JSES Reviews, Reports, and Techniques 2 (2022) 350–353

Contents lists available at ScienceDirect

JSES Reviews, Reports, and Techniques

journal homepage: www.jsesreviewsreportstech.org

Endosteal plating in proximal humerus fractures: a novel technique and alternative to fibular strut allograft for medial column support

Jonathan P. Braman, MD[a], Timothy N. Nyangacha, BS[b,*], Michael L. Knudsen, MD[c]

[a]Department of Orthopedic Surgery, University of Minnesota, Minneapolis, MN, USA
[b]University of Minnesota, Minneapolis, MN, USA
[c]Division of Shoulder, Elbow and Sports Medicine, Columbia University Medical Center, New York, NY, USA

ARTICLE INFO

Keywords:
Proximal humerus fracture
Endosteal plate
Radiographic outcomes
Medial columnar support
Locking plate
Complications

Level of Evidence: Level IV; Treatment Study

Hypothesis: The purpose of this retrospective study is to investigate the clinical and radiographic outcomes associated with the use of a standard metal plate as an endosteal implant in combination with a lateral locking plate to treat 4 patients with displaced proximal humerus fractures.
Methods: A retrospective case series study design was utilized, and the medical records of 4 patients with displaced, 3-part proximal humerus fractures treated using this technique between January 2019 and July 2021 were reviewed for this study. The mean age was 52 years (range, 44-57 years). The radiographic outcome of interest was humeral neck-shaft angle preoperatively, intraoperatively, and at the latest follow-up. The average follow-up duration was 62 weeks (range, 12-161 weeks).
Results: All fractures healed without loss of reduction or neurovascular deficits. Avascular necrosis was not observed in the 2 patients with sufficient follow-up time to make such an evaluation. The average neck-shaft angles preoperatively, intraoperatively, and at the latest follow-up were 104.8°, 139.8°, and 137°, respectively.
Conclusion: Locking plate technology augmented with an endosteal plate provided stable reduction and restoration of physiologic alignment in a small number of patients with displaced proximal humerus fractures. This construct creates a second column of fixation, providing medial column support, and could be removed in the event of a future revision to a reverse shoulder arthroplasty.

Proximal humerus fractures (PHFs) are among the most common fractures in the elderly population, accounting for 5%-9% of all fractures.[1,2] Most cases are nondisplaced or minimally displaced and successfully treated nonoperatively with sling immobilization and physical therapy. Displaced fractures and those involving complex fracture patterns are indications for surgical management, which includes internal fixation, arthroplasty, and intramedullary nailing. In particular, open reduction with internal fixation (ORIF) using a locking plate has become an increasingly popular[3] treatment choice for displaced fractures. However, the existing literature does not reflect a consensus on its superiority compared to other surgical treatments or nonoperative management. Additionally, the frequency of complications associated with this surgical intervention including intra-articular screw penetration, implant failure, and varus collapse warrants further consideration as to how the application of locking plate technology for this fracture location can be improved to generate better outcomes. Support of the medial column, defined as radiographic evidence of anatomic reduction in the immediate postoperative period or the insertion of an oblique locking screw in the inferomedial proximal humeral head in one study,[4] has been shown to play an important role in maintaining fracture reduction when using a locking plate. Specifically, none of the 18 patients with evidence of medial support had a >5 mm loss of height of the humeral head, whereas 9 of 17 patients lacking medial support had >5 mm height loss ($P < .001$).

Several studies have explored the use of an endosteal construct to provide such additional support and stability. Notably, in a retrospective study of 38 patients with displaced PHFs treated using a locking plate and an endosteal fibular allograft, Neviaser et al[5] found that 37 of 38 patients maintained reduction and reported no instances of intra-articular screw penetration or any other significant complication requiring reoperation. Similar studies using endosteal fibular allografts[6,7] have reported low rates of loss of reduction, infection, and other complications. As with all bone allografts, incorporation into the surrounding host bone and remodeling occur gradually. Consequently, removal or revision

Institutional review board approval was not required for this study.

