Purpose: The purpose of this study was to determine the outcomes of arthroscopy after proximal humeral plating and the occurrence of concomitant pathology and avascular necrosis. Methods: Forty-five patients (28 women; median age, 58.5 years [range, 30 to 82 years]) underwent arthroscopies of 46 shoulders because of unsatisfactory results after locked plating of proximal humeral fractures. They were prospectively followed up for 3, 12, and 24 months postoperatively. Relevant intra-articular lesions were documented. The patients were assigned to 1 of the following groups: (1) articular screw perforation, (2) subacromial plate impingement, or (3) post-traumatic/postoperative shoulder stiffness. Shoulder range of motion and function as measured with the age- and gender-adjusted Constant-Murley score, as well as the Simple Shoulder Test, were compared among the groups. Results: Concomitant lesions of the articular cartilage, long head of the biceps tendon, tuberosities, and rotator cuff were found in 34 patients (75%). Two-thirds of patients (n = 31) had a partial or complete 270° capsular release. Of the patients, 84% (n = 38) underwent 3 and 12 months’ follow-up and 82% (n = 37) underwent 24 months’ follow-up. The active range of abduction (P = .029), flexion (P = .048), and internal rotation (P = .0005) had improved significantly at 24 months’ follow-up compared with the preoperative status. The mean adjusted Constant-Murley score of patients with post-traumatic shoulder stiffness (n = 15, 64.2% ± 7.9%) and articular screw perforation (n = 19, 73.3% ± 8.4%) was significantly lower (P = .0089 and P = .042, respectively) than that of patients with subacromial plate impingement (n = 12, 93.4% ± 4.3%). Conclusions: High rates of relevant articular pathologies and the necessity of capsular release in a majority of patients with unsatisfactory results after locked plating of proximal humeral fractures make arthroscopy a valuable revision tool with promising results in cases of high plate positioning, screw perforation, and postoperative/post-traumatic shoulder stiffness. Level of Evidence: Level IV, therapeutic case series.

The incidence of displaced proximal humeral fractures increases with an aging society. Although it is established as a standard surgical treatment, locked plating of displaced proximal humeral fractures is associated with complications, leading to revision surgery in up to 25% of cases. The most frequent primary revision procedure after unsatisfactory courses of locked plating of proximal humeral fractures is partial or complete removal of implants. Commonly, open removal of locked plating occurs for patients with subacromial plate impingement, leading to significant improvement of shoulder function as shown in previous studies. In patients with rotational deficits, open removal has been shown to have poor clinical benefit because the underlying capsular contraction cannot be addressed adequately.

The technique of arthroscopic implant removal has evolved from the necessity of an arthroscopic complete 270° capsular release before implant removal in patients with postoperative and post-traumatic shoulder stiffness. Moreover, potential neurovascular injury associated with repeat open surgery was to be avoided, and potential intra-articular pathologies were to be diagnosed and treated. Preliminary results (mean follow-up, 10 months) after arthroscopic implant removal were similar to those of the open procedure...
accompanied by the advantages of minimally invasive surgery.\textsuperscript{10} Recent retrospective results of arthroscopic plate removal and glenohumeral arthrolysis showed consensus with regard to the feasibility and benefit of the arthroscopic procedure.\textsuperscript{11-13} Discrepancy exists with the occurrence of concomitant articular pathologies.\textsuperscript{10,11} Furthermore, the outcome of arthroscopy after unsatisfactory results of locked plating of proximal humeral fractures (e.g., screw perforation, material impingement, and shoulder stiffness) remains unclear.

The purpose of this study was to determine the outcomes of arthroscopy after proximal humeral plating and the occurrence of concomitant pathology and avascular necrosis. We hypothesized the comprehensive arthroscopic revision procedure to be beneficial with improvement of clinical function in cases of high plate positioning, articular screw perforation, and postoperative/post-traumatic shoulder stiffness.

