Arthroscopic Treatment of Distal Radius Fractures

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1. Introduction

Distal radius fracture (DRF) is one of the most common traumatic events for the hand surgeon to treat. Numerous surgical procedures have been described for this fracture (Ruch et al., 2004); however, the ideal method of surgical management is still controversial. The latest development of a volar locking plate fixation markedly changed the treatment of DRF (Chen & Jupiter, 2007; Chung et al., 2006). Volar locking plate fixation creates a more rigid mechanical construct and allows early rehabilitation that can be initiated with the goal of an improved functional outcome; therefore, volar locking plate fixation currently has widespread popularity, even for dorsally displaced intraarticular fracture (Orbay & Fernandez, 2002; Willis et al., 2006).
The functional outcome of the treatment of DRF is considered to be affected by extraarticular alignment, anatomical reduction of the articular surface, intraarticular soft tissue injuries and postoperative complications. Wrist arthroscopy is currently recognized as an important adjunctive procedure in the management of DRF (Doi et al., 1999; Freeland & Geissler, 2000; Ruch et al., 2004). This is because arthroscopically assisted reduction and internal fixation of DRF cause minimal surgical intervention and provide not only excellent visualization of the joint surface for anatomical restoration of articular fragments but evaluate and treat intraarticular soft tissue injuries. Although it is better used in conjunction with percutaneous pinning and external fixation, wrist arthroscopy becomes problematic when plate fixation is performed because vertical traction has to be both applied and released during surgery; therefore, a plate presetting arthroscopic reduction technique (PART) using a volar locking plate has been developed, that can simplify the combination of plating and arthroscopy (Abe et al., 2008). PART can also be performed with minimal skin incision and is less invasive. This chapter will describe the procedure of PART and its effectiveness for the treatment of DRF.

2. Technique

All patients with DRF were managed initially with closed reduction and casting at the first visit to our clinic. Consecutive patients with inadequate reduction or re-displacement underwent arthroscopic reduction and volar locking plate fixation. Our surgical indications regarding radiological assessment included less than -10 degrees or over 20 degrees of palmar tilt, and over 2 mm of ulnar plus variance compared to the normal side.

Between July 2005 and May 2011, PART was performed in 155 wrists of 153 consecutive DRF patients. Thirty men and 123 women ranged in age from 18 to 84 years old (average age 62 years old). Besides the standard anteroposterior and lateral radiographs, internal and external rotation of the wrist radiographs, computerized tomography (CT), and 3-dimensional reconstruction CT are valuable in deciding a strategy for the reduction of DRF. Intraarticular fractures of the DRF were routinely investigated using these oblique views of radiographs and CT. Contralateral wrist radiographs must be taken with the goal of reducing the fracture for all patients. All the fractures were classified using the AO/ASIF classification system. The fractures consisted of 37 extra-articular (A2: 7, A3: 30) and 118 intra-articular (B3: 6, C1: 40, C2: 18, C3: 54) fractures. For restoration of the articular surface and treatment of soft tissue injury of intracarpal lesions, we consider that wrist arthroscopy may be indicated for all DRF. For this reason, even if it is an extraarticular fracture, arthroscopy was performed to evaluate intraarticular soft tissue injury. Contraindications include severe soft-tissue injury with an open fracture, multiple systemic fractures and compartment syndrome. The locking plates consisted of 106 Acu-Loc plates (Acumed, Hillsboro, Oregon), 39 DRV locking plates (Mizuho, Tokyo, Japan), and 10 other locking plates. The injuries of the scapholunate interosseous ligament (SLIL) and lunotriquetral interosseous ligament (LTIL) were evaluated according to Geissler's classification (Geissler et al., 1996), and triangular fibrocartilage complex (TFCC) tear was evaluated with Palmer's classification (Palmer, 1989).

2.1 Surgical technique

While carrying out PART, intraarticular fragments are almost reduced by manipulation before presetting the plate in AO type B, C1 and C2 of intraarticular fractures; in those cases, a small step-off or separation can easily be reduced arthroscopically; however, in the C3 type, central depression fragments or multifragments, in particular, are hardly reduced by manipulation, and reduction techniques, such as the joy-stick maneuver, tenaculum cramping, or pushing up the fragment from the intramedullary canal, are essential for arthroscopic reduction after presetting the plate (Fig.1).

The patient is positioned supine on the operating table, with the arm draped free on a hand table. A tourniquet is routinely applied to the upper arm and inflated. A longitudinal incision is made between the flexor carpi radialis tendon and the radial artery. The length of the skin incision can change by the severity of comminution at the volar cortex. The shortest one is 2.5cm for a simple metaphyseal fracture (Fig. 2A). The radial artery is identified and retracted radially. The median nerve is retracted ulnarly with the flexor digitorum profundus tendons. Care must be taken throughout the procedure to minimize excessive retraction of the median, palmar cutaneous, and radial sensory nerves. Retracting the flexor pollicis longus muscle ulnarly exposes the pronator quadratus muscle, which is not split but is elevated from the subperiosteum or split distal just one third to expose and reduce the fracture (Fig. 2B).

