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Adjunctive intraosseous wiring fixation technique for the comminuted distal humeral fractures

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A R T I C L E I N F O

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Level of evidence: Technical Note

Distal humeral fractures are among the most challenging injuries to treat. Although precise repair of the articular surface is essential during surgery, accurate reconstruction of the metaphysis contributes to the overall stability of the fracture construct. The intraosseous wiring technique has been used for small-fragment fractures. However, its efficacy as an adjunct for distal humerus fixation has yet to be thoroughly investigated. This study aimed to demonstrate the applicability of this technique to comminuted, distal humeral fractures. In this retrospective case series, we describe 6 cases of intra-articular distal humerus fractures treated with this technique, followed by dual plating. We observed successful bone union in all patients, with the Mayo Elbow Performance Scores indicating "good" to "excellent" clinical outcomes for this procedure at the final follow-up. We believe that this intraosseous wiring technique should be an integral part of the toolbox of every surgeon because it is a relatively simple and highly effective procedure that requires no special instrument and can be used on various types of fractures.

Distal humeral fractures are considered challenging injuries. Secure fixation with anatomical reduction is required for successful results; however, it has limitations, especially when dealing with severely comminuted fractures.[1,10,11,20,25,32] In treating intra-articular fractures, accurate restoration of the articular surface is critical, but it is often equally important to repair the metaphyseal segment, which is the foundation of articular fragments. Therefore, the fixation of small metaphyseal fragments can be critical to accurate bone reconstruction and overall success in some cases. There are several options for fixing small metaphyseal fragments, Kirschner wires (K-wires), small fragment screws, and mini-plates[24] are commonly used to temporarily or definitively fix small bone fragments. Another option is intraosseous wiring (IOW) with stainless steel wires. IOW has traditionally been used for the definitive fixation of small bone fractures of the hand, such as intra-articular fractures of the interphalangeal joint[26] and phalangeal mid-shaft fractures.[19] However, IOW is especially effective for fixing small bone fragments and providing relatively secure stability against external forces. Therefore, this study aimed to broaden the indications for this technique by describing its additional feasibility in the temporary fixation of other fractures, especially the small metaphyseal fragments of intra-articular distal humerus fractures.

In this article, we describe 6 clinical cases in which we used the IOW surgical technique, emphasizing its application to AO Foundation/Orthopedic Trauma Association (AO/OTA) type C2 or C3 comminuted intra-articular distal humerus fractures.

Anatomy

The distal humerus has a complex shape with a triangular structure that increases in width distally from the humeral diaphysis. The distal humerus is divided into 3 main parts: the medial column, lateral column, and articular section, which form the horizontal limb of the triangle.[12] This triangular concept is considered useful for systematic distal humerus fracture reconstruction.[23] The reconstruction of the articular surface and both columns is key to achieving overall construct stability. In addition, there are 3 essential osseous structures termed olecranon fossa,

Showa University Research Ethics Review Board approved this study (study number: 22-179-B).

