Arthroscopic Reduction of Comminuted Intra-Articular Distal Radius Fractures With Diaphyseal-Metaphyseal Comminution

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Purpose In the setting of severely comminuted diaphyseal-metaphyseal fractures of the distal radius, arthroscopic reduction of the joint surface is difficult and often results in shortening and collapse. Yet, several authors have shown the benefits of arthroscopy in articular distal radius fractures. We present a method that safely allows a combination of arthroscopic reduction and rigid fixation and describe the outcomes in a small group of patients.

Methods Four consecutive patients with severely comminuted diaphyseal-metaphyseal articular fractures of the distal radius were treated using the stable reference fragment technique. For all cases, we used an extra-long volar locking plate applied to the diaphysis of the radius. Preoperative computed tomography scanning was used to identify the largest articular fragment. This reference fragment was reduced and stabilized with locking pegs or screws to the volar plate under fluoroscopic guidance. The articular reduction continued arthroscopically, using the reference fragment as a guide. Once the articular reduction was complete, the comminuted metaphysis was addressed and secured to the plate.

Results All patients achieved excellent clinical and radiological results. Flexion-extension averaged 124° and pronation-supination averaged 174°. One patient showed minor signs of radiocarpal osteoarthritis on radiographs at 3 years.

Conclusions By securing the reference fragment before addressing the metaphyseal comminution, a stable platform was created. Thus, intra-articular reduction was achieved while maintaining extra-articular alignment. Although the results were excellent, the number of cases was small. *(J Hand Surg Am. 2014;39(5):835–843. Copyright © 2014 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Arthroscopy, wrist, articular distal radius, comminuted fractures.

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Received for publication November 15, 2013; accepted in revised form February 5, 2014.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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0363-5023/14/3905-0001$36.00/0
http://dx.doi.org/10.1016/j.jhsa.2014.02.013

Intra-articular fractures of the distal radius with comminution of both the diaphysis and metaphysis pose a particular reconstructive challenge because they have a tendency to shorten and collapse. Residual intra-articular stepoff and gap are common.[1,2] Recent literature supports a clinical benefit when arthroscopy is used for intra-articular distal radius fractures,[3–8] particularly with high-energy injuries,[9,10] but it does not address the situation in which there is severe extra-articular comminution. We

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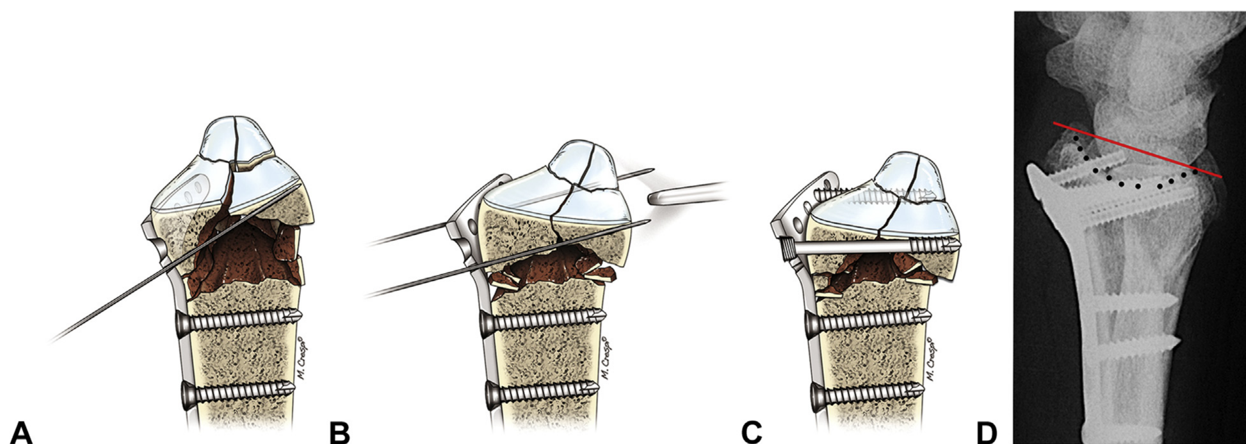

FIGURE 1: A−C Placement of K-wires through the metaphyseal bone may cause loss of reduction during the arthroscopic reduction, ending in a good articular reduction and an extra-articular malunion. **D** Paradigmatic clinical example belonging to the first author (F.d.P.).

explored the use of arthroscopy in less severe degrees of metaphyseal comminution and occasionally experienced undetected loss of extra-articular reduction while arthroscopically performing the intra-articular reduction (Fig. 1).

