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Clinical Evaluation of Locking Compression Plate Fixation for Comminuted Olecranon Fractures

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Background: In patients managed with plate fixation for the treatment of an olecranon fracture, the placement of an axial intramedullary screw may obstruct the placement of bicortical screws in the ulnar shaft. To overcome this problem, unicortical screws can be applied with use of a contoured locking compression plate. The present study was designed to assess the effectiveness of this fixation method.

Methods: Nineteen consecutive patients with an acute comminuted olecranon fracture were managed with a contoured locking compression plate and intramedullary screw fixation. Sixteen patients were available for follow-up at a minimum of twelve months after fixation. Patient-based outcomes were assessed, and patient satisfaction and pain were evaluated.

Results: All nineteen fractures healed. The mean time to fracture union was four months. The mean Disabilities of the Arm, Shoulder and Hand score was 13. According to the Mayo Elbow Performance Index and the Broberg and Morrey grading system, fifteen of the sixteen patients with at least one year of follow-up had a good or excellent outcome. Nine patients underwent hardware removal at a mean of twelve months postoperatively. The mean elbow extension deficit in these patients improved significantly from 34° to 10° following hardware removal. The mean flexion improved from 118° to 138°, but this difference was not significant.

Conclusions: In the treatment of comminuted olecranon fractures, a contoured locking compression plate combined with an intramedullary screw provides sufficient stability for early postoperative functional rehabilitation, with an excellent fracture union rate and very good clinical outcomes.

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

Olecranon fractures comprise 10% of all upper extremity fractures¹. Noncomminuted transverse fractures with articular displacement are the most common type. After reduction, they can be effectively stabilized with tension band wiring². Comminuted fractures of the olecranon, especially those involving the coronoid process and those associated with a trans-olecranon fracture-dislocation, often require plate fixation because tension band fixation cannot provide enough stability to allow early postoperative motion of the elbow. In addition, plate fixation lowers the risk of fatigue failure caused by extreme bending stresses³.

Since 1883, there have been many reports on plate fixation of comminuted olecranon fractures, with variable results, as noted by Hak and Golladay in a review article⁴. Plate fixation is the current gold standard for the treatment of these frac-

tures⁴⁻⁷. Contoured plating of the olecranon, in which the proximal end of the plate is wrapped around the tip of the olecranon, leads to good results when used for the treatment of oblique fractures⁷⁻¹². Because of the contoured shape of the plate, orthogonal screw fixation can be used to augment this construct. The AO group recommends the use of a 3.5-mm metaphyseal locking compression plate with a proximal cortical lag screw and bicortical screw fixation³. Recently, the biomechanical advantage of using an intramedullary screw in combination with conventional plating and bicortical screw fixation has been reported¹³. This intramedullary screw can be applied in combination with the locking compression plate and acts as an internal splint, analogous to an intramedullary nail, providing more support for the construct. The placement of an intramedullary screw, however, may obstruct the placement of bicortical screws in the

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ulnar shaft. To overcome this problem, unicortical locking screws can be used instead. Unlike conventional plates, the locking compression plate allows for the placement of unicortical locking screws, which have been reported to significantly increase the rigidity of unicortical screw-plate systems in comparison with standard unicortical screws, which can toggle in the screw hole of the plate^{14,15}. To our knowledge, the use of the locking compression plate for the treatment of olecranon fractures has not been reported previously. The purpose of the present study was to evaluate the results of locking compression plate fixation when combined with an intramedullary screw in a consecutive series of patients with a comminuted olecranon fracture. The results were evaluated with use of validated outcome scores.

Materials and Methods

Between 2005 and 2007, nineteen consecutive patients with an acute comminuted olecranon fracture were managed with a titanium 3.5-mm locking compression plate (LCP; Synthes, Zeist, The Netherlands) by the senior author (P.K.). The fixation technique consisted of contoured dorsal locking compression plate fixation with a proximally inserted 3.5-mm intramedullary screw and a minimum of two unicortical locking screws distal to the fracture (Figs. 1-A, 1-B, and 1-C). Our medical ethics committee approved the study protocol. All patients gave consent to participate in the present study and were followed at regular intervals at least until the time of osseous healing, defined as the presence of crossing trabeculae on both anteroposterior and lateral radiographs. Fracture union was assessed by the treating physician (P.K.) and a radiologist.

