



# Combined Approach for Intra-articular Distal Radius Fracture: A Case Series and Literature Review

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**Background:** The purpose of this study was to classify the possible indications for a combined approach to distal radius fractures (DRFs) by investigating surgical outcomes of patients treated according to our treatment algorithm.

**Methods:** A combined approach was performed in 32 patients. Patients who were thought to need a combined approach were classified into three types according to the combined injuries associated with loss of volar cortical buttresses in DRFs. The classifications included the following: type 1, free intra-articular fragments; type 2, distally migrated dorsal fragments located beyond the wrist joint; and type 3, centrally impacted articular fragments and displaced dorsal fragments, not reduced by indirect methods.

**Results:** Seven patients had type 1 fractures treated with volar plates and excision of the intra-articular fragments. Fourteen patients had type 2 fractures: 12 were treated with volar plates and excision of dorsal fragments, and 2 with relatively large unstable dorsal fragments were treated with combined volar and dorsal plates. The remaining 11 patients had type 3 fractures treated with combined volar and dorsal plates. At the latest follow-up, the radiographs revealed an average of 16.9° of radial inclination, an average of 4.2° of volar tilt, and an average of 7.5 mm of radial height. According to the Garland and Werley scores, the functional results were excellent for 3 patients, good for 25, and fair for 4.

**Conclusions:** The classification system indicated when an additional dorsal approach was needed in unstable DRFs, and it may establish useful guidelines for appropriate surgical decision-making.

**Keywords:** *Radius, Approach, Plate*

The placement of volar locking plates has become a popular technique in the surgical treatment of distal radius fractures (DRFs). The reasons for this include the ease of the surgical approach, reduced tendon irritation, and sufficient mechanical stability. Despite these advantages, it is not a panacea for managing all DRFs.<sup>1)</sup> In some cases, such as in dorsal Barton fractures, comminuted intra-articular

fractures requiring direct visualisation of the joint, and other carpal injury fractures, a dorsal approach with or without dorsal plating is necessary.<sup>1,2)</sup> A dorsal approach to the wrist allows for direct visualisation of the articular surface to ensure adequate anatomic reduction.<sup>2)</sup>

However, when there is an extensive comminution of the volar and dorsal aspects of the wrist, single plating from the dorsal or volar surface alone may not provide sufficient stability.<sup>3)</sup> These fractures are referred to as complex DRFs and they are more commonly seen in elderly patients with osteoporosis or in younger patients after high-energy trauma.<sup>1,3)</sup> Treatment of these types of fractures has been challenging for orthopedic surgeons and many treatment options have been introduced. Among the many treatment options, recent studies have focused on volar and dorsal plating techniques in a combined ap-

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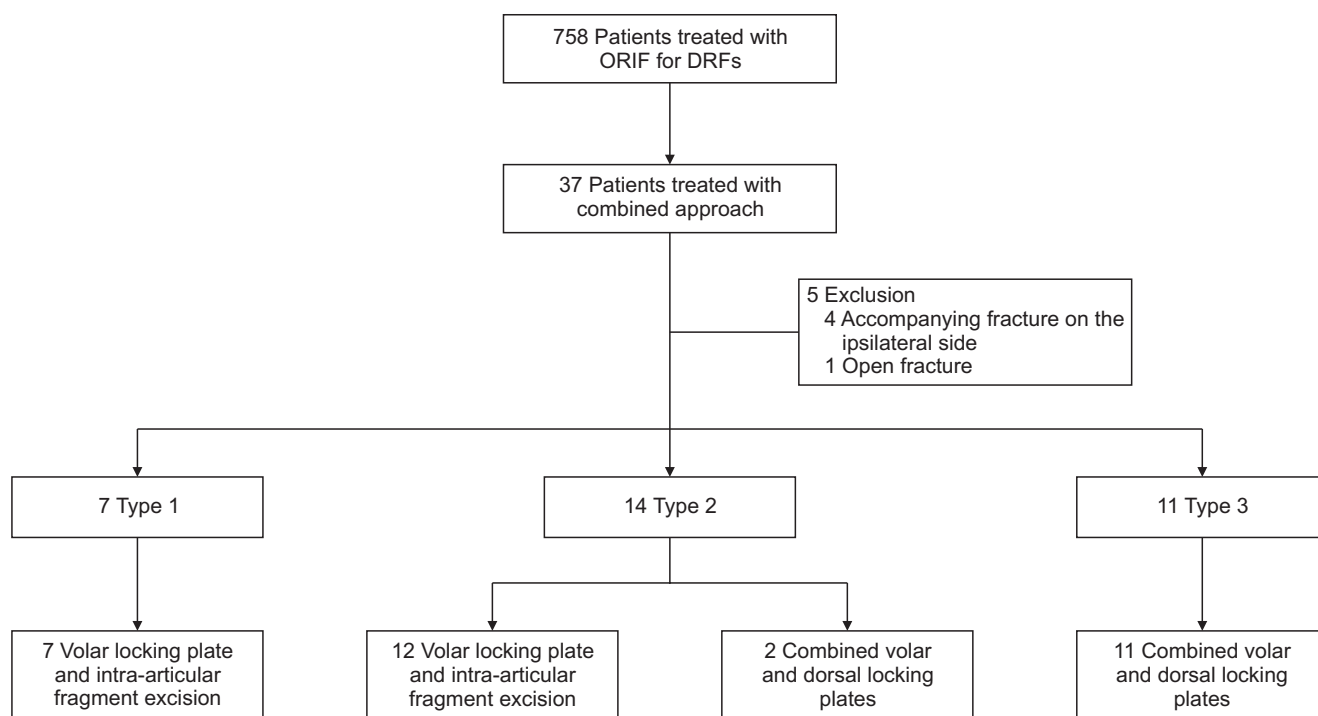
proach, and good functional outcomes have been reported.<sup>4-6)</sup> In many of the previous studies, combined volar and dorsal plating was performed in a similar fashion. First, the volar plate was fixed in the standard volar approach to restore extra-articular alignment. Next, the intra-articular fragments were reduced via the dorsal approach, which allows direct visualisation of the articular surface. Subsequently, the dorsal plate was fixed on the dorsal surface.<sup>3-5)</sup> However, in our experience, a dorsal plate was not always necessary when a dorsal approach was performed after fixation of the volar plate. Furthermore, in some cases, an additional dorsal approach was needed even if the DRF was not complex. Thus, in the clinical setting, it is not always easy to determine whether an additional dorsal approach is needed after volar plate fixation.