To overcome the situation in which congruity of the joint is achieved at the expense of the extra-articular reduction, we devised a technique that safely allows use of the arthroscope even in the most comminuted diaphyseal cases by creating a stable reference fragment to guide the rest of the reduction.

The purposes of this study were to detail the surgical technique and to present clinical and radiological outcomes with a minimum of 1-year follow-up in a small group of patients with intra-articular fracture and a high degree of diaphyseal-metaphyseal comminution.

MATERIALS AND METHODS

Between 2009 and 2012, the first author (F.P.) treated 4 consecutive patients with intra-articular comminuted diaphyseal-metaphyseal fractures of the distal radius with this technique. Two fractures were closed injuries and 2 were open injuries; 1 of the latter required emergent revascularization. One fracture was referred at 6 weeks with a persistent radial shortening of 1.5 cm although the patient had been treated with an external fixator. The rest were treated within a week of injury.

The average age was 45 years (range, 31−61 y) (Table 1). Two patients had injuries that occurred at work, 1 was a home accident, and 1 was a motorcycle accident. Preoperatively, the patients were evaluated with standard radiographs (posteroanterior and lateral) as well as computed tomography. All were treated with the technique described subsequently.

At the latest follow-up visit (mean, 3 y; range, 1−4 y), patients were evaluated by the first and third authors for range of motion with a handheld goniometer, grip strength with a Jamar Dynamometer (Clifton, NJ), and pain with an 11-point (range, 0−10 points) visual analog scale. The Patient-Rated Wrist-Hand Evaluation and Disability of the Arm, Shoulder, and Hand questionnaires were administered. Radiographic assessment included standard posteroanterior and lateral radiographs.

Our institution does not require institutional review board approval; however, all patients were aware of the treatment aims and understood the risks and benefits of the procedure. Informed consent was obtained for each patient.

Surgical technique

We used a flexor carpi radialis approach to expose the radius. After a preliminary reduction to restore the length of the radius, an extended volar locking plate (DVR; Depuy, Warsaw, IN) was provisionally applied and stabilized to the intact diaphysis of the radius by inserting a screw into the proximal elliptical hole on the stem of the plate. Then, the largest articular fragment(s), which we refer to here as the reference fragment(s), was identified by computed tomography scan and was reduced and secured to the transverse component of the plate with provisional K-wires inserted through the auxiliary holes of the plate. Once adequate reduction of the reference fragment was confirmed with fluoroscopy, it was rigidly secured to the plate by 1 or 2 locking pegs or screws to construct a bridging column that was resistant to shortening and collapse during the rest of the procedure. Reduction of the reference fragment had to be perfect in the coronal and sagittal planes because it served as the cornerstone for accurate reduction of the remaining articular fragments. If the reference

TABLE 1. Demographics

Patient	Age, y	Sex/ Dominance	Days from Injury to Treatment	Mechanism of Injury	Initial Treatment	Associated Injuries	Soft Tissue Defect	Antecedent Injuries
1	40	M/ND	4	Crush	Splint plus closure of ulnar wound	Open ulnar shaft fracture	Volar radius	Asymptomatic scaphoid nonunion
2	61	F/D	4	Fall	Cast	None	None	
3	31	M/ND	4	Crush	Emergent revascular plus Ex-fix	Comminuted ulna fracture/ base of ulnar styloid	Large ulnar and volar defect	
4	48	M/ND	46	Motorcycle accident	Ex-Fix*	Pelvic fracture, femur fracture, bowel trauma	None	

D/ND, dominant/nondominant; Ex-Fix, external fixator.
*Treatment occurring before to referral.

fragment were inadequately reduced, the final outcome would be severely compromised.

