The purpose of this study was to evaluate the functional outcome of patients with complex proximal humeral fractures fixated by locking plate technology. Eighty-nine patients (27 men, 62 women) older than 50 years with 3- and 4-part proximal humeral fractures were treated using locking plate fixation and followed up for more than 1 year. Functional outcomes were assessed by using the Disabilities of the Arm, Shoulder, and Hand (DASH) and Constant scores, and the complications were evaluated through physical and radiographic examinations. Mean DASH and Constant scores for all 89 patients were 19.6 and 66.6 points, respectively. No significant differences existed in the 2 scores between patients with 3- and 4-part fractures. Of the 71 patients without complications, 68 had an excellent functional outcome according to the DASH score, whereas 2 patients had an excellent outcome on the Constant score. For the 18 patients with complications, the functional outcomes were significantly poorer compared with patients without complications. According to the Constant score, all patients with complications were classified into a moderate or poor functional outcome, but the rate was 12% with the DASH score. In patients with 3- and 4-part proximal humeral fractures fixed with locking plate fixation, complications were the major cause of compromised functional outcomes. Based on these results, different conclusions would be reached when the functional outcome was assessed by using the DASH and Constant scores separately. Because the clinician-based Constant score may bias the results, patient-based assessments, such as the DASH score, are required for the evaluation of functional outcome after shoulder surgery.
Proximal humeral fractures account for approximately 5% of all fractures and usually affect women aged older than 50 years with osteopenia or osteoporosis. It has been suggested that patients with osteoporosis may sustain more complex fractures. Neer designed a 4-segment classification system for proximal humeral fractures by considering the anatomic components of the proximal humerus (head, shaft, and greater and lesser tuberosities). This system has been used extensively for many years for determining the treatment of proximal humeral fractures. In general, patients who sustained 1- or 2-part minimally displaced fractures were treated nonoperatively. Surgical management is usually required for patients with displaced and multiple fragmented fractures.

Open reduction and internal fixation is commonly performed in patients with 3- and 4-part proximal humeral fractures. Various fixation options have been recommended, including tension bending, intramedullary nailing, and plate fixation. However, several complications of these fixations, such as reduction loss, fracture nonunion or malunion, avascular necrosis of the humeral head, and impingement syndrome, may compromise shoulder function. During the past decade, locking plate devices have been developed for the treatment of complex proximal humeral fractures. Locking plate technology can reach anatomic reduction and rigid fixation for multiple fragmented fractures. In particular, this technique improves the stability of osteoporotic bone. These advantages make the locking plate the preferred choice for the treatment of proximal humeral fractures in elderly patients, particularly those with osteoporosis. Due to the short history of application, few studies are available for evaluating the results after locking plate fixation of proximal humeral fractures, and most of those studies included a small number of patients.

The purpose of this study was to evaluate the functional shoulders outcomes after locking plate fixation of displaced 3- and 4-part proximal humeral fractures in elderly Chinese patients.

**Materials and Methods**

**Patients**

The authors retrospectively reviewed 237 patients with proximal humeral fractures who underwent locking plate fixation between May 2007 and December 2010. Eighty-nine patients older than 50 years with 3- and 4-part fractures were included. Body weight and height were measured, and body mass index was calculated. All patients were followed up for more than 1 year. Patients were excluded if they had a glenohumeral dislocation, pathologic fracture, or a previous fracture at the ipsilateral humerus or glenoid or had died during the review period. Fractures were classified according to the Neer classification based on initial radiographs and computed tomography scans on which the fracture parts were either greater than 1 cm of displacement or 45° of angulation. This study was approved by the Institutional Review Board of Shanghai Ruijin Hospital.