The purpose of this study was to suggest and classify the possible indications for a combined approach in the management of DRFs. We also evaluated the functional and radiologic outcomes in patients managed according to our treatment algorithm.

## METHODS

As this study was retrospective in nature, informed consent was not obtained according to the guidelines of our Institutional Review Board. This retrospective, single-center, case series study was approved by the Institutional

Review Board of our institution (IRB No. 1809-001-16202). From March 2012 to November 2016, a total of 758 patients were treated with open reduction and internal fixation for DRFs at our institution. Among them, 37 patients who underwent a combined approach for surgical management of a DRF were enrolled in the study. Patients were treated with this method of treatment if the fracture pattern was included in the following classification. The classification took account of the combined injuries associated with displacement volar fragments and/or loss of volar cortical buttresses. Type 1 injuries were defined by a free intra-articular fragment without connection to a metaphysis. Type 2 injuries were defined by distal migration of a dorsal fragment beyond the wrist joint. Type 3 injuries were defined by a centrally impacted articular fragment and displaced dorsal fragment, which was not reduced by an indirect method. A volar approach was necessary for reduction of displaced volar fragment and volar cortical buttress plating. When restoration of the articular surface with indirect method was insufficient, a dorsal approach was used to approach the dorsal fragment or visualize the radiocarpal joint. Of the 37 study patients, 4 had accompanying fractures of the scaphoid (2 patients), radial head (1 patient), and ulnar shaft (1 patient) on the ipsilateral side. One patient had a Gustilo and Anderson type 3 wound at the fracture site, which was initially treated with external fixation. The patient underwent a second operation after



**Fig. 1.** Flowchart and treatment algorithm used in the current study. ORIF: open reduction and internal fixation, DRF: distal radius fracture.

3 weeks and a combined approach was used.<sup>7)</sup> These 5 patients were excluded from the study (Fig. 1).

All patients were evaluated using three-dimensional computed tomography (CT) preoperatively and operated on by a single surgeon (JSL) within 2 weeks of their initial evaluations. They were followed clinically and radiographically for a minimum of 1 year. Each patient's medical records and radiographs were reviewed and the demographic, mechanism of injury, and operative findings data were collected.

The study group included 8 men and 24 women with an average age of 56 years (range, 22–77 years). The mean duration of follow-up was 32 months (range, 13–84 months). The mechanisms of injury were as follows: falls from standing height (9 patients), falls from great height (17 patients), motor-vehicle accidents (4 patients), and sports-related injuries (2 patients) (Table 1).

### Surgical Technique

Under general anaesthesia or brachial plexus block, the patients were placed in the supine position, and the injured hand was placed on a radiolucent operating table. A skin incision measuring about 4 cm was made and the fracture was exposed using a volar Henry approach. Once the volar metaphyseal fracture site was visualised, the fracture was reduced by longitudinal traction or an intra-focal method and was temporarily fixed using Kirschner wires. Under image intensification, a volar locking plate (Synthes, Paoli, PA, USA or Biomet, Miami, Florida, USA)

was placed, which served as a buttress for the distal fragment, and a proximal screw was inserted first. In type 1 or 2 fractures, distal locking screws that fixed more than 75% of the bone thickness were then inserted. In type 3 fractures, distal locking screws that fixed less than 50% of the bone thickness were inserted just to maintain the extra-articular alignment of the DRF. With the volar buttress plate in place, an additional dorsal approach was performed through the third and fourth extensor compartment to excise the fracture fragments in type 1 or 2 fractures and to achieve an accurate reduction of the joint surface in type 3 fractures. The extensor pollicis longus (EPL) was mobilised from the third dorsal compartment, and the exposed joint capsule was incised longitudinally. In type 1 or 2 fractures, intra-articular free fragments or distally migrated fragments could be removed through a dorsal approach (Figs. 2 and 3).

