Angular-Stable Locked Intramedullary Nailing of Two-Part Surgical Neck Fractures of the Proximal Part of the Humerus
A Multicenter Retrospective Observational Study

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Background: The ideal fixation technique for the treatment of proximal humeral fractures remains unclear. In the present study, we evaluated the experience of three surgeons with the treatment of two-part surgical neck fractures with angular-stable intramedullary fixation.

Methods: Forty-eight patients with forty-eight Neer two-part surgical neck proximal humeral fractures were managed with locked angular-stable intramedullary nail fixation by three surgeons. Shoulder pain and outcomes were quantified with Constant scores and standard radiographs.

Results: Thirty-eight patients (including twenty-eight female patients and ten male patients) with a mean age of sixty-five years were followed for at least twelve months (mean, twenty months; range, twelve to thirty-six months). All fractures healed primarily. The mean follow-up Constant score (and standard deviation) was 71 ± 12 points (range, 37 to 88 points), with a mean age-adjusted Constant score of 97% (range, 58% to 119%). The mean Constant pain score was 13 ± 2.2 (possible range, 0 to 15 points, with 15 points representing no pain). The mean forward flexion was 132° ± 22°. All fractures but one healed with a neck-shaft angle of ≥125°.

Conclusions: Patients who were managed with locked angular-stable intramedullary nailing of two-part surgical neck proximal humeral fractures via an articular entry point had reliable fracture-healing, favorable clinical outcomes, and little residual shoulder pain.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Proximal humeral fractures are the third most common fracture in individuals older than sixty-five years. Approximately 50% to 85% of these fractures are classified as nondisplaced or minimally displaced fractures, for which nonoperative treatment may be used effectively. For displaced fractures, many forms of surgical treatment have been utilized, with variable success. Intramedullary nailing of proximal humeral fractures has been associated with good results in some studies, whereas other studies have demonstrated persistent shoulder pain and unsatisfactory outcomes. Recently, locked plate-and-screw devices have gained popularity for the treatment of these fractures, although recent studies have demonstrated numerous complications and variability of outcomes with these devices.

Technological changes have theoretically improved the fixation of proximal humeral fractures with intramedullary nails. Newer locked proximal humeral nails are different from previously utilized devices in that they are “angular-stable.”

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with varying mechanisms of “locking” the proximal fixation to the nail. Locking the proximal fixation to the nail converts the nail construct to a fixed-angle intramedullary device, improving fracture stability. Preliminary reports on the use of these devices have shown favorable patient outcomes\(^{17,18}\). A subtle change in technique also may lead to better results in association with intramedullary nailing of humeral fractures. Previously, the greater tuberosity has been suggested\(^ {19} \) as the starting point for the nail, analogous to a trochanteric entry for a femoral nail. Recently, some investigators have suggested a more medial articular starting point for the nail, avoiding the greater tuberosity\(^ {17,20-22} \). Those authors have suggested that this technique of nail insertion spares the rotator cuff insertion and has little consequence to the articulating surface of the humeral head, leading to a decreased rate and severity of postoperative shoulder pain\(^ {17,20-22} \).

The literature evaluating the treatment of proximal humeral fractures is difficult to interpret because of the heterogeneity of the fractures treated\(^ {\text{16}} \). The goal of the present study was to evaluate the results of treatment only with two-part surgical neck fractures. These fractures represent the most common type of displaced proximal humeral fracture, comprising 55% of displaced fractures in a recent epidemiological study\(^ {5} \). We considered this group to be ideal for the evaluation of the prevalence of postoperative shoulder pain as the greater tuberosity is intact or nondisplaced. We hypothesized that locked angular-stable intramedullary nailing for the fixation of displaced two-part surgical neck fractures with a medial articular entry would result in predictable healing and little residual shoulder pain.