*Corresponding author: Timothy N. Nyangacha, BS, University of Minnesota, 4011 Zane Ave. North, Robbinsdale, Minneapolis, MN 55422, USA.
E-mail address: tnyangac@umn.edu (T.N. Nyangacha).

https://doi.org/10.1016/j.xrrt.2022.03.007
2666-6391/

(eg, to a reverse shoulder arthroplasty) for placement of the endosteal stem for humeral implant support becomes significantly more challenging over time. In addition, fibular allograft is not available in all countries and is expensive when it is available. A 2012 prospective clinical study[7] and another[8] in 2011 used a semitubular plate as the endosteal implant in a small subset of patients while primarily using fibular allograft but reported their findings using the 2 implant types in aggregate. Both studies remarked on the increased technical challenge when placing the locking screws through a semitubular plate compared to a fibular allograft.

Considering these challenges with fibular strut allograft and recognizing the importance of medial column support, we propose the use of a standard dynamic compression plate (DCP) as an endosteal implant in combination with a locking plate for patients with PHFs requiring surgical management. This idea was initially suggested by Dr. Dean Lorich during a 2014 visit to the senior author's institution[9] and modified by the senior author. The aim of this study is to investigate the functional and radiographic outcomes of patients with displaced PHFs treated with the locking plate technology augmented by a DCP endosteal implant.

Materials and methods

A retrospective case series study design was utilized, and the medical records of 4 patients with displaced PHFs treated operatively using the technique described between January 2019 and July 2021 were reviewed for this study. A stainless steel Zimmer proximal lateral locking plate (Zimmer Biomet, Warsaw, IN, USA) combined with a stainless steel Zimmer 3.5-mm endosteal DCP was used for 3 patients. A titanium Stryker VariAx locking plate (Kalamazoo, MI, USA) combined with a titanium Stryker 2.7-mm endosteal broad locking straight plate was used for 1 patient. Plate selection was per surgeon discretion based on what was available on the institutional implant formulary. The average follow-up duration was 62 ± 70.1 weeks (range, 12-161 weeks). Two of the patients were male, and 2 were female. The mean age of the patients was 52 ± 5.6 years (range, 44-57 years). Three of the fractures were a result of low-energy trauma due to a fall while the fourth fracture occurred following an high-energy impact. Using preoperative anteroposterior (AP) radiographs, all 4 cases were classified as 3-part fractures according to the Neer classification[10] of PHFs. Comminution and varus alignment were identified in 3 patients. One patient included in the study was treated using the technique described 3 weeks after an initial ORIF that was complicated by varus collapse and posterior screw penetration.

All procedures were conducted by a shoulder and elbow fellowship-trained orthopedic surgeon. Three of the procedures were performed by Jonathan Braman, and 1 by Michael Knudsen with the former serving as the surgical assistant. The average procedure duration was 147 ± 28 minutes (range, 107-174 minutes).

Patients were oriented in a beach chair position followed by appropriate sterile prepping and draping of the affected upper extremity. An anterior deltopectoral incision was made. The cephalic vein was identified and taken laterally. The subdeltoid space was then entered and mobilized. This was followed by biceps tendon tenodesis and opening of the rotator interval capsule. The axillary nerve was identified using the tug test periodically and protected throughout the case.

Mobilization of the fracture site to allow exposure of the humeral shaft was facilitated by #2 Fiberwire sutures placed through the bone tendon interfaces of the supraspinatus, infraspinatus, subscapularis, and teres minor. Using intraoperative fluoroscopic imaging, an appropriate endosteal plate was selected. The endosteal plate was then introduced into the proximal humeral shaft using a K-wire and positioned along the medial cortex of the humeral shaft. This was followed by insertion and fixation of a locking plate along the lateral cortex of the proximal humerus with sutures being passed through the plate. Tentative reduction was achieved. All 4 cases were further supplemented by crouton/morselized allograft into the cavitary humeral head defect and metaphysis to prevent sag. Intraoperative fluoroscopic AP and lateral images were taken at this time to confirm acceptable reduction and plate positioning. Then, the sutures were tied.

A distal, nonlocking bicortical screw was placed through the endosteal implant to keep it from migrating distally, and another was used to push the implant medially against the far medial endosteal surface of the humerus. This was followed by the insertion of additional screws in the humeral head to secure the lateral plate. Fluoroscopic AP and lateral images were obtained at this time point and during approach withdrawal to confirm that intra-articular screw penetration had not occurred. The surgical site was copiously irrigated, closed, and covered with sterile dressing.