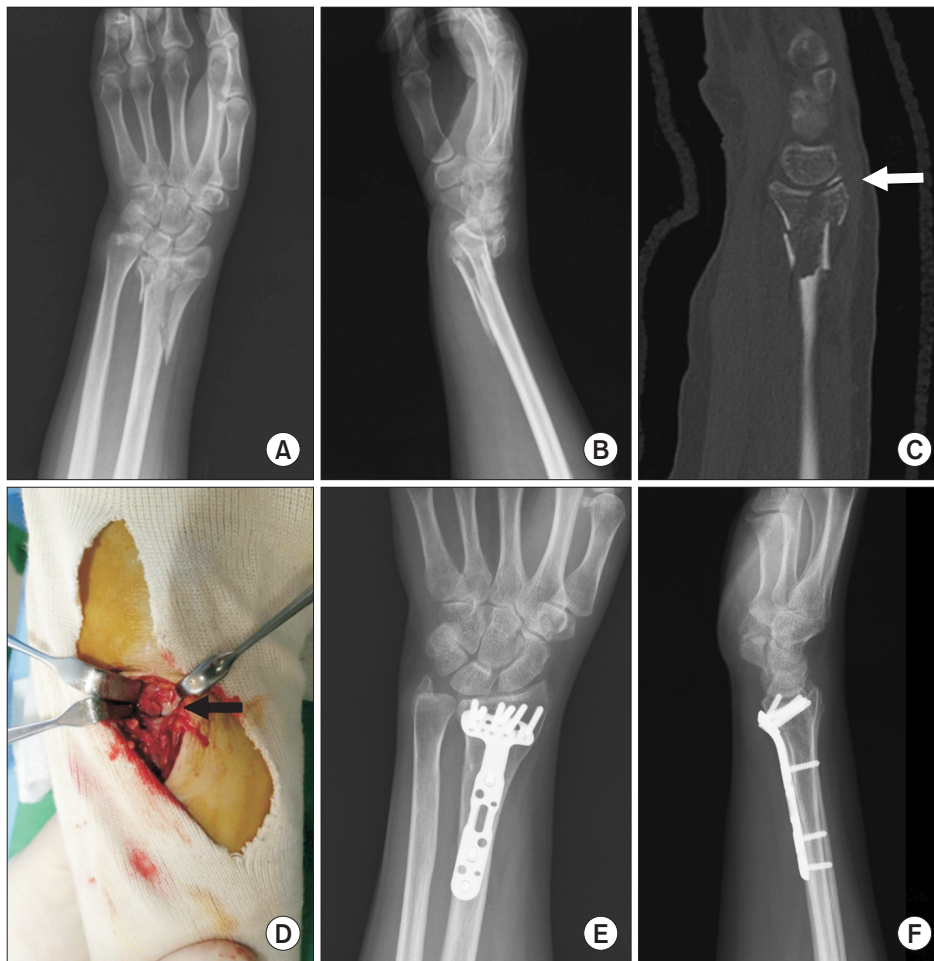
If a distally migrated dorsal fragment was relatively large and involved articular surface such as dorsal partial articular shearing fractures, it was repositioned and fixed using a dorsal locking plate (Synthes) (Fig. 4). In type 3 fractures, the impacted articular and dorsal fragment was reduced and bone grafting was performed. During periosteal dissection, disruption to the capsular attachments of dorsal fragment, which makes reduction of fragments difficult and results in devascularization, was avoided. The impacted articular fragments were reduced initially to the lunate facet fragment and then supported by the bone graft placed into the metaphyseal defect. While locking plates provide a great deal of support to the articular surface, we always used bone graft substitute to fill the metaphyseal defect in type 3. Once a satisfactory reduction was obtained, one or two fracture-specific dorsal locking plates (Synthes), typically a combination of a left and right-angled L shaped, were placed according to the location of dorsal fragments. The radial styloid can then be fixed from screws from the volar locking plate. Next, the distal locking screws of the volar plate were replaced with longer-sized screws to compress and hold the fracture fragments (Fig. 5).