At this stage, small adjustments in the radioulnar relationship were made by loosening the screw in the proximal elliptical hole in the diaphyseal portion of the plate and moving the reference fragment–plate construct *en bloc*. The aim of this step was to restore the radial length and ulnar variance. Once the reference fragment reduction and fixation were achieved, additional diaphyseal screws were inserted into the stem of the plate (proximal to the comminution) to secure the plate to the diaphysis. This provided a rigid construct and avoided migration during the arthroscopic portion of the operation (Fig. 2B).

We then placed the hand on a traction tower and reduced the rest of the fragments to the reference fragment with dry arthroscopic assistance in a manner similar to that reported by del Piñal[11] (Fig. 2C). Although in the standard technique the reduction is performed from ulnar to radial,[11] we had to deviate from this protocol when the reference fragment was radial. In that instance, the reduction progressed from radial to ulnar. Finally, the central diaphyseal-metaphyseal comminution was stabilized by interfragmentary fixation or directly to the plate when possible (Fig. 2D).

Management of a concomitant ulna fracture depended on the degree of comminution. If it was a simple fracture (patient 1), it was reduced first with the intention of providing the guide to restore the radioulnar relationships. Otherwise, it was addressed after the radius reduction and fixation (patient 3). Soft tissue coverage was addressed at the completion of the bony fixation.

Postoperatively, each patient was placed in a protective orthosis. The fixation of the radius was sufficiently stable to allow immediate range of motion after the first dressing change at 48 hours. Self-directed active and assisted exercises were encouraged at that time. A removable plastic orthosis was fabricated to be worn only when at risk of further trauma. After 4 or 5 weeks, any limitation of arc of motion was addressed by assisted exercises under the supervision of a physiotherapist, who put special emphasis on pronation-supination in the early postoperative period. Any deficit was addressed with assisted exercises.

RESULTS

Intraoperative findings

We noted during the reduction that in 2 patients the largest articular fragment was ulnar and in 2 patients

