Original Article
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The Novel Hooked Kirschner Wire Technique for Ulna Coronoid Process Fractures

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Background: The aim of this study was to introduce a novel technique to improve the ease of fixing of even small fragments of the coronoid process and report the clinical outcomes of this method.

Methods: Forty-nine patients with ulnar coronoid process fractures fixed using the hooked Kirschner wire (K-wire) technique at our hospital from 2007 to 2019 were reviewed. Radiological features and fracture union were assessed using simple radiographs. Functional outcomes of the treated elbows were evaluated at the final follow-up visit using the Mayo Elbow Performance Score (MEPS).

Results: All patients were examined at a mean follow-up of 17.7 months (range, 6–62 months). We observed bony union in patients at a mean of 10.9 weeks (range, 6–22 weeks). The mean flexion and extension ranges of the elbow were 132.0° (range, 106° –151°) and 4.5° (range, –20° to 30°), respectively. The mean pronation and supination ranges of the forearm were 81.1° (range, 60°–90°) and 88.3° (range, 60°–120°), respectively. The mean arc of the elbow was 127.4° (range, 78°–160°). All patients were evaluated using the MEPS at the final follow-up visit, with a mean score of 96.9 points (range, 80–100 points). One case of coronoid nonunion was observed and re-fixation was performed. One case of infection was observed and also treated with additional surgery. Three patients complained of ulnar nerve symptoms and 1 patient underwent surgical release for tardy ulnar nerve palsy.

Conclusions: Despite its limitations, the hooked K-wire technique was a useful method for even smaller coronoid process fractures. K-wires were also a useful temporary intraoperative fixation method and could provide permanent fixation.

Keywords: *Elbow joint, Ulnar coronoid process, Kirschner wires*

The ulnar coronoid process provides essential stability to the ulnohumeral joint. It functions as an anterior buttress against posterior displacement of the elbow joint. Owing to its anatomical and functional features, the ulnar coronoid process fractures are usually accompanied by injury to the surrounding soft tissue and bony structures, resulting in traumatic elbow joint instability. Several poor outcomes, such as pain, instability, functional limitations, and traumatic arthritis, are related to this injury.[1,2] Previously, the fixation of coronoid process fractures seemed essential, but there remains a controversy about the effectiveness of fixation of the smaller coronoid process. Recently, some authors have recommended the repair of any coronoid fractures associated with elbow instability, regardless of their size.[3-5] Owing to the small size of the fragments and the difficult approach, fixation of coronoid process fractures remains challenging.

We herein introduce the novel hooked Kirschner wire (K-wire) technique that can be used to improve the ease of fixing of even small fragments of the coronoid process and report the clinical outcomes of this method obtained from 36 patients who had coronoid fractures with ulnohumeral joint instability.

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METHODS

This retrospective study was exempted from the institutional review board approval because it used previously collected data. Informed consent was obtained from patients. We also obtained approval for publication from the patients whose photos were used.

Patients and Methods

Forty-nine patients with ulnar coronoid process fractures fixed using the current method at our hospital from 2007 to 2019 were included. Thirteen of these were excluded owing to follow-up periods of under 6 months or due to loss to follow-up (Table 1). There were 27 men and 9 women, and the average age at the time of injury was 45.1 years (range, 16–79 years). All the participants were treated using the hooked K-wire technique. Additional plate or wire fixation was performed depending on fracture type and stability following K-wire fixation. Patients were classified according to the O'Driscoll and Regan-Morrey classifications, and their postoperative radiological and functional outcomes were evaluated retrospectively by one surgeon (DJS). Radiological features and fracture union were assessed using simple radiographs. Functional outcomes of the treated elbows were evaluated at the patients' final follow-up visit using the Mayo Elbow Performance Score (MEPS).