**Methods**

Patients who underwent arthroscopy after locked plating of proximal humeral fractures were prospectively included in this study after approval by the local institutional review board of the Medical School Hannover (October 2009) (No. 600) until March 2011. The exclusion criteria were age younger than 18 years, previous revision surgery after locked plating of the proximal humeral fracture, and impairing neuromuscular diseases such as hemiplegia. Depending on the primary indication for arthroscopy, patients were assigned to 1 of 3 groups: (1) articular screw perforation, (2) subacromial plate impingement, or (3) postoperative/post-traumatic shoulder stiffness.

In cases of articular screw perforation and subacromial plate impingement, arthroscopy was indicated once the fracture had healed. Arthroscopy because of postoperative/post-traumatic shoulder stiffness was indicated in cases of persistent shoulder stiffness (abduction $<90^\circ$ and/or range of rotation $<60^\circ$) despite intensive physical therapy over a period of 3 months. Preoperative range of motion was assessed, and the maximal possible extent of shoulder flexion, abduction, and internal and external rotation was noted. Range of motion was measured before and after surgery by one of the authors following a standard procedure.

Arthroscopic implant removal was performed by several shoulder surgeons according to a previously published technique.\textsuperscript{8} The portals used for comprehensive arthroscopic implant removal are the posterior, anteroinferior, and anterolateral standard portals; in addition, 2 small incisions were made at the lateral-proximal humerus directly in the lane of the plate. Before implant removal, relevant articular concomitant pathologies of the cartilage, long head of the biceps tendon, and rotator cuff, as well as malpositioned tuberosities, were identified and treated during standard glenohumeral arthroscopy. Dependent on the limitation of passive range of motion, either a partial or complete capsular release was performed. Subsequently, the arthroscope was placed in the subacromial space to perform subacromial bursectomy until the superior margin of the plate could be visualized. The plate was debrided with a shaver, electronic dissector, or small rasp close to the plate. Once all soft tissue was removed from the plate and the screws heads, the screws were removed through the anterolateral portal and the additional skin incisions along the plate. After removal of all screws, the plate was mobilized with the help of a small chisel and then extracted through the slightly enlarged anterolateral portal. Intraoperative findings, treatments, and complications were documented.

The postoperative aftercare protocol consisted of unlimited passive and active movement of the affected shoulder with intensive physiotherapy and demand-adapted pain therapy. Patients were followed up prospectively and data were collected at 3, 12, and 24 months. The postoperative follow-up examination protocol consisted of the assessment of active range of motion (shoulder flexion and abduction, as well as external and internal rotation), the native Constant-Murley score (CMS) plus the age- and gender-adjusted CMS, and the Simple Shoulder Test. Furthermore, the patients’ satisfaction with the outcome after the operation was evaluated. The results of the assessments of preoperative and postoperative range of motion at 24 months’ follow-up of the whole patient collective and the adjusted CMS results at 24 months’ follow-up for all groups were compared by statistical means.

All radiographs and computed tomography scans of the affected shoulder that were taken during the postoperative course during the follow-up period were screened for late onset of partial or complete avascular necrosis (AVN) of the humeral head by a radiologist and the authors. Implementation of radiographic controls depended on the clinical situation; there were no fixed time points for radiographs. Computed tomography scans were only obtained in cases of clinical and radiographic suspicion of AVN ($n = 5$). The postoperative functional results of patients with radiologic proof of AVN of the humeral head were compared with those of patients without AVN.

Statistical analysis was performed with SPSS Statistics (Student Version 18.0; SPSS, Chicago, IL). Descriptive statistics were assessed for all variables and parameters. Results are presented as mean ± standard error of the mean. A normal distribution could not be assumed as tested with the Kolmogorov-Smirnoff test. The statistical comparison of preoperative and postoperative range of motion of the whole collective was performed with the Wilcoxon matched-pairs test. Statistical comparison among groups according to primary indication and between patients with and without AVN was
performed with the Mann-Whitney U test. \( P < .05 \) was used as the threshold for significance.

