Use of Fine-threaded K-wires in the Treatment of Coronoid Fractures in Complex Elbow Instability

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abstract

Full article available online at Healio.com/Orthopedics. Search: 20130920-12

The coronoid process is one of the main elbow constraints that provides ulnohumeral joint stability. Coronoid fractures may be fixed using multiple techniques, including transosseous sutures, screws, and plates. The goal of this study was to analyze the clinical and radiographic outcomes in a series of patients with complex elbow instability in whom coronoid fractures were repaired using fine-threaded K-wires.

Eight men and 10 women (mean age, 47 years) were followed prospectively for a mean of 26 months. Surgical treatment consisted of open reduction and internal fixation of all fractures; radial head replacement in Mason III injuries; lateral collateral ligament repair in all patients; and, in cases of persistent instability, medial collateral ligament repair, hinged fixator application, or both. Coronoid fixation was performed using 2 or more fine-threaded K-wires, depending on the fragment size, inserted from the posterior aspect of the ulna and directed toward the coronoid fragment using a 1-step fixation technique. At last follow-up, mean extension was 15°, mean flexion was 133°, mean pronation was 78°, and mean supination was 69°; mean Disabilities of the Arm, Shoulder and Hand score was 9.7, mean American Shoulder and Elbow Surgeons score was 85, and mean Mayo Elbow Performance Score was 89. According to the Mayo Elbow Performance Index, 10 excellent, 7 good, and 1 fair result were recorded. All but 1 patient had a stable elbow. Fracture healing was observed in all but 1 patient. No secondary coronoid fragment dislocation or implant failures were reported.

This study shows that using fine-threaded K-wires provides easy, minimally invasive, stable, and successful 1-step fixation that can be used to obtain osteosynthesis of coronoid fractures in patients with complex elbow instability.

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The authors have no relevant financial relationships to disclose.

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doi: 10.3928/01477447-20130920-12
Coronoid fractures are rare, usually occurring as part of an elbow fracture-dislocation.\textsuperscript{1-4} Recognizing that the coronoid process is a primary constraint of the elbow has led to greater attention dedicated to the diagnosis and treatment of these difficult fractures.\textsuperscript{5-10} The techniques proposed to obtain osteosynthesis include those using suture fixation, K-wires, screws, and plates\textsuperscript{1,3,4,11,12}; however, because no established guidelines exist, it is unclear which technique for osteosynthesis should be recommended for each type of coronoid fracture.

The goal of this prospective study was to analyze the results yielded by an alternative fracture fixation technique consisting of the insertion of fine-threaded K-wires (Fragment Fixation System [FFS]; Orthofix, Bussolengo, Italy). These devices have been successfully used in small-fragment fixation in other joints, as well as in capitulum humeri, radial head, and olecranon fractures\textsuperscript{13-17}; however, no information is available on their use in coronoid fixation. The authors hypothesized that the FFS is an easy, minimally invasive, and stable 1-step fixation technique that may be helpful in the management of these difficult fractures.

**Materials and Methods**

Between 2005 and 2011, a single surgeon (G.G.) operated on 40 consecutive patients with coronoid process fractures that were part of an elbow fracture-dislocation. Twenty-one patients were excluded because the coronoid fracture was fixed using surgical procedures other than the FFS alone: transosseous sutures alone were used in 13 patients (type 1 comminuted osteocondral fragments), medial plates either alone or in combination with the FFS were used in 7 patients (type 3 displaced large fragments), and a radial head allograft fixed with the FFS was used for the coronoid reconstruction in 1 patient. Therefore, the study population comprised 19 patients in whom osteosynthesis was performed using the FFS alone. One patient was lost to follow-up. Thus, 8 men and 10 women (mean age, 47 years [range, 22-74 years]) were available for final examination. The left arm was involved in 10 patients and the right arm in 8.

