RESEARCH ARTICLE

Early Clinical Outcomes of Polyaxial Locking Cap Plate Fixation for Fixation of Displaced Olecranon Fractures

Michael Jason Gutman, MD; Manan Sunil Patel, MD; James William Connelly, MD; Edward Scott Paxton, MD; Surena Namdari, MD; John Gabriel Horneff, MD

Research performed at the Rothman Orthopaedic Institute at Thomas Jefferson University Hospital in Philadelphia, PA and at Brown University, East Providence, RI, USA

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Abstract

Objectives: The purpose of this study is to evaluate the outcomes of a polyaxial locking plate utilizing locking-cap fixation for treatment of patients with displaced olecranon fractures.

Methods: A retrospective review was performed for all consecutive patients at two institutions with displaced olecranon fractures treated with a polyaxial locking plate. Patients were required to have at least 1-year follow up. Clinical outcomes including the Disabilities of the Arm, Shoulder, and Hand (DASH) score, Single Assessment Numeric Evaluation (SANE), along with a Likert-scaled satisfaction survey ranging between 1-5 (1= very unsatisfied and 5= very satisfied) were collected.

Results: The plate osteosynthesis was performed on 24 patients with displaced olecranon fractures. Functional outcome scores were collected on 19 (79.2%) patients. The mean age at the time of surgery was 57.9 years (range, 23 to 78) and mean clinical follow-up was 21.0 ± 6.6 months (range, 12-34 months). All patients achieved osseous union in an acceptable position. Four (16.7%) patients complained of plate related pain and 6 (25%) patients complained of postoperative stiffness. Complications were found in 3 (12.5 %) patients, which included two neuropathies and one hardware failure in which a patient presented following a fall with a broken screw. No patients required revision surgery nor removal of hardware. A total of 16 (84%) patients were somewhat to very satisfied. The mean SANE score was 87.8 ± 14.6 (range: 45-100) and the mean DASH score was 13.8 + 17.5 (range: 0-55.8). Seventeen (89%) patients rated their elbows as 75% or better on SANE assessment and 16 (84%) patients achieved DASH scores of less than 30.

Conclusion: Polyaxial plate fixation utilizing locking-cap technology resulted in excellent short-term functional outcomes in patients with displaced olecranon fractures. Further follow-up is needed to determine the long-term outcomes of locking-cap constructs for olecranon fractures.

Level of evidence: IV

Keywords: Clinical outcomes, Elbow fractures, Elbow surgery, Locking cap, Locking plate, Mayo classification, Olecranon fracture, Polyaxial

Introduction

Olecranon fractures account for about 10% of all upper extremity fractures.[1] These fractures often require internal fixation due to the proximally directed pull of the triceps attachment causing fracture distraction. Traditionally, tension band wiring (TBW) has been considered the gold standard treatment for these fractures. However, use of the TBW is often limited to transverse fracture patterns without comminution.[2]

Corresponding Author: John Gabriel Horneff, Clinical Orthopaedic Surgery, Shoulder & Elbow Division, University of Pennsylvania, Philadelphia, Pennsylvania, USA

Email: jghorneff3@gmail.com

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Advances in locking plate technology have demonstrated improved outcomes compared to TBW and are better suited for oblique fractures, comminuted fractures, and fractures associated with dislocation.[3–5] Modern locking technology allows for polyaxial locking of screws into a plate. Previous studies have demonstrated the advantage of the locking cap design by allowing for more angulation of screw trajectory without increased risk of screw fatigue.[6] Such characteristics could prove advantageous in fractures of the olecranon where variability in fracture pattern often limit fixation options.

The purpose of this study is to evaluate the radiographic findings, postoperative clinical outcomes, and complication rates in patients who underwent open reduction and internal fixation for olecranon fractures with a polyaxial locking plate.

