Combined Volar and Dorsal Approach for Fixation of Comminuted Intra-Articular Distal Radial Fractures

G. Medlock, FRCSGlasg¹ M. Smith, MBCHB, FRCSE¹ A. J. Johnstone, MBCHB, FRCSE¹

¹ Trauma and Orthopaedics Unit, Aberdeen Royal Infirmary, Foresterhill, Aberdeen, United Kingdom

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Address for correspondence G. Medlock, FRCSGlasg, Trauma and Orthopaedics Unit, Wards 212/213, Aberdeen Royal Infirmary, Foresterhill, Aberdeen, AB25 2ZN, United Kingdom (e-mail: gareth.medlock@nhs.net).

Abstract

Purpose Multifragmentary intra-articular fractures displaced in multiple planes are a challenge. We use a reproducible technique of fracture and articular reduction using an initial volar approach targeting reduction in the volar lunate facet first with plate and unicortical locking screws. This creates a template for reduction in dorsal fragments through a dorsal approach. Our study investigated the radiological, clinical, and functional outcomes of patients treated with this technique.

Materials and Methods We reviewed the postoperative radiographs and notes of 18 patients that had this method of fixation between the years 2008 and 2015, the mean age being 43. These patients were reviewed functionally on average 2 years and 3 months following their definitive operation.

Results Normal alignment and length to the distal radius were restored with on average a 0.6 mm articular step. The average range of motion was 64% and preservation of grip strength was 71% compared with the uninjured wrist. Functional assessment averages were 29 for both the quick Disabilities of the Arm, Shoulder and Hand (DASH) and for Patient Rated Wrist Evaluation. The modified system of Green and O'Brien had results of good in 10, fair in 7, and poor in 1. With respect to the Gartland and Werley system, three patients had an excellent result, four had a good result, six had a fair result, and five had a poor result. The mean arthritic grading was 1 (grading 0–3) according to Knirk and Jupiter.

Conclusion This reproducible technique provides an option for these devastating fractures providing a functioning wrist with all of the patients returning to their original form of employment.

Keywords

- ▶ distal radius fracture
- ▶ internal fixation
- ▶ dual approach
- ▶ fracture specific

Displaced fractures of the distal radius are extremely common injuries that present to, and are treated by, most general orthopaedic surgeons. Thankfully, the majority of these fractures are relatively simple in terms of their fracture configuration and their intra-articular component. Depending on the complexity, the majority of distal radius fractures can be treated adequately using several well-established modalities, which in part reflect the complexity of the injury but also

individual surgeons preference. All of the available treatments aim to restore normal or near normal anatomy since it has been well recognized that long-term functional outcome is improved when an anatomical reduction is obtained¹ and subsequent union is achieved. With respect to plate fixation, there is little doubt that volar locking plate fixation has become the preferred plating technique for the majority of surgeons undertaking open reduction and internal fixation.

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In part, this is due to the ease of the surgical approach but also the benefits of early mobility and reduced soft tissue complications compared with dorsally inserted plates.² Recently several intramedullary devices have become available for treating distal radius fractures; however, these implants tend to be used predominantly for treating extra-articular distal radius fractures³ and have not gained widespread acceptance among the orthopedic community.

Frequently multifragmentary distal radius fractures may not be suitable for the treatment options mentioned above; these are typically seen in younger and middle-aged patients as the result of significant trauma, but are also occasionally seen in the elderly due to structural weakness of the bone. In particular, intra-articular fractures are significantly comminuted with displacement in multiple planes. Fracture complexity can often only be appreciated following CT scanning and this is used to guide a suitable treatment strategy. For years, the standard treatment for these devastating comminuted distal radial injuries would be to use a bridging external fixator, which can be combined with a limited internal fixation or more commonly supplementary percutaneous Kirschner wire fixation. The major drawbacks of this method are that the articular surface is often not adequately reduced if this is done on isolation without an arthrotomy and early range of motion is not possible. A previous randomized controlled study comparing external fixators against volar plate fixation for the treatment of all unstable distal radial fractures demonstrated that range of motion was better at all times with plate fixation even when the fixator patient group received twice as much physiotherapy.⁴

Volar locking plates weakness in fracture fixation lies with dorsally comminuted and displaced distal radial fractures; these fragments cannot be reduced adequately using a volar approach or stabilized using volar fixed angle screws. In these situations, the additional intra-articular fracture fragments that are not supported by a standard locking plate screw placement require fragment-specific plates and variable screw sizes for adequate fixation.