The fracture is reduced by manipulating the fragments using a periosteal elevator or by intrafocal pinning. Generally, the volar cortex of the radius is less comminuted, reduction of the volar cortex is an indicator of anatomical reduction. Anatomical reduction is confirmed under a fluoroscopy including the joint surface, and the temporary fixation is held with 3 smooth 1.5mm Kirschner wires (K-wires) inserted radially and dorsally. Placement of these wires should not interfere with the placement of the volar locking plate. Four or more K-wires are often necessary for osteoporotic patients. After temporary fixation, the volar locking plate is preset on the volar surface of the radius (Fig. 3). Subchondral support wires are inserted into the distal fragment through the distal hole of the plate, and a screw is inserted into the proximal fragment using the dynamic hole of the plate barrel as a temporary fixation. This screw is inserted in the center of the dynamic hole to slightly regulate the placement of the plate at the secure fixation. Because of a small skin incision, wrist has to be flexed to facilitate inserting this screw.

A

B

C

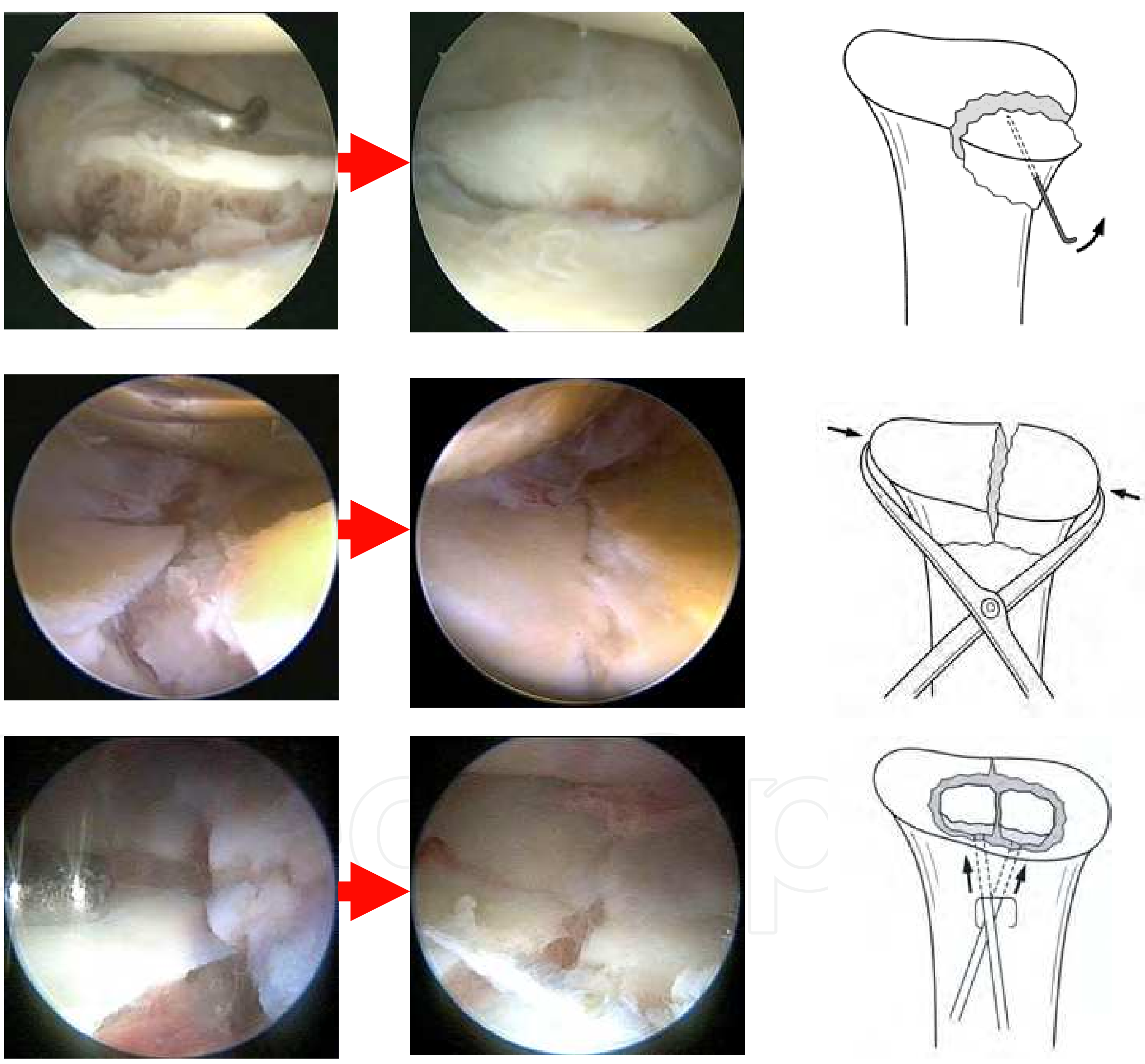
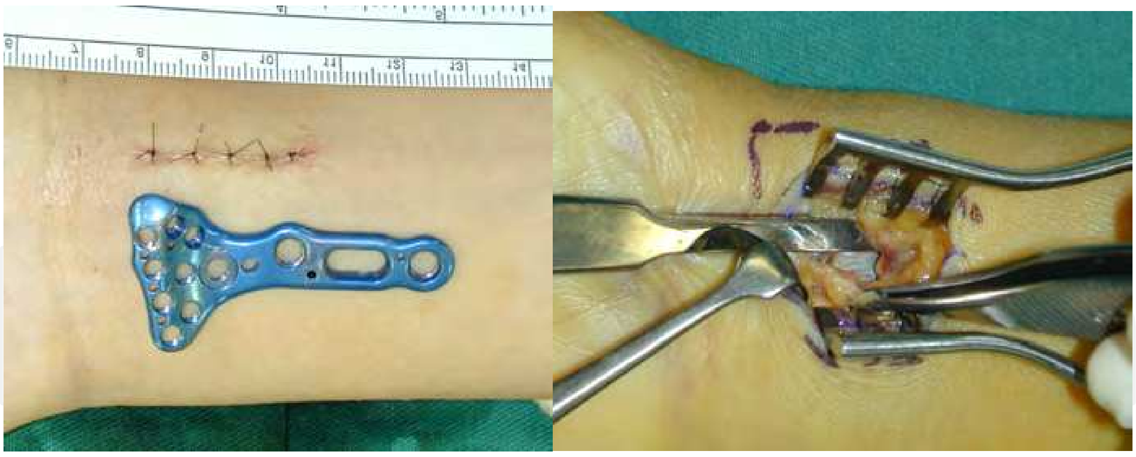