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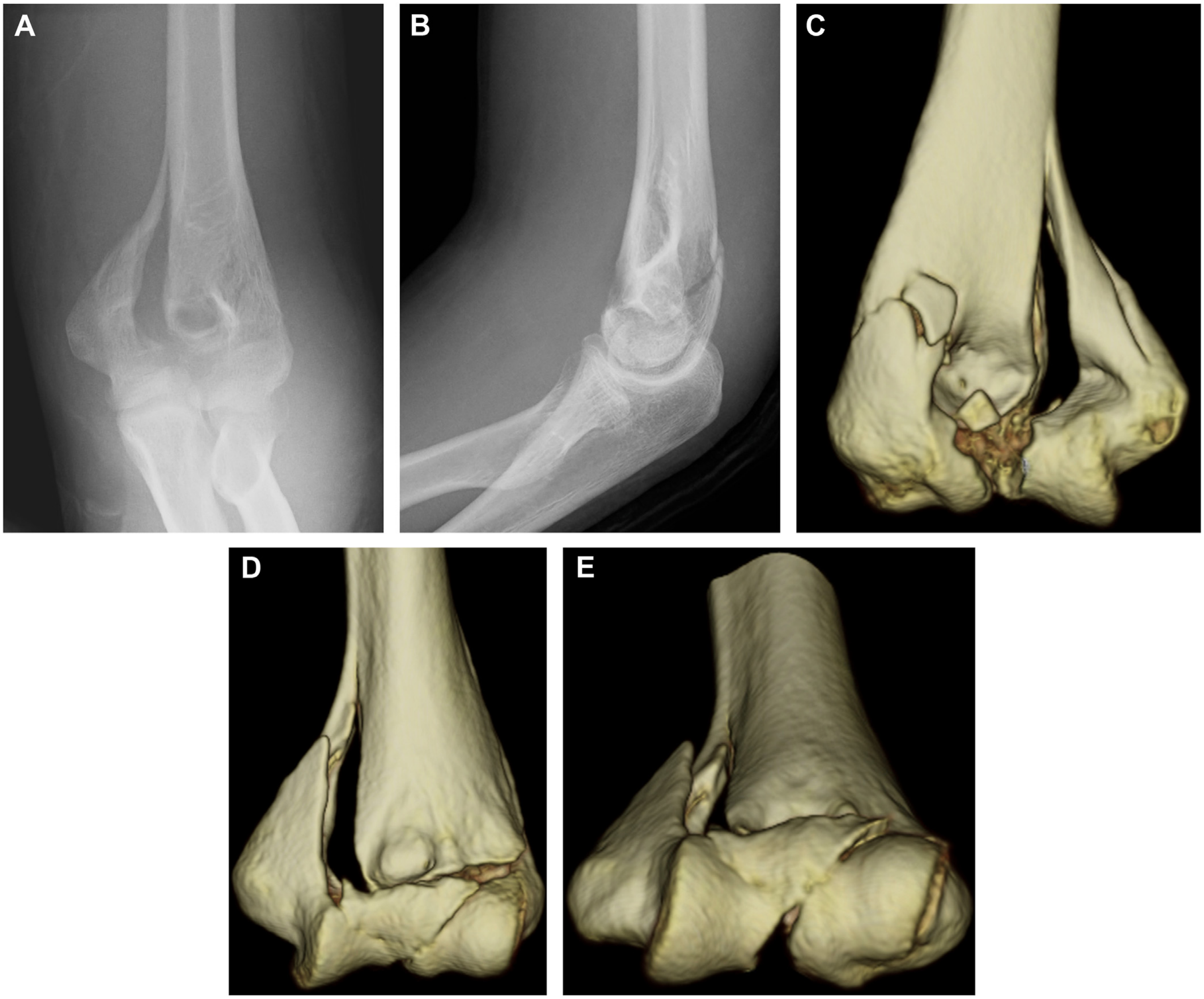

Figure 1 Preoperative (**A**) anteroposterior and (**B**) lateral elbow radiographs and 3-dimensional computed tomography images (**C-E**) of the patient in the described technique show a comminuted fracture of the distal humerus fracture.

coronoid fossa, and radial fossa. During elbow extension, the olecranon slides into the olecranon fossa. In contrast, during elbow flexion, the coronoid process slides into the coronoid fossa and the radial head slides into the radial fossa. Owing to the limited capacity of both fossae to tolerate incongruity, accurate repositioning of articular fragments is required to avoid postoperative restriction of range of motion (ROM).

Indications/contraindications

Indications: Adequate fixation stability with this technique is only possible with precise anatomical reduction of the corresponding bone fragments. Consequently, this technique requires the corresponding bone fragments to be anatomically repositioned without defects.[3] In addition, the bone fragments must be large enough to accommodate the small-diameter wire to pass through. To avoid cutting the cortical bone, the fracture line must be at least 5 mm from the osseous hole through which the wire passes.[19] Therefore, IOW is usually applicable to the fragments must be large enough for K-wire to pass through. This technique can be used on any fracture if these conditions are satisfied (Fig. 1).

Contraindications: As described above, this technique is not appropriate for severe comminution, bone defects, or fragments that are too small to pass through the wire. Osteoporosis itself is not a contraindication; nonetheless, care must be taken in patients with osteoporosis because wires can easily cut the cortical bone during fixation.

Materials and methods

Instruments and surgical setup

The following instruments should be prepared in advance for IOW: 25-gauge (0.5 mm) and 23-gauge (0.7 mm) stainless steel wires, an 18-gauge needle, a fine Hegar needle holder, and 1.2- or 1.5-mm K-wire.