Surgical Technique

All the operations were performed by the same surgeon (DJS). Under general or regional anesthesia, the patient was placed in the supine position on a radiolucent operation table. The fracture site was approached using a posterior global incision, medial incision, lateral incision, or both medial and lateral approaches considering accompanying injuries and fracture type. Over-the-top approach, flexor carpi ulnaris splitting approach, or Taylor and Scham approach was also used when using the medial approach. A pneumatic tourniquet was applied to the upper arm.

The surgical procedure is outlined in Figs. 1 and 2. Hematoma and debris were removed from the fracture site, and the ulnar fracture footprint was exposed. A small stab incision was made at the ulnar dorsal border, and the K-wire (0.9 mm in diameter) was drilled in the posterior to anterior direction, making the K-wire's tip flush with the ulnar fracture footprint. After fracture reduction and maintenance of the coronoid fragment, the K-wire was drilled further, penetrating the coronoid fragment. Pulling the capsule attached to the coronoid fragment in the direction of the fracture surface after fixing it with a suture helped maintain the reduction. Directly pressing the fracture fragment using surgical instruments such as Kelly can also be helpful.

After the K-wire tip was found protruding through the fracture fragment and the soft tissue, it was bent to form a hook and pulled downwards to reduce the fracture. Several K-wires were used depending on the fracture pattern. Plates or wires were added according to the fracture pattern. In fracture patterns requiring a buttress using a plate, the location of the plate was facilitated by locating the tip of the K-wire into the screw hole of the plate. The hook was rotated depending on the shape of the fracture and placed in the most appropriate location. The K-wire was bent and buried at the back. All accompanying injuries such as medial and lateral collateral ligament tears or radial head or neck fractures were treated. The ulnar nerve was released in situ to prevent tardy ulnar nerve palsy when the medial approach was used.

Postoperative Care and Rehabilitation

Prophylactic antibiotics were applied for 1–3 days postoperatively. Stitches were removed routinely 7–10 days postoperatively. A long arm splint was used to immobilize the elbow for 1 week, and the elbows were further partially immobilized for 5–8 weeks using a long arm splint or hinged brace if needed. No external fixators were used in any of our cases.

RESULTS

All patients were examined at a mean follow-up of 17.7 months (range, 6–62 months). According to the O'Driscoll's classification, there were 5 tip type, 27 anteromedial facet type, and 4 basal type. According to the Regan-Morrey classification, there were 5 type I, 29 type II, and 2 type III fractures. The injury occurred following a fall in 19 patients, traffic accident in 9, and fall from height in 7, and 1 suffered a blunt-force trauma. Twenty-four lateral collateral ligaments and 16 medial collateral ligaments were repaired.

Eleven patients had radial head fractures; fixation was performed in 10, and replacement was performed in 1. One patient experienced nonunion after radial head fixation, and reoperation was performed with radial head replacement. We observed bony union in patients at a mean of 10.9 weeks (range, 6–22 weeks). The range of motion of the elbow was measured at the last follow-up visit. The mean flexion and extension ranges of the elbow were 132.0° (range, 106°–151°) and 4.5° (range, –20° to 30°),