Fig. 1. Reduction techniques for intraarticular fragments. A: joy-stick maneuver, B: tenaculum cramping, C: pushing up from the intramedullary canal.



A B

Fig. 2. Minimally invasive technique in PART. The length of the skin incision is usually from 2.5cm to 3.0cm (A). The pronator quadratus muscle is not split but is elevated from the subperiosteum to protect the muscle belly (B).

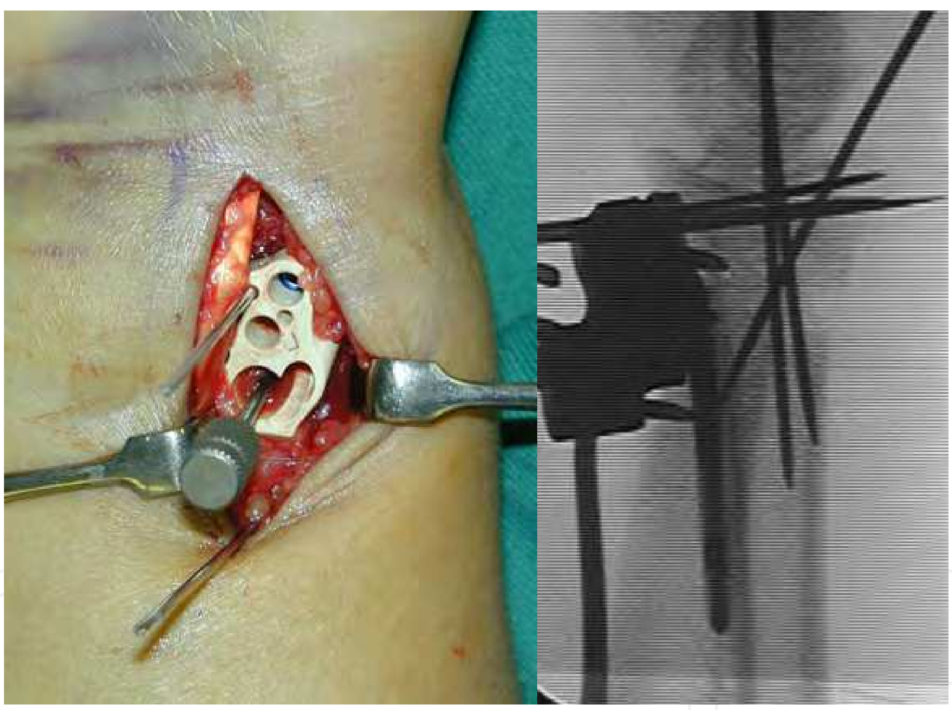


Fig. 3. A volar locking plate was preset on the radius

After the plate is preset, the wrist is suspended in vertical traction, and arthroscopy is performed. We generally use 3 arthroscopic portals to totally evaluate and treat the intraarticular fragments and soft tissue injuries (Fig. 4). Two dorsal portals are 3-4 portal (between the extensor pollicis longus tendon and the extensor digitorum communis tendons) and 4-5 portals (between the extensor digitorum communis tendons and the extensor digiti minimi tendon) that are well known and popularly used. Another portal is the volar radial portal (between the flexor carpi radialis tendon and the radial artery). Through this portal, we can adequately visualize the dorsal fragment of the intraarticular fracture and volar segment tear of the SLIL and LTIL (Abe et al., 2003; Abe et al., 2003). Because the volar side of the skin is already open, and the tendons, nerves, and artery are retracted, the volar portal can be safely accessed.