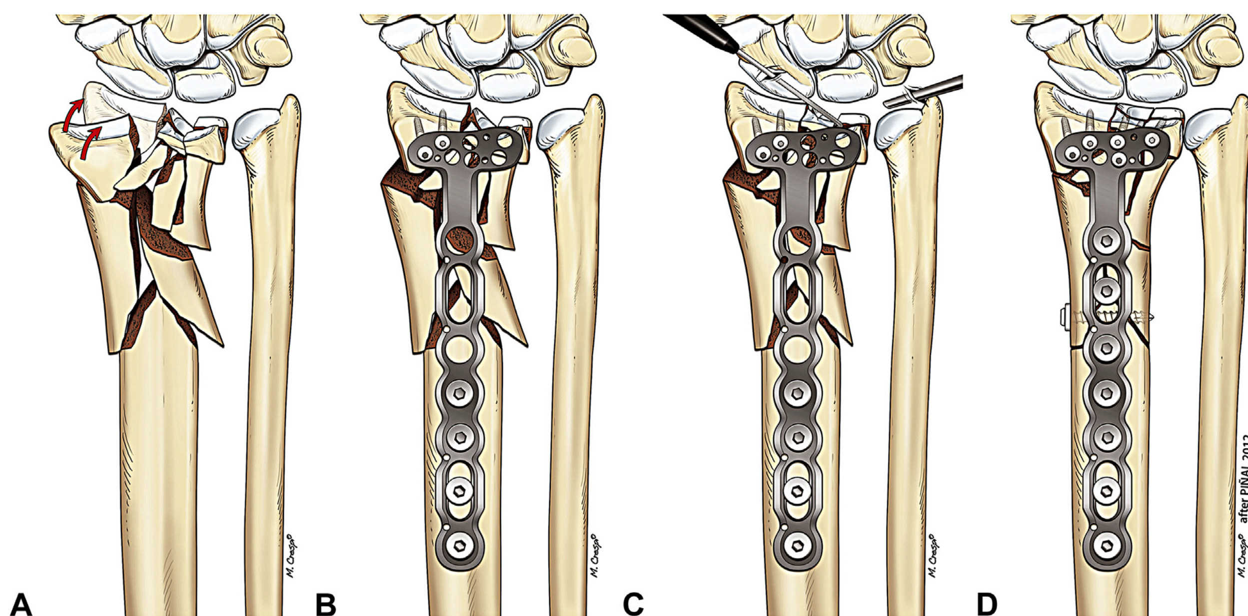

FIGURE 2: Steps of the procedure. **A** Restoration of length and anatomy of the least comminuted fragments (in this case, the radial styloid). **B** Creation of the stable platform by inserting 2 locking pegs or screws. **C** Arthroscopic fine-tuning of the ulnar aspect of the articular surface. **D** Final result after insertion of the locking pegs or screws and fixation of the diaphyseal fragments.

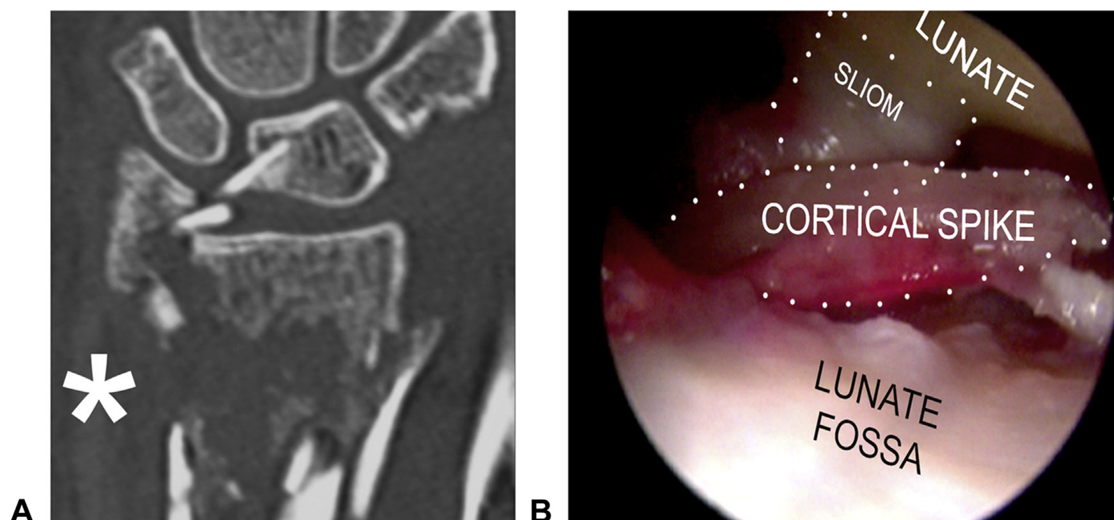

FIGURE 3: Patient 2. **A** A large cortical fragment is missing (asterisk) on the radial cortex and is seen abutting the lunate. **B** At arthroscopy, the cortical fragment was retrieved with a grasper. At the same time, the scapholunate interosseous membrane (SLIOM) was debrided, and the articular surface was reduced.

it was radial. During arthroscopy, it was possible to reduce the articular surface to within 1 mm in all cases. Arthroscopy was also used to extract cortical fragments from the joint in 2 patients (patients 2 and 4) (Fig. 3).

On the ulnar side of the joint, detachment of the triangular fibrocartilage from the dorsal capsule was seen in patients 1, 2, and 4, but because there was no distal radioulnar instability clinically, it was not addressed surgically. In patient 3, an ulnar styloid fracture was fixed with a tension band, and a metaphyseal defect was spanned with a 2.7-mm AO plate (Fig. 4).

Multiple other procedures were performed concomitantly to address other bony and soft tissue injuries (Table 2), including 2 free flaps.