Materials and Methods

Between 2003 and 2007, forty-eight patients with displaced Neer two-part surgical neck proximal humeral fractures were managed with antegrade intramedullary locked nailing by three surgeons at three institutions. Ten patients were lost to follow-up, leaving thirty-eight patients available for inclusion in the present study. The medical records were reviewed for demographic data, perioperative complications, and associated procedures. The type of fracture was determined with preoperative true anteroposterior, scapular lateral, and axillary radiographs. According to the criteria described by Neer, a fracture was considered to be displaced if the proximal fragment was displaced at least 1 cm or angulated >45° from the distal fragment at the surgical neck\(^ {2} \). Nine patients had fracture lines between the greater tuberosity and the humeral head, but the tuberosity was nondisplaced in all cases. One of these patients also had fracture lines between the greater tuberosity and the humeral head, but the tuberosity was intact or nondisplaced. We hypothesized that locked angular-stable intramedullary nailing for the fixation of displaced two-part surgical neck fractures with a medial articular entry would result in predictable healing and little residual shoulder pain.

Surgery was performed with the patient in the modified beach-chair or “lazy-lateral” position on a beanbag and radiolucent operating table. Fluoroscopy was used to visualize the fracture in the anteroposterior plane and the scapular or axillary lateral plane. A superior deltoid-splitting approach was used, along with an articular starting point. In eight (21%) of the thirty-eight patients, the deltoid and the coracohumeral ligament were partially released from the anterior aspect of the acromion to facilitate exposure and medial insertion of the nail. Occasionally, concomitant abnormality was encountered, and, in eight patients (21%), an acromioplasty, biceps tenodesis, and/or rotator cuff repair was performed. The fracture was reduced with use of longitudinal traction and manipulation of the humeral shaft; in some patients, a wire or Schanz pin was used as a “joystick” to manipulate the humeral head into a nearly anatomic position in relation to the shaft. A longitudinal supraspinatus split was performed at the musculotendinous junction to gain access to the humeral head, avoiding violation of the supraspinatus insertion on the greater tuberosity. If there was a preexisting rotator cuff tear, the nail was simply placed into the articular surface through the rent in the supraspinatus. Standard instrumentation and reamers were used to gain entry into the humeral head and the proximal aspect of the humeral shaft.

According to the preference of the individual surgeon, the fracture was fixed with an antegrade Synthes EX spiral blade (Synthes, West Chester, Pennsylvania) or a Stryker T2 nail (Stryker Orthopaedics, Mahwah, New Jersey). Proximal fixation of the Synthes EX nail was achieved by placing a spiral blade into the humeral head and locking the blade to the nail with a superior end-cap (see Appendix). The Stryker T2 nail is fixed with use of one to four proximal screws; the first screw is “locked” with a superior end-cap and all four screws are fixed to the nail through threaded nail holes with a nylon bushing (see Appendix). Insertion of the proximal spiral blade (Synthes EX nail) or screws (Stryker T2 nail) was performed percutaneously using a jig attached to the nail. The soft tissue was carefully and bluntly dissected to the bone to avoid injury to the axillary nerve.

One surgeon used the Synthes EX nail. Two surgeons used the Stryker T2 nail because of concerns regarding the availability of only one plane of fixation and the size of the blade with the Synthes EX nail\(^ {17,20} \). According to the discretion of the surgeon and the type of nail used, static and/or dynamic interlocking was utilized for distal fixation in all cases. As the Synthes EX nail does not allow for dynamic fixation, only static distal interlocking was utilized for those patients. In the procedures performed with the Stryker T2 nail, dynamic distal interlocking was used if the reduction was rotationally stable and if there was a lack of severe comminution at the fracture site. Fluoroscopy was utilized to determine the proper length of the blade and/or screws. No proximal locking fixation devices perforated the articular surface. Supraspinatus and deltoid splits were closed with absorbable suture. If required, a preexisting rotator cuff tear was repaired to the intact greater tuberosity with use of nonabsorbable braided nonabsorbable sutures. If the deltoid and coracohumeral ligament had been partially released, meticulous repair was done with use of nonabsorbable braided suture.

The shoulder was protected in a sling for six weeks postoperatively. A uniform postoperative rehabilitation protocol was utilized, with only gentle passive motion allowed initially and active assistive motion allowed at three weeks postoperatively with no aggressive end-range stretching. Active shoulder motion and light end-range stretching was allowed six weeks postoperatively, and light strengthening was allowed at three months. The patients were evaluated on the basis of a physical examination and repeat anteroposterior (neutral rotation), scapular lateral, and axillary radiographs of the involved shoulder at one week, six weeks, three months, six months, twelve months, and yearly thereafter following surgical intervention. The Constant score was calculated at the yearly and latest follow-up visits\(^ {25} \). Strength testing was performed according to the method of Constant and Murley, with elevation strength at 90° of elevation being measured with an electronic isometric dynamometer\(^ {25} \). Radiographs were evaluated for fracture union, measurement of the neck-shaft angle, implant complications, and osteonecrosis.