Finally, intraoperative fluoroscopy was performed to obtain a 20° elevated tangential lateral view and confirm the absence of intra-articular screw penetration. The extensor retinaculum was then repaired, and if a dorsal locking plate was used, the EPL was placed out of its sheath to prevent an attenuated rupture. Immediately after surgery, all patients had short-arm splints applied for approximately 2 days, and they were encouraged to move the fingers and metacarpophalangeal joints. All patients wore removable splints for 4 weeks and were allowed early movement

**Table 1.** Patient Demographics

Characteristics	Value
Age (yr)	56 (22–77)
Sex	
Male	8 (25)
Female	24 (75)
Side	
Right	22 (69)
Left	10 (31)
AO classification	
C2	14 (44)
C3	18 (56)
Follow-up (mo)	32 (13–84)

Values are presented as median (range) or number (%).



**Fig. 2.** Type 1 injury. Preoperative anteroposterior radiograph (A) and lateral radiograph (B). (C) Sagittal view of computed tomography scan showing a free intra-articular fragment (white arrow). (D) The intra-articular free fragment (black arrow) was removed through the additional dorsal approach. One-year postoperative anteroposterior radiograph (E) and lateral radiograph (F).

of their wrist and fingers as tolerated to avoid stiffness.

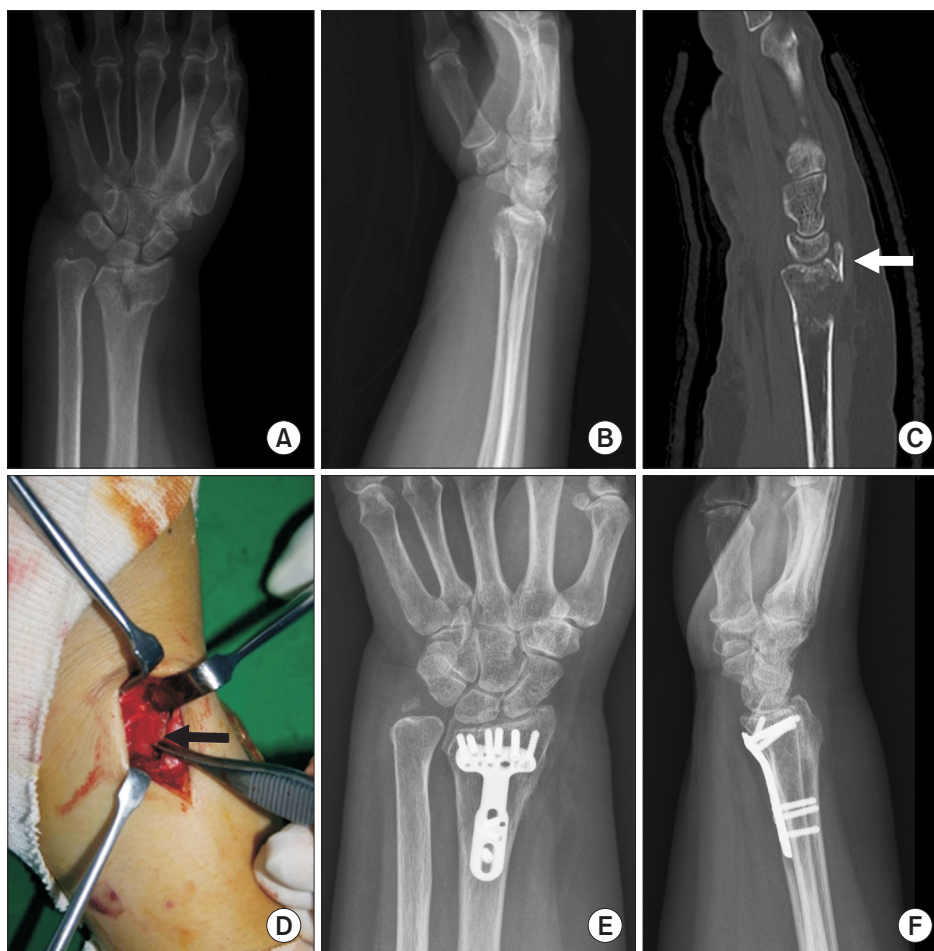
### Clinical and Radiological Evaluations

The patients returned to the clinic for evaluations at 2 weeks, 6 weeks, 12 weeks, 6 months, and 1 year after surgery. Quick Disabilities of the Arm, Shoulder and Hand (DASH), and Gartland and Werley scores were collected from the patients at each follow-up visit to assess the general postoperative quality.<sup>8,9)</sup> The wrist range of motion including flexion/extension and pronation/supination and grip strength data were collected and compared with those of the contralateral uninjured wrist. We measured the ranges of motion using a goniometer and the grip strength using a Jamar dynamometer. Radiological parameters such as radial inclination, radial length, and volar tilt were measured at the final follow-up. Posttraumatic arthritis indicators were identified according to the system of Knirk and

Jupiter.<sup>10)</sup> All measurements were performed by the first author, and the same medical consultant (HCC) evaluated every wrist. Postoperative complications including infection, neuropathy, nonunion, tendon injury, and implant failure were recorded.