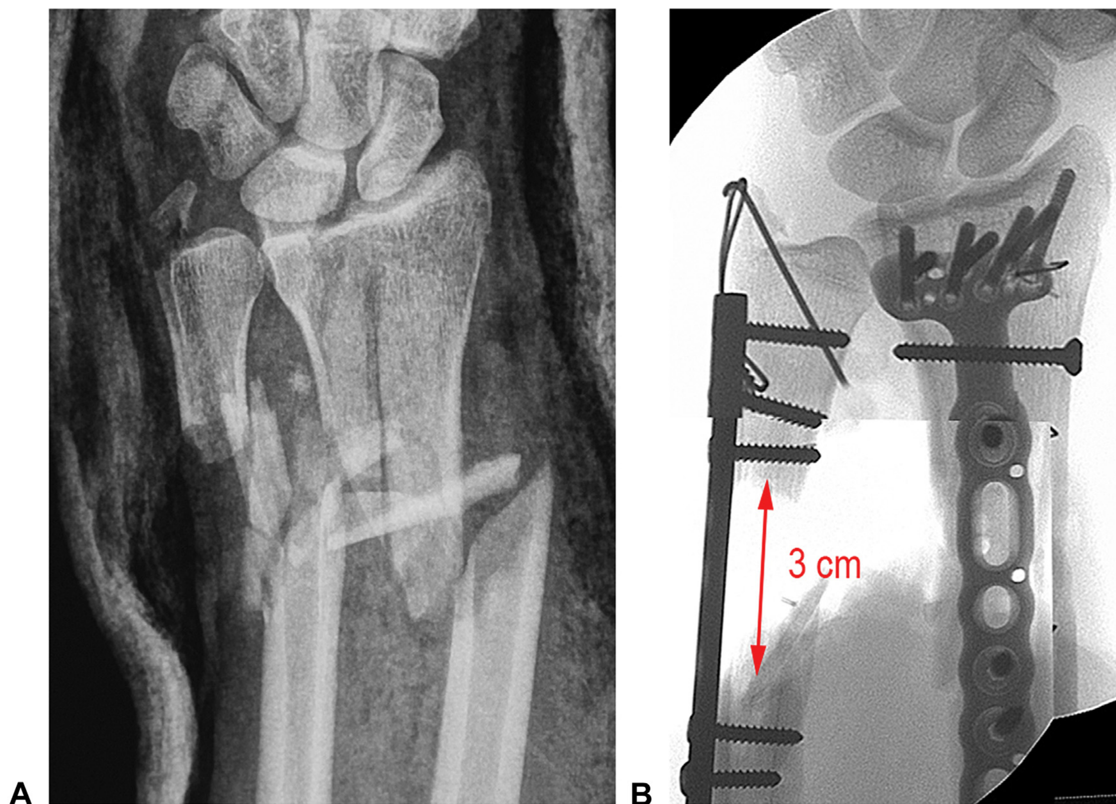

FIGURE 4: **A** In patient 3, reduction and fixation of the radius was performed first, followed by the ulna. **B** A free medial femoral condyle flap was performed to reconstruct the ulnar diaphysis 11 days later.

TABLE 2. Surgical Findings

Patient	Concomitant Bone Fixation	Concomitant Soft Tissue Procedures	Subsequent Procedures
1	Ulnar diaphysis with 3.5-mm AO plate	Free lateral arm flap	None
2	None	None	None
3	Ulnar styloid tension band. Bridging ulnar diaphysis 2.7-mm AO plate	Free iliac flap	11 d: MFC flap for ulna 5 mo: MFC for radius shaft 9 mo: HWR ulna
4	Cancellous bone graft to radius	None	Several unrelated

HWR, hardware removal; MFC, medial femoral condyle corticoperiosteal flap.

In patient 4 (the late referral), the defect in the metaphysis was bone grafted with cancellous bone from the ipsilateral olecranon after the arthroscopic portion of the procedure was completed.

CLINICAL RESULTS

The postoperative flexion–extension averaged 77% and 90%, respectively, of the contralateral side. Grip strength was 95% of the contralateral side. Disabilities of the Arm, Shoulder, and Hand scores ranged from 0 to 16. All patients returned to their preoperative occupation (Table 3).