We typically use 0.5-0.7 mm stainless steel soft wire because wires <0.5 mm (25 gauge) lack enough strength to maintain

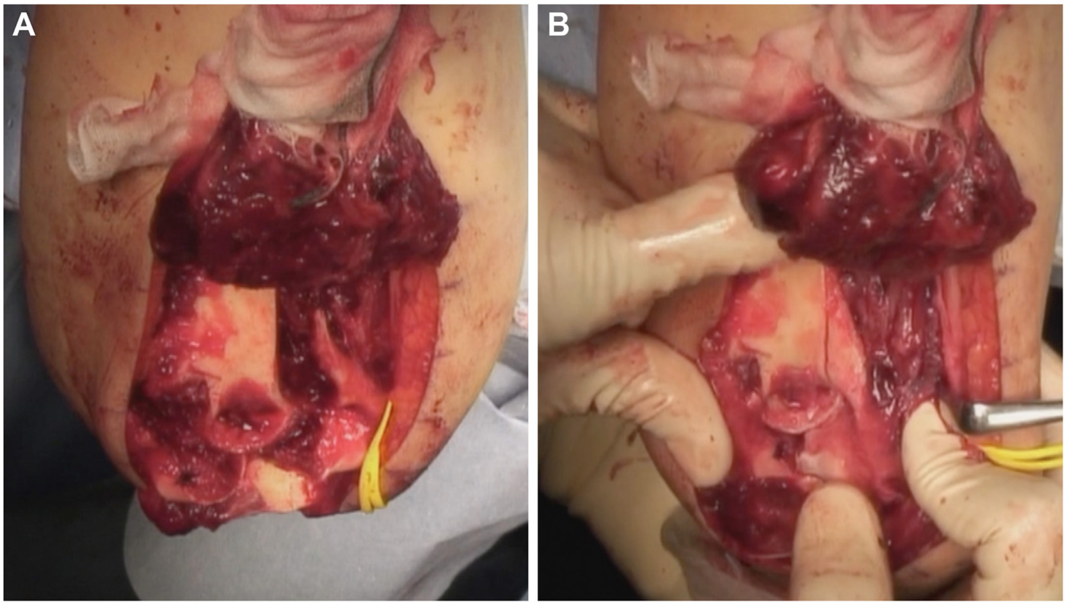

Figure 2 (**A, B**) Clinical photographs of the fracture site of the patients. Anatomical reduction of the fracture site was confirmed manually or with forceps before intraosseous wire fixation.

fracture reduction in the distal humerus. In contrast, a larger wire may be stronger, but it is more cumbersome when attempting to fit over the bone and tighten appropriately.

Under general anesthesia, the patient is placed in the lateral decubitus position. A sterilized tourniquet is placed on the upper limb and a sterile field is set up as usual for distal humeral open reduction and internal fixation (ORIF).

The trans-olecranon posterior or para-tricipital approaches can be used depending on the condition of the fractures. Following humeral bone exposure, each fragment is identified and moved for the following procedure.

Intraosseous wiring

Before IOW fixation, anatomical reduction of the fracture site is confirmed manually or with forceps (Fig. 2). The osseous hole, through which the wires are intended to pass, is marked. Next, if possible, all osseous holes are made perpendicular to the fracture line and approximately 5 mm away from it (Fig. 3). Thereafter, osseous holes are created at the marked location using a 1.2- or 1.5-mm K-wire.

It is critical not to pierce the articular surface or the osseous fossa (Fig. 4). The wires are passed through 1 or 2 cortices of each bone, depending on the size of each fragment and the location of the hole. In principle, 1 wire passes through 1 hole (Fig. 5); however, if a small bone fragment is to be bridged to the main bone fragments, 2 wires are passed through 1 hole and fixed in 2 places. Further, if passing the wires directly through the osseous hole is difficult, an 18-gauge needle can be used to guide the wire (Fig. 6).[29] Almost all wires that are planned to be fixed should be passed in advance because it is easier to pass wires when the bone fragments are separated.