### Results

Forty-five consecutively treated patients (28 women) with indications for arthroscopy after locked plating of proximal humeral fractures of 46 shoulders were included in this study. At the time of arthroscopic implant removal, the median patient age was 58.5 years (range, 30 to 82 years). The mean duration between locked-plate fracture fixation and arthroscopy with implant removal, capsular release, and treatment of concomitant articular injuries was 9.4 ± 8.3 months.

Evaluation of intraoperative findings of all 46 shoulders showed 1 or more relevant concomitant intra-articular pathologies in 75% of patients (\( n = 34 \)). Chondral lesions (grade II through IV chondromalacia) of the articular cartilage were found in 23 shoulders (50%). The glenoid showed chondral damage in 18 cases and the humeral head in 13 cases. Most of the cartilage damage was intraoperatively found to be associated with articular screw perforation.

In 22 patients (48%) a lesion of the long head of the biceps tendon was identified and treated with either debridement or tenotomy (Table 1). If reasonable, the long head of the biceps tendon was debrided and preserved, especially in younger patients (<60 years). Partial rupture and tendinitis of the long head of the biceps tendon were rated as being associated with articular screw penetration in the majority of cases as well (Fig 1). Partial articular avulsion of the supraspinatus tendon was found in 15 patients (33%) and was treated with debridement in 14 cases; 1 patient underwent suture anchor reconstruction. Tubroplasty of 1 malunited tuberosity or both malunited tuberosities (\( n = 2 \)) was performed in 11 patients (24%). These tubroplasties were not performed in a way to change the tension and, subsequently, the mechanics of the rotator cuff.

Restricted passive range of motion made a complete 270° capsular release necessary in 18 patients (39%).

Partial, mainly anteroinferior arthrolysis with release of the entrapped subscapularis tendon was performed in 13 cases (28%).

Of the patients, 38 participated at the 3-month follow-up and at the 12-month follow-up (84%); at the time of the 24-month follow-up, 37 patients could be examined (82%). Of the remaining 8 patients, 2 had died of unrelated causes and 6 were lost to follow-up. The active range of abduction, flexion, and internal rotation of the affected shoulder had improved significantly at the time of the 24-month follow-up compared with the preoperative status (Table 2). The native CMS, as well as the age- and gender-adjusted CMS, showed improvement from the 3-month to the 12-month follow-up (Table 3). At the time of the 24-month examination, no further progress was observed. Improvement in the Simple Shoulder Test results was noted throughout the first postoperative year (Table 3).

**Table 1. Concomitant Lesion/Pathology of Articular Portion of LHB Treated With Either Debridement or Tenotomy**

<table>
<thead>
<tr>
<th>Pathology of LHB (( n = 22 ))</th>
<th>Debridement (( n ))</th>
<th>Tenotomy (( n ))</th>
<th>Total (( n ))</th>
<th>Association With Screw Perforation (( n ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-thickness rupture</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Partial rupture</td>
<td>0</td>
<td>7</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Tendinitis</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Captured biceps</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Instability</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>14</td>
<td>22</td>
<td>8</td>
</tr>
</tbody>
</table>

LHB, long head of biceps tendon.

**Table 2. Active Range of Shoulder Motion**

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>24-mo Follow-up</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(( n = 37, 82% ))</td>
<td>(( n = 37, 82% ))</td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>85.9° ± 5.8°</td>
<td>104.9° ± 7.4°</td>
<td>( P = .048^* )</td>
</tr>
<tr>
<td>Abduction</td>
<td>76.7° ± 5.9°</td>
<td>96.6° ± 7.7°</td>
<td>( P = .029^* )</td>
</tr>
<tr>
<td>External rotation</td>
<td>29.6° ± 4.1°</td>
<td>41.5° ± 5.4°</td>
<td>( P = .079 )</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>57.8° ± 4.8°</td>
<td>80.8° ± 2.1°</td>
<td>( P = .0005^* )</td>
</tr>
</tbody>
</table>