Radiographic results

We noted no loss of reduction during or after surgery. We found no signs of osteoarthritic changes such as subchondral cysts, joint space narrowing, or sclerosis (Fig. 5), except in patient 1. This patient showed moderate changes, but he had a longstanding scaphoid nonunion, so it was difficult to know which injury contributed to the arthrosis. His wrist was

TABLE 3. Clinical Outcomes

Patient	Grip Strength (°)		Extension (°)		Radial Deviation (°)		Ulnar Deviation (°)		Pronation (°)		Supination (°)		Grip Strength		PRWE	DASH	Return to Work, mo
	Postoperative for AF	CL	Postoperative for AF	CL	Postoperative for AF	CL	Postoperative for AF	CL	Postoperative for AF	CL	Postoperative for AF	CL	Postoperative for AF	CL			
1*	45	70	50	60	10	20	30	40	90	90	90	90	52	39	12	11	7
2	62	80	75	80	30	25	40	42	90	90	90	90	24	22	4	0	4
3	60	80	70	80	20	20	40	45	90	90	90	90	40	54	14	12	10
4	65	70	70	70	10	20	30	40	75	90	80	90	46	58	5	16	8†
Average	58	75	66	73	18	21	35	42	86	90	88	90	41	43	9	10	7

AF, affected; CL, contralateral; PRWE, Patient-Rated Wrist-Hand Evaluation; DASH, Disabilities of the Arm, Shoulder, and Hand.

*This patient had an asymptomatic scaphoid nonunion.

†Back to motorcycle, but because of associated injuries, not yet back to competition.

grade 1 on the Knirk and Jupiter scale of osteoarthritis[12] (Table 4).

Complications

At 48 hours, the free iliac flap of patient 3 developed signs of venous congestion. In the operating room, the skin of the distal forearm was extremely tight. Fenestrations of the forearm skin allowed skin expansion until flow was reestablished.

Patient 3 had delayed healing of the diaphyseal radius fracture at 5 months. The radius was debrided through a dorsal approach, and a free medial femoral corticoperiosteal flap[13] was used to treat the nonunion. During the operation the radial fixation was not adjusted, and rehabilitation continued after the immediate postoperative period. Patient 3 had the ulna hardware removed at 9 months after union was evident. No further procedures have been performed to address the radiocarpal joint thus far.

DISCUSSION

Fractures with diaphyseal-metaphyseal comminution represent a small subset of radius articular fractures. Most studies consist of small numbers of patients, and hence the experience of each team is limited. Not surprisingly, the reported outcomes are worse than less severe articular fractures of the radius,[1,14] with some of the cases ending in arthrodesis. Massive corticocancellous grafts and/or double plating[1,2,15] and spanning plates[16] have been presented as therapeutic alternatives. However, inherent drawbacks such as donor site morbidity, the need for plate removal, and poor clinical results are often reported. Use of the arthroscope seems prohibited for the subgroup of articular fractures with diaphyseal-metaphyseal comminution.[17,18] Nevertheless, the benefit of arthroscopy seems to be widely accepted,[3–10,19] although several studies showed that fluoroscopy was unreliable (Fig. 6).[3,5]

Arthroscopic reduction is often considered contraindicated in open fractures or those with extensive soft tissue damage,[18,20] for fear of contributing to compartment syndrome or the inability to maintain fluid within the joint. When the dry technique is used,[21] those concerns are alleviated. Most important, the dry technique allows the surgeon to use rigid fixation without the difficulty of having tissues infiltrated by the arthroscopic fluid.[11]

Before using this technique, we experienced loss of extra-articular reduction while fine-tuning some of the articular fractures with metaphyseal comminution (Fig. 1), because the K-wires used for temporary fixation travel through the comminuted metaphysis,