Following the preparation mentioned above, the fragments are manually reduced and tightened. Before tightening, the wire is tugged to remove redundancy as much as possible and fit into the opposite side of the cortex (Fig. 7).[19] A Hegar needle holder is used to grasp the base of the wire, which is then pulled to apply tension[33] and twisted clockwise at a constant speed. The wire twisting should not exceed the point of maximum resistance to avoid shredding the wires (Fig. 8). Subsequently, the twisted portion of the wire is severed, leaving an approximately 5-mm stump. Afterward, the twisted part is then grasped by a

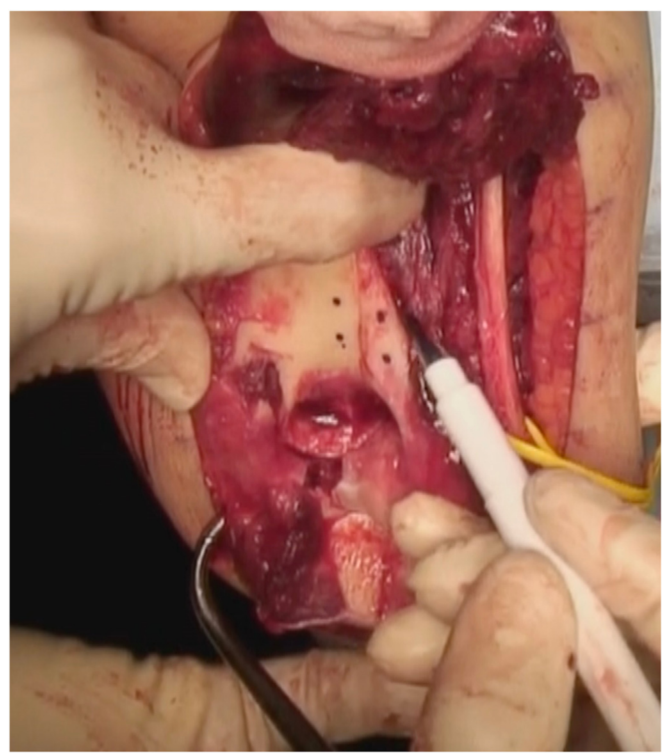

Figure 3 Marking: some perpendicular marks are made in which the wires are intended to pass through approximately 5 mm from the fracture line.

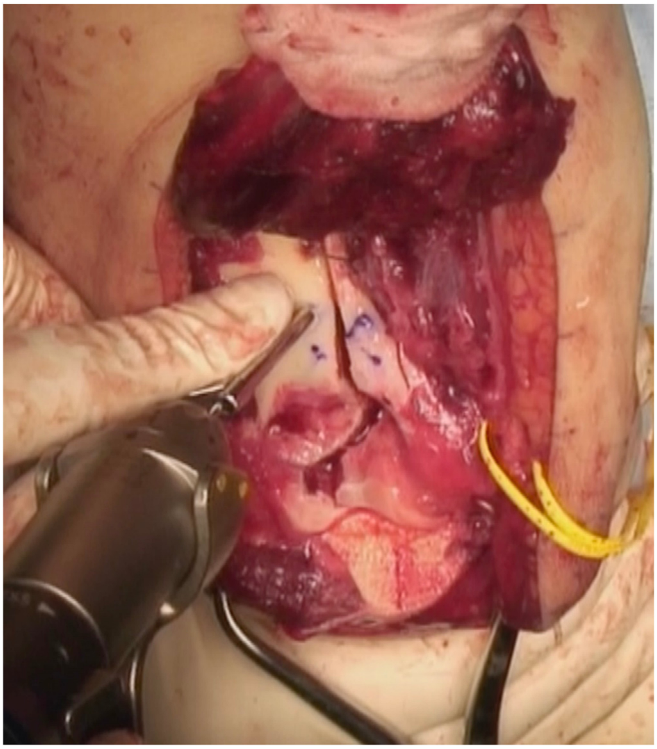

Figure 4 Creating holes: osseous holes were created using a 1.2- or 1.5-mm Kirschner-wire at the marked location.