Statistical Analysis

Changes in clinical and functional outcomes were compared within groups with use of a paired t test. Patient satisfaction was assigned a score of 0 points (dissatisfied), 1 point (satisfied), or 2 points (very satisfied). The SAS/STAT software package (Version 9.2 of the SAS System for Windows XP; SAS Institute, Middleton, Massachusetts) was utilized. Ninety-five percent confidence intervals were established for each outcome with use of 10,000 bootstrap replications of the thirty-eight observations\(^ {16-18,28} \).

Source of Funding

There was no external funding for this study.
TABLE I Clinical and Functional Outcomes as a Function of Nail Type*

<table>
<thead>
<tr>
<th></th>
<th>Stryker T2 Group</th>
<th>Synthes EX Group</th>
<th>Pooled Mean and 95% CI†</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>29</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Age† (yr)</td>
<td>66 (43 to 93)</td>
<td>64 (46 to 87)</td>
<td>65 (61 to 70)</td>
</tr>
<tr>
<td>Male:female ratio (no. of patients)</td>
<td>7:22</td>
<td>3:6</td>
<td></td>
</tr>
<tr>
<td>Duration of follow-up‡ (mo)</td>
<td>13 (12 to 36)</td>
<td>21 (15 to 31)</td>
<td>20 (17 to 22)</td>
</tr>
<tr>
<td>Constant score‡ (points)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>73 (37 to 88)</td>
<td>64 (48 to 79)</td>
<td>71 (66 to 74)</td>
</tr>
<tr>
<td>Age-adjusted</td>
<td>101 (58 to 125)</td>
<td>85 (60 to 108)</td>
<td>97 (91 to 102)</td>
</tr>
<tr>
<td>Pain</td>
<td>13 (10 to 15)</td>
<td>12 (5 to 15)</td>
<td>13 (12.1 to 13.6)</td>
</tr>
<tr>
<td>Strength‡§ (lb)</td>
<td>5 (2 to 10)</td>
<td>9 (4 to 15)</td>
<td>6 (5 to 7)</td>
</tr>
<tr>
<td>Forward flexion‡ (deg)</td>
<td>132 (70 to 165)</td>
<td>135 (110 to 160)</td>
<td>132 (125 to 139)</td>
</tr>
<tr>
<td>Latest neck-shaft angle‡ (deg)</td>
<td>131 (125 to 140)</td>
<td>129 (125 to 140)</td>
<td>131 (126 to 132)</td>
</tr>
<tr>
<td>Satisfaction‡ (points)</td>
<td>1.4 (1 to 2)</td>
<td>1.6 (0 to 2)</td>
<td>1.4 (1.2 to 1.6)</td>
</tr>
<tr>
<td>Complication/reoperation rate</td>
<td>7% (2 of 29)</td>
<td>33% (3 of 33)</td>
<td>13% (3% to 24%)</td>
</tr>
</tbody>
</table>

*Because patients were not randomized according to nail type, p values for the comparisons between nail types were not meaningful.
†Estimated from 10,000 bootstrap replications of the thirty-eight observations (the entire study group). †The values for the Stryker T2 and Synthes EX groups are given as the mean, with the range in parentheses. §1 lb = 0.45 kg. #The one outlier of 84° is not included as it distorts the range of values.

Results

Of the forty-eight patients who were identified, ten were lost to follow-up: six had died, one was incarcerated, two had moved, and one had dementia and was unable to provide consent for the study. The thirty-eight patients who were included in the present study were followed for an average of 20±8 months (range, twelve to thirty-six months) after the index procedure. The average age at the time of the operation was 65±13 years (range, forty-three to ninety-three years). Twenty-eight patients were female, and ten were male. The Synthes EX nail was utilized in nine patients, and the Stryker T2 nail was used for the other twenty-nine. In three cases, a long nail was utilized because of extension of the fracture into the proximal humeral metaphysis-shaft junction. Dynamic interlocking screw fixation was utilized distally for twelve patients who were managed with the Stryker nail, with the constructs in the remaining twenty-six patients locked statically.