All patients were invited to return for assessment of the elbow at a minimum duration of follow-up of twelve months, and sixteen patients returned after a mean duration of follow-up of twenty-two months (range, twelve to forty-eight months). At the time of the latest follow-up, the ranges of motion of the elbow and forearm, varus-valgus instability, nerve injury, and physician-rated forearm strength were assessed by an independent evaluator (G.B.) who was not involved in the initial treatment and rehabilitation. Forearm strength was rated subjectively with use of a 6-point Likert scale ranging from 0 (no contraction) to 5 (normal strength). Patients rated the outcome with use of the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire¹⁶, the Mayo Elbow Performance Index (MEPI)¹⁷, the Broberg and Morrey rating system¹⁸, and 10-point visual analog scales for patient satisfaction and pain. Furthermore, anteroposterior and lateral radiographs were evaluated by an independent radiologist and arthritis was graded by an experienced elbow surgeon who was not involved in their care. Arthritis was classified according to the system of Broberg and Morrey¹⁹ as Grade 0 (normal joint), Grade 1 (slight joint-space narrowing with minimal osteophyte formation), Grade 2 (moderate joint-space narrowing with moderate osteophyte formation), or Grade 3 (severe degenerative change with gross destruction of the joint). Finally, the results of the study were analyzed by an independent data analyst (G.B.). Statistical analysis of the measurements of the range of motion of the elbow before and after hardware removal was

performed with a paired t test, with the level of significance set at $p < 0.05$.

Source of Funding

Stichting Wetenschappelijk Onderzoek Orthopaedische Chirurgie (Foundation for Scientific Research in Orthopaedic Surgery) provided financial support for the materials (e.g., radiographs) used in this study.

Results

The study group included eleven women and eight men with an average age of fifty-six years (range, nineteen to eighty-seven years). There were nineteen acute fractures (including four Monteggia fractures), two of which were open and were classified as Gustilo-Anderson grade II²⁰. The coronoid process was involved in five patients, all of whom had a type-3 fracture according to the system of Regan and Morrey²¹. Two patients had a posterior fracture-dislocation, and one had an anterior trans-olecranon fracture-dislocation. Nine fractures involved the right upper extremity, and ten involved the left. According to the AO system, there were four extra-articular fractures (type A), including one multifragmentary metaphyseal ulnar fracture (type A1.3) and three multifragmentary metaphyseal ulnar fractures with a simple proximal radial fracture (type A3.2); fourteen intra-articular proximal ulnar fractures (type B), including three multifragmentary olecranon fractures (type B1.1), four simple fractures of both the olecranon and the coronoid process (type B1.2), and seven multifragmentary combined intra-articular and extra-articular ulnar fractures (type B1.3); and one multifragmentary fracture involving the proximal parts of both the ulna and radius (type C3.1). The mechanism of injury was a fall from a height for thirteen patients, a bicycle accident for three patients, a motorcycle accident for two patients, and physical abuse for one patient. The mean interval between the injury and operative treatment was three days (range, zero to eight days).

Bone graft was used in two patients because of severe impaction of the articular surface. Local graft was used in one patient, and an iliac crest bone graft was used in the other. In one patient, a cerclage wire loop was used to stabilize the comminuted medial and lateral metaphyseal walls because there was not enough bone proximally for a small buttressing plate. Two patients had a radial head fracture. One was managed nonoperatively, and the other underwent radial head excision and the placement of a radial head prosthesis.

All fractures healed. The mean time to union was four months (range, two to nine months). Complications occurred in two patients: one patient had a wound infection that resolved after débridement and treatment with antibiotics, and one patient had a preoperative ulnar and median neuropathy that did not resolve. Three patients were lost to follow-up: one was incarcerated and exiled, one died of unrelated causes, and one had development of severe Alzheimer disease. These patients were followed at least until osseous union, for a mean of three months (range, two to four months), but did not have additional assessments.