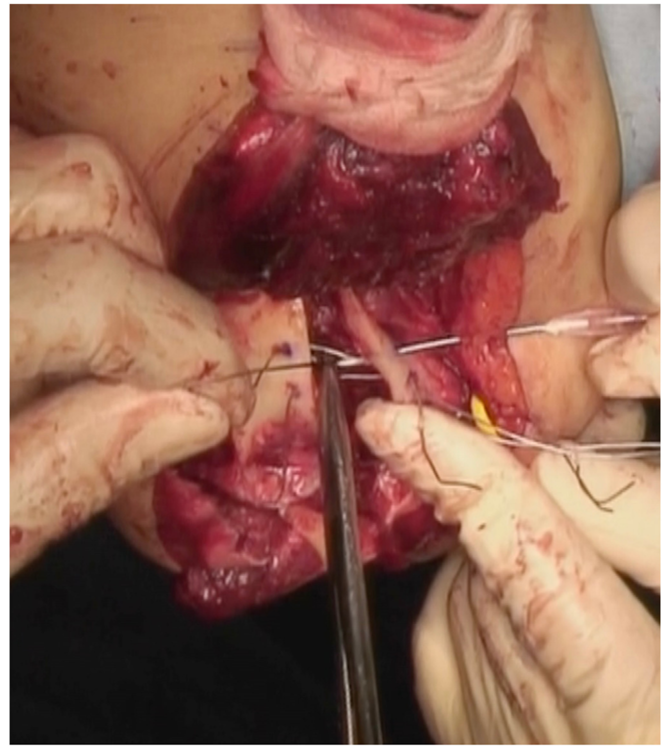

Figure 6 Supplementary technique: an 18-gauge needle can be helpful as a guide for the wire, if it is difficult to pass directly.

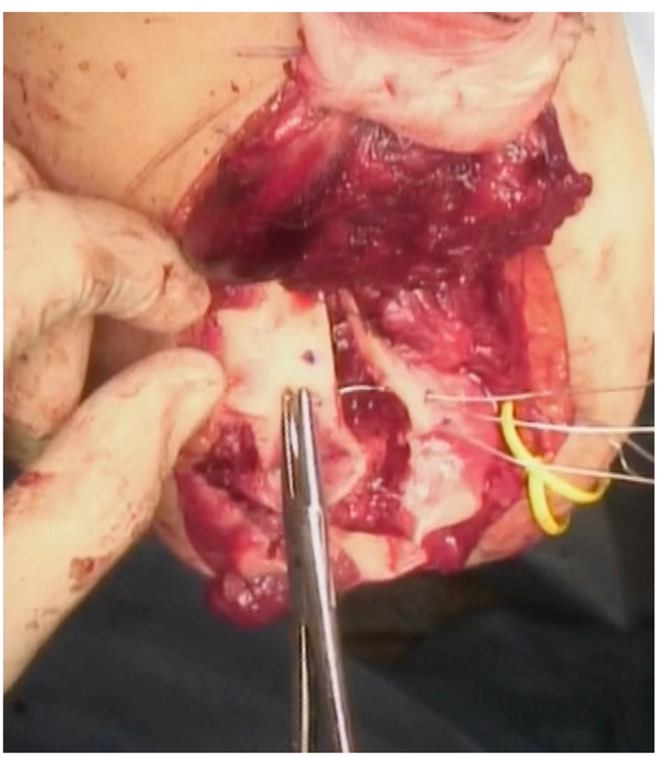

Figure 5 Passing through a wire: a wire was passed through the osseous hole.

Figure 7 Taking up the slack: the wire was tugged to take up the slack and fit onto the opposite side of the cortex.

needle holder, adhered to the bone, and twisted again in the same direction for additional tightening. Moreover, if additional IOWs are required, a K-wire is inserted to fix inter-fragments, likely as a usual temporary fixation, and subsequently the K-wire can be replaced with a soft wire and then tightened as an IOW fixation. Finally, after temporary fixation with IOW (Fig. 9), anatomical locking plates are used for definitive fixation (Fig. 10).