Preoperative diagnoses consisted of the terrible triad (n=12), fracture-dislocation of the proximal ulna and radius (Monteggia-like lesions) (n=3), and coronoid fracture dislocation (posteromedial instability) (n=3). Coronoid fractures were classified according to Regan-Morrey\textsuperscript{18} and O’Driscoll\textsuperscript{19} classifications using anteroposterior and lateral elbow radiographs and 2- and 3-dimensional computed tomography reconstructions. Mean time from injury to surgery was 3 days (range, 1-6 days).

**Surgical Technique**

A posterior skin incision was performed in all patients. The Kocher interval was used to expose the lateral compartment. Either an over-the-top approach or elevation of the flexor-pronator muscles from the subcutaneous and medial border of the ulna was performed to visualize the medial compartment. Surgical management was based on the current therapeutic algorithms of complex elbow instability: open reduction and internal fixation of all fractures; radial head replacement in Mason III injuries; lateral collateral ligament repair in all patients; fluoroscopic assessment of elbow stability; and medial collateral ligament repair, hinged fixator application, or both in patients with persistent instability.\textsuperscript{19-23}

Coronoid fractures were approached through either the Kocher interval when an associated radial head comminuted fracture occurred (n=10) or medially if no such association was present (n=8). Once the coronoid was exposed, the fracture was reduced and temporarily stabilized with a clamp, thin K-wires, or transosseous sutures. Definitive fixation was performed by inserting the FFS through the posterior aspect of the ulna and directing it toward the coronoid using a 1-step fixation technique. Depending on the number and size of the fragments, 2 or more FFSs of different diameters (1.2, 1.6, or 2.2 mm) were positioned in all patients to increase primary and rotational stability.
A fluoroscopic assessment was performed to evaluate the accuracy of the reduction during coronoid osteosynthesis. At the end of procedure, all of the FFSs were cut approximately 1 to 2 mm above the posterior aspect of the ulna.

**Postoperative Care**

All patients underwent the same postoperative protocol, including articular drains with a plaster splint in extension for 48 hours, raised position, cryotherapy, and analgesic drugs. Two days postoperatively, patients began full active and passive extension/flexion while using a hinged elbow brace, which was worn for 45 days postoperatively. During the extension exercises, the forearm was positioned in neutral rotation. In addition, 100 mg daily of indomethacin was prescribed for 4 weeks postoperatively to prevent heterotopic ossifications. Patients were discharged an average of 3 days (range, 2-5 days) postoperatively. Strength exercises were prescribed after fracture healing.

**Evaluation**

Patients were followed up clinically and radiographically for a mean of 26 months (range, 6-85 months). A clinical evaluation was performed every 3 weeks in the first 3 months, every 6 weeks in the subsequent 3 months, and every 3 months thereafter; evaluations were performed annually after the first year.

At 6-month follow-up, elbow stability was evaluated using varus and valgus stress tests, the pivot shift test, and the drawer test. Functional outcomes were evaluated using the Mayo Elbow Performance Score (MEPS), American Shoulder and Elbow Surgeons (ASES) score, and Disabilities of the Arm, Shoulder and Hand (DASH) score. Anteroposterior, lateral, and medioloblique radiographs were performed to detect the presence of coronoid nonunion or malunion, heterotopic ossifications, instability, and posttraumatic osteoarthritis. Degenerative changes and heterotopic ossifications were classified using the Broberg and Morrey system and the functional classification of Hastings and Graham,

**RESULTS**

Patient characteristics, fracture classifications, coronoid treatment, and clinical results are shown in the Table. At last follow-up, mean extension and flexion were 15° (range, 0°-50°) and 133° (range, 100°-145°), respectively; mean forearm rotation was 78° (range, 10°-90°) in pronation and 69° (range, 10°-90°) in supination. Mean DASH and ASES scores were 9.7 (range, 0-26.8) and 85 (range, 65-100), respectively. Mean MEPS score was 89 (range, 70-100); according to the Mayo Elbow Performance Index, results were excellent in 10 patients, good in 7, and fair in 1. All patients except 1 (patient 3) had a stable elbow at last follow-up.