Table 1. Demographic Data

Case	Sex	Age (yr)	O'Driscoll classification	Regan-Morrey classification	Injury mechanism	Approach	ROM (°)	MEPS
1	M	41	Tip/2	2	FH	Lateral	78	95
2	M	17	Anteromedial/2	2	TA	Medial	146	100
3	M	28	Anteromedial/2	2	FH	Medial	120	100
4	F	74	Anteromedial/2	2	FG	Medial	96	80
5	M	58	Anteromedial/2	1	FH	Medial	95	80
6	M	38	Anteromedial/2	2	FH	Medial	128	100
7	M	47	Anteromedial/2	2	FG	Medial	122	100
8	M	41	Anteromedial/2	2	FG	Medial	144	100
9	F	62	Basal/1	2	TA	Medial	135	100
10	M	79	Basal/2	3	FG	Medial	118	100
11	M	20	Basal/1	2	TA	Medial	126	100
12	F	48	Anteromedial/2	1	FG	Medial	145	100
13	M	33	Tip/2	2	FG	Medial	135	100
14	M	38	Anteromedial/2	2	FG	Medial	142	100
15	M	39	Anteromedial/1	2	HM	Medial	122	85
16	M	29	Tip/2	2	FH	Lateral	130	100
17	F	69	Anteromedial/3	2	FG	Medial	140	85
18	M	39	Anteromedial/2	2	TA	Medial	135	100
19	M	46	Anteromedial/2	2	FG	Medial	130	100
20	F	28	Anteromedial/2	2	FG	Medial	160	100
21	M	61	Anteromedial/3	2	FG	Medial	138	85
22	F	66	Anteromedial/2	2	FG	Medial	100	100
23	M	48	Anteromedial/2	2	TA	Medial	102	100
24	M	42	Anteromedial/2	2	FG	Medial	100	100
25	M	61	Anteromedial/2	2	TA	Medial	130	100
26	F	60	Anteromedial/2	2	FH	Medial	120	100
27	M	21	Tip/2	1	FG	Lateral	120	100
28	F	56	Anteromedial/2	2	FG	Medial	148	100
29	F	56	Anteromedial/2	2	FG	Medial	110	100
30	M	65	Basal/2	3	FH	Medial	95	80
31	M	42	Anteromedial/2	2	TA	Medial	130	100
32	M	19	Tip/2	1	FG	Lateral	148	100
33	M	16	Anteromedial/2	1	FG	Medial	160	100
34	M	62	Anteromedial/2	2	FG	Medial	145	100

Table 1. Continued

Case	Sex	Age (yr)	O'Driscoll classification	Regan-Morrey classification	Injury mechanism	Approach	ROM (°)	MEPS
35	M	31	Anteromedial/2	2	TA	Medial	145	100
36	M	45	Anteromedial/2	2	TA	Medial	148	100

ROM: range of motion, MEPS: Mayo Elbow Performance Score, FH: fall from height, TA: traffic accident, FG: fall down on ground, HM: hit by mass.