Materials and Methods

Patient Selection and Data Collection

Following institutional review board approval (IRB # 19D.712), a retrospective review was performed for all consecutive patients with displaced olecranon fractures treated with a polyaxial locking-cap Olecranon Plating System (Miami Device Solutions, Miami, FL) Figure 1 at two institutions with at least 1-year clinical follow-up [Figure 1]. Patients concomitant distal humerus or radial head fractures were excluded. Patients were treated by one of three fellowship-trained shoulder and elbow surgeons. Twenty-four consecutive patients with olecranon fractures were treated with this technique between August 30, 2017 and November 30, 2019. Chart review was performed to collect age, gender, hand dominance, body mass index (BMI), mechanism of injury, medical comorbidities, Charlson Comorbidity Index (CCI), and smoking status. Operative reports were analyzed to confirm screw number and the use of triceps suture augmentation. Patients had radiographs taken preoperatively, immediately postoperatively, and at latest clinical follow-up (minimum 3-months postoperatively). Radiographs were assessed by a fellowship-trained shoulder and elbow surgeon (C.J.S). The initial postoperative radiographs were assessed for adequate reduction. Patients with 0 mm of articular step offs on postoperative radiographs were determined to have complete reduction, while patients with articular step off less than 2mm were considered to have adequate reduction. The last postoperative radiographs were assessed for osseous union, heterotopic ossification, and hardware failure. The reviewer (C.J.S) was blinded to the patient's current elbow functional scores.

To assess clinical outcomes, patients charts were reviewed for range of motion at a minimum of 3-months postoperatively, and all patients were contacted for functional scores, complications, and revision surgeries via REDCap surveys.[7] The survey was composed of Single Assessment Numeric Evaluation (SANE) and Disabilities of the Arm, Shoulder, and Hand (DASH) surveys, along with a Likert-scaled satisfaction survey ranging between 1-5 (1= very unsatisfied and 5= very satisfied).

Description of Surgical Technique

A tourniquet was elevated to 250 mmHg. A longitudinal, posterior incision was made and curved laterally around the olecranon tip and dissection was carried down through skin and subcutaneous tissues to the fascia at the level of the triceps tendon. The medial and lateral skin flaps were elevated. Any hematoma present was evacuated. After debridement of the fracture site, the fracture was reduced and provisionally held with reduction clamps and/or Kirschner wires (K-wires). The triceps was split in order to allow for placement of the plate against the bone. The appropriately sized olecranon plate was applied and held in place by K-wires. Typically, a single distally aimed longitudinal bicortical screw was first placed in a proximal hole aiming towards the coronoid. This initial screw was placed in polyaxial locking fashion with a goal of achieving bicortical fixation into the coronoid and compression of the plate to the bone. Bicortical nonlocking screws were placed distally, and reduction was confirmed with a C-arm. Proximal fixation was completed with 1 or 2 additional bicortical or unicortical screws, based on the fracture pattern. All proximal screws were locked with locking caps. Multiple fluoroscopy views were utilized to confirm fracture reduction and hardware position. The wound was irrigated. In all patients, the triceps was repaired in a side-to-side fashion with #2 non-absorbable suture. In situations when the surgeon felt triceps suture augmentation was needed, a #2 non-absorbable suture was passed through the plate distally and through the triceps proximally to create a tension-band stitch. A layered wound closure was then performed. The patient was then placed in a posterior based splint for 1-2 weeks or a hinged brace at 75°. At the initial postoperative visit, occupational therapy was initiated to improve active and passive range of motion with the goal of reaching full flexion and extension to do activities of daily living at 6-7weeks postoperatively. At 7-8 weeks, patients began strengthening with a goal of returning to activity as tolerated at 3 months postoperatively.

Figure 1. Miami Device Solutions Olecranon Plating System

Statistics

This was a descriptive study in which all continuous data is provided as means with standard deviations (SD) and ranges, and all qualitative data is presented with counts and percentages. All statistical analysis was carried out on Statistical Package for the Social Science (SPSS) version 26 (IBM Corp., Armonk, NY). Statistical significance was defined at p-value of <0.05 for all output.

Results

In the 24 patients meeting inclusion criteria, the mean age was 57.9 years (range, 23 to 78) at the time of surgery [Table 1]. Functional outcomes were collected for 19 patients (79.1%) with a mean follow-up of 21.0 ± 6.6 months (range, 12-34 months). One patient declined to participate and four were unable to be contacted.

Table 1. Pre-operative and intra-operative demographic data (N=24)

	Mean ± SD	Range
Age (years)	57.9 ± 15.5	23.0 - 78.0
BMI (kg/m^2)	26.0 ± 6.1	18.0 - 45.0
CCI (Age adjusted)	2.2 ± 1.8	0.0 – 5.0
Gender	15F, 9M	
Hand Dominance	3L, 21R	
No. with History of Tobacco use (%)	10 (41.7)	
No. with History of Opioid use (%)	1 (4.1)	
No. with History of Alcohol use (%)	9 (37.5)	
No. Worker's Compensation (%)	3 (12.5)	
Laterality	15L, 9R	
Number of screws per plate	5.9 ± 1.1	4 – 8
Concomitant Injuries (%)	5 (20.8)	
Proximal ulna fracture (%)	1 (4.1)	
Monteggia fracture (%)	1 (4.1)	
Sacral fracture (%)	1 (4.1)	
Hip fracture (%)	1 (4.1)	
Proximal humerus fracture	1 (4.1)	