For the remaining sixteen patients, the postoperative arc of flexion at the time of the latest follow-up was from a mean

Fig. 1-A

Fig. 1-B

Fig. 1-C

Fig. 1-A Lateral radiograph showing a comminuted olecranon fracture (AO type B1.3). (Reprinted, with permission, from: Buijze GA, Maas M, Kloen P. Fixatie van complexe olecranonfracturen met de Locking Compression Plate. *Ned Tijdschr Traum.* 2007;15:50-3.) **Fig. 1-B** A contoured locking compression plating was applied, and the coronoid fragment (classified as type 3 according to the system of Regan and Morrey²¹) was fixed with a bicortical screw aimed toward the tip of the coronoid. (Reprinted, with permission, from: Buijze GA, Maas M, Kloen P. Fixatie van complexe olecranonfracturen met de Locking Compression Plate. *Ned Tijdschr Traum.* 2007;15:50-3.) **Fig. 1-C** At twenty-three months, the hardware had been removed and the functional result was excellent.

extension deficit of 13° (range, 0° to 50°; median, 10°) to a mean flexion of 136° (range, 120° to 150°; median, 140°). The arc of rotation of the forearm was from a mean supination of 71° (range, 10° to 80°; median, 80°) to a mean pronation of 74° (range, 10° to 80°; median, 80°). None of the patients had elbow instability. Forearm strength was rated as normal in thirteen patients, as 4 of 5 (movement against resistance) in two patients, and as 3 of 5 (movement against gravity) in one. In seven patients, the injury involved the dominant arm.

The mean DASH score was 13 (range, 0 to 42), with 0 representing a perfectly functioning arm and 100 representing the worst score. The mean MEPI score was 93 (range, 70 to 100), with higher scores indicating better function; according to this system, twelve patients had an excellent result, three had a good result, and one had a fair result. The average Broberg and Morrey score was 93 (range, 45 to 100); according to this system, nine patients had an excellent result, six had a good result, and one had a fair result. Extensive heterotopic ossification, grade-3 osteoarthritis, and a lack of postoperative functional exercises were the major causes of the severely decreased forearm motion that produced the one fair result. The mean visual analog scale pain score was 1.0 (range, 0 to 4), with 0 correlating with no pain and 10 correlating with the worst pain. The average visual analog scale satisfaction rating was 8.8 (range, 4 to 10), with 10 representing complete satisfaction. The two unsatisfactory ratings for satisfaction (4 and 5) were due to severe ulnar neuropathy in the case of one patient and higher expectations in the case of one patient. Radiographs that were made at the time of the latest follow-up confirmed articular congruity in all cases. Ulnohumeral osteoarthritis was present in seven of the sixteen patients, including five with a Broberg and Morrey grade of 1 and two with a grade of 3. Nine patients underwent hardware removal as outpatients at a mean of twelve months (range, five to eighteen months) postoperatively because of pain at the site of the hardware. After hardware removal, the mean elbow extension deficit in these patients improved significantly ($p < 0.05$) from 34° (range, 5° to 80°) to 10° (range, 0° to 50°). The mean flexion improved from 118° (range, 90° to 140°) to 138° (range, 120° to 150°), but this difference was not significant. No capsular release or manipulation with the patient under anesthesia was performed.

Discussion

The aims of operative treatment of comminuted intra-articular olecranon fractures are realignment of the longitudinal axis, restoration of joint stability, articular congruity, normal strength, and a pain-free functional arc of motion of the elbow. Postoperatively, immediate functional rehabilitation of the elbow is essential given that immobilization after an injury, even for a period of as short as three weeks, has been shown to adversely affect the range of motion of the elbow and the functional outcome^{22,23}. Therefore, stable fixation is important. Furthermore, long-term reliability of plate fixation is crucial because extreme bending stresses at the proximal part of the ulna occasionally can lead to fatigue failure of internal fixation devices^{9,12}.