**NOTE.** Data are given as mean ± standard error of the mean for maximum active range of motion of the affected shoulder preoperatively and at 24 months’ follow-up. The significance of the difference was measured with the Wilcoxon matched-pairs test. *Statistically significant.
Overall, 37 patients (82%) were satisfied with the outcome 24 months postoperatively and rated the arthroscopic procedure as being beneficial. We assigned 19 patients (12 women; median age, 69 years [range, 45 to 82 years]) to group 1 because of intra-articular penetration of the humeral head by 1 or more screws (Fig 2). Arthroscopy was performed 6.7/4.7 months (range, 2 to 24 months) after fracture fixation; fracture union had been ascertained earlier. The cause of screw penetration was varus collapse of varying degrees in all cases. The mean adjusted CMS of these patients 24 months postoperatively was 73.3% ± 8.4% (CMS, 52.1 ± 5.7 points).

Arthroscopy was performed because of subacromial plate impingement (Fig 3) in 12 patients (8 women; median age, 59.5 years [range, 30 to 70 years]), comprising group 2. At 24 months postoperatively, the mean adjusted CMS of patients with subacromial plate impingement was 93.4% ± 4.3% (CMS, 72.9 ± 4.6 points). We assigned 15 patients (8 women; median age, 53 years [range, 35 to 70 years]) with postoperative/post-traumatic shoulder stiffness to group 3. The mean

<table>
<thead>
<tr>
<th>Table 3. Shoulder Scores at Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>3-mo Follow-up</td>
</tr>
<tr>
<td>Native CMS (of 100)</td>
</tr>
<tr>
<td>Adjusted CMS</td>
</tr>
<tr>
<td>SST (of 12)</td>
</tr>
</tbody>
</table>

NOTE. Data are given as mean ± standard error of the mean for the native CMS, age- and gender-adjusted CMS, and SST at 3, 12, and 24 months’ follow-up. The significance of the difference was measured with the Wilcoxon matched-pairs test.

SST, Simple Shoulder Test.

*Statistically significant.

Fig 2. Sixty-two—year—old woman with a secondary intra-articular perforation of 2 screws after loss of the medial buttress and subsequent varus collapse of the humeral head after locked plating of a dislocated 4-part fracture of the proximal humerus. The initial reduction was acceptable though without entire contact of the medial cortex. (A) Preoperative radiograph, anteroposterior view. (B) Preoperative radiograph, axial view. (C) Postoperative radiograph, anteroposterior view, with documentation of complete implant removal. (D) Shoulder function (abduction, flexion, external rotation, and internal rotation from left to right) 24 months after 270° capsular release, tenotomy of the long head of the biceps tendon, and complete implant removal of locked plate and screws.
The comprehensive arthroscopic revision procedure in the case of an unsatisfactory or prolonged course after locked plating of proximal humeral fractures showed significant improvement of shoulder function and patient satisfaction in this prospectively followed patient cohort. This finding is in concordance with previously published retrospective and short-term comparative prospective investigations. As measured with the adjusted CMS, the results showed progress within the first 12 months. No further improvement was observed during the second postoperative year. In the case of an unsatisfactory clinical situation remaining after the comprehensive arthroscopic procedure, AVN must be suspected and secondary arthroplasty might be considered because no further improvement of shoulder function is to be expected.

In contrast to findings described by Maqdes et al., the rate of intra-articular pathologies was found to be relevant because 75% of our patients underwent treatment of lesions of the long head of the biceps tendon, rotator cuff, articular cartilage, or tuberosities during arthroscopy. Nonetheless, this percentage reflects preliminary results of another study. The fact that no concomitant articular pathologies were found by Maqdes et al. might have occurred by chance and might be explained by their comparably small patient collective. Previous studies have shown the increased prevalence of rotator cuff tears after proximal humeral fractures. In a series of 80 patients with preoperative arthroscopy, in the case of fracture about the shoulder, Schai et al. showed significant numbers of labral, capsuloligamentous, and rotator cuff lesions, as well as cartilage damage. They suggested that “it is important not to underestimate soft tissue pathology in fractures that seem radiologically relatively harmless.”