**Surgical Technique**

A periarticular locking plate (Zimmer, Warsaw, Indiana) or a Philos plate (Synthes, Oberdorf, Switzerland) was used to fixate the fracture, depending on surgeon’s preference. The patient was placed in a beach-chair position on a radiolucent table. The glenohumeral joint was exposed using a deltopectoral approach. The tuberosity fragments were manipulated with sutures passing through the rotator cuff. Open reduction of the main fracture and tuberosity fragments was achieved using an image intensifier. The reduction was temporarily fixed with K-wires. Once a satisfactory anatomic reduction was achieved, the K-wires were replaced by the locking plate and fixation was performed under an image intensifier to verify the reduction of bone fragments, plate position, and screw length. Subsequently, the sutures initially brought into the rotator cuff were tied to the plate to maintain the stability of the tuberosities.

The affected arm was placed in a sling for 4 weeks. Pendulum and passive elevation and abduction exercises were started 2 days postoperatively. Controlled active mobilization with abduction and flexion beyond 90° was started 4 weeks postoperatively. Patients were allowed to perform free active range of motion beginning at 6 weeks postoperatively.

**Follow-up**

Patients underwent a detailed follow-up examination at an average of 30 months (range, 13-55 months) postoperatively. Radiological examination, with anteroposterior radiographs in external rotation and axillary views, was used to evaluate the adequacy of reduction, bone union, implant loosening, condition of glenohumeral osteoarthritis, and avascular necrosis of the humeral head. Functional outcomes were assessed using the Constant score and the Disabilities of the Arm, Shoulder and Hand (DASH) score. The DASH score was graded as excellent (0-25 points), good (26-50 points), moderate (51-75 points), or poor (76-100 points). The Constant score was also graded as excellent (86-100 points), good (71-85 points), moderate (56-70 points), or poor (0-55 points). Complications were recorded and analyzed.

**Statistical Analysis**

Continuous variables were expressed as mean ± SD. For continuous variables, the mean values between the 2 groups were compared using Student’s t test. The Mann-Whitney U test was used if the variable was not normally distributed. Categorical variables were compared using Fisher’s exact test. The correlation was analyzed with Spearman’s correlation coefficient. The ability of the Constant and DASH scores to discriminate between patients with and without complications was examined by constructing receiver operating characteristic (ROC) curves.
The values for the sensitivity, specificity, area under the curve (AUC), and cut-off point for both variables were obtained from the ROC analysis. An AUC value of 60% to 69% was defined as poor, 70% to 79% as fair, 80% to 89% as good, and 90% to 100% as excellent. The level of significance for all statistics was set at a P value less than .05.

**RESULTS**

Patient characteristics are shown in Table 1. Of 89 patients with 3- and 4-part proximal humeral fractures, 27 (30.3%) were men, 30 (33.7%) were treated with a periarticular locking plate, and 18 (20.2%) sustained complications. No significant differences existed in sex, age, body mass index, plate type, and follow-up period between patients with 3- and 4-part fractures (Table 1).

Functional outcomes, assessed by using the DASH and Constant scores, were similar between patients with 3- and 4-part fractures (Table 2). The mean values of the DASH and Constant scores remained at excellent and moderate levels, respectively, in both groups. According to the DASH scoring, the results were excellent in 73 patients (82%), good in 14 (15.7%) and moderate in 2 (2.2%). However, according to the Constant score, the results were excellent in 2 patients (2.2%), good in 32 (36%), moderate in 40 (44.9%), and poor in 15 (16.9%). Although the DASH score was significantly correlated with the Constant score and its subitems (Table 3), the values of these 2 scores were often not at the same level in many patients. Two of 73 patients with an excellent DASH score had an excellent Constant score, whereas the other 71 had good or moderate levels on the Constant score. Moreover, all patients who had a good DASH score were associated with a moderate or poor Constant score (Figure 1).