## RESULTS

In our study, 7 of 32 patients were included in type 1 fractures, which were treated with volar locking plates and excision of the intra-articular fragments. Among all the patients, more than one intra-articular fragment was found on the CT scans obtained after a closed reduction. Fourteen patients who had distally migrated dorsal fragments beyond the wrist joint were included in type 2 fractures and 12 of those 14 patients were treated with volar locking plates and excision of the dorsal fragments. Two of the 14



**Fig. 3.** Type 2 injury. Preoperative anteroposterior radiograph (A) and lateral radiograph (B). (C) Sagittal view of computed tomography scan showing distally migrated dorsal fragments beyond the wrist joint (white arrow). (D) The distally migrated fragment (black arrow) was removed through the additional dorsal approach. One-year postoperative anteroposterior radiograph (E) and lateral radiograph (F).

patients had relatively large dorsal fragments, such as dorsal Barton fractures, and they were treated with combined volar and dorsal locking plates. The remaining 11 patients were included in type 3 fractures, all of whom were treated with combined volar and dorsal locking plates.

At the latest follow-up, radiographs revealed an average of  $16.9^\circ$  of radial inclination (range,  $6.5^\circ$ – $24^\circ$ ), an average of  $4.2^\circ$  of volar tilt (range,  $-2.2^\circ$  to  $8.9^\circ$ ), and an average of 7.5 mm of radial height (range, 3.2–12.81 mm). According to the scale of Knirk and Jupiter, 3 patients had grade 1 and 2 patients had grade 2 arthritic changes identified during the follow-up period. There were no signs of devitalization of the fracture fragments on the follow-up radiologic examinations in any of the patients. We also measured grip strength in the injured and uninjured wrists and compared the measurements. The average grip strength was 80.1% compared to the uninjured wrist. We

have demonstrated the radiologic parameters and grip strength according to the types in Table 2.

The average Quick DASH score was 18.3 (range, 6.8–34.1) and the average Garland and Werley score was 5.8 (range, 1–11). According to the Garland and Werley scores, the functional results were excellent in 3 patients, good in 25, and fair in 4. The final wrist range of motion assessed using a goniometer showed an average  $63.9^\circ$  of wrist extension (range,  $58^\circ$ – $80^\circ$ ),  $59.8^\circ$  of wrist flexion (range,  $50^\circ$ – $72^\circ$ ),  $87.4^\circ$  of pronation (range,  $70^\circ$ – $90^\circ$ ) and  $87.4^\circ$  of supination (range,  $70^\circ$ – $90^\circ$ ). The range of motion according to the types is presented in Table 3.

Ten patients (2 type 1, 4 type 2, and 4 type 3) underwent plate removal within the follow-up period because of pain (2 type 3) or by patient request (2 type 1, 4 type 2, and 2 type 3). The postoperative complication rate was relatively low with no cases of nonunion, no deep infec-



**Fig. 4.** If a distally migrated dorsal fragment was relatively large in a type 2 injury, the dorsal fragment was repositioned and fixed with a dorsal locking plate. Preoperative anteroposterior radiograph (A) and lateral radiograph (B) showing distally migrated dorsal fragments. One-year postoperative anteroposterior radiograph (C) and lateral radiograph (D).

tions, no tendon injuries, and no major nerve or vessel injuries. Three complications occurred in this study. One patient had a mild wound infection after a combined volar and dorsal locking plate placement. The patient was treated with drainage under local anaesthesia and intravenous antibiotics. The other two patients complained of chronic wrist pain, which was improved after implant removal. No patients complained of stiffness of the fingers or suffered from complex regional pain syndrome.

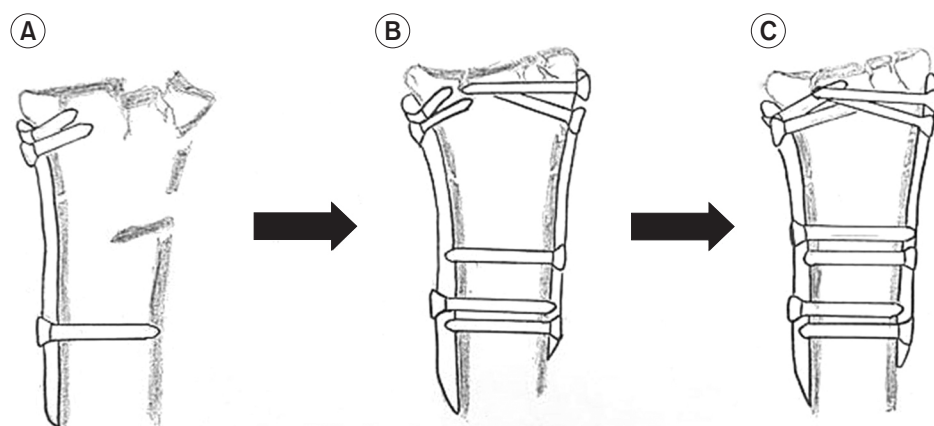
## DISCUSSION

In the present study, after fixation of the volar locking plate in DRFs, an additional dorsal approach was performed to remove intra-articular fragments or distally migrated