To our knowledge, locking plate technology combined with an intramedullary screw has not been evaluated for the treatment of olecranon fractures. The locking compression plate differs substantially from similar devices in that it allows for the insertion of distal unicortical locking screws. Unlike bicortical screws, unicortical screws do not impede the placement of a long intramedullary screw to augment the construct¹³. In the present case series, we found the locking compression plate fixation technique to be a secure and effective treatment option as it led to a 94% rate of good or excellent results, with no instances of construct failure, nonunion, or major complications after a mean duration of follow-up of nearly two years. The main complication encountered was hardware prominence, especially when the patient leaned on a table; this complication necessitated hardware removal in most cases.

Our findings are comparable with those reported in previous studies of olecranon plating. Anderson et al. reported on thirty-two patients who were managed with congruent plate fixation for the treatment of olecranon fractures, nine of which were comminuted¹². That type of plate has several differences from the locking compression plate. It does not have locking capability, and therefore it requires bicortical screw fixation. Moreover, a proximal “home run” screw is positioned through the coronoid process, instead of the longer intramedullary screw that is used in our technique. In the study by Anderson et al., 92% of the patients had a good or excellent result, but among the patients with a comminuted olecranon fracture the mean DASH score (26) and mean MEPI score (88) were slightly less favorable than the scores in our patients. Anderson et al. reported one case of construct failure and a much lower rate of plate removal (9.3%) as compared with that in our series (56%).

Bailey et al., in a retrospective study, reported on the use of plate fixation for sixteen patients with comminuted olecranon fractures¹¹. After a mean duration of follow-up of three years, 94% of the patients had a good or excellent outcome and the mean DASH and MEPI scores were 11 and 88, respectively. No significant relationship between functional outcome and fracture patterns was found. Finally, Simpson et al.⁹ reported a good or excellent result for twenty-seven (73%) of thirty-seven comminuted olecranon fractures that were treated with contoured low-contact dynamic compression plating.

The average arc of elbow motion in those studies^{9,11,12} ranged from 107° to 130° of flexion to 9° to 14° of extension deficit, and postoperative motion was therefore comparable with that in our series. However, in those reports, a substantial proportion of patients (as many as 26%) had an extension deficit of ≥30°. In the present series, such a deficit was present in three (19%) of sixteen patients. Severe limitation in extension and hardware prominence are the two most commonly reported complications following plate fixation of olecranon fractures.

Nine (56%) of sixteen plates in the present series were removed because of pain in the elbow when the patient leaned on a table. This rate was considerably higher than the rates in most other studies, in which the plate removal rate has ranged from 0% to 20%^{9,11,12,24,25}. A possible explanation is that the locking compression plate does not contour closely to the

bone, although it has been our experience that patients are inconvenienced by the implant regardless of how well it is contoured to the bone. Long-term follow-up studies on tension band fixation for the treatment of olecranon fractures have shown rates of hardware removal of >80%²⁶⁻²⁸. Furthermore, at some institutions, hardware removal has even been considered as routine practice²⁸. In our series, the mean elbow extension deficit improved significantly from 34° to 10° after plate removal. Limited extension may have been caused by the proximal part of the plate, although none of the patients had radiographic signs of hardware impingement with the elbow in extension. Nevertheless, when applying this plate, the surgeon should be sure that impingement in the olecranon fossa does not occur when the elbow is extended.

The limitations of the present study include its retrospective nature, the small number of patients, and the relatively short duration of follow-up. As osteoarthritis develops over the course of many years, no conclusions can be drawn from the present series with regard to the rate and severity of ulno-

humeral osteoarthritis. Nonetheless, the present study had several strengths, such as the inclusion of consecutive patients and the use of multiple validated patient-based assessment scores. In summary, this method of fixation of comminuted olecranon fractures seems to provide enough stability to allow for the early start of postoperative functional rehabilitation with a predictably high rate of fracture-healing. ■

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