Eighteen (20.2%) patients sustained various complications after undergoing locking plate fixation. No significant difference existed in the complication rate between patients with 3- and 4-part fractures (Table 1). Mean age (69.4 years) of patients with complications was approximately 3 years older than the patients without complications (66.6 years), but the difference did not reach statistical significance. Complications included 8 (44.4%) subacromial impingements, 3 (16.7%) screw cut-outs, 2 (11.1%) malunions, 2 (11.1%) tuberosity resorptions, 2 (11.1%) incidences of avascular necroses of the humeral head, and 1 (5.6%) screw breakage. Compared with patients without complications, the DASH score increased by 2.3 times and the Constant score decreased by 16.2 points.

### Table 1

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total</th>
<th>3-part Fracture</th>
<th>4-part Fracture</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>89</td>
<td>67</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>No. of M/F</td>
<td>27/62</td>
<td>22/45</td>
<td>5/17</td>
<td>.434</td>
</tr>
<tr>
<td>Mean±SD age, y</td>
<td>67.2±10.6</td>
<td>67.2±10.8</td>
<td>67.1±10.1</td>
<td>.983</td>
</tr>
<tr>
<td>Mean±SD BMI, kg/m²</td>
<td>23.2±2.37</td>
<td>23.1±2.38</td>
<td>23.5±2.37</td>
<td>.327</td>
</tr>
<tr>
<td>Periarticular PHILOS plate, No.</td>
<td>30/59</td>
<td>25/42</td>
<td>5/17</td>
<td>.299</td>
</tr>
<tr>
<td>With/without complication, No.</td>
<td>18/71</td>
<td>12/55</td>
<td>6/16</td>
<td>.368</td>
</tr>
<tr>
<td>Mean±SD follow-up, mo</td>
<td>30.1±10.3</td>
<td>29.5±10.9</td>
<td>31.8±7.79</td>
<td>.173</td>
</tr>
</tbody>
</table>

**Abbreviations:** BMI, body mass index.
**Comparison between 3- and 4-part fractures.**
**Zimmer, Warsaw, Indiana.**
**Synthes, Oberdorf, Switzerland.**

### Table 2

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Total</th>
<th>3-part Fracture</th>
<th>4-part Fracture</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>DASH (0-100)</td>
<td>19.6±10.8</td>
<td>19.6±11.3</td>
<td>19.6±9.45</td>
<td>.594</td>
</tr>
<tr>
<td>Constant (0-100)</td>
<td>66.6±11.6</td>
<td>67.3±11.4</td>
<td>64.5±12.4</td>
<td>.259</td>
</tr>
<tr>
<td>Pain (0-15)</td>
<td>11.5±2.88</td>
<td>11.7±2.87</td>
<td>10.9±2.88</td>
<td>.145</td>
</tr>
<tr>
<td>Activities of daily living (0-20)</td>
<td>16.3±3.18</td>
<td>16.5±2.99</td>
<td>15.8±3.72</td>
<td>.502</td>
</tr>
<tr>
<td>ROM (0-40)</td>
<td>28.1±5.37</td>
<td>28.1±5.36</td>
<td>27.9±5.54</td>
<td>.649</td>
</tr>
<tr>
<td>Strength (0-25)</td>
<td>10.7±4.45</td>
<td>10.9±4.67</td>
<td>9.95±3.70</td>
<td>.269</td>
</tr>
</tbody>
</table>

**Abbreviations:** DASH, Disabilities of the Arm, Shoulder, and Hand score; ROM, range of motion.
**Data were expressed as mean±SD.**

### Table 3

<table>
<thead>
<tr>
<th>Constant (0-100) DASH (0-100)</th>
<th>Constant (0-100)</th>
<th>DASH (0-100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant (0-100)</td>
<td>−.854</td>
<td>−.399</td>
</tr>
<tr>
<td>Pain (0-15)</td>
<td>−.399</td>
<td>.465</td>
</tr>
<tr>
<td>Activities of daily living (0-20)</td>
<td>−.465</td>
<td>.715</td>
</tr>
<tr>
<td>ROM (0-40)</td>
<td>−.715</td>
<td>−.586</td>
</tr>
</tbody>
</table>