The mean Constant score at the time of the latest follow-up was 71±12 points (range, 37 to 88 points). The age-adjusted mean Constant score was 97% (range, 58% to 119%) of that for age-matched controls. The mean Constant pain score was 13±2.2 points (range, 5 to 15 points [with 15 points representing no pain]). The mean forward flexion, measured with use of the thorax (not the vertical plane) as a reference, was 132°±22°. The mean isometric strength at 90° of elevation was 6.0±3.2 lb (2.7±1.5 kg). Thirty-seven (97%) of the thirty-eight patients were either satisfied or very satisfied with the latest clinical result (Figs. 1-A and 1-B).

The fracture was defined as healed when there was an absence of a fracture line and visible bridging corticocancellous bone on postoperative anteroposterior and axillary radiographs. All fractures were healed by three months postoperatively. The neck-shaft angle was measured on true anteroposterior (Grashey) radiographs made at the time of the latest follow-up. All but one of the fractures healed with a neck-shaft angle of ≥125°, with one patient having a neck-shaft angle of 84° (average neck-shaft angle, 131°±8.8°). That patient had limited shoulder motion but was without pain. Dynamic distal interlocking was associated with controlled settling of the fracture site in all twelve patients in whom it was employed (Fig. 2).

Four patients (11%) required a second procedure after fracture-healing. Specifically, one patient had implant removal alone, one had excision of heterotopic bone, one had manipulation and implant exchange, and one had manipulation alone. This reoperation rate is comparable with those in studies of locked plating for the treatment of proximal humeral fractures (range, 13% to 19%)12,13. The details of the repeat procedures are available in the Appendix.

Statistical analysis was performed to isolate the effect of the type of implant used and the potential effect of concomitant procedures on the results (Tables I and II). In terms of the type of implant used, there was a higher absolute Constant score (mean, 73 points [95% confidence interval (CI), 68 to 78 points] compared with 64 points [95% CI, 56 to 72 points]) and age-adjusted Constant score (mean, 101 points [95% CI, 95 to 107 points] compared with 85 points [95% CI, 72 to 98 points]) in the Stryker T2 group (Table I). Strength in elevation was significantly higher in the Synthes EX group (mean, 9 lb [4.1 kg] [95% CI, 6.3 to 11.9 lb] [2.9 to 5.4 kg] compared with 5 lb [2.3 kg] [95% CI, 4.3 to 6.0 lb] [2.0 to 2.7 kg]). With the numbers available, no other subjective or objective parameters were significantly different between the two implant groups.
A ninety-year-old woman who sustained a displaced two-part proximal humeral fracture as a result of a mechanical fall. **Fig. 1-A** Preoperative anteroposterior and axillary radiographs showing a displaced and angulated two-part surgical neck proximal humeral fracture. **Fig. 1-B** Postoperative anteroposterior and axillary radiographs made six months after fixation with use of the Stryker T2 nail. At the time of the latest follow-up, the patient demonstrated 120° of forward flexion with a Constant score of 60 points (age-adjusted score, 94%).
Concomitant procedures were performed in eight patients at the time of initial fixation. These procedures included an isolated subacromial decompression in two patients, a concomitant rotator cuff repair in two patients, a biceps tenodesis in one patient, combined subacromial decompression and biceps tenodesis in two patients, and a rotator cuff repair and biceps tenodesis in one patient. The clinical results in these patients were analyzed statistically and are shown in Table II. With the numbers available, there were no obvious differences between the groups in terms of demographic characteristics or clinical results.

![Image of radiographs demonstrating controlled settling of the fracture site following the use of dynamic distal fixation alone. Dynamic distal fixation allowed the fracture to settle (but heal) between the time of the acute radiograph (left) and the time of the radiograph that showed healing six weeks later (right). Green arrows depict the “dynamization” that has occurred from the acute radiograph to the six-week radiograph. The green arrow on the left points to the distal screw in the distal part of the dynamic slot. The green arrow on the right depicts the sliding of the entire proximal nail construct distally on the distal screw.](https://example.com/radiographs.png)
Radiographic Analysis