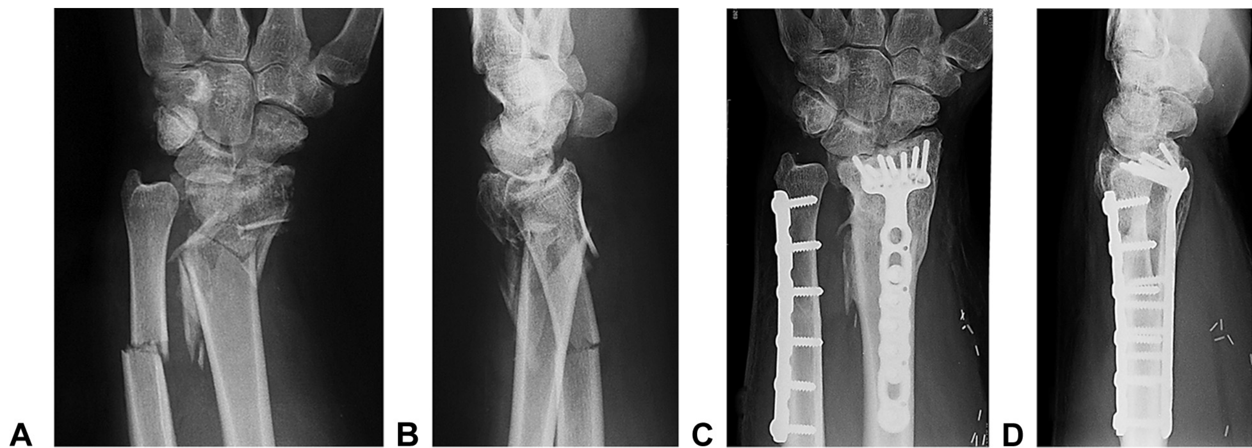

FIGURE 5: **A** Preoperative posteroanterior and **B** lateral radiograms of patient 1. **C** Posteroanterior and **D** lateral radiograms at 3 years. Some joint narrowing is evident, although some changes were also present preoperatively as a result of the scaphoid nonunion.

TABLE 4. Radiographic Results

Patient	Follow-Up, y	Ulnar Variance, mm (Postoperative)	Volar Tilt (°) (Postoperative)	Radial Length, mm (Postoperative)	Osteoarthritis*
1	4	−2	0	6	1†
2	3	+1	8	5	0
3	3	−1	10	8	0
4	1	−3	0	11	0

*According to Knirk and Jupiter, 0 = normal, 1 = some narrowing, 2 = osteophytes, and 3 = bone-to-bone contact.
†This patient had an untreated asymptomatic scaphoid nonunion.

resulting in extra-articular malunion. By creating a stable platform, loss of extra-articular reduction is avoided, simplifying the approach to the articular portion of the fracture. Failure to place the keystone fragment into its perfect anatomical position might compromise the end result. Considerable spatial imagination is needed at the time of placement of the reference fragment(s).

Our radiographic and clinical results compare favorably with reported results of similar fractures.[14,22,23] Less than 1 mm stepoff was achieved in all of our cases with the assistance of arthroscopy. Fluoroscopy may be insufficient to achieve this precise reduction (Fig. 6).[3,5] Indeed, this technique allows for restoration of radial length and reduces the risk of intra-articular gap and stepoff, which are critical factors in the outcome of this type of fracture.[24]

Although open wounds and massive local trauma are associated with decreased range of motion of intra-articular distal radius fractures,[1,2,22] our results do not support this finding. In our opinion, aggressive management of soft tissue and bone defects by vascularized free tissue transfer is a major contribution to our results. Other coverage alternatives such as pedicled local flaps are unreliable or may not be advisable when local trauma is extensive. Distant flaps would limit rehabilitation. We chose fasciocutaneous flaps to provide adequate coverage, allow for primary closure of donor sites, and minimize donor site morbidity.

Unlike other authors[1,25–27] who systematically bone grafted the fracture defects, we did not. We believe that the current locking plates allow the metaphyseal comminution to be left ungrafted. However, diaphyseal comminution is problematic if large fragments are stripped of soft tissues and are therefore dysvascular. Those fractures, as well as fractures presenting late, are probably better treated with bone graft.