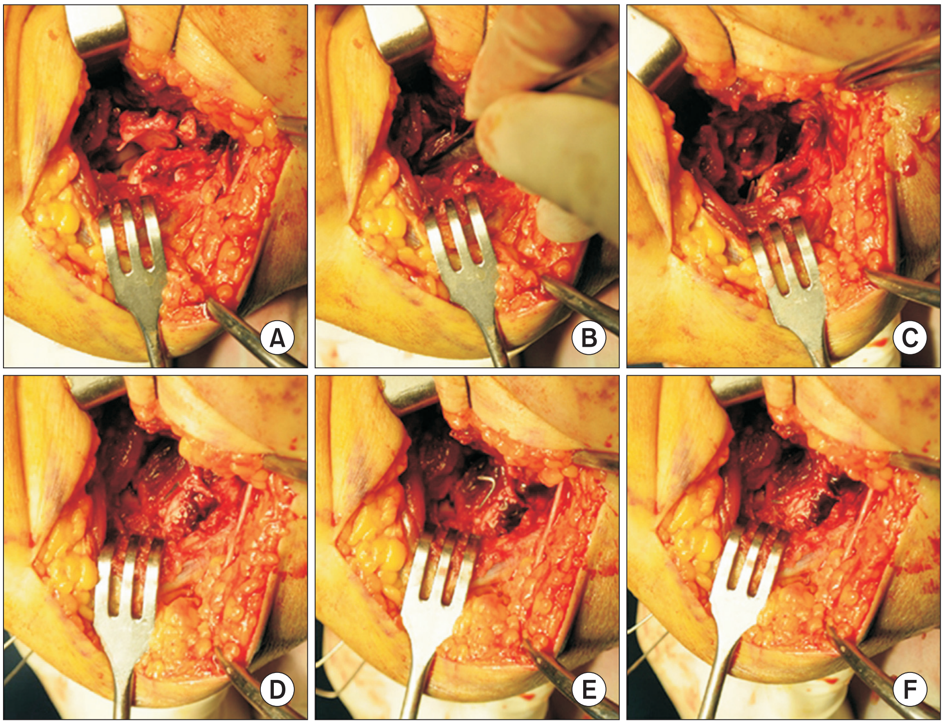

Fig. 1. The fracture site was approached using the medial approach (A) and reduction was attempted by compressing the fragment (B). (C) The Kirschner wire (K-wire) was drilled forward to the fracture surface, ensuring it to flush with the fracture footprint. The compressed bone fragment was penetrated (D) and the end of the K-wire was bent to make a hook (E). (F) Finally, the hooked K-wire was pulled backward and the distal end was bent and buried.

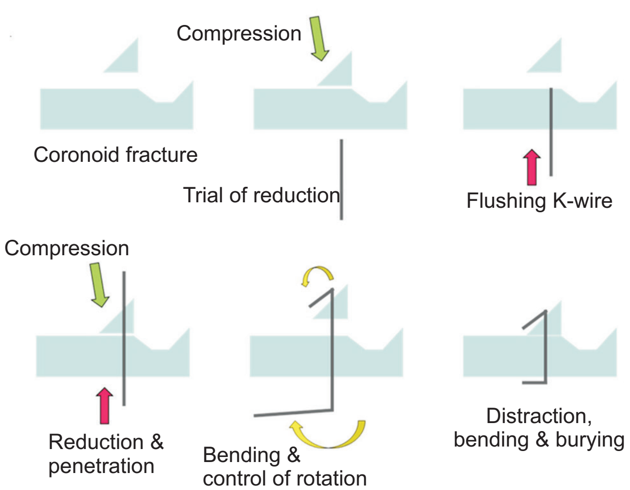

Fig. 2. Schematic diagram of the hooked Kirschner wire (K-wire) technique.

respectively. The mean pronation and supination ranges of the forearm were 81.1° (range, 60°–90°) and 88.3° (range, 60°–120°), respectively. The mean arc of the elbow was 127.4° (range, 78°–160°).

All patients were evaluated using the MEPS at the final follow-up visit, with a mean score of 96.9 points (range, 80–100 points). Thirty patients showed excellent results, and 6 showed good results. A mean of 3.08 K-wires were used for fixation. Twenty-five fractures were fixed with additional plates, 3 with wiring alone, and 1 fracture was fixed with both a plate and a wire (Fig. 3). The lateral approach was used in 4 patients, and the medial approach was used in the remaining 32.

One case of coronoid nonunion was observed. This patient had fallen to the ground, and the fracture was classified as a type II anteromedial facet fracture of the coronoid process at the initial visit (Fig. 4). It was fixed with 1 hooked K-wire and a buttress mini plate. Upon