Postoperatively, patients were placed in a sling with abduction. Supine gravity eliminated forward elevation, and passive external rotation exercises were initiated 1 week after surgery following radiographic confirmation of alignment. At 6 weeks postoperatively, patients began gentle, progressive 4-quadrant stretching, and the sling was discontinued. At 3 months postoperatively, patients began unrestricted 4-quadrant stretching, periscapular stabilization, and strengthening. Additional AP and lateral radiographs were taken at follow-up appointments occurring after 1 week, 6 weeks, and 3 months postoperatively (Fig. 1*A-C*).

The radiographic outcome of interest was humeral neck-shaft angle preoperatively, intraoperatively, and at the last follow-up. Using AP radiographs, the neck-shaft angle was defined as the angle formed by drawing a vertical line along the midline of the humeral shaft extending into the center of the humeral head and another from the center of the articular surface to the center of the humeral head.

Results

On average, patients had 135 ± 20 degrees of active forward flexion, 106.3 ± 48.7 degrees of active abduction, and 41 ± 21 degrees of active external rotation on the affected side at their 3-month follow-up. At the latest follow-up, patients had 150 ± 29.2 degrees of active forward flexion, 128.3 ± 58.4 degrees of active abduction, and 49.8 ± 26.0 degrees of active external rotation on the affected side.

All fractures healed without loss of reduction or neurovascular deficits. Avascular necrosis was not observed in the 2 patients with sufficient follow-up time to make such an evaluation. No deficits in axillary nerve function were observed preoperatively or postoperatively. One patient underwent arthroscopic removal of the proximal humerus plate and capsular resection at 1 year postoperatively after radiographic evidence of a single posterior screw penetration approaching the articular surface was observed at the 2-week follow-up. Another patient had radiographic evidence of varus alignment at the 3-month follow-up, which has not required reoperation to date.

The average preoperative neck-shaft angle was 104.8 ± 20.1°. The average intraoperative neck-shaft angle was 139.8 ± 6.2°. The average neck-shaft angle at the latest follow-up was 137 ± 4.5° (Table I). For the patient whose initial ORIF failed, the initial injury pattern was valgus; however, after a postoperative fall from standing, revision using our technique was required for a varus fracture pattern.

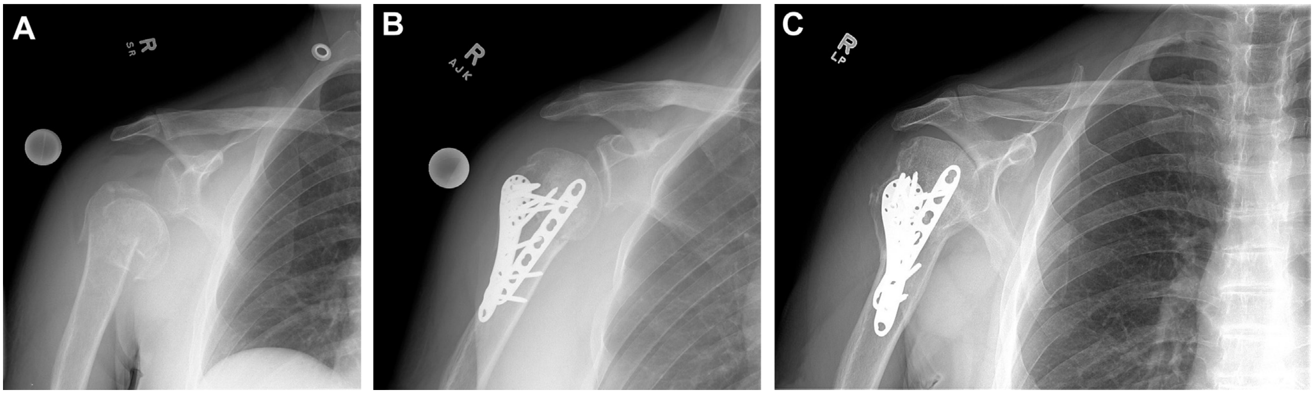

Figure 1 Preoperative (**A**), postoperative (**B**), and 13-month follow-up (**C**) anteroposterior radiographs of a displaced 3-part proximal humerus fracture.