SD, Standard deviation; BMI, Body mass index; CCI, Charlson comorbidity index; L, Left; R, Right; M, Male; F, Female

Eighteen (75%) patients achieved anatomic reduction and six (25%) had near anatomic reduction in the operating room. Bicortical fixation was successfully achieved with at least one proximal screw for all but one patient (95.8%). In the proximal aspect of the plate, two polyaxial screws were placed for all patients. Each polyaxial plate was secured with an average of 6 ± 1 screws placed in the plate (range: 4-8). 10 patients (41.6 %) underwent triceps suture augmentation. Postoperatively, patients had a mean extension deficit of 6º (range, 0º-30º) and a mean flexion of 137º (range, 105º-150º). The arc of rotation of the forearm was from a mean supination of 86º (range, 80º to 90º) to a mean pronation of 86º (range, 80º -90º) [Table 2]. Four (16.7%) patients complained of plate-related pain and six (25%) patients complained of postoperative stiffness [Table 3]. Complications were found in three (12.5%) patients, which included two neuropathies and one hardware failure in which a patient with a healed fracture presented following a fall with a broken screw. In the two patients that developed neuropathies, both patients did not have any prominent hardware or unique fracture characteristics. One patient developed complex reginal pain syndrome and subsequently required an ulnar release as part of the treatment. One patient developed radial neuropathy during anesthesia prior to surgery which never resolved after surgery. No patients required revision surgery or had removal of hardware. At final radiographic follow up, 24 (100%) patients achieved osseous union [Figure 2].

Table 2. Post-operative range of motion (N=24)

	Mean ± SD	Range
Latest Follow Up (months)	17.7 ± 9.5	3 - 34
Elbow ROM		
Flexion (º)	137.5 ± 8.6	105 - 150
Extension (º)	5.7 ± 8.6	0 - 30
Pronation (º)	86.3 ± 4.9	80 - 90
Supination (º)	86.2 ± 4.9	80 - 90

SD, Standard deviation; ROM, Range of Motion

Table 3. Postoperative complications (n=24)

Complications (%)	3 (12.5)
Neuropathy (%)	2 (8.3)
Broken Screw After Fall	1 (4.2)
Infection (%)	0
HO (%)	0
Reoperation (%)	0
Plate Pain (%)	4 (16.7)
Stiffness (%)	6 (25)

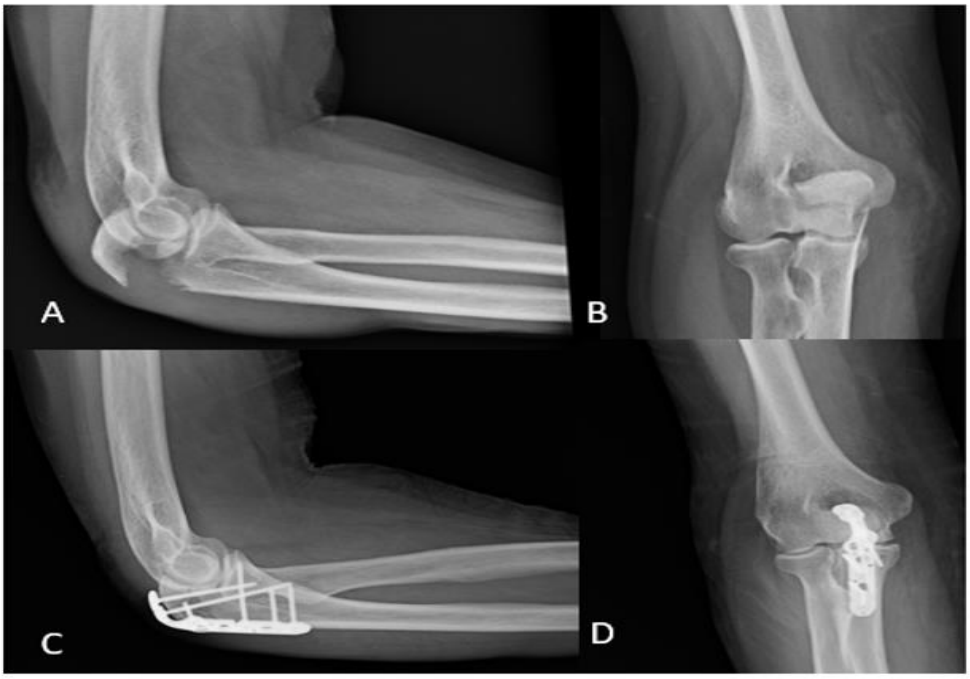

Figure 2. Preoperative Lateral (A) and Anteroposterior (B) and Postoperative (C&D) Radiographs of a Displaced Olecranon Fracture Treated with Polyaxial Locking Cap Plate Fixation