dorsal fragments and restore articular congruency. Certain fracture patterns including dorsal shear fractures (dorsal Barton) or “die-punch” fractures could be stabilised with dorsal plate fixation alone; thus, these types of fractures were not included in our cohort. The combined approach for DRFs allowed our patients to gain satisfactory radiographic and clinical outcomes. There were no cases of tendinitis, tendon rupture, or deep infection in this cohort, despite these being known as possible complications.<sup>3,5)</sup> Based on the Garland and Werley scoring system, 88% of patients had either good or excellent functional outcomes, which were similar to the results of Iselin et al.,<sup>4)</sup> who reported that postoperative median grip strength was 107% of the contralateral side, and the median DASH score and patient-rated wrist evaluation (PRWE) were 2.3 and 6, respectively, at 10 years of follow-up. These results support the safety of this surgical approach with minimal adverse effect. However, there are a number of limitations obviating the ability to directly compare our outcomes to those of other studies because of differences in the inclusion criteria. For instance, most of the type 1 or type 2 fractures based on our classification system were less severe injuries than the complex DRFs providing the main indications for a combined approach in many previous studies.

The combined volar and dorsal plate approach is known to be a useful method for patients with severely comminuted or displaced intra-articular fractures. Ring et al.<sup>6)</sup> reported that combined volar and dorsal plate fixation could achieve a stable but mobile wrist in patients that have very complex DRFs with extensive metaphyseal comminution. Day et al.<sup>3)</sup> introduced the “sandwich” plating technique, which refers to a combined volar and dorsal plating that was an effective method for intra-articular fractures with volar and dorsal comminution. Medlock et al.<sup>5)</sup> also reported that combined volar and dorsal plating can provide a functioning wrist in patients with multifragmentary intra-articular DRFs. A review of the literature involving smaller studies demonstrated that most of the combined approach techniques were performed in complex DRFs and this technique focused on the reduction and fixation of displaced articular fractures.<sup>3,5,6,11)</sup> In our investigation, the combined approach was a useful method in cases other than complex DRFs (Table 4).

According to our classification system, type 3 fractures refer to complex DRFs that, in many previous reports, have presented good indications for the combined approach. Dorsoulnar fragments that are part of the lunate fossa were usually reduced by the indirect method, and even for intra-articular fractures, an indirect reduction by a volar approach is possible with an accurate reduction



**Fig. 5.** The illustration shows how to treat a type 3 injury with combined volar and dorsal locking plates. (A) The fracture was reduced through a volar approach and fixed with a volar plate. When the volar plate was placed, distal locking screws of the plate that fixed less than 50% of the bone thickness were inserted just to maintain the extra-articular alignment. (B) The impacted articular or dorsal fragment was reduced and fixed with a dorsal locking plate. Screws that lock to the plate are very useful for maintaining elevated joint articulation, particularly when there is poor-quality bone. (C) Once satisfactory reduction was obtained, distal locking screws of the volar plate were replaced with longer-sized screws to compress and hold the fracture fragments.

**Table 2.** Postoperative Radiographic Parameters and Grip Strength of the Injured Compared with the Uninjured Wrist at Final Follow-up

Variable	Type 1 (n = 7)	Type 2 (n = 14)	Type 3 (n = 11)
Radiographic parameter			
Radial inclination (°)	18.3 ± 2.9	17.8 ± 3.6	14.9 ± 4.0
Volar tilt (°)	4.5 ± 2.5	5.5 ± 2.8	2.5 ± 3.0
Radial height (mm)	7.7 ± 1.4	7.9 ± 2.0	6.9 ± 2.5
Grip strength (%)	78.1 ± 18.4	80.2 ± 10.6	80.4 ± 16.5

Values are presented as the mean ± standard deviation.

of the metaphysis.<sup>12)</sup> However, when this fragment was comminuted, impacted into the joint, or was significantly distally displaced, it was difficult to reduce by an indirect method. In these cases, an additional dorsal approach is necessary.<sup>13)</sup> Displaced dorsal rim fractures that affect the posterior articular surface of the distal radius were sometimes observed after volar locking fixation. One study reported that a displaced dorsal rim fracture does not adversely affect the outcomes after volar plate fixation.<sup>14)</sup> Therefore, unstable DRFs combined with displaced dorsal rim fragments were not classified as type 3 fractures in our study.

To our knowledge, there were few studies that have investigated the effects of intra-articular free fragments or distal migration of dorsal fragments on clinical outcomes.