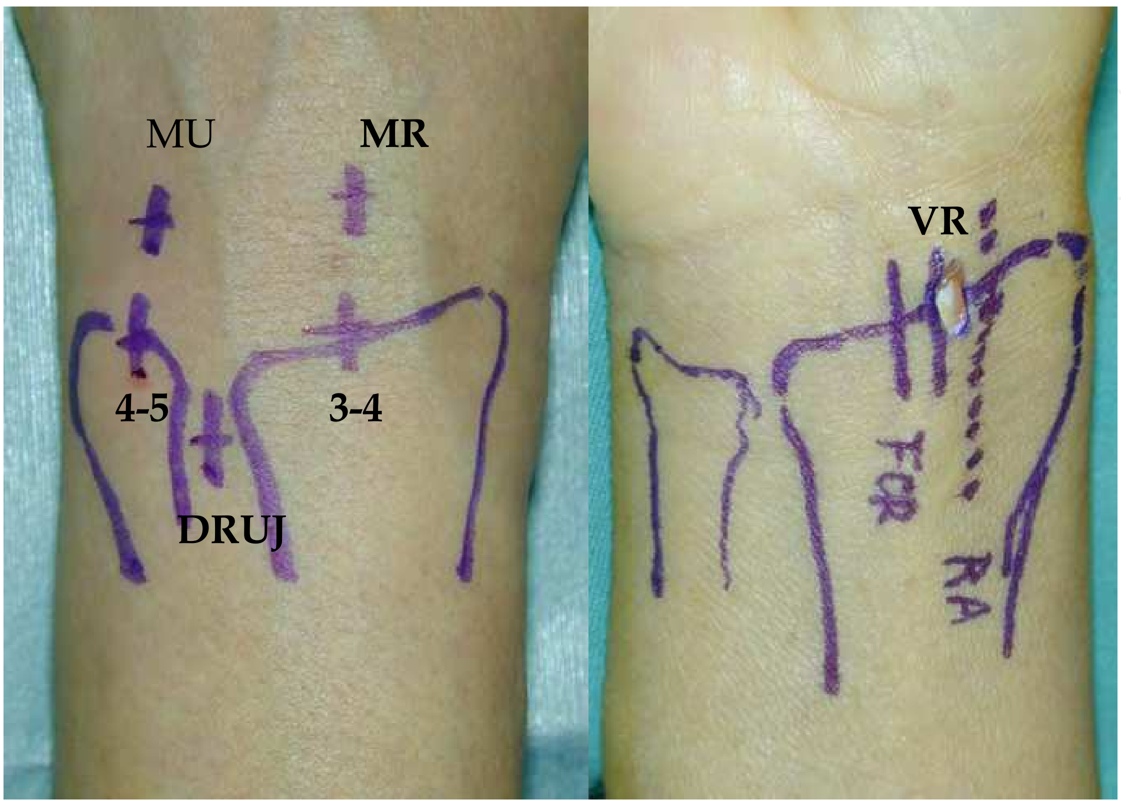


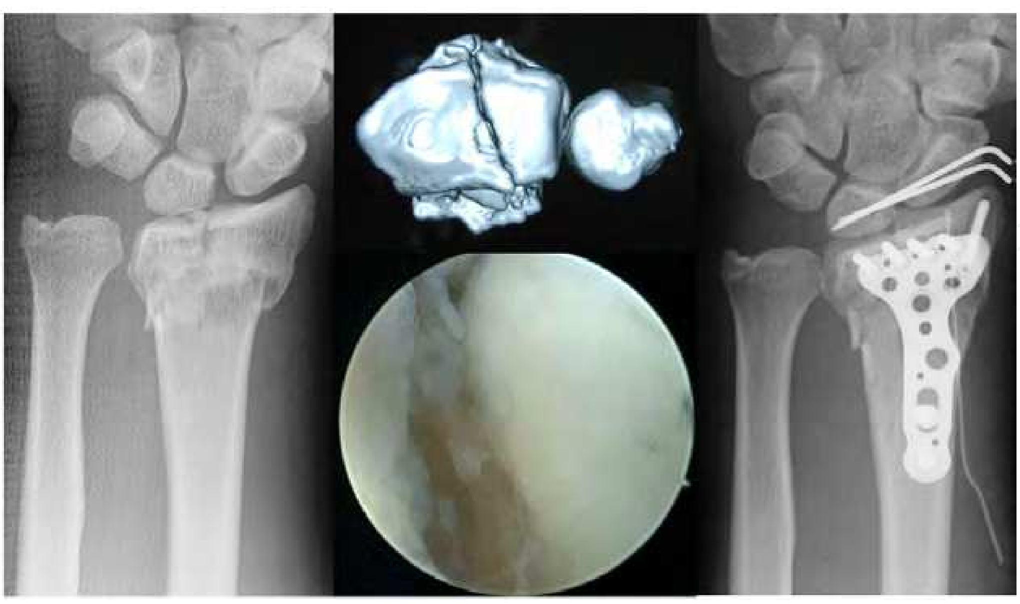
Fig. 4. Arthroscopic portals. MR (radial midcarpal portal) and MU (ulnar midcarpal portal) are used to evaluate the instability between scaphoid and lunate, lunate and triquetrum. DRUJ portal is used to investigate the foveal tear of the TFCC. VR: volar radial portal.

A 2.3-mm arthroscope with a 30-degree field of vision is introduced through the volar portal. The remaining hematoma in the joint is removed using a shaver inserted through the dorsal portal. The degree of dislocation of the dorsal fragments is evaluated initially from the volar portal. The volar side of the SLIL and the LTIL are also evaluated. An arthroscope is subsequently inserted from the dorsal portal, and total intraarticular fragments, including on the volar side, must be evaluated. The volar fragment is already reduced on initial manipulation, an intraarticular