The majority of patients had excellent functional outcomes. A total of 16 (84.2%) patients were somewhat to very satisfied with their outcome. The mean postoperative SANE score was 87.8 ± 14.6 (range: 45-100) and the mean postoperative DASH score was 13.8 ± 17.5 (range: 0-55.8) [Table 4]. Seventeen (89.4%) patients rated their elbows as 75% or better on SANE assessment and 16 (84.2%) patients achieved DASH scores of less than 30. In the 2 patients with SANE scores below 75, one of them developed ulnar neuropathy postoperatively. There was no difference in SANE (*P=0.669*) or DASH (*P=0.666*) scores between males and females. There was also no difference in SANE (*P=0.563*) or DASH (*P=0.325*) scores among patients with complete anatomic reduction compared to those that had near anatomic reduction in the operating room. Lastly, there was no difference in SANE (*P=0.702*) or DASH score (*P=0.351*) between patients with Mayo 1, 2, and 3 fractures.

Table 4. Post-operative patient reported outcomes (N=19)

	Mean ± SD	Range
Latest Follow up (months)	21.0 ± 6.6	12.0 - 34.0
Satisfaction	4.6 ± 0.9	2.0 - 5.0
SANE	87.8 ± 14.6	45.0 - 100.0
DASH	13.8 ± 17.5	0.0 - 55.8

SD, Standard deviation; SANE, Single assessment numeric evaluation score; DASH, Disabilities of the arm, shoulder and hand

Discussion

Displaced olecranon fractures are associated with many different fracture patterns and are commonly difficult to treat. Polyaxial plate fixation with locking-cap technology allows for sufficient fixation of displaced small fracture fragments that may be insufficiently captured by a standard cross-threaded (CT) locking plate design or by TBW. In this study, most patients had excellent outcomes in range of motion (flexion: 137°) and functional outcomes (DASH: 13.8) at short term follow-up of at least 1-year. Furthermore, patients had excellent outcomes regardless of their fracture pattern. Although polyaxial plate fixation is especially advantageous with displaced comminuted olecranon fractures, they are also useful for management of simple fracture patterns. Moreover, the high rate of osseous union combined with great functional outcomes and low rates associated residual plain associated with retained hardware make the polyaxial locking-cap Olecranon Plating System an excellent option for management of olecranon fractures. The outcomes of this study can be attributed to the low-profile design of the polyaxial plate. Additionally, the locking-cap construct allows for more flexibility in plate position and increased screw angulation that cannot be achieved with standard CT locking plates.[6,8–15] Biomechanical studies have demonstrated that plate fixation utilizing locking cap technology allows for greater screw angulation with decreased risk of screw fatigue, making it especially advantageous for displaced and comminuted fractures.[6] This was seen in our study, where only 1 patient (4.1%) experienced screw loosening at an acute event.

Surgical management of olecranon fractures is commonly performed with plate fixation or TBW.[16–18] Biomechanical studies have demonstrated that plate fixation provides

better fracture compression than TBW.[19,20] Duckworth et al performed a randomized control trial comparing non-locking plate fixation to TBW in patients with simple displaced olecranon fractures.[4] The clinical outcomes were comparable between the two methods. Patients DASH scores for TBW were 12.8 compared to 8.5 in non- plate fixation (P=0.315).[4] While TBW is a viable option for simple fractures, it is not for complex and highly comminuted fractures due to insufficient reduction and compression.[18,21] Additionally, TBW is associated with higher rates of symptomatic hardware.[22] Furthermore, locking screws during plate osteosynthesis allows for improved fixation of small fragments.[23,24] Recent studies have shown excellent outcomes using polyaxial locking plates with average DASH scores ranging from 6-17.[23,25,26] In our study, the patients had similar outcomes with a mean DASH Score of 13.8.