Penetrating screws were found not only to “have the potential to damage the glenoid” but also to damage the long head of the biceps tendon in our study. The quote of 24% of patients with arthroscopic tuberoplasty underlines its importance. An even more differentiated
approach with retensioning of the rotator cuff after tuberoplasty might lead to a further improvement of results. Relevant intra-articular concomitant pathologies of the articular cartilage, long head of the biceps tendon, rotator cuff, and tuberosities are expected in a large patient group with unsatisfactory results after locked plating of proximal humeral fractures. As such, in our point of view, revision arthroscopy in this patient population has been shown to be a valuable tool.

Another crucial aspect about arthroscopy in cases of sequelae of locked plating of proximal humeral fractures is the capsular release, which cannot be carried out to the same extent during common open revision surgery. Our focus should lie even more on capsular release and the corresponding aftercare because abduction and external rotation showed the lowest progress during the postoperative follow-up. Although two-thirds of patients underwent partial or complete arthrotomy, this quote might be considered undersized in retrospect. More patients possibly should have undergone such releases.

The groups assigned according to primary indication formed for the comparison of results are clinically relevant because postoperative shoulder stiffness, high plate positioning, and screw perforation have been shown to appear regularly, and each strongly influences the CMS. Post-traumatic/postoperative shoulder stiffness had a greater negative impact on shoulder function than screw perforation as measured with the adjusted CMS. Patients with subacromial plate impingement as the primary indication for arthroscopy can await good to excellent clinical results. The mechanical problem is basically solved after implant removal. Isolated high plate positioning without signs of screw perforation or shoulder stiffness can, for that reason, be rated as a minor complication, as suggested previously. Nonetheless, this complication should be avoided in the first instance during fracture fixation because proper plate positioning can prevent impingement at the superior aspect of the plate.

Although articular screw perforation is associated with an inferior clinical outcome, the damage to the articular cartilage does not seem to be such a large impairment as remaining restrictions of range of motion in the case of postoperative shoulder stiffness. Collapse and subsequent screw penetration may principally be due to improperly addressing and reducing the medial buttress. Similar to correct plate positioning, this must be considered during fracture fixation to avoid a complicated postoperative course. For patients with postoperative shoulder stiffness as an indication for arthroscopy, the focus should be placed extensively on a thorough and complete capsular release.

In the case of poor postoperative outcomes after the described arthroscopic procedure, patients should be screened intensively for humeral head AVN because this entity is accompanied by severely poorer clinical results. The native CMS and adjusted CMS indicate residual impaired shoulder function especially in the case of AVN and after post-traumatic/postoperative shoulder stiffness.

The comprehensive arthroscopic joint-preserving revision procedure with capsular release, treatment of articular pathologies, and complete implant removal was shown to be clinically beneficial. Even if the overall outcome is fair as measured with the adjusted CMS, improvement of shoulder function and patient satisfaction emphasizes the role of arthroscopy after unsuccessful locked plating of proximal humeral fractures in our study. Arthroscopy is relevant and important in this clinical situation because symptoms caused by concomitant articular pathologies and capsular contraction can be addressed and treated, leading to improvement of shoulder function.

Limitations

The major limitation of this study’s design is the lack of a control group, for example, with open implant removal or even without surgical revision within a comparative or randomized study design. The groups formed for the comparison of outcomes dependent on the primary indication for arthroscopy are unequal in size. The influence of the patient’s compliance with the postoperative aftercare protocol on the functional outcome remains unclear.

Conclusions

High rates of relevant articular pathologies and the necessity of capsular release in a majority of patients with unsatisfactory results after locked plating of proximal humeral fractures make arthroscopy a valuable revision tool with promising results in cases of high plate positioning, screw perforation, and postoperative/post-traumatic shoulder stiffness.

References

5. Solberg BD, Moon CN, Franco DP, Paiement GD. Locked plating of 3- and 4-part proximal humeral fractures in