The patient with a fair result (patient 3) developed elbow stiffness due to proximal radioulnar synostosis (heterotopic ossifications IIIC), grade 3 osteoarthritis, and elbow subluxation with radial head malunion following a fall 1 month postoperatively. This patient did not undergo reoperation due to her poor compliance and general clinical condition.

Radiological evaluation revealed fracture healing in all but 1 patient within the first 6 months. One patient with an excellent result (patient 6) displayed an asymptomatic nonunion of the coronoid fracture.
without bone fragment resorption after 21 months (Figure 4). No secondary fragment dislocation or implant failures were observed. According to the Broberg and Morrey system, the arthritic changes in the elbow joint that occurred in 4 patients were rated as grade 1 in patients 6 and 12, grade 2 in patient 16, and grade 3 in patient 3. Heterotopic ossifications, which were observed in 3 patients, were rated as class I in patients 4 and 13 and class IIIC in patient 3.

**DISCUSSION**

The goal of the current study was to evaluate the clinical and radiographic results of coronoid fracture osteosynthesis using the FFS in patients with complex elbow instability. The findings show satisfactory clinical results, fracture healing, and recovery of elbow stability in the majority of patients, confirming the hypothesis that open reduction and internal fixation with the FFS is an easy, minimally invasive, effective, and stable 1-step fixation technique.

Various techniques for coronoid fixation have been described, including those using transosseous sutures, K-wires, screws, and mini-plates. Techniques using transosseous sutures are indicated above all options for small and comminuted coronoid fractures but do not provide fixation that is sufficiently stable to allow full and early mobilization. Open reduction and internal fixation with screws alone or with a plate is indicated in larger coronoid fragments and ensures adequate reconstruction stability. Screws alone are indicated in the presence of an isolated large fragment with good bone stock and when more than 1 screw can be placed to obtain an adequate rotational stability. Mini-plates, either alone or associated with osseosutures, have been successfully used in comminuted fractures to increase reconstruction stability and to neutralize the biomechanical stress during early joint mobilization, although they require wide medial exposure.

A recent study compared the biomechanical characteristics of screws, plates, and combined screw and plate fixation for large coronoid fractures. The results showed that although both screws and plates used on their own yielded a good

<table>
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<td>80</td>
<td>11.4</td>
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Abbreviations: ASES, American Shoulder and Elbow Surgeons score; CEI, complex elbow instability; C f-d, coronoid fracture-dislocation; DASH, Disabilities of the Arm, Shoulder, and Hand score; FFS, Fragment Fixation System; FU, follow-up; MEPI, Mayo Elbow Performance Index; MEPS, Mayo Elbow Performance Score; PUR f-d, proximal radio and ulnar fracture-dislocation; TT, terrible triad.
level of stability, the combination of these 2 devices significantly increased stability.28

The majority of the coronoid fractures in complex elbow instability are small, involving less than 50% of the coronoid height, and are frequently comminuted.29,31 These small coronoid fractures always require surgical treatment, as reported in several anatomical, biomechanical, and clinical studies that have demonstrated the important role played by the coronoid tip in maintaining elbow stability.5-10,19-22,32,33

In the current series of 40 patients with complex elbow instability, only 25% of patients had a large fragment of the coronoid process. These findings suggest that the most urgent issue is determining which fixation system is likely to ensure adequate stability in small fractures by means of a simple and rapid technique. Small anterior and anteromedial coronoid fractures are currently often treated with the suture-fixation technique because the small size of the fragments does not allow osteosynthesis with screws.1-4,11,12 Osteosynthesis with screws alone requires predrilling, which is difficult to perform in this setting.