**Abbreviation:** DASH, Disabilities of the Arm, Shoulder, and Hand score; ROM, range of motion.
**Spearman correlation.**
**All P values were less than .0001.**
score decreased by 30% in patients with complications (all \( P < .001 \)) (Table 4). The functional levels graded by the DASH and Constant scores were lower in patients with complications than those without (Table 5). Receiver operating characteristic analyses are shown in Figure 2. Values for the cut-off point and AUC were 60 and 96.6% (95% confidence interval: 90.4%-99.2%), respectively, for the Constant score, and 24 and 95.7% (95% confidence interval, 89.1%-98.8%), respectively, for the DASH score. Both AUCs exhibited excellent test accuracy (90%-100%). Four-quadrant values were set by the cut-off points obtained from the ROC analyses for the DASH and Constant scores (quadrant 1: Constant score of 60 or more and DASH score of 24 or less; quadrant 2: Constant score of 60 or more and DASH score of more than 24; quadrant 3: Constant score of less than 60 and DASH score of 24 or less; and quadrant 4: Constant score of less than 60 and DASH score of more than 24). Of the patients without complications, 95.7% had a Constant score of 60 or more and a DASH score of 24 or less (quadrant 1). In contrast, 83.3% of patients with complications had a Constant score of less than 60 and a DASH score of more than 24 (quadrant 4) (Figure 3).

**DISCUSSION**

In the current study, the authors used locking plate fixation for the treatment of 3- and 4-part proximal humeral fractures in patients older than 50 years. In elderly patients, proximal humeral fractures often resulted from low-energy injuries to osteoporotic bone, and many were displaced 3- and 4-part fractures. Nonoperative treatment for these fractures is more likely to yield poor functional outcomes and a high complication rate. Therefore, surgical management is often a good option for such patients. Recently, the locking plate system has been developed to fixate complex proximal humeral fractures. Compared with conventional plate fixation, the locking plate system offers an anatomic reduction with angular stability in osteoporotic bone and allows early limb mobilization, which may minimize complications and improve postoperative shoulder function. Therefore, locking plate fixation is recommended for the treatment of 3- and 4-part fractures, especially those associated with osteoporosis.

The results showed that no significant difference existed in functional outcome between patients with 3- and 4-part fractures treated with locking plate fixation. A similar conclusion was reported by Ruchholz et al. Three- and 4-part fractures require anatomic reconstruction and stable fixation of the fragments. Stable fixation of all fragments is the key for the

<table>
<thead>
<tr>
<th>Table 4</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Functional Outcome</th>
<th>No Complication</th>
<th>With Complication</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>DASH (0-100)</td>
<td>15.5±5.53</td>
<td>35.6±11.9</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Constant (0-100)</td>
<td>70.9±7.50</td>
<td>49.6±9.01</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Pain (0-15)</td>
<td>12.6±2.40</td>
<td>9.28±3.59</td>
<td>.002</td>
</tr>
<tr>
<td>Activities of daily living (0-20)</td>
<td>17.1±2.46</td>
<td>13.2±3.81</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>ROM (0-40)</td>
<td>29.8±4.06</td>
<td>21.4±4.84</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Strength (0-25)</td>
<td>12.0±3.63</td>
<td>5.56±3.63</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

**Abbreviation:** ROM, range of motion. *Data are expressed as mean±SD.*
successful repair of complex proximal humeral fractures.11,17

As in many other studies,16,19,31 the current authors used the DASH and Constant scores to determine the functional shoulder outcomes. The DASH score is a subjective assessment in which the functional results are reported by patients, whereas the Constant score is an objective assessment in which the functional results are determined by clinicians.32-34 The DASH and Constant scores were classified as excellent, good, moderate, and poor.23,24 In the current study, the results showed that the mean DASH and Constant scores were 19.6 and 66.6 points, respectively, for all patients. More than 80% of the patients had an excellent functional outcome on the DASH score. However, more than 60% of the patients had a moderate or poor outcome according to the Constant score. These data suggest that many patients who had an excellent functional outcome on the DASH score may have a moderate or poor outcome on the Constant score.