Table I
Neck-shaft angles.

Variable	Mean ± SD (°)
Preoperative neck-shaft angle	104.8 ± 20.1
Postoperative neck-shaft angle	139.8 ± 6.2
Neck-shaft angle at latest follow-up	137 ± 4.5

Discussion

The proximal humerus is the fourth most common site for osteoporotic fracture, trailing fractures of the proximal femur, vertebrae, and distal radius in incidence.[11] Reduced bone mineral density and loss of compressive strength at this site with aging increase the risk of fracture and complicate clinical management. While PHFs are commonly treated nonoperatively, surgical treatment is indicated for displaced fractures, especially in cases involving osteoporotic bone and comminution. What remains unclear is whether surgical intervention generates better outcomes and fewer complications than nonoperative management. A 2015 multicenter, randomized clinical trial study[12] of 114 patients with displaced PHFs treated with surgical fixation compared to 117 patients treated nonoperatively found no significant differences in self-reported functional outcomes (Oxford Shoulder Score), complication rate (infection, symptomatic malunion, and avascular necrosis of the humeral head), or mortality between the 2 groups during a 2-year follow-up period. No statistically significant interaction was found between treatment group (surgical vs. nonsurgical) and fracture type according to the Neer classification, raising doubts regarding the effectiveness of surgical fixation even for severely displaced fractures. Similarly, a 2015 retrospective study[13] found no significant difference in functional outcomes (Constant and disabilities of the arm, shoulder and hand scores) between 44 patients with displaced PHFs treated with a locking plate and 25 patients treated conservatively regardless of fracture type. Other studies have reported overall complication rates[14] as high as 39% and a primary screw cut-out rate[15,16] of around 12% when using a locking plate for PHFs. Complications using this approach are the main contributor to reoperation rates ranging from 13%-29% in the literature.[14-16]

Recently, investigators have sought to enhance the use of locking plate technology for displaced PHFs with the insertion of an endosteal strut into the humeral shaft to provide greater medial columnar support[6,7] and a more stable fixation. This construct shortens the lever arm of the locking screws compared to a locking plate alone, potentially increasing its mechanical advantage and reducing the likelihood of varus collapse. In our retrospective study, we have aimed to report the functional/radiographic outcomes and complications of 4 patients with displaced 3-part PHFs treated using this surgical intervention as well as explore technical ways to facilitate screw passage through the endosteal plate and simplify the procedure.

While a considerable number of previous studies have investigated the use of an endosteal fibular allograft in tandem with a locking plate for displaced PHFs, there is no existing literature on the use of a DCP as the endosteal implant. In this case series study investigating this novel technique, we have found that using such a construct can provide stable anatomic reduction and restoration of physiologic alignment in a small number of patients with displaced PHFs. Specifically, the intraoperative and 3-month follow-up neck-shaft angles in our patients were comparable to those reported in a 2012 clinical series using endosteal fibular allografts.[7]

The use of a metal endosteal implant compared to a fibular allograft not only has similar mechanical advantages but also provides benefit in the event of a future revision to a reverse shoulder arthroplasty. Following humeral head resection, the metal implant could be removed prior to intramedullary insertion of the prosthetic stem into the humerus by loosening it with an osteotome. In addition, this preserves the medullary cavity. In contrast, fibular allograft incorporation would potentially preclude such a maneuver and require the surgeon to drill out the endosteal cavity, which could cause penetration of the cortex and thereby jeopardize humeral implant fixation. This scenario has yet to be explored in the literature.

Limitations of this study include a small sample size limiting statistical analysis and the absence of a control group. In addition, given that patient outcomes were associated with 2 surgeons, the external validity of the study is weakened. Lastly, range of motion in the contralateral shoulder was not consistently documented at every follow-up visit and could have served as an important comparator.

Conclusion

Surgical management of displaced PHFs using a locking plate with an endosteal DCP can be performed safely and provide lasting fixation. Further investigation is needed to evaluate the biomechanics of the construct, assess associated functional outcomes with greater granularity, and compare outcomes with other interventions indicated for this fracture type.

Disclaimers:

Funding: No funding was disclosed by the authors.