**Table 3.** Range of Motion Compared with the Contralateral Side at Final Follow-up

Variable	Type 1 (n = 7)	Type 2 (n = 14)	Type 3 (n = 11)
Extension (°)	66.1 ± 2.7	65.3 ± 5.7	60.8 ± 2.0
Flexion (°)	62.3 ± 5.8	60.6 ± 4.7	57.2 ± 7.9
Pronation (°)	88.4 ± 2.1	87.5 ± 3.6	86.7 ± 6.3
Supination (°)	88.4 ± 1.8	88.0 ± 1.8	86.1 ± 6.2

Values are presented as the mean ± standard deviation.

If an intra-articular free fragment is not removed from the joint, it could become a loose body and induce pain or locking symptoms.<sup>15-17)</sup> One case series reported that the majority of loose bodies were caused by traumatic events and could be removed via arthroscopy.<sup>16)</sup> In our study, the additional dorsal approach with a capsular incision was used to excise intra-articular fragments. Distal migration of dorsal fragments was often seen in DRFs, especially in those with a comminuted dorsal cortex. We treated 4 patients who had unstable DRFs and distal migration of dorsal fragments using volar locking fixation alone. Although a comparative study could not be performed due to the small sample size, all patients had persistent dorsal side pain especially in the dorsiflexion position.

Type 1, 2, and 3 are all situations in which an arthroscopic approach can be considered instead of a dorsal approach after the volar approach. Wrist arthroscopy is recognized as an important adjunctive procedure in the

**Table 4.** Summary of Studies on the Combined Approach for Distal Radius Fractures

Study	Number	Mean age (yr)	Mechanism of injury	AO/OTA classification	Treatment	Outcome	complication	Implant removed	Mean follow-up (m)
Ring et al. <sup>6)</sup>	25	46	9 Fall from a standing height 14 Fall from a great height 2 Motor-vehicle accident	25 C3-2	Combined volar and dorsal locking plates	5 Excellent 5 Good 14 Fair 1 Poor	2 Tendon rupture	21	26
Day et al. <sup>3)</sup>	10	58	3 Fall from a standing height 5 Fall from a great height 2 Motor-vehicle accident	3 C2 7 C3	Combined volar and dorsal locking plates	3 Excellent 4 Good 2 Fair 1 Poor	None	0	17
Fathan et al. <sup>11)</sup>	24	53.3	19 Fall on an outstretched hand 2 Blunt trauma 3 Motor-vehicle accident	24 C3	Combined volar and dorsal locking plates	Grip strength, 69.2% of the uninjured hand Volar tilt, 5 Radial inclination, 18.6 Radial height, 8.5 mm	1 Collapse 1 Extensor tendon irritation 1 Chronic wrist pain	4	17
Iselin et al. <sup>4)</sup>	10	46.8	10 High-velocity trauma with a hyperextension injury	10 C3	Combined volar and dorsal locking plates	Grip strength, 107% of the uninjured hand PRWE, 6 DASH, 2,3	1 CRPS	3	120
Medlock et al. <sup>5)</sup>	18	13	3 Fall from a standing height 13 Fall from a great height 2 Motor-vehicle accident	15 C3-2 3 C3-3	Combined volar and dorsal locking plates	3 Excellent 4 Good 6 Fair 5 Poor	None	0	27
This study	32	57	9 Fall from a standing height 17 Fall from a great height 4 Motor-vehicle accident 2 Sports related injury	14 C2 18 C3	Volar locking plate and intra-articular fragment excision or Volar locking plate and dorsal fragment excision or Combined volar and dorsal locking plates	3 Excellent 25 Good 4 Fair	1 Wound infection 2 Chronic wrist pain	10	32

OTA: Orthopaedic Trauma Association, PRWE: patient-related wrist evaluation, DASH: Disabilities of the Arm, Shoulder and Hand.



management of DRF because arthroscopically assisted reduction provides excellent visualization of the articular condition.<sup>18-21)</sup> However, performing wrist arthroscopy during volar plating seems to be troublesome. Thus, plate presetting arthroscopic reduction technique has been recently introduced.<sup>18,22)</sup> A volar locking plate is preset by inserting subchondral wires and a screw at the dynamic hole. After the volar locking plate is preset, wrist arthroscopy is performed in vertical traction. After achieving reduction of the fragment, volar locking plate is subsequently and securely fixed to the distal radius. Although arthroscopically assisted reduction achieved satisfactory outcome in many previous studies, we thought dorsal plating is necessary to maintain reduction and firm fixation of the dorsal fragment especially in type 3. Hence, we used the combined approach in the present study.

Some limitations of this study require consideration. The main limitation is that there was no control group for treatment outcomes between the classification types or treatment methods. Furthermore, reliability testing was not performed in the current study. Thus, comparison with other treatment methods could not be performed. After a volar approach, wrist arthroscopy can be used instead of a dorsal approach. Future research will be necessary to compare the combined approach and volar plating with an arthroscopic approach.