This dichotomy between the DASH and Constant assessments has also been previously reported.19,35 Bigorre et al19 reported that after locking plate fixation for proximal humeral fractures, the mean Constant score was 65 points (moderate) but the mean DASH score was 30 points (good). Although 90% of the patients stated that they were able to return to the level of activity that they had before fracture, 30% had a moderate or poor outcome according to the Constant score. Likewise, Sudkamp et al16 reported that the mean DASH score was 15.2 points, whereas the mean Constant score was 70.6 points at 1-year follow-up for 155 patients with acute proximal humeral fractures treated with locking plate fixation. Based on these data, the authors postulated that different conclusions could be reached when the functional outcomes were assessed using DASH and Constant scores separately.

The large discord in outcome assessment that existed between the patient-based DASH score and the clinician-based Constant score exists because the Constant score is susceptible to bias and may not represent the view of the patient.36,37 Accordingly, patient-based outcome scores have gained higher popularity compared with the clinician-based scores.37 Using the absolute value of the Constant score may lead to inconsistent results, particularly in inhomogeneous groups of patients with different ages and sexes.36,38 Therefore, the relative Constant score, which is calculated by dividing the obtained score of the patients by the age- and sex-matched score of the healthy population, has been introduced.39,40 However, using the age- and sex-adjusted Constant score has resulted in a broad range of values is seen in previous studies.38,41 An individual relative Constant score has been used for evaluating shoulder function.38,42 Instead of using the values obtained from the healthy population, the functional performance of the uninjured contralateral shoulder in the same individual was used as a reference, which is referred to as the individual relative Constant score. However, Constant et al40 proposed that comparison with the opposite side should be avoided because too many patients in a
given population have problems with their contralateral shoulders.

Overestimation of shoulder strength may be a major factor contributing to the bias of the Constant score.\(^43,44\) Strength testing has been questioned because few people reached the maximum strength (25 pounds) on the Constant score,\(^45\) suggesting that many patients, even those with healthy shoulders, are unable to get 100 points on the Constant score.\(^41,45\) Patel et al\(^46\) reported the defect of the strength subscore in the Constant system and developed an abbreviated Constant score in which the strength item was excluded. Othman and Taylor\(^44\) reported that the correlation between the Oxford score (a subjective assessment) and the Constant score was significantly improved when the strength subscore was excluded.

A large variation in complication rate (range, 9%-64%) has been reported in patients with proximal humeral fractures treated with locking plate fixation.\(^19,22,24,26,30,47\) The complication risk is usually associated with older age, compromised bone quality, fracture complexity, reduction loss, implant loosening or breakage, and bone ischemia.\(^16,26,48-51\) In the current study, all patients were older than 50 years and sustained 3- and 4-part fractures, both of which increased the complication risk. However, the complication rate (20.2%) in the current patients was relatively lower compared with other studies\(^22,31,48\) and was possibly attributed to the higher success rate of the surgery.

Konrad et al\(^31\) reported that 40% of complications were due to incorrect surgical technique. Ruchholtz et al\(^30\) reported that the complication rate depends on the surgeons’ experience. They reported that a 9% complication rate for a surgery performed by experienced surgeons would increase to 25% and 45%, respectively, if the surgery had been performed by junior or untrained surgeons.\(^30\) In the current study, all operations were performed or assisted by surgeons with more than 15 years of experience with shoulder surgery (L.W., Y.W., C.Z.), which may have contributed to the reduction of complications.

Subacromial impingement accounted for 44.4% of complications in the current patient population. Other complications included screw cut-out, fracture malunion, tuberosity resorption, avascular necrosis of the humeral head, and screw breakage. Complications were a major cause of decreased functional outcome. The DASH and Constant scores were significantly worse in patients with complications than those without. According to the Constant score, all patients with complications were associated with a moderate or poor functional outcome.