A reproducible technique of fracture reduction using both volar and dorsal approaches and the application of fracture-specific plates has been developed and utilized by a single surgeon at our center. The aim of the study was to investigate radiological, clinical, and functional outcomes of patients treated with our technique of fracture fixation using these dual approaches.

Materials and Methods

Patients and Fractures

We retrospectively identified and reviewed the clinical records from initial inpatient stay to final postoperative review in clinic. Initially 23 patients were found, but due to lack of both radiographic and functional assessments, 5 were excluded leaving a study group consisting of 18 patients (►Table 1), 13 males and 5 females of average age 43 years (range 19–70 years). Eight right wrists were injured and were all dominant; whereas ten injured left wrists involved the nondominant hand. Two of the patients had bilateral wrist fractures; one of each of the wrists required this method of

Table 1 Demographics, fracture grade, and postoperative radiographic measurements

Patient number	Sex	Age	Fracture classification	Radial inclination	Volar tilt	Max articular step	Ulna variance	Arthritic grading
1	M	51	C3–2	18	12	2	–1	2
2	M	20	C3–2	24	7.2	1	–4	2
3	M	54	C3–2	24	12	0	1	1
4	M	51	C3–2	25	6	1	–2	2
5	F	24	C3–2	23	14	1	1	2
6	M	32	C3–2	18	18	0	–1	1
7	F	30	C3–3	14	13	1	–2	0
8	M	50	C3–2	17	3	0	3	0
9	M	32	C3–2	18	7	1	3	1
10	M	19	C3–2	23	6	0	6	2
11	M	70	C3–3	18	7	0	–3	2
12	F	59	C3–2	20	9	0	5	1
13	F	47	C3–2	18	9	2	3	2
14	M	58	C3–2	19	8	1	0	1
15	M	27	C3–3	21	9	1	0	0
16	M	51	C3–2	15	6	0	2	1
17	F	48	C3–2	18	8	1	1	0
18	M	44	C3–2	21	9	0	–3	0

fixation but the less complex wrist fracture of each patient required fixation only from a single approach. Seventeen of the patients were in employment; one was retired. Thirteen were involved in manual work, four were office based, and one other was a carer. The mechanisms of injury included a fall from a height for 13 of the patients; two resulted from a motorcycle accident and the other three resulted from a fall from standing height.

Patients were treated with this method of treatment if the fracture was multifragmentary and significantly displaced in multiple planes (► **Fig. 1**). Fifteen of the patients had AO grade C3–2 fractures and the remaining three were C3–3. Fifteen patients had associated ulna styloid fractures; one patient had both a scapholunate ligament rupture and a thumb metacarpal phalangeal joint dislocation; and one other had a fracture dislocation of the proximal carpal row. Other injuries were as follows: right ankle Weber A fracture and base of fifth metatarsal fracture; right shoulder anterior glenohumeral dislocation with eventual avascular necrosis; right segmental femoral shaft fracture and two patients had lumbar vertebral level one compression wedge fractures.

Fractures were definitively fixed on average 16 days following the original injury (range 0–41 days). Two were revision procedures performed for inadequate open reduction and internal fixation from other institutions and another with a long delay to surgery was a tertiary referral. Exclusion of the revision cases the average time to fixation was 12 days, this delay resulted from allowing soft tissues swelling to reduce. Six of the patients were placed in a spanning external fixator, while the rest of the fresh fractures were reduced acutely and placed in a cast. Sixteen wrists underwent preoperative CT scanning to facilitate surgical planning (► **Fig. 2**).

Fig. 2 CT scan coronal and axial sections demonstrating the comminution and displacement of the articular surface that can be targeted during the operation.

Operative Technique

The indication for this operative technique is a severely comminuted distal radius fracture with fracture lines in multiple planes with associated significant displacement in

Fig. 1 Posteroanterior and lateral radiograph of multifragmentary fracture in several planes.

Fig. 3 Extended volar approach to the distal radius.

Fig. 4 Unicortical fixation of the distal radial volar lunate facet.

these same planes. These fractures were judged to be difficult to reduce and then stabilize through a single approach alone due to the significant displacement of the fracture fragments rather than just in a single plane.