For these reasons, the majority of type I and II coronoid fractures are treated with transosseous sutures either alone or combined with a plate or hinged elbow fixator. When the transosseous suture is used alone, a period of partial or total immobilization is frequently needed to avoid secondary fragment mobilization; elbow contractures are often observed in these cases.1-4,12,22,26,27 When a hinged fixator or plate is used, the combination of both devices increases the surgical complexity, the operative time, and the likelihood of complications.1-4,11,12,19,22 The current study shows that the FFS may be a new, effective, quick, and easy therapeutic option in these difficult fractures.

The FFS was designed as a 1-step fixation system for the treatment of small fracture fragments.13-17 These implants are inserted without predrilling or tapping and have an autocompression effect on bone fragments.34-36 In recent biomechanical studies, the FFS has displayed substantial pullout strength and a comparable resistance to offset axial load when compared with partially threaded cancellous screws in medial malleolar fractures,37 as well as better reduction and stability than the mini-plate in Mason type III fractures.38 Furthermore, Gausepohl et al16 found that, relative to their thread diameter, the maximum holding power of the FFS was superior to that of conventional cancellous and cortical screws in cancellous bone. The FFS has since successfully been used in the clinical setting for small-fragment fixation in various fractures, such as medial malleolar, metatarsal, radial head, capitulum humeri, and olecranon fractures.13-17

Despite the encouraging results observed in other sites, no previous studies have analyzed the clinical results of the FFS in coronoid osteosynthesis. In the current study, the authors obtained satisfactory clinic results for the majority of patients using the FFS. Type I and II coronoid fractures fixed with 2 or more small to medium FFSs provided enough stability to allow an early mobilization program in all cases. Osteosuture was performed before FFS fixation in 6 of 18 patients with small comminuted fractures to reduce the fracture of smaller fragments, facilitate the osteosynthesis of larger fragments, and increase elbow stability by pulling down the anterior capsule. Use of the FFS instead of plates allowed the authors to avoid exposure of the medial compartment in approximately half the cases in the current series because anterior coronoid osteosynthesis was performed by means of the Kocher approach in a 1-step fixation procedure. In another 8 patients without severe radial head involvement, the use of the FFS instead of the plates allowed the authors to reduce the medial exposure of the fracture site and perform osteosynthesis more easily and rapidly.

The authors believe that threaded wires afford more easily performed and more stable fixation than transosseous sutures and are not as bulky as plates and screws; consequently, they allow the rapid insertion of more than 1 implant and a subsequent increase in primary and rotational stability. Furthermore, open reduction and internal fixation with the FFS does not require the application of the hinged external fixator needed to guarantee fixation of coronoid osteosynthesis when osteosutures alone are used.

Large coronoid fracture fragments, usually encountered in olecranon fracture-dislocation, are generally fixed with screws, plates, or both with good clinical results.1-4,11,12 In the current study, the authors treated 5 type III coronoid fractures with an average of 3 FFSs, achieving satisfactory clinical results. However, 1 patient developed a coronoid asymptomatic nonunion, most likely due to an inadequate reduction of the fragment. The authors believe that synthesis with plates and screws should only be performed in cases with large anteromedial fragments extended to the ulnar metaphysis and when coronoid fracture reduction requires wide exposure of the medial compartment; in all other cases, osteosynthesis may be performed using the FFS posterior...
to anterior because this type of synthesis does not require wide medial exposure or the isolation or transposition of the ulnar nerve.

This study has some limitations. First is the absence of a control group, which prevented the comparison of the results obtained using the FFS with those obtained using plates or screws, and, consequently, the ability to determine which osteosynthesis system is most reliable. The second limitation is the relatively small number of cases examined; however, the low prevalence of this type of fracture may justify the small case series.

CONCLUSION

In this study, reconstruction of coronoid fractures using the FFS demonstrated that this technique provides easy, stable, minimally invasive, and successful osteosynthesis. The FFS should be considered as a valid method of treatment for coronoid fractures in complex elbow instability.

REFERENCES