volar fragment may be an indicator of arthroscopic reduction. The subchondral K-wire that prevents reduction of the fragment then has to be removed. Central depression is reduced by pushing up from the intramedullary canal using a probe inserted at the dorsal fracture site. Radial and dorsal fragments are reduced using a joy-stick maneuver (Fig. 5). The K-wire, inserted initially to maintain the reduction, is often used as a joy-stick. The separate fragments are well reduced by a tenaculum cramping on the outside of the skin. After achieving reduction of the fragments, the subchondral K-wire is reinserted to maintain reduction. The major dorsal fragment is often fixed with a screw or a small plate independently.

A B

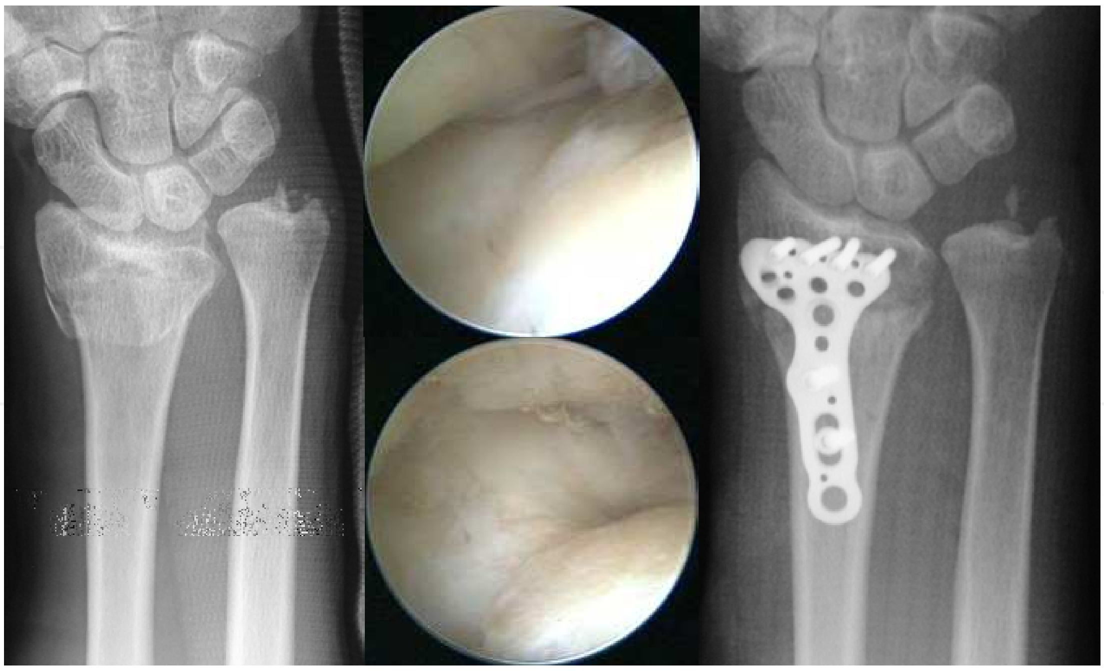
Fig. 5. Arthroscopic reduction for the intraarticular fragments. A: pre-reduction, B: post-reduction. Dorsal fragment was elevated using joy-stick maneuver.

