31.3%), moderate in 1cases (6.2%), and poor in 0 cases (0%) in group A; while excellent in 10cases (47.6%), good in 9 cases (42.9%), moderate in 2 cases (9.5%), and poor in 0 cases (0%) in group B. Furthermore, in group A, there were no axillary nerve injury, fracture reduction loss, bone nonunion, postoperative infection, ischemic osteonecrosis and other complications. In group B, there were 2 cases of shoulder impingement syndrome without secondary rotator cuff tear, with remission after the removal of internal fixation 8 months after operation(Table 2). In addition, all patients had no nonunion, loss of fracture reduction, nerve injury, postoperative infection, or ischemic necrosis.

Table 2  Comparison of procedure-related variables and Constant-Murley and Postoperative complication between group A and group B
Groups

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=16)</th>
<th>Group B (n=21)</th>
<th>t/c²</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval from injury to operation</td>
<td>3.75±0.45</td>
<td>4.14±0.73</td>
<td>-1.901</td>
<td>0.066</td>
</tr>
<tr>
<td>Operation time</td>
<td>57.56±7.39</td>
<td>60.24±10.85</td>
<td>-0.846</td>
<td>0.403</td>
</tr>
<tr>
<td>Incision length</td>
<td>6.16±1.07</td>
<td>9.09±1.30</td>
<td>-7.304</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Bleeding volume</td>
<td>45.41±11.19</td>
<td>106.06±11.12</td>
<td>-16.393</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Constant-Murley score</td>
<td>87.94±5.70</td>
<td>79.81±8.62</td>
<td>3.261</td>
<td>0.002</td>
</tr>
<tr>
<td>Postoperative complication (shoulder impingement syndrome)</td>
<td>0</td>
<td>2</td>
<td>1.611</td>
<td>0.204</td>
</tr>
<tr>
<td>Postoperative complication (without)</td>
<td>16</td>
<td>19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discussion

With the aging of the population, there is an increase in the incidence of osteoporosis-related fractures. It is predicted that the incidence of proximal humeral fracture will increase three times in the next three decades, accompanied by an increase in the incidence of isolated fractures of the greater tuberosity of the humerus accordingly. Approximately 90% of the fractures of the greater tuberosity of the humerus had no or slight displacement and can be treated through non-operative approaches[9]. However, due to the difference in the type of the injured, mechanisms of injury, anatomical structures and prognosis expectations, the therapeutic option for patients with isolated fractures of the greater tuberosity of the humerus should be different from the elderly with proximal humeral fractures, and a more active surgical treatment should be preferred. It remains controversial concerning the indications for surgical treatment of fractures of the greater tuberosity of the humerus, but the most common surgical criterion is the displacement of the main bone fragment >5mm and/or the angulation >45°[3,10]. Some foreign scholars[19] even suggested that for young and active patients who need to engage in professional sports activities or sports, the surgical indication of isolated fractures of the greater tuberosity of the humerus can be expanded to the displacement of about 3mm.

At present, there are multiple therapeutic choices for the surgical treatment of patients. Arthroscopic and open approach treatments have been proposed and applied clinically, including transosseous suture fixation, tension band wires, anchors, simple screws, various plate fixation, and arthroscopic double-row suture anchors. However, it is still disputed with regard to the optimal treatment of displaced fractures[11-12]. For avulsion fracture with small fracture fragments, it can be treated by[6] arthroscopy or double-row suture anchor under the minimally invasive small incision, or by transosseous suture and tension band internal fixation.

Furthermore, internal fixation with 4.5 mm cancellous bone screws and washers may be a simple and rapid choice for isolated fractures of the greater tuberosity. However, if there are multiple fracture
fragments in the fracture of the greater tuberosity, fixation through independent screws cannot achieve good functional effects, and it is difficult to preserve and stabilize the bone fragments in the comminuted fracture. Moreover, simple screws may lead to further aggravation of fracture fragments, and screws combined with washers may cause protrusion of the implant, which may further increase the risk of secondary impingement \cite{13-15}. Besides, even trickier, in patients with fractures of the greater tuberosity accompanied by rotator cuff injuries, additional anchors are still needed for rotator cuff injury repair for the fixation with independent screws. It is questionable concerning the strength of anchor fixation in patients with comminuted fractures. In addition, it is important to consider that although lag screws alone can fix fracture fragments randomly, the failure rate of internal fixation is relatively high due to the unique anatomical structure of the greater tuberosity of the humerus, especially for young patients who require rapid recovery postoperatively. Simultaneously, transosseous suture fixation is a traditional practice with the disadvantage of insufficient biomechanical strength although it can avoid the problems of metal implant reaction and second operation for removal \cite{16-17}. Indeed, there are various surgical approaches for treatment. Nevertheless, the most popular technique in the past 15 years has still been ORIF with plates and locking screws on the basis of its advantages in providing good biomechanical and anatomical stability \cite{18}.