Despite these limitations, our study has some

strength. First, to the best of our knowledge, this is the first report to suggest and classify the indications for a combined approach in the treatment of DRFs. Second, we reported the outcomes for excision of intra-articular fragments and distally migrated dorsal fragments after fixation of the volar locking plate. Even though this was a case series and a retrospective study, our study demonstrated the indication for an additional dorsal approach based on the location of the fracture fragments and comminution of intra-articular fractures.

In conclusion, the classification system described in this article identified the situations when an additional dorsal approach is needed in unstable DRFs and may establish useful guidelines for appropriate surgical decision-making in the future.

## CONFLICT OF INTEREST

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

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## REFERENCES

1. Brogan DM, Richard MJ, Ruch D, Kakar S. Management of severely comminuted distal radius fractures. *J Hand Surg Am.* 2015;40(9):1905-14.
2. Lutsky K, Boyer M, Goldfarb C. Dorsal locked plate fixation of distal radius fractures. *J Hand Surg Am.* 2013;38(7):1414-22.
3. Day CS, Kamath AF, Makhni E, Jean-Gilles J, Zurakowski D. "Sandwich" plating for intra-articular distal radius fractures with volar and dorsal metaphyseal comminution. *Hand (N Y).* 2008;3(1):47-54.
4. Iselin LD, Massy-Budmiger AS, Droeser RA, Mett TR, Babst R, Rikli DA. Ten years' follow-up on combined palmar and dorsal internal fixation of complex distal radius fractures. *Medicine (Baltimore).* 2016;95(18):e3509.
5. Medlock G, Smith M, Johnstone AJ. Combined volar and dorsal approach for fixation of comminuted intra-articular distal radial fractures. *J Wrist Surg.* 2018;7(3):219-26.
6. Ring D, Prommersberger K, Jupiter JB. Combined dorsal and volar plate fixation of complex fractures of the distal part of the radius. *J Bone Joint Surg Am.* 2004;86(8):1646-52.
7. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Joint Surg Am.* 1976;58(4):453-8.
8. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). *Am J Ind Med.* 1996;29(6):602-8.
9. Smith DW, Henry MH. Volar fixed-angle plating of the distal radius. *J Am Acad Orthop Surg.* 2005;13(1):28-36.
10. Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. *J Bone Joint Surg Am.* 1986;68(5):647-59.
11. Farhan MF, Wong JH, Sreedharan S, Yong FC, Teoh LC.

- Combined volar and dorsal plating for complex comminuted distal radial fractures. *J Orthop Surg (Hong Kong)*. 2015;23(1):19-23.
12. Fok MW, Klausmeyer MA, Fernandez DL, Orbay JL, Bergada AL. Volar plate fixation of intra-articular distal radius fractures: a retrospective study. *J Wrist Surg*. 2013;2(3):247-54.
  13. Ikeda K, Osamura N, Tada K. Fixation of an ulnodorsal fragment when treating an intra-articular fracture in the distal radius. *Hand Surg*. 2014;19(1):139-44.
  14. Kim JK, Cho SW. The effects of a displaced dorsal rim fracture on outcomes after volar plate fixation of a distal radius fracture. *Injury*. 2012;43(2):143-6.
  15. De Smet L, Van Wetter P. Synovial chondromatosis of the distal radio-ulnar joint. *Acta Orthop Belg*. 1987;53(1):106-8.
  16. Koh S, Nakamura R, Horii E, Nakao E, Shionoya K, Yajima H. Loose body in the wrist: diagnosis and treatment. *Arthroscopy*. 2003;19(8):820-4.
  17. Ono H, Yajima H, Fukui A, Tamai S. Locking wrist with synovial chondromatosis: report of two cases. *J Hand Surg Am*. 1994;19(5):797-9.
  18. Abe Y, Fujii K. Arthroscopic-assisted reduction of intra-articular distal radius fracture. *Hand Clin*. 2017;33(4):659-68.
  19. Kastenberger T, Kaiser P, Schmidle G, Schwendinger P, Gabl M, Arora R. Arthroscopic assisted treatment of distal radius fractures and concomitant injuries. *Arch Orthop Trauma Surg*. 2020;140(5):623-38.
  20. Ono H, Furuta K, Fujitani R, Katayama T, Akahane M. Distal radius fracture arthroscopic intraarticular displacement measurement after open reduction and internal fixation from a volar approach. *J Orthop Sci*. 2010;15(4):502-8.
  21. Saab M, Wunenburger PE, Guerre E, et al. Does arthroscopic assistance improve reduction in distal articular radius fracture? A retrospective comparative study using a blind CT assessment. *Eur J Orthop Surg Traumatol*. 2019;29(2):405-11.
  22. Abe Y, Tsubone T, Tominaga Y. Plate presetting arthroscopic reduction technique for the distal radius fractures. *Tech Hand Up Extrem Surg*. 2008;12(3):136-43.