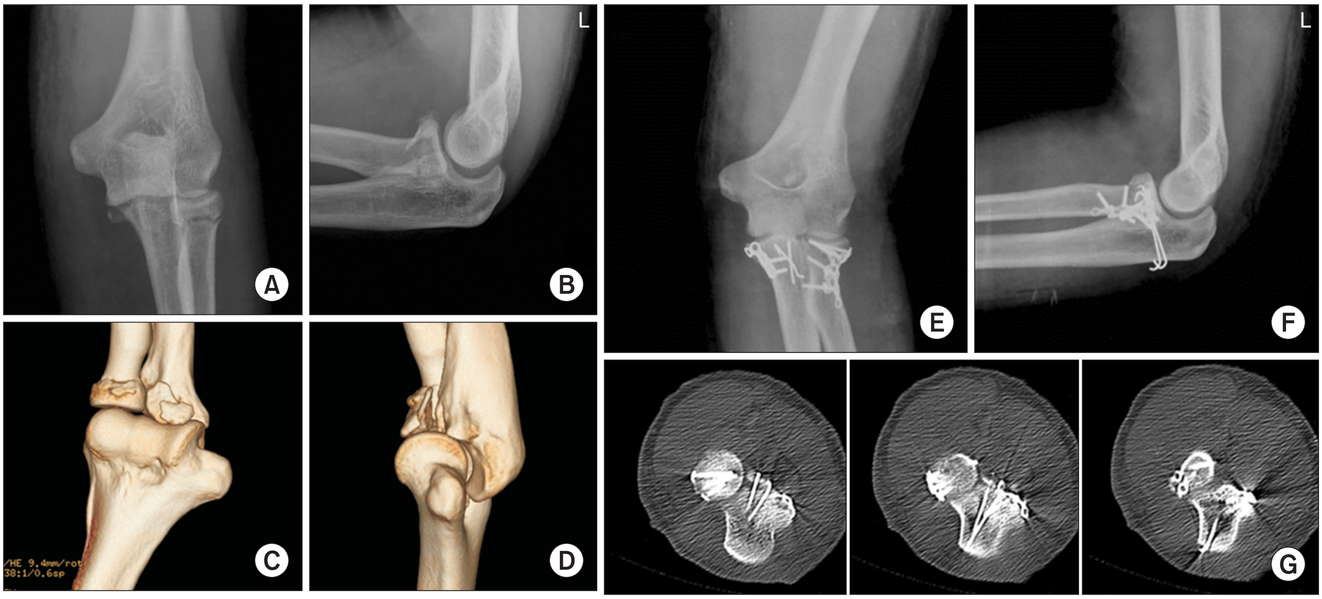

Fig. 3. (A-D) A 28-year-old male patient was diagnosed with a type II coronoid process fracture (tip fracture type) accompanied by a radial head fracture. (E, F) The coronoid process was fixed with a mini buttress plate using the hooked Kirschner wire technique. (G) Computed tomography images obtained after fixation.

examination of follow-up radiographs at 16 weeks postoperatively, 1 screw breakage was found, and nonunion of the coronoid process was diagnosed. Revision surgery was performed using re-fixation and autogenous iliac bone graft. Successful bone union and a good functional outcome were seen 5 months after the second surgery. One case of postoperative infection was treated with additional surgery. Three patients complained of ulnar nerve symptoms; 1 underwent surgical release for tardy ulnar nerve palsy, and the symptoms of other patients improved spontaneously (Fig. 5). Eight patients complained of soft-tissue irritation caused by the K-wires at the dorsal ulna, and the implants were removed in 4 cases owing to irritation. In 11 patients with no symptoms such as soft-tissue irritation, implant removal was performed at the patients' request.

DISCUSSION

It is widely accepted that the coronoid process plays a vital role in maintaining the stability of the elbow joint by acting as a buttress against posterior translation and varus rotation of the ulna on the distal humerus.[6,7] The anteromedial facet of the coronoid acts as a buttress against varus posteromedial instability, and even smaller fractures of the facet show poor functional prognoses without surgical treatment.[2,8] Traditionally, small coronoid process fractures were underestimated and conservatively treated, but many studies revealed poor outcomes of conservative treatment.[2,8)]

In 2000, Terada et al.[9] reported the importance of reducing small coronoid fractures. They reported 3 coronoid process fractures (Regan-Morrey type I) with elbow dislocation, and repair of coronoid fractures showed better outcomes than conservatively treated elbow fractures.[10] Rafehi et al.[11] also reported about anatomical features of the coronoid cartilage and found that cartilage thickness was the highest at the coronoid tip, with a mean thickness of 3.0 mm. Clinically, coronoid process fractures are larger than they appear, and the need for surgery is likely to be underestimated. Recently, many studies have reported the necessity of coronoid fixation, regardless of the fracture size.[4,5] Furthermore, coronoid process fractures should be assessed based not only on their size but also in relation to the displacement and stability of the elbow joint.[12]