Conflicts of interest: Dr. Braman serves as a paid consultant for Zimmer Biomet. The other authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. Injury 2006;37:691-7. https://doi.org/10.1016/j.injury.2006.04.130.
2. Sporer SM, Weinstein JN, Koval KJ. The geographic incidence and treatment variation of common fractures of elderly patients. J Am Acad Orthopaedic Surgeons 2006;14:246-55. https://doi.org/10.5435/00124635-200604000-00006.
3. Bell JE, Leung BC, Spratt KF, Koval KJ, Weinstein JD, Goodman DC, et al. Trends and variation in incidence, surgical treatment, and repeat surgery of proximal humeral fractures in the elderly. J Bone Joint Surg Am 2011;93:121-31. https://doi.org/10.2106/JBJS.I.01505.
4. Gardner MJ, Weil Y, Barker JU, Kelly BT, Helfet DL, Lorich DG. The importance of medial support in locked plating of proximal humerus fractures. J Orthop Trauma 2007;21:185-91. https://doi.org/10.1097/BOT.0b013e3180333094.
5. Neviaser AS, Hettrich CM, Beamer BS, Dines JS, Lorich DG. Endosteal strut augment reduces complications associated with proximal humeral locking plates. Clin Orthop Relat Res 2011;469:3300-6. https://doi.org/10.1007/s11999-011-1949-0.
6. Gardner MJ, Boraiah S, Helfet DL, Lorich DG. Indirect medial reduction and strut support of proximal humerus fractures using an endosteal implant. J Orthop Trauma 2008;22:195-200. https://doi.org/10.1097/BOT.0b013e31815b3922.
7. Hettrich CM, Neviaser A, Beamer BS, Paul O, Helfet DL, Lorich DG. Locked plating of the proximal humerus using an endosteal implant. J Orthop Trauma 2012;26:212-5. https://doi.org/10.1097/BOT.0b013e318243909c.
8. Neviaser AS, Hettrich CM, Dines JS, Lorich DG. Rate of avascular necrosis following proximal humerus fractures treated with a lateral locking plate and endosteal implant. Arch Orthop Trauma Surg 2011;131:1617-22. https://doi.org/10.1007/s00402-011-1366-6.
9. Lorich D. Lecture presented at: University of Minnesota Department of Orthopedic Surgery grand rounds. 2014. Minneapolis, MN.
10. Neer CS 2nd. Displaced proximal humeral fractures. I. Classification and evaluation. J Bone Joint Surg Am 1970;52:1077-89.
11. Mantila Roosa SM, Hurd AL, Xu H, Fuchs RK, Warden SJ. Age-related changes in proximal humerus bone health in healthy, white males. Osteoporos Int 2012;23:2775-83. https://doi.org/10.1007/s00198-012-1893-1.
12. Rangan A, Handoll H, Brealey S, Jefferson L, Keding A, Martin BC, et al. Surgical vs nonsurgical treatment of adults with displaced fractures of the proximal humerus: the PROFHER randomized clinical trial. JAMA 2015;313:1037-47. https://doi.org/10.1001/jama.2015.1629.
13. Tamimi I, Montesa G, Collado F, Gonzalez D, Carnero P, Rojas F, et al. Displaced proximal humeral fractures: when is surgery necessary? Injury 2015;46:1921-9. https://doi.org/10.1016/j.injury.2015.05.049.
14. Faraj D, Kooistra BW, Vd Stappen WA, Werre AJ. Results of 131 consecutive operated patients with a displaced proximal humerus fracture: an analysis with more than two years follow-up. Eur J Orthop Surg Traumatol 2011;21:7-12. https://doi.org/10.1007/s00590-010-0655-z.
15. Jost B, Spross C, Grehn H, Gerber C. Locking plate fixation of fractures of the proximal humerus: analysis of complications, revision strategies and outcome. J Shoulder Elbow Surg 2013;22:542-9. https://doi.org/10.1016/j.jse.2012.06.008.
16. Thanasas C, Kontakis G, Angoules A, Limb D, Giannoudis P. Treatment of proximal humerus fractures with locking plates: a systematic review. J Shoulder Elbow Surg 2009;18:837-44. https://doi.org/10.1016/j.jse.2009.06.004.