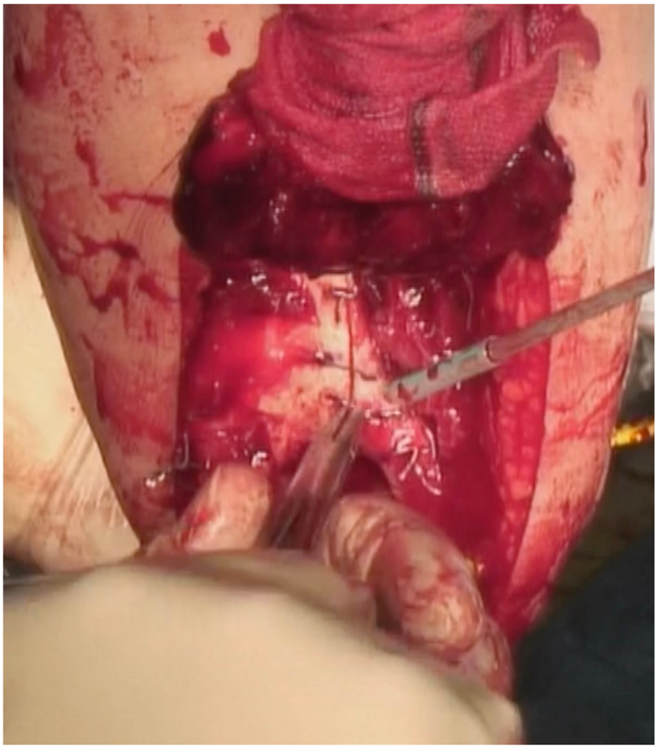

Figure 8 Twisting and tightening the wire: the base of the twisting part is grasped with a Hegar needle holder, pulled to apply tension, and then twisted clockwise at a constant speed.

Figure 9 The appearance after the temporary fixation with intraosseous wiring.

Postoperative care

Following surgery, the operated arm is immobilized for 1 week with an above-elbow splint. Physical therapy, including supervised gentle ROM exercises, is used during this period, depending on the extent of soft tissue damage. Elbow ROM exercises are resumed after the splint is removed. Weight bearing on the affected arm is prohibited for 12 weeks or until the definitive union of the bone is confirmed. The patient can usually resume normal activities without restrictions after 12 weeks.

Results

Case series

This retrospective case series examined the records of all patients with ORIF and IOW for AO/OTA 13-C2 or C3 fractures between 2020 and 2022 at our institution. A minimum of 12 months of clinical and radiological follow-ups were necessary. Six patients were identified in this study. One case involved a complicated comminuted olecranon fracture of the same limb, resulting in a floating elbow (Fig. 11). The IOW technique was used on all the patients, followed by dual plating (Video 1). The measured outcomes included bony union, articular surface fracture gap/step-off, ROM, Mayo Elbow Performance Score (MEPS), and complications. All 6 fractures healed uneventfully. Bone union at the fracture site was observed in all patients within 3 months. There were no more than 2 mm step-offs or gaps in the intra-articular surfaces. The median elbow flexion was 136.7°, extension lag was 10.8°, pronation was 83.3°, supination was 90°, and MEPS was 97.5 points. (Table I).

Complications

One patient experienced radial nerve irritation, which spontaneously resolved. One patient had class I heterotopic ossification[18]; however, revision surgery was not required (Fig. 11).

In addition, the same patient required implant removal for the olecranon plate due to discomfort (case 3). In this study, no surgical site infection, nonunion or ulnar nerve palsy was reported.

Discussion

The clinical and radiologic outcomes of adult patients with IOW as temporary fixation added to dual plating for AO/OTA type C2 and C3 complete articular fractures of the distal humerus were reported in this study.

All patients achieved successful bone union and had favorable clinical and functional outcomes. The goal of treating complicated distal humeral fractures is to achieve adequate stability so that early and intensive rehabilitation can begin. Previous studies have found that patients treated with ORIF for type C distal humeral fractures had good outcomes, with MEPS, values ranging from 78 to 94.[1,10,11,20,25,32] The number of patients in this study was smaller than that in previous studies; however, the outcomes were comparable.

Anatomical reconstruction of the articular surface is a priority in ORIF of intra-articular fractures. The tolerance for an articular surface imperfection on an elbow joint has not yet been identified[13]; however, accurate reconstructions of the articular surfaces tend to achieve better clinical results, especially when the surfaces are repositioned accurately.[4]

In previous studies on distal humerus fractures, the quality of articular surface reconstruction was often evaluated based on