After reduction of the intraarticular fragments arthroscopically, associated cartilage and soft tissue injuries should be evaluated and treated. Our strategy for the treatment of SLIL injury is percutaneous pinning for grade III instability (Fig. 6), pinning, repair of the dorsal part of SLIL, and augmentation using a dorsal intercarpal ligament for grade IV instability in active patients. For TFCC injury, debridement is indicated for traumatic disk tears. Peripheral tear is repaired arthroscopically (Fig. 7). Both procedures are also indicated for active patients.



A B/C D

Fig. 6. This is a 47 y.o. male, C2 fracture (A, B) associated with grade III SLIL tear confirmed with midcarpal arthroscopy (C). Scapholunate joint was fixed with K-wires (D).



A B / C D

Fig. 7. This is a 53 y.o. male, A3 fracture (A) with TFCC ulnar styloid tear (B). Fracture was fixed with a volar locking plate (D), TFCC tear was repaired arthroscopically (C).

Intraarticular fragments and soft tissue injuries are treated, then vertical traction is removed, and the volar locking plate is subsequently and securely fixed to the distal radius (Fig. 8). After introducing the volar locking plate, we rarely perform bone grafting for dorsal bone defect. The wound is irrigated, a drain is inserted, and the overlying skin is closed.

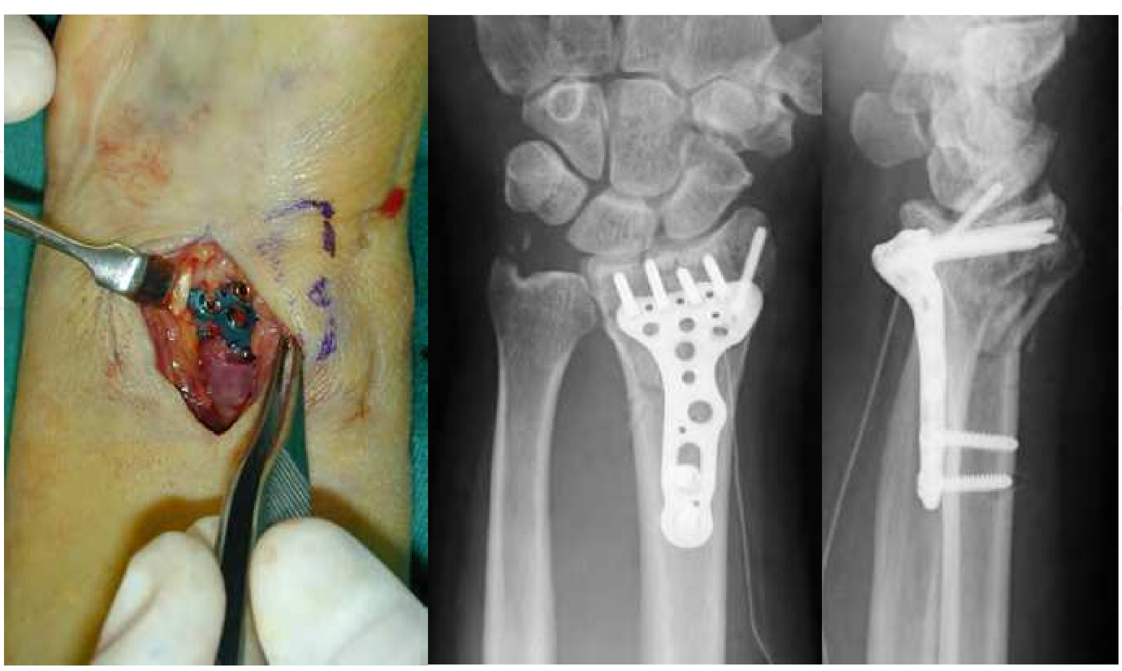


Fig. 8. Final fixation. The pronator quadratus muscle was preserved.

2.2 Postoperative management

Since the volar locking plate provides rigid fixation, early rehabilitation can be allowed. A dorsal splint is applied just after surgery, the splint is then removed during the daytime, and active wrist motion is started on the first day after surgery. From the second day, passive motion and grasping exercises are started with a therapist. The night splint is removed within 7 days after surgery. Forearm rotation exercises are prohibited in patients who have ulnar side injuries, such as distal ulna fracture, ulnar styloid fracture and TFCC repair until 3 weeks after surgery.