Receiver operating characteristic analyses showed that both 60 points on the Constant score and 24 points on the DASH score were excellent cut-off points to discriminate between patients with and without complications. According to the results of both ROC analyses, the 4-quadrant values were divided by the cut-off points of the DASH and Constant scores (Figure 3). The results showed that in patients without complications, 95.8% were associated with scores within quadrant 1. However, in patients with complications, 89% had scores beyond quadrant 1. Accordingly, the authors proposed that the value in quadrant 1, in which the Constant score was 60 points or more and the DASH score was 24 points or less, represents a satisfactory functional outcome.

The primary weakness of this study is its retrospective design and lack of a control group treated with an alternative modality. In addition, locking plate selection (from Zimmer or Synthes) was based on the surgeons’ preference. Nevertheless, the results suggest that locking plate fixation for complex proximal humeral fractures would restore shoulder function and reduce the complication risk, which may be related to the accurate reduction, strong fixation, and early movement of the shoulder.

**CONCLUSION**

In patients with 3- and 4-part proximal humeral fractures fixed with locking plate fixation, the DASH and Constant scores were significantly worse in patients with complications than those without. According to the Constant score, all patients with complications were associated with a moderate or poor functional outcome. Receiver operating characteristic analyses showed that both 60 points on the Constant score and 24 points on the DASH score were excellent cut-off points to discriminate between patients with and without complications. According to the results of both ROC analyses, the 4-quadrant values were divided by the cut-off points of the DASH and Constant scores (Figure 3). The results showed that in patients without complications, 95.8% were associated with scores within quadrant 1. However, in patients with complications, 89% had scores beyond quadrant 1. Accordingly, the authors proposed that the value in quadrant 1, in which the Constant score was 60 points or more and the DASH score was 24 points or less, represents a satisfactory functional outcome.

The primary weakness of this study is its retrospective design and lack of a control group treated with an alternative modality. In addition, locking plate selection (from Zimmer or Synthes) was based on the surgeons’ preference. Nevertheless, the results suggest that locking plate fixation for complex proximal humeral fractures would restore shoulder function and reduce the complication risk, which may be related to the accurate reduction, strong fixation, and early movement of the shoulder.

**CONCLUSION**

In patients with 3- and 4-part proximal humeral fractures fixed with locking plate fixation, the DASH and Constant scores were significantly worse in patients with complications than those without. According to the Constant score, all patients with complications were associated with a moderate or poor functional outcome. Receiver operating characteristic analyses showed that both 60 points on the Constant score and 24 points on the DASH score were excellent cut-off points to discriminate between patients with and without complications. According to the results of both ROC analyses, the 4-quadrant values were divided by the cut-off points of the DASH and Constant scores (Figure 3). The results showed that in patients without complications, 95.8% were associated with scores within quadrant 1. However, in patients with complications, 89% had scores beyond quadrant 1. Accordingly, the authors proposed that the value in quadrant 1, in which the Constant score was 60 points or more and the DASH score was 24 points or less, represents a satisfactory functional outcome.

The primary weakness of this study is its retrospective design and lack of a control group treated with an alternative modality. In addition, locking plate selection (from Zimmer or Synthes) was based on the surgeons’ preference. Nevertheless, the results suggest that locking plate fixation for complex proximal humeral fractures would restore shoulder function and reduce the complication risk, which may be related to the accurate reduction, strong fixation, and early movement of the shoulder.
fixation, complications rather than the complexity of the fractures are the major cause of compromised functional outcomes. The functional outcome assessed by the Constant score is likely to yield a different conclusion than that assessed by DASH score. Because the clinician-based Constant score may bias the results, patient-based assessments, such as the DASH score, are required for the evaluation of functional outcome after shoulder surgery.

**References**