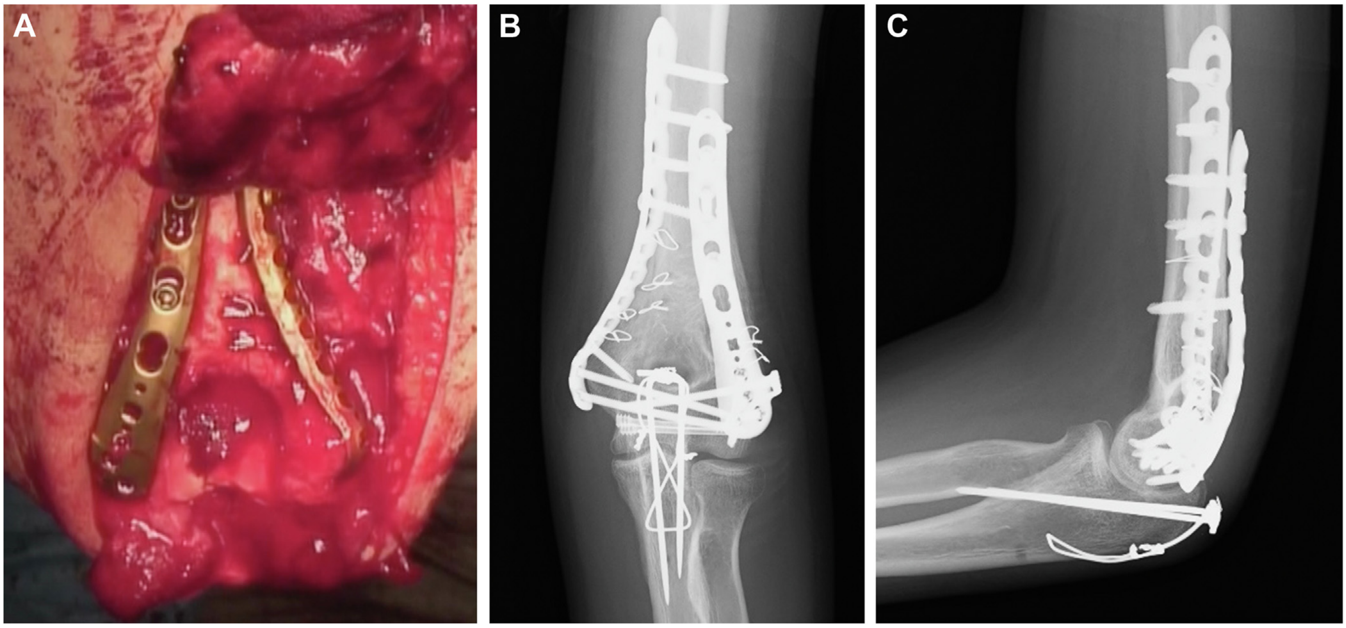

Figure 10 After the fixation: (**A**) the definitive fixation with anatomical locking plates and screws is applied. Radiographs 6 months after surgery: (**B**) anteroposterior and (**C**) lateral.

whether the repair was performed within 2 mm of the gaps.[4,15] In this study, quality was also evaluated and all patients achieved good-quality results.

To obtain a precise reconstruction of the articular surface, it is of great benefit to fix metaphyseal segments anatomically. Because the reconstruction of the medial and lateral columns supports the articular fragments, preventing displacement. Moreover, since some metaphyseal fragments have articular surfaces, repairing them will further contribute to the anatomical reconstruction of the articular surfaces. The reduction and fixation of metaphyseal fragments also influence the biomechanical strength of fracture fixation. Biomechanical studies revealed that when a gap at the metaphyseal segment remained, the orthogonally placed plate construct was significantly less stiff than the parallel-placed construct.[8,30,34] In contrast, when the metaphyseal segment was anatomically restored without gaps, the orthogonal plate construct had equivalent stiffness to the parallel-placed construct.[16,30,31] Based on these findings, we note that leaving a gap in the metaphyseal segment influenced the entire strength of the construct.[6] Clinical research has also revealed that stabilizing the entire construct is as important as restoring the anatomical joint surface.[13]

An anatomical reduction is commonly achieved by compressing the articular and metaphyseal segments with reduction forceps.[28] However, the metaphyseal fragments are often comminuted to be reduced solely with forceps.[27] This issue is significant for distal humerus fractures due to the complicated bony shape, the existence of osseous fossa, and the need for reconstruction of both columns. In addition, because metal implants cannot be placed in the osseous fossa or articular segments, small fragment fixation devices must be placed within a limited space. Comminuted small metaphyseal fragments can be stabilized using K-wires, screws, or miniplates.[24] Every fixation device has advantages and disadvantages. K-wire fixation is the easiest and most commonly used technique for temporarily immobilizing bone fragments. However, the fracture pattern affects the position of the K-wire, which frequently interferes with the proper placement of the main plates.[24] In such instances, the K-wire must be removed before applying the plate, possibly resulting in fracture site redisplacement. In contrast, screw fixation is a commonly used technique.[5] In principle, screws should be inserted perpendicular to the fracture line and fixation should be achieved by applying pressure in the direction of screw insertion. However, depending on the direction of screw insertion and the shape of the bone fragments, the screw can unexpectedly cause displacement as it tightens. Other limitations in screw insertion include difficulty controlling the applied pressure and fixing multiple bone fragments simultaneously. Miniplate fixation is useful in fractures with comminuted bone fragments.[14,24] The plate can function as a bridging device by joining small fragments together and as a buttressing device. However, miniplate fixation is difficult to implement in the setting of complex bone geometries, and it interferes with the placement of the main implant.