3. Outcomes

Final evaluation was obtained from the radiological outcome, measurements of wrist and forearm motion, grip strength, the Mayo modified wrist score (Cooney et al., 1994) and the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire. Wrist flexion-extension was assessed with a goniometer. Forearm supination and pronation were assessed with the elbow flexed 90 degrees at the patient's side. Grip strength was measured with a calibrated Jamar dynamometer. The average of three trials for both hands was recorded for all strength measurements. We could recognize several advantages of arthroscopic surgery for DRF. During PART, anatomical reduction of the articular surface was achieved with fluoroscopy initially, and reduction was re-confirmed with arthroscopy. In this process, we can recognize the dissociation between fluoroscopic and arthroscopic reduction, and this dissociation was assessed. The frequency and severity of intraarticular soft tissue injury could also be evaluated using arthroscopy.

Surgical time ranged from 38 to 150 minutes (average 82 minutes). The case that needed 150 minutes included SLIL repair and TFCC debridement. One-hundred ten wrists were followed up for over 1 year so far (by May 2011). The follow-up period ranged from 12 to 48 months (average 18 months). At final follow-up, the mean palmar tilt was 5.6 degrees (-10 to 16 degrees), radial inclination 26.1 degrees (18 to 31 degrees), and ulnar variance 0.1mm (-2mm to 5mm). The mean active extension of the wrist was 62.5 degrees (45 to 80 degrees, 92% on the uninjured side), and the mean flexion was 60.1 degrees (45 to 80 degrees, 88% on the uninjured side). The mean pronation of the forearm was 83.1 degrees (70 to 90 degrees, 96% on the uninjured side), and the mean supination was 86.5 degrees (75 to 95 degrees, 97% on the uninjured side). The mean grip strength was 88.2% (38% to 110% on the uninjured side).

In 118 wrists of intraarticular fractures, 108 wrists seemed to achieve reduction with fluoroscopy; however, there remained a gap or step-off of over 2mm in 38 cases (35.2%), confirmed arthroscopically. Among 155 wrists, SLIL injury was recognized in 44 wrists (28.9 %). According to Geissler's classification, 24 wrists were grade I, 4 were grade II, 13 were grade III and 3 were grade IV. Debridement for a torn ligament was performed in 4 wrists (grade I: 2, grade III: 2), scapholunate pinning was performed for 3 wrists of grade III, and 1 wrist of grade IV underwent reconstruction. LTIL injury was recognized in 23 wrists (14.8%). Nineteen wrists were grade I, 2 were grade II, 1 was grade III, and 1 was grade IV. Only 2 wrists of grade I were debrided for the torn ligament hung down. TFCC injury was recognized in 98 wrists (63.2%). Sixty-seven wrists were 1A tear, 5 were 1B, 1 was 1D, 7 were 1A+1B, 1 wrist was a foveal tear and 17 wrists were degenerative tear. Debridement was performed for 53 wrists (1A: 50, 1A+1B: 3), debridement and repair were performed in 1

wrist (1A+1B), repair was performed for one wrist of 1B tear and one foveal tear. Pinning was applied for one wrist of 1D tear.
The final results of 110 wrists according to the Mayo modified wrist score were 84 excellent, 24 good and 2 fair. The mean DASH score at final follow-up was 4.2 points (0 to 30). There were few complications: 3 re-dislocation of the distal fragment, 2 extensor pollicis longus rupture and 1 complex regional pain syndrome. The final results of these 6 cases were 4 good and 2 fair.