In order to evaluate the maintenance of reduction, the neck-shaft angle on the first postoperative anteroposterior radiograph was compared with that on the latest anteroposterior radiograph. The average neck-shaft angle decreased 3.2° from the first radiograph to the latest follow-up radiograph (from 133.6° ± 4.3° to 130.4° ± 8.9°; p = 0.04, paired t test). If the patient with the obvious loss of reduction and malunion was excluded, the average decrease in the neck-shaft angle was 1.8° (p < 0.001, paired t test). When separated according to nail type, the average decrease in the neck-shaft angle was 2.2° for the Stryker T2 nail group (with exclusion of the patient who had a malunion) (p < 0.001, paired t test) and 0.6° for the Synthes nail group (p = 0.40, paired t test). The radiographs for patients who had dynamic distal interlocking alone also were compared with those for patients who had static distal interlocking. In patients who had dynamic distal interlocking alone, the average decrease in the neck-shaft angle was 3.3° (p < 0.001, paired t test). In patients who had static distal interlocking, the average decrease in the neck-shaft angle (with exclusion of the patient who had a malunion) was 1.1° (p = 0.06, paired t test). None of these differences were thought to be clinically important. No patient had evidence of glenohumeral arthritis or osteonecrosis on the latest follow-up radiograph.

Discussion

As a large proportion of proximal humeral fractures occur in the elderly population, conventional intramedullary nail and compression plate-and-screw techniques may fail as they rely on screw torque in the bone to provide fracture stability4-6,11,29. Osteoporotic bone is porous and is unable to resist the shear forces generated by advancing compression screw threads, resulting in failure of fixation and screw loosening8. As locked plating provides angular-stable fixation, it has been introduced as an alternative to conventional plate-and-screw techniques for the fixation of these fractures5,12-16. Technology for angular-stable fixation also has been made available for intramedullary nails used for the treatment of proximal humeral fractures. Early biomechanical data and clinical results comparing these devices with locked plating for the treatment of these fractures have been sparse but favorable17,18,20,30-33.

A reported drawback to intramedullary fixation of humeral fractures is postoperative shoulder pain, with a reported prevalence of 20% to 45% after intramedullary nailing of humeral shaft fractures24-30. Possible causes include damage to the subacromial space and the rotator cuff insertion on the greater tuberosity. Theoretically, inserting a nail through the greater tuberosity creates a partial to full-thickness rotator cuff tear that is irreparable secondary to the removal of footprint bone. Splitting the rotator cuff more medial to the tuberosity passes through more muscle and well-vascularized tissue and spares the rotator cuff insertion, potentially leading to less pain28-32. The disadvantage of utilizing a medial starting point is that the nail enters through the articular surface. Our work and that of others have shown favorable short and intermediate-term results in terms of shoulder pain and clinical outcomes, but the long-term effect of articular entry is unknown20-22. Screw backout, with a reported prevalence of 10% to 24%17,34, is still a problematic complication associated with other modern intramedullary devices as the screws in these devices simply thread into the interlocking holes and are not “captured” with a superior set screw or nylon bushing. Loosening of the proximal fixation blade or screws was not noted in any of the patients in the present study, lending support to the use of a superior “end-cap” locking screw and/or polymer bushing material for all proximal nail screw holes (see Appendix).

Percutaneous pinning and locked plating are two very commonly used methods of fixation of proximal humeral fractures. The vascular supply to the proximal part of the humerus and the humeral head is an important consideration related to these techniques. Depending on the fracture pattern, the degree of comminution, and the operative dissection, the blood supply to the fracture site and the humeral head may be compromised37-39. Like intramedullary nailing, percutaneous pinning has the advantage of minimal dissection of the fracture site40,41. The disadvantages of this technique are that it is more technically demanding, that more fluoroscopy imaging is used, and that there is less biomechanical stability than there is with the use of intramedullary nailing for the treatment of these fractures40-42. In a recent report by Keener et al., a malunion developed in two of six displaced two-part surgical neck fractures that were treated with modern percutaneous pinning techniques39. This malunion rate was relatively high in comparison with the malunion rate of 11% (two of eighteen) for three and four-part fractures that were treated similarly in the same study40 and the malunion rate of 3% (one of thirty-eight) in our cohort of patients with two-part surgical neck fractures.