The IOW technique has been used for a long time in hand,[2,19] craniomaxillofacial,[9,17] and cardiovascular surgery.[21] The IOW is more appealing than other methods due to its ease of application and efficacy in maintaining reduction before definitive fixation. The IOW relies on the static forces generated by wire tension and the friction between the bone surfaces at the fracture site. Therefore, an appropriate fixation force can be achieved with correct anatomical reduction and adaptation of the bone surfaces.[3] According to biomechanical studies, the fixation strength of the IOW is comparable to that of the miniplate and multiple wiring; thus, the IOW is likely strong enough for the temporary fracture fixation.[7,22] The advantages of IOW for comminuted, distal humeral fractures can be summarized as follows: (1) brings bone fragments together by applying pressure to the same plane, (2) accommodates complex bone geometries, (3) causes less interference with the main implant due to its small size, (4)

Figure 11 Case 3: right distal humerus fracture associated with olecranon fracture in a 38-year-old male. (**A**) Anteroposterior and (**B**) lateral radiographs of the elbow at the time of injury. (**C**) Anteroposterior and (**D**) lateral elbow radiographs at the 12-month follow-up after osteosynthesis.

allows for stage reduction and fixation of comminuted fractures, and (5) offers a cost-effective method with a widespread availability of soft wires.

However, IOW has certain drawbacks. IOW depends on the anatomical reduction and adaptation of the corresponding bone surface, and thus, it cannot be used as a bridging device over the bone defect. The IOW does not adequately immobilize bone fragments in cases of severe comminution, where bone fragments cannot pass through the wires and bone defects prevent precise apposition of bone fragments.[3] In addition, a single intraosseous wire can only provide 2-dimensional stability and cannot withstand 3-dimensional forces.[17] To stabilize bone fragments in 3 dimensions, 2 or more wires must be placed between each pair of fragments or multiple fragments must be fixed together. Further, because wire fixation depends on wire tension, inadequate reduction, improper wire placement, and insufficient

Table I
Individual patient data and postoperative evaluation

Patient no.	Age (y)	Sex	Follow-up length (mo)	AO/OTA classification	Injury mechanism	Elbow ROM (degree)				MEPS (points)	Complication
						Flexion	Extension	Pronation	Supination		
1	72	Female	24	13-C2	Fall	140	−15	90	90	100	None
2	71	Female	36	13-C3	Fall	125	−20	90	90	100	None
3	38	Male	21	13-C3	Traffic accident	130	−5	80	90	100	Heterotopic ossification, Implant removal
4	73	Female	12	12-C2	Fall	140	−10	80	90	100	None
5	56	Female	12	12-C2	Fall	145	−10	80	90	100	Radial nerve palsy
6	33	Female	12	13-C3	Sports accident	140	−5	80	90	85	None
Mean	57.2		19.5			136.7	−10.8	83.3	90.0	97.5	

AO/OTA, AO Foundation/Orthopedic Trauma Association; *ROM*, Range of motion; *MEPS*, Mayo Elbow Performance Score.

wire tightening may cause fixation failure. Finally, IOW may be a simple technique, but implementing it may require a learning curve.

The limitations of this case series include its retrospective nature, a small number of patients, and relatively short-term follow-up. Long-term results may be more reliable if the patients in this study are followed up on and more cases are recruited over time.

Conclusion

In this study, the IOW technique was described in detail. This technique provides solid anatomical fixation to gather small bone fragments for comminuted fractures. This technique was used to treat 6 patients with comminuted distal humeral fractures and the results were favorable. This strategy is suitable for challenging comminuted intra-articular fractures.

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Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.xrrt.2023.05.009

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