Previous studies with TBW have reported loss of reduction rates as high as 53%.[2] In this case series, fracture reduction was successfully maintained in all patients. Zero patients developed osseous non-union or required reoperation. This is consistent with studies using other polyaxial plating systems.[25] Additionally, complication rates were low in this study. Out of the three patients that had complications, one patient developed a neuropathy preoperatively from anesthesia while a second patient developed an ulnar neuropathy postoperatively. The patient with ulnar neuropathy had a satisfaction score of 2, and SANE and DASH scores of 45 and 55, respectively. Although ulnar nerve palsy is an uncommon complication after olecranon open reduction internal fixation (ORIF), it often leads to inferior outcomes.[25,27] Only one patient had a screw break, which occurred due to a trauma, rather than cyclic screw fatigue. Additionally, extension deficits are common after olecranon fractures.[28] In this study, the average extension deficit was 6°. This is slightly better than other studies using polyaxial plating systems where the average extension deficits ranged from to 10- 13°.[25,29,30] Klug et al found that after plate removal, there was significant improvement in extension deficit from 10° to 5°, but there was no significant improvement in functional scores.[25]

In previous studies, the rate of removal of hardware with TBW and conventional plate fixation were as high as 82% and 62.5%, respectively.[31,32] Recent studies have shown that the rate of removal of polyaxial locking plate fixation for olecranon fractures ranges from 11-47%.[25,26] The rate of hardware removal was significantly lower in this study compared to prior studies, in which, none of the patients had their polyaxial plate removed at the conclusion of this study. The shorter duration time of this study may have contributed to the decreased incidence of removal of hardware. However, in prior studies, the mean time of locking plate removal ranged from 12 to 16 months on average.[25] Since the mean follow-up time in this study was 21.0 months (range: 12-34 months), it is unlikely that many of the plates in this study will be removed in the future. In this study, three of the four patients with plate related pain were offered to have the plate removed at one year postoperatively but the patients felt that the pain level was mild and did not wish to undergo an additional operation. The decreased incidence of plate removal makes this polyaxial locking system advantageous since it minimizes the potential risks associated with reoperation. The lower incidence of plate removal in this study makes the MDS polyaxial plate useful in both comminuted olecranon fractures that require a polyaxial plating system and non-comminuted fractures that could be fixed with a standard locking plate.

Posterior locking plate fixation with the addition of an intramedullary screw provides the most stable fixation method and has resulted in excellent functional outcomes. However different manufacturers have created different polyaxial plate designs which differ in the methods in which the polyaxial screws are secured to the plate.[6,25,26,33] The most common methods are locking-cap fixation and cross threaded systems allowing for variable-angle screw fixation. A biomechanical study demonstrated better stability with polyaxial systems utilizing locking-cap technology compared to other variable-angle plate fixation systems, since it is less susceptible to screw fatigue.[6] However, the clinical superiority of plate osteosynthesis with locking-cap fixation compared to variable-angle plate fixation are less clear. The functional outcomes in this study using a polyaxial locking plate with locking caps were comparable to the variable-angle plate fixation systems used in prior studies.[25,26] 84% of patients in this study were either somewhat or very satisfied, and the mean flexion was 137°, with zero patients developing nonunion. A randomized control trial is needed to properly compare the long-term functional outcomes between polyaxial plates utilizing locking-cap technology and other variable-angle designs for olecranon fractures.

This study is not without its limitations. Our case series only included a follow up rate of 79% of patients. In addition, the limited numbers in this series does make it difficult to extrapolate any significant differences in outcomes based on fracture pattern. However, this case series is the largest to date describing olecranon fixation with polyaxial locking plate with a locking cap mechanism. While biomechanical studies have shown polyaxial plate fixation with locking caps to be advantageous over other variable-angle locking constructs, a randomized control study is needed to evaluate the optimal polyaxial locking plate treatment option.

Conclusion

Polyaxial locking plate fixation with a locking cap design for patients with displaced olecranon fractures resulted in excellent short-term functional outcomes, excellent osseous union, and low rate of reoperation or plate removal. Further follow up is needed to determine the rates of plate removal and the long-term outcomes for these patients.

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Authors Contribution:

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Michael Jason Gutman MD [1]
Manan Sunil Patel MD [1]
James William Connelly MD [2]
Edward Scott Paxton MD [2]
Surena Namdari MD [1]
John Gabriel Horneff MD [3]

1 Rothman Orthopaedic Institute at Thomas Jefferson University Hospital, Philadelphia, Pennsylvania, USA
2 Brown University, East Providence, Rhode Island, USA
3 Clinical Orthopaedic Surgery, Shoulder & Elbow Division, University of Pennsylvania, Philadelphia, Pennsylvania, USA

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