Several surgical methods, such as suture lasso,[13,14] lasso plate,[15] screw fixation,[16] tension band wiring,[17] and buttress plate fixation,[18] have been introduced for coronoid fractures. Suture lassos have been widely used as an effective fixation method for smaller fragments. Zeiders and Patel[13] evaluated 32 elbows that had severe triad injuries. They used the suture lasso technique for coronoid fixation in all cases with posterior or lateral approach. Twenty-one patients were partially immobilized using a hinged external fixator for 6 weeks. Garrigues et al.[14] evaluated 28 elbows treated using the suture lasso technique and compared them to screw fixation or suture anchor

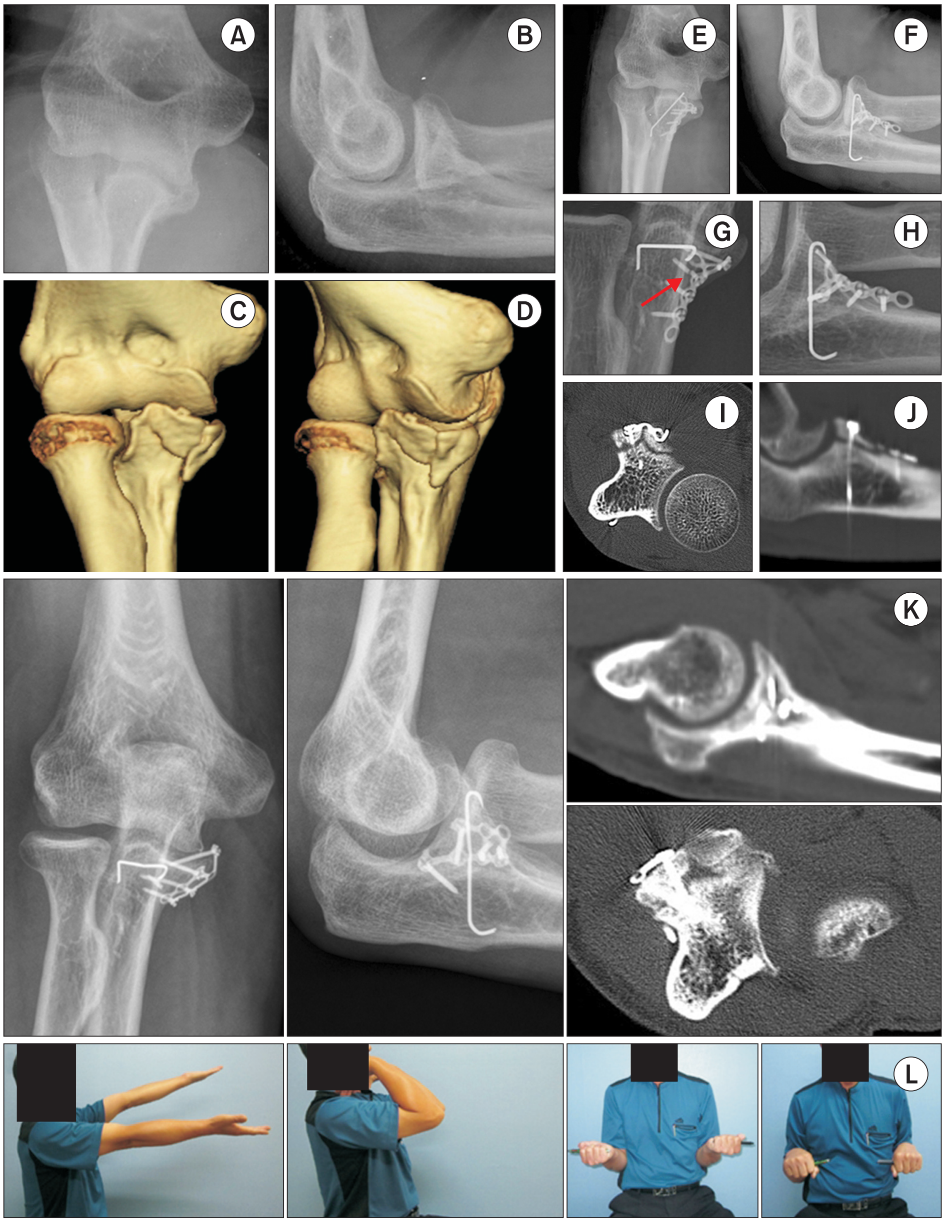

Fig. 4. (A-D) A 61-year-old male patient was diagnosed with a type II coronoid process fracture (anteromedial facet type). (E, F) Fixation was done with a Kirschner wire and an additional buttress plate. Appropriate reduction and fixation were confirmed. (G, H) Radiographs obtained 16 weeks after surgery. One screw breakage was shown (red arrow). (I, J) Nonunion of the fracture site was checked on the computed tomography image. (K) Reoperation was done with the same technique using an autogenous iliac bone graft. Bony union was checked at 5 months after the revision surgery. (L) Good functional outcome was shown with 138° of arc of motion (Mayo Elbow Performance Score, 85).

fixation. The study showed that the suture lasso group had lower nonunion or malunion rates and higher residual instability. They used a long arm splint for 5–7 days, and 3 patients required a hinged external fixator for 3 weeks. In their study, 3 patients underwent additional capsulectomy, and another 3 were managed with ulnar nerve transposition. One patient required additional surgical fixation due to nonunion. The mean postoperative arc of elbow motion was 118° with an average flexion contracture of 18° and further flexion of 136°.

In our study, no patient required capsulectomy; however, 1 patient required additional surgery due to nonunion. Since the lasso technique indirectly fixes the capsule-brachialis complex attached to the bone rather than fixing the bone itself, it is limited in restoring stability through fixation of the fracture fragment. According to a biomechanical study by Wake et al.,[3] the compression force applied to the coronoid tip from the trochlea becomes stronger during extension of the elbow joint, and the indirect fixation of bone fragments using soft-tissue sutures may be limited in overcoming this compression force. A plate could provide the best support, but its use may be limited owing to the small size of the bone fragment and anatomical complexity. Using multiple K-wires, the support force of the bone fragment itself could be obtained.