Limitations of our study include the small number of patients, the retrospective design, and the lack of a control group. However, this type of fracture is uncommon, and most series report only a few cases. Strengths of the study include a uniform treatment protocol for this fracture pattern. Despite our limited

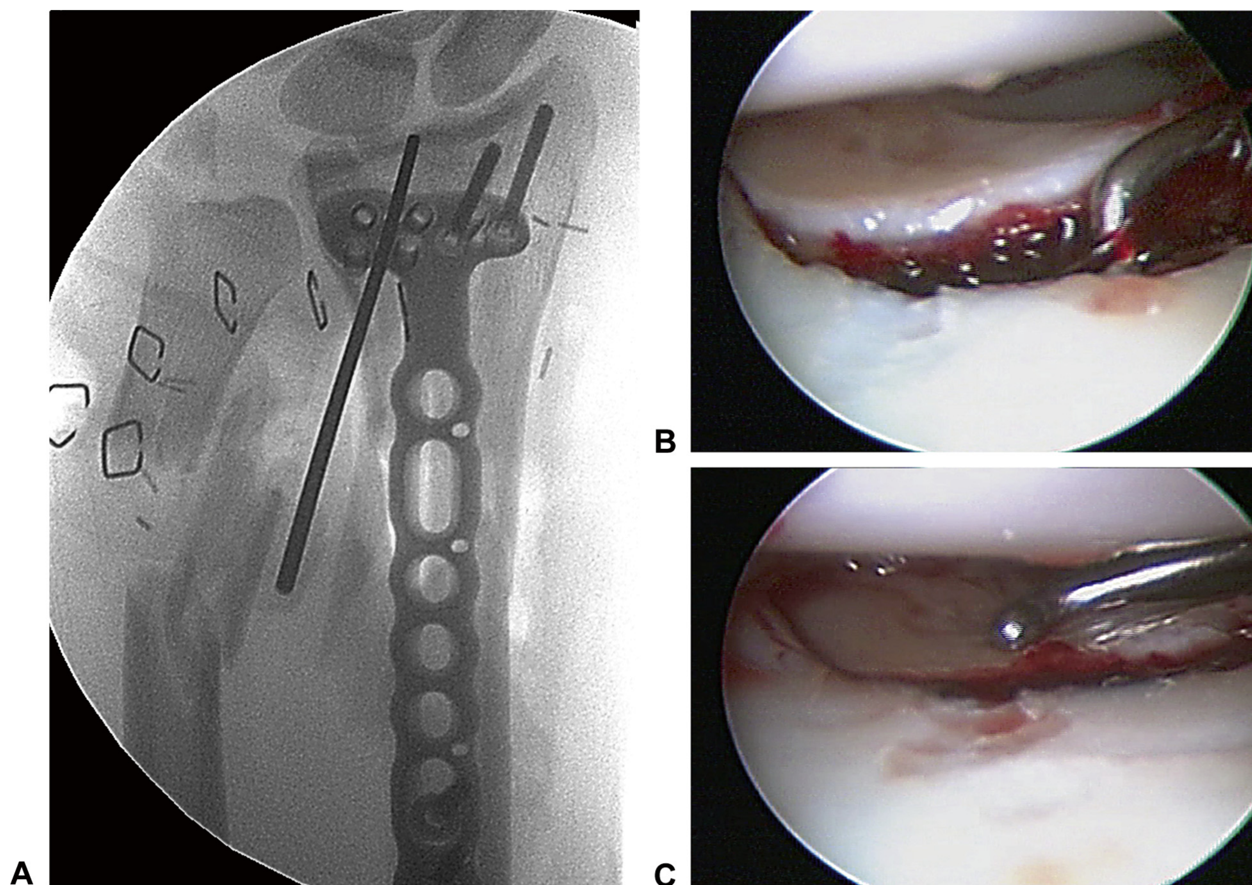

FIGURE 6: Images for patient 3. **A** The radial aspect of the radius was used to restore the length, and the styloid fragment was used as the reference fragment (2 locking pegs already in place). The ulnar side was held temporarily with a K-wire through the plate. **B** Although an apparently perfect reduction was obtained in fluoroscopy, an obvious stepoff of more than 2 mm was still present in the lunate fossa. **C** Anatomic reduction was obtained after arthroscopic fine-tuning. (Arthroscope in the 6R portal. A shoulder probe in the 3−4 portal gives scale to the size of the stepoff.)

numbers, we are encouraged that this method can provide positive reproducible results.

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