At present, PHILOS has been widely used in the surgical treatment of displaced fractures of the greater tuberosity of the humerus \cite{19}. However, its thick and hard titanium alloy material is difficult to carry out plastic processing, and its size is not enough for anatomy and matching when fixing the isolated greater tuberosity of the humerus. Moreover, the traditional anatomical locking plate of the proximal humerus is designed with the proximal directional screw inserted into the humeral head. The proposed directional and non-adjustable insertion trajectory can not address the problem of adequate fixation of different shapes of isolated fracture fragments of the greater tuberosity, especially for comminuted fractures of the greater tuberosity of the humerus. Occasionally, implantation of this anatomical plate in a more proximal position to capture more fracture fragments may increase the risk of shoulder impingement \cite{20}. As proposed by many scholars, various micro-locking plates could be used to treat fractures of the greater tuberosity \cite{12,21}. In fact, this low-profile mesh-like plate is advantageous for fractures of greater tuberosity. It can not only adjust the implantation position according to the distribution of fracture fragments \cite{12,22}, but also reduce the risk of shoulder impingement syndrome. Besides, this type of plate has smaller surgical incisions and trauma and less bleeding compared with the traditional PHILOS. However, the micro-plates commonly used in most countries and regions are generally small in size, which is difficult to cover and fix all fracture fragments perfectly. In this regard, two or more plates are commonly required for combined fixation intraoperatively, which reduces the overall stability. For patients who require simultaneous rotator cuff injury repair, it is often necessary to use additional anchors for repair due to the limitation of this type of plate. For instance, Zeng Longqing et al. \cite{23} designed a new anatomical locking plate for isolated fractures of the greater tuberosity of the humerus, which can realize a better repair of the rotator cuff with its separate suture hole, in addition to capturing and fixing the fracture fragments satisfactorily. At present, it is of great significance to find a suitable alternative treatment strategy as there are no such specially designed plates in most countries and regions.
According to our research, calcaneal plates may be a good choice based on our summary of the advantages and disadvantages of various implant and surgical treatment methods as well as the local anatomical characteristics of the greater tuberosity of the humerus. To be specific, compared with the traditional proximal humeral locking plate, the calcaneal mesh anatomical locking plate has a lower notch, better elasticity and thinner thickness, which can facilitate intraoperative plastic processing and trimming, and can reduce the incidence of shoulder impingement syndrome. Moreover, there are various calcaneal plates of different sizes and specifications (Figs. 3). The overall size of the plate can perfectly match and fix fractures at any part of the greater tuberosity of the humerus, especially for comminuted fractures. Furthermore, compared with the proximal humeral locking plate, the calcaneal mesh plate can be used jointly with a variety of screws to fix the humeral head and humeral axis in multiple planes, capture separate fragments, and increase the stability of the structure. Additionally, when the calcaneal mesh plate is fixed on the humeral head, it can contain the soft tissue and rotator cuff, just like a string bag, which can increase the stability of the structure in a way that independent screws can not achieve. This type of implant can promote good fracture healing as its tension is distributed in a wider area and hence provides a larger area. Besides, for some patients with rotator cuff injury, it allows the suture for repairing the rotator cuff to be bound to the plate to strengthen the fixation, similar to the principle of point contact and steel slab bridge, leading to an extensive dispersion of the tension, without impact on the blood supply of the rotator cuff.[24,25] Owing to the use of a smaller calcaneal plate, it is feasible to adopt the simple subacromial deltoid space approach, of which the largest calcaneal plate is about 65mm in length. Moreover, in view of the anatomical shape and size of the greater tuberosity, the size of the plate will be smaller after trimming according to the size of the fracture fragment during the operation, without the requirement for intraoperative exposure of the axillary nerve, leading to a lower risk of injury. In addition, considering the anatomical morphology of the greater tuberosity of the humerus, the contralateral calcaneal plate may have higher compatibility after pre-springing and plastic processing, and hence better stability.

In our study, a calcaneal anatomic locking plate was used for the treatment of split fractures of the greater tuberosity of the humerus and achieved satisfactory results. However, the present study still has some limitations. For example, this study was performed based on a small sample size, with the performance of surgery through different approaches by different surgeons in the two groups, which might affect the therapeutic effect consequently. Besides, due to the short follow-up time, age and other factors, the implants were not completely removed in all patients at the last follow-up, which would produce a negative impact on the scoring of shoulder joint function at the last time.

In conclusion, the calcaneal anatomical locking plate has the advantages of less surgical trauma and less bleeding, etc., which can achieve satisfactory therapeutic outcomes in the treatment of adult fractures of the greater tuberosity of the humerus. Findings in our study may provide a new choice for the surgical treatment of isolated fractures of the greater tuberosity of the humerus.

**Declarations**
Ethics approval and consent to participate

This study was approved by the ethics committee of the People's Hospital of Lishui City. Informed consent was obtained from all the participants. All methods were carried out in accordance with Strengthening the Reporting of Cohort Studies in Surgery (STROCSS) guideline.

Consent for publication

Written informed consent was obtained from each patient to authorize the publication of their data. Informed consent was obtained from all subjects for publication of identifying information/images in an online open-access publication (when applicable).

Availability of data and materials

All the data will be available upon motivated request to the corresponding author of the present paper.

Competing interests

The authors declare that they have no competing interests.

Authors’ contributions

Jun Lan conceived the idea and designed the study. Xiaohui Niu, HaiBo Xia and Wei Liang collected the relevant and data; prepared the figures and tables. Fei Wang performed the statistical analyses. All the authors interpreted the data and contributed to preparation of the manuscript. Fei Wang wrote the manuscript. The author(s) read and approved the final manuscript.

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References


Figures
Figure 1

Preoperative X-ray and CT 3d reconstruction of a fracture of the greater tuberosity
Figure 2

Surgical incision postoperative X-ray and CT 3d reconstruction

Figure 3

Calcaneal plates of different sizes