4. Summary

The theories of the treatment of peri- or intraarticular fractures are 1) recover alignment, 2) reduce intraarticular fragments, 3) treatment for intraarticular soft tissue injuries, 4) rigid fixation that allows early rehabilitation. Less invasive technique is recently advocated. Prognosis is generally less favorable for displaced, comminuted, intraarticular fractures. Treatment for DRF should also be performed according to these theories. Although various factors affect the prognosis of DRF, accurate reconstruction of the alignment of the radius with its carpal and ulnar articulations, articular surface and treatment of soft tissue injury of intracarpal lesions are the most important factors. Accurate reconstruction of the articular surface, with the goal of establishing anatomic congruency of that surface, is important to minimize the risk of late osteoarthritis. Knirk and Jupiter (1986) reported that displacement of 2 mm or more of the distal radial articular fragments resulted in traumatic osteoarthritis. Further investigation indicated that the critical tolerance for joint surface incongruity may be as little as 1mm (Fernandez & Geissler, 1991; Mehta et al., 2000; Trumble et al., 1994). We have experienced that reduction with a fluoroscopy is not always accurate compared to reduction with wrist arthroscopy. Dissociation between two reduction procedures was 35.2%. This rate is similar to other reports, such as 33% in Edwards (2001) and Lutsky's (2008).
If an associated carpal ligament or TFCC injury is suspected even in a nondisplaced DRF, adequate treatment is mandatory to prevent the development of carpal instability or ulnar side wrist pain. Geissler et al. (1996) demonstrated a considerable rate of soft tissue injuries associated with DRF. These soft tissue injuries have been thought to influence the functional outcome; however, the evaluations performed to date for intraarticular soft tissue injuries combined with DRF have not been sufficient. The causes of chronic wrist pain after DRF treatment were analyzed by Cheng et al. (2008): ulnocarpal abutment caused by mal-union, ulnar styloid non-union, intraarticular soft tissue injury and chondral lesion. Especially regarding the TFCC, some authors recommend acute arthroscopic repair of peripheral tear of TFCC in conjunction with distal radius fixation resulted in a highly satisfaction (Lindau et al., 2000; Ruch et al., 2003). Furthermore we have experienced over 10 cases of chronic wrist pain due to TFCC disk tear after healing of DRF with almost normal alignment. They were treated volar locking plate fixation without arthroscopic assessment or conservative treatment. For this reason, we consider that slit or flap tear of the disk should be debrided.
Wrist arthroscopy is an effective adjunct for this pathology; therefore, wrist arthroscopy may be indicated for all DRF. When volar plate fixation is indicated, the standard upright position makes it problematic to combine arthroscopy and plate fixation because traction has to be both applied and released; PART is able to solve this problem. An alternative is to use a traction table, which makes it possible to perform arthroscopy in a horizontal position (Culp & Osterman, 1995); however, this technique is sometimes more technically

demanding and, using a volar and dorsal approach simultaneously, may be difficult in this position. Slade et al. (2005) reported provisional K-wire fixation of the fracture fragments of the radius after arthroscopic reduction and volar locking plate fixation; however, several cases where re-displacement of the fragments occurred when performing arthroscopy in this sequence were experienced in our series.

The volar locking plate system has been shown a reliable and satisfactory result for the DRF without arthroscopy in some chapters. Chung et al. (2006) reported the results of 87 patients, mean age of 48.9 years old, including 65% of intraarticular fracture. One year after surgery, mean grip strength was 78.7% of the contralateral side, mean flexion was 58.0 degrees, extension was 60.5 degrees, pronation was 78.6 degrees and supination was 79.6 degrees. Lozano-Calderón et al. (2008) reported the results of 60 patients treated with a single, fixed angle volar plate. They were classified into 2 groups of early motion group (range of motion was started within 2 weeks) and late motion group (range of motion was started at 6 weeks). Early motion group that was similar with our series, demonstrated 68 degrees of flexion, 56 degrees of extension, 90 degrees of pronation and 88 degrees of supination at 6 months after surgery. Grip strength was 78% of contralateral side and DASH score was 8.5. The report of 54 patients with intraarticular DRF and a mean age of 63 years by Gruber et al. (2010) demonstrated 58 degrees of flexion, 57 degrees of extension, 83 degrees of pronation, 68 degrees of supination, grasping power was 71% of contralateral side at 6 years after surgery. DASH score was 5 points at 2 years follow up. Our results were superior to those of these reports. Our results were considered to be derived from the several advantages of PART. A volar locking plate that seems to offer the most stable construct (Osada et al., 2003) enables early range of motion and grasping exercises. PART is possible with a small skin incision and preserving the pronator quadratus muscle. Arthroscopic management is less harmful to soft tissue around the wrist joint; therefore, early rehabilitation can also be indicated. Irrigation to remove fracture hematoma and debris potentially reduces the inflammatory reaction and improves the range of motion. In addition, initial treatment for concomitant SLIL injury and TFCC tear may contribute these satisfactory results.

In conclusion, wrist arthroscopy is a feasible adjunct for the treatment of DRF, especially as it can evaluate the reduction of intraarticular fragments and soft tissue injury. In recent years, volar locking plate fixation has become popular, and simultaneous arthroscopic procedures for reduction have become problematic because vertical traction has to be applied and released during surgery. A PART can overcome these difficulties, and this technique can be performed with a small skin incision, preserving the pronator quadratus muscle, and simplifies the combination of plating and arthroscopy, and achieves good final result.

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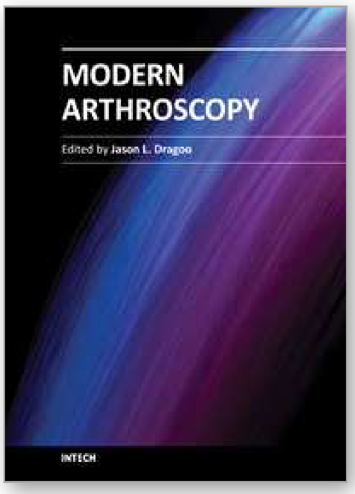

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