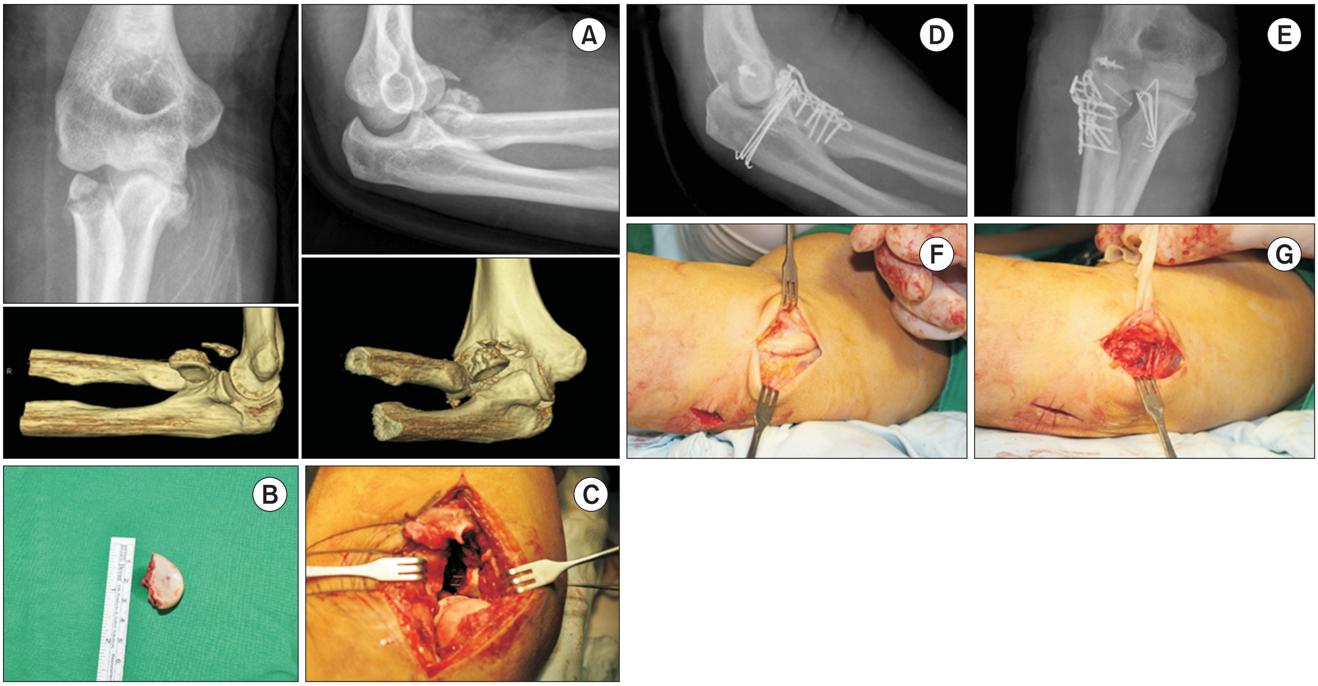

Fig. 5. (A) A 41-year-old male patient was diagnosed with a type II coronoid process fracture (tip type). (B, C) Radial head was removed during coronoid fixation. (D, E) Coronoid process was fixed with 4 Kirschner wires (K-wires) using the hooked K-wire technique and radial head fixation was done. (F, G) The patient suffered ulnar nerve symptoms, and ulnar nerve in situ release was performed 18 months after surgery.

Compared to the limited extension motion shown in the clinical results of the lasso technique, our study showed a relatively low extension lag. This could be attributed to the fixation force obtained by directly fixing the bone fragment itself at an anatomical position. In the lasso technique, even after internal fixation, instability was observed to the extent that an external fixator was required. In our study, no external fixator was required. This implies that the lasso technique does not provide a strong enough fixation force to allow early mobilization. Considering that capsulectomies were required, it can be assumed that long-term fixation was necessary for the same reason as described above. The hooked K-wire technique is thought to be a useful method to directly fix even a small bone fragment to minimize immobilization periods. It also showed slightly superior results with a mean arc of elbow motion of 127°.

We would like to further explain the advantages of the K-wire technique. First, it is cheap and easy to perform, and most orthopedic surgeons are familiar with handling K-wires. Second, the small fragment can be fixed medially or laterally, avoiding the large dissection required for plate fixation. It can be used in various approaches, as required, according to the accompanying injuries. Last, it could be used as a temporary fixator for additional plating or screwing. If a plate is used for coronoid process fixation, elbow extension is required to position the plate. However, elbow extension causes displacement of the fracture. In this situation, if temporary fixation is performed via a hooked K-wire, plate application becomes easier. K-wires are a useful temporary intraoperative fixation method and can provide permanent fixation.

Some patients complained of soft-tissue irritation by K-wires in the dorsal part of the ulna. All the K-wires were easily removed by pulling them quickly and firmly from the entry of the dorsal ulna, and there was no case of removal failure. Although not included in this study, in 1 recent case, the K-wire was not removed by this method, so it was removed directly via the medial approach. Nevertheless, all the K-wires were easily removed in this study, which is thought to be due to the use of thin K-wires with a 0.9-mm diameter.

This study is limited because no control group was included, and the hooked K-wire technique was not used in all patient groups. In some cases where the bone fragment was so small that the K-wire could not pass through it, a suture anchor or pull-out technique was used, and they were excluded from this study. Although the short follow-up period is another limitation of this study, bony union was obtained in all but 1 patient, and satisfactory functional outcomes were obtained. Although further biomechanical studies are needed to evaluate the fixation power of hooked K-wires, clinically satisfactory results were reported in this study.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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