Surgical insult to the fragile blood supply via nonlocked plating can increase the rates of malunion, nonunion, and osteonecrosis in comparison with less-invasive methods of fixation43. These complications also have been noted with locked plate-and-screw treatment of two-part surgical neck fractures. Recent investigations of locked plating of two-part surgical neck fractures have revealed somewhat unexpected rates of nonunion, osteonecrosis, malunion, loss of reduction of both the surgical neck and undisplaced tuberosity fracture sites, and eventual hemiarthroplasty12,13,45. None of our patients had evidence of osteonecrosis, but longer follow-up is needed to determine the actual prevalence of this complication46. It has been suggested that proximal humeral fractures “want to settle” into a position of healing, leading to varus collapse and screw cutout after locked plate-and-screw fixation12. This tendency also may contribute to pin loosening and/or joint penetration in patients with percutaneously pinned fractures. The present study supports this concept, as fracture-site impaction occurred in all twelve patients in whom distal interlocking alone was utilized. Allowing this impaction in a controlled fashion is a potential advantage of angular-stable intramedullary fixation over both percutaneous pinning and locked plating. Other advantages of using nail devices over plate-and-screw devices include less soft-tissue and vascular supply violation, ease of insertion, and the ability to extend the fixation further down the humerus without increased surgical exposure if the fracture...
extends substantially past the metaphysis. Breakage of the nail and loss of distal fixation have not been reported after intra-
medullary nailing for the treatment of proximal humeral frac-
tures, but these are well-recognized complications of locked
plate-and-screw fixation.13,15,16,44,45.
An additional potential advantage of proximal humeral
intramedullary nailing is the utilization of a limited superior
approach to the proximal part of the humerus. This approach
does not violate any of the important blood supply to the fracture
site or the humeral head and allows for the recognition and
treatment of concomitant abnormalities, either preexisting or
having occurred as a result of the trauma that caused the fracture.
Although the data from this study do not lead to definitive
treatment recommendations for concomitant abnormalities, this
is a relevant topic because of the substantial prevalence of asso-
ciated rotator cuff and biceps abnormalities in older individ-
uals.65-67 We agree with others that it is crucial to meticulously
avoid violation of the tendinous insertion of the rotator cuff on
the greater tuberosity in order to prevent the postoperative
complication of rotator cuff-related shoulder pain.20-22,49,50
The present study is the third study to demonstrate fa-
vorable outcomes following angular-stable locked intramed-
ullary nailing fixation in an isolated cohort of two-part surgical
neck fractures. Zhu et al. evaluated twenty-two patients with
two-part surgical neck fractures that were treated with the
Synthes proximal humeral nail.51 Patients were followed for an
average of twenty-five months (minimum, one year). All fractures
healed without reported complications. Good clinical
outcomes were noted, with an average forward flexion of 145°
and an average Constant score of 85 points, similar to the
values found in the present study. Although ten (45%) of
twenty-two patients exhibited tenderness above the entry point
of the nail, the overall visual analog pain score was low (1.5 of
10). The same authors performed a randomized clinical trial in
which locking intramedullary nailing was compared with
locked plating in a group of fifty-one patients with two-part surgical neck fractures.49. Similar clinical results were noted in both
groups at the time of the three-year follow-up, with a
higher complication rate in the locked plate-and-screw group.
The strengths of the present study include the uniformity of
the operative technique, the standardized measurement of clinical
and radiographic outcomes, the relatively large number of pa-
tients with two-part surgical neck fractures who were enrolled,51-54
and the uniformity of results between three different surgeons,
suggesting that the technique is reproducible. The weaknesses of
the present study include its retrospective nature, the potential for
detection bias, and the relatively short duration of follow-up
(average, twenty months), the latter of which is common among
studies on the operative treatment of proximal humeral frac-
tures.12,13,15,16,44,45,52-54. One of the major limitations is that two
different types of implants were used, with one involving the use
of a locked angular-stable spiral blade proximally and one in-
volving the use of screws in multiple planes to obtain proximal
fixation. Nonetheless, the uniform outcomes that were achieved
and the low rate of complications encountered with both devices
lend support to the use of angular-stable intramedullary nailing of
two-part surgical neck proximal humeral fractures.

Appendix
A description of the details of the repeat procedures and
illustrations of the Synthes EX and Stryker proximal
humeral nails are available with the online version of this article
as a data supplement at jbjs.org.

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