Clear alcoholic chlorhexidine skin preparation was used prior to draping so that the postoperative vascularity of the extremity could be assessed easily perioperatively. All patients received a general anesthetic and intravenous cefuroxime until a change in departmental policy when the remaining 11 patients received gentamicin and flucloxacillin. An upper arm tourniquet was used in all cases with a pressure of 250 mm Hg for an average of 114 minutes (range 90–160 minutes), released prior to closure to achieve adequate hemostasis.

A standard volar Henry approach was performed and in all cases the brachioradialis insertion was released from the radial styloid to permit restoration of the radial inclination. Care was taken not to open the distal radioulnar joint. All patients had a carpal tunnel decompression performed by extending the volar incision distally by curving the distal forearm incision across the proximal transverse wrist skin crease (►Fig. 3). The reasoning for this was twofold; it gave unparalleled exposure to all the fracture fragments without compromising the radio-carpal ligaments and released the median nerve in these high-energy injuries protecting it from acute carpal tunnel syndrome. The initial aim of the volar approach is to reduce and fix the fragments of the volar lunate fossa aspect of the distal radial fracture. This combined volar plate and fracture fragment construct provides a reference point and stability for all

other fracture fragments to be reduced and fixed on to. In the majority of cases, the volar component of the lunate fossa was stabilized using unicortical locking screws inserted both proximally and distally through a dedicated volar locking plate, so as to minimize interfering with the placement of the dorsal plates and screws. A wide Acumed Acu-Loc plate and screws were used in most cases to give the largest footprint for its role in buttressing the fracture volarly (►Fig. 4).

Next a dorsal longitudinal incision centered over Lister's tubercle was used to access the dorsal distal radius. Extensor pollicis longus was mobilized from the third extensor compartment and the tendons in the second and third compartment were mobilized subperiosteally allowing direct visualization of dorsal surface of the distal radius. Dorsal capsulotomy was created if required to allow direct visualization of the articular fracture (►Fig. 5). This was indicated if there was depressed or comminuted articular surface, particularly in the central unreachable area still requiring elevation and accurate reduction. Fracture fragments were reduced initially to the lunate facet fragment of the template created by the fixation of the volar aspect. These are then held with fracture-specific plates (Synthes 2.4 mm), typically a combination of a left and right-angled "L" shaped plate and unicortical screws (►Fig. 6). The radial styloid can then be tackled with a radial column-specific plate or from screws from the volar locking plate. The construct strength can be improved with the addition of bicortical screws from the volar locking plate if required. All implants were made from titanium alloy.

Fig. 5 Dorsal capsulotomy to aid articular reduction.

Fig. 6 Application of dorsal radial fracture-specific plates.

Autograft was used if required for loss of periarticular supporting cancellous bone and large cortical voids requiring structural support over 5 mL; six patients had local autograft from the distal radial metaphysis and shaft and a further three required iliac crest autograft. Surgical wounds were closed using nylon sutures and these were removed at 10–14 days postoperatively.

Postoperative Management

The wounds were dressed with self-adhesive, absorbent and breathable dressings, dressing swabs, and bulky wool and crepe. This allowed the patient full digit movement but limited wrist movement to allow the wounds to heal and the swelling to subside. Only one patient required a plaster of Paris back slab and this was for wound support. When returning to the ward, the arm was elevated in a Bradford sling suspended from a drip stand to aid with postoperative swelling. Patients attended the outpatient clinic at 2 weeks to have their wounds inspected, removal of any sutures, and radiograph. Following this full range of motion was permitted but they remained nonload bearing. Load bearing was reintroduced once healing was established clinically and radiographically. Supervised physiotherapy was not instituted routinely and was recommended usually at 6 weeks if it was deemed the patient would benefit from some closely supervised exercises. Plates and screws were not routinely removed.

Fracture Classification and Follow-Up Assessment

Radiographic assessment was performed retrospectively by two of the authors (GM and MS). Assessment of radiographic parameters was made using the initial postoperative films, which were taken within 1 week of the definitive surgery

(→ Fig. 7). The severity of the arthritis was graded using the system devised by Knirk and Jupiter⁵ and this was performed on the last available film.

Patients were evaluated by an impartial research nurse, who was trained in these assessment methods, for their range of motion, grip strength, and functional scoring system. The scoring systems used were the Modified Gartland and Werley by Stewart et al,⁶ Green and O'Brien Wrist score, Patient Rated Wrist Evaluation by JC MacDermid, and the Quick DASH questionnaire. If the patient was unable to attend the clinic, we offered them the opportunity to fill in functional scoring assessments by post.

Results

There were no wound infections, no tendon ruptures or major nerve injuries. One patient was too swollen for primary closure of their volar wound and required a subsequent split skin graft, which healed without any complication. This patient was taken to theatre as an emergency after their injury to reduce and fix a carpal fracture dislocation along with the definitive fixation of their distal radial fracture. They returned to theater at 48 hours postoperatively for a split skin graft.

The average tourniquet time for the whole series was 114 minutes (range 90–160 minutes). The average for the first half was 122 minutes (range 104–160 minutes) and 107 minutes (range 90–120) in the second half of patients.

Cancellous local bone graft was used to support the articular surface in six of the cases and one required a larger structural amount to fill a cortical void greater than 5 mm and iliac bone was utilized. Eight of the cases required a dorsal capsulotomy to ensure anatomical reduction in the articular surface.

Fig. 7 Radiographic appearances of a typical case post operatively.

Radiographs taken following surgery revealed an average of 9° (range 3°–18°) of volar tilt, an average of 20° (range 14–25°) of radial inclination, an average of 0.7 mm (range 0–2 mm) maximum articular step, and an average of 0.6 mm (–4–6 mm) ulna variance. There was no loss of correction following fixation of the fractures.

All 18 study patients were available for radiographic evaluation. All the fractures healed; one patient demonstrated translation of the carpus in a volar direction; he continued to work as a heavy digger operator. The average arthritic grading according to Knirk and Jupiter was 1 (range 0–3) at an average of 34 weeks following definitive fixation (range of radiographic follow-up 4–104 weeks). There were no signs of devitalization of the fracture fragments.

Functional assessment was on average 2 years and 3 months following their definitive operation (range 8–69 months) (►Table 2). Quick DASH questionnaire revealed an average score of 30 (range 0–82). Patient Rated Wrist Evaluation questionnaire demonstrated an average score of 35 (range 2–82). The modified system of Green and O'Brien had functional results of good in ten, fair in seven, and poor in one. This also highlighted that all patients returned to their former employment; 14 of which are manual jobs. According to the Gartland and Werley system, three patients had excellent results, four had good results, six had fair results, and five had poor results.

Sixteen patients were available for measurements and the average percentage range of motion comparable to the other side was 64% (range 30–96%), 69% (range 38–100%) of exten-

sion, 60% (range 25–100%) of flexion, 55% (range 14–100%) of ulna deviation, 53% (range 33–93%) of radial deviation, 92% (range 53–100%) of pronation, and 89% (range 53–100%) of supination. The average grip strength was 71% (range 31–100%) when comparing it with their contralateral hand, excluding patients with bilateral wrist fractures. ►Table 3 has the injured wrist's range of motion measured in degrees. No patient had stiffness of their uninjured fingers or thumb or suffered from complex regional pain syndrome.

Discussion

The combined volar and dorsal approach for fracture fixation has been utilized in our department for patients with severely comminuted and displaced intra-articular distal radial fractures. This has allowed patients to mobilize their wrists early following their devastating injury, in an attempt to regain a range of motion much earlier than alternative modalities of treatment allowing an earlier return to their original employment. It was also a viable option for revision surgery either through loss of fixation or initial inadequate reduction and internal fixation of severely comminuted and displaced articular fractures.

Complications following the operation were low with no infections, no tendon injuries, no major nerve or vessel injuries, and in particular no osteonecrosis as a consequence of approaching the bone from both volar and dorsal surfaces. None of the patients developed a painful neuroma of the median palmar cutaneous nerve and did not complain of the resulting lack of sensation. One patient required a skin graft to close the volar wound, as stated this patient required emergent surgery due to fracture dislocation of the carpus. Another patient developed severe osteoarthritis and translation of the carpus anteriorly; however, as mentioned previously, he is still able to function as a digger operator.

The technique targets the major common fragments that Melone described in his distal radial fracture classification system.⁷ The volar lunate facet is separated from the radial styloid by a sagittal split but also from the dorsal lunate fragment by a coronal splint. Starting with reduction and fixation of the volar lunate fragment or fragments creates a template for others components to be fixed to. In terms of the operative technique, once the steps to the technique were honed the tourniquet time reduced, reflected in the last half of patients having an average tourniquet time of 107 minutes (range 90–120) compared with 122 (range 104–160) minutes in the first half.

CT scanning was deemed extremely important in preoperative planning having been performed in 89% of patients aiding in targeting particular fragments and especially for locating and elevating severely displaced articular surface. In these cases of severe articular depression or significant loss of cortical bone, bone graft was often utilized accounting for 39% of cases. The bone graft provided structural support and accelerated bone healing. Location of donor bone was dependent on the quantity, structural requirement, and availability starting local to the fracture.

It is difficult to directly compare our fracture series to others because of the severe nature of the fractures. For instance, a

Table 2 Patients' functional outcome scores

Patient number	Quick DASH	Green & O'Brien	PRWE	Gartland & Werley
1	23	Fair	37	Fair
2	9	Fair	17	Good
3	64	Fair	68	Poor
4	9	Good	15	Excellent
5	14	Fair	10	Fair
6	68	Fair	82	Fair
7	16	Good	23	Good
8	25	Fair	26	Poor
9	16	Good	34	Poor
10	27	Good	32	Fair
11	75	Good	79	Fair
12	68	Fair	60	Good
13	7	Good	4	Excellent
14	8	Good	17	Fair
15	0	Good	2	Excellent
16	5	Good	14	Poor
17	82	Poor	78	Poor
18	23	Good	37	Good
Average	30		35	

Abbreviation: PRWE, Patient Rated Wrist Evaluation.

Table 3 Patients' postoperative range of motion, measurements in degrees

Patient number	Flexion	Extension	Arc of motion	Supination	Pronation	Radial deviation	Ulna deviation
1	35	15	50	70	60	5	5
2	–	–	–	–	–	–	–
3	30	34	64	85	75	12	12
4	40	45	85	85	80	30	35
5	35	40	75	90	82.5	30	15
6	–	–	–	–	–	–	–
7	50	45	95	85	75	20	15
8	15	20	35	60	70	8	5
9	20	38	58	85	90	12	8
10	25	30	55	85	90	10	15
11	55	35	90	85	80	30	5
12	38	48	86	65	70	18	20
13	40	80	120	85	70	28	15
14	45	44	89	68	75	10	15
15	45	70	115	85	70	15	25
16	28	46	74	85	90	10	14
17	30	30	60	85	80	8	5
18	50	45	95	85	90	12	35
Average	36	42	78	81	78	16	15

recent randomized controlled trial comparing volar locking plates versus external fixation and additional K-wires⁸ had only 6% of comparable fractures, the rest being of a less complex nature. In terms of movement combined extension of the two methods was 22% greater than our series. The combined grip strengths compared with their uninjured wrist at a year were only 14% greater than our group. There was one series which used a dual approach for similarly complex fractures which had a grip strength of 73% compared with our 71% but had an increased range of motion in comparison which can be attributed to an increased level of energy imparted during the injury in our series.⁹ Our cohort of patients tended to have preservation of forearm rotational movements, which are very functional movements, but the average arc of flexion and extension was reduced at 64%. This arc of motion in flexion and extension was found to be on average 79° which is close to the functional range of motion required to perform activities of daily living found by Ryu et al¹⁰ at 80°. Combined radial and ulna deviation was 30° compared with the required 40°. Organized formal physiotherapy was not instituted on our patients and was recommend on an individual basis; we hypothesize whether early and intensive physiotherapy may have improved final range of motion given that we were confident that the fixation was ridged enough to allow this.

Despite these reduced physical measurements, a poor functional result was only found in 13% of evaluations across all scoring systems; all were able to return to their original employment with 78% of these being manual jobs. The average age of the patients in our study was generally younger than most

studies and the mechanisms tended to be of higher energy as demonstrated by the associated injuries our group of patients suffered from. This high energy undoubtedly had an affect both on reduced range of motion but on the degree of cartilage loss. The patients that obtained poor functional results along with the reduced range of motion reflect the residual difficulties faced by these patients with these devastating injuries.

Radiographic analysis has shown that accurate reduction in all intra-articular fragments and restoration of radial length and other parameters can be made without devitalization of the fracture fragments. Seventy-three percent of the patients had radiographic evidence of arthritis over a relatively short period of time (average of 32 weeks). Because of the short time interval, the cartilage loss is most likely the result of the initial injury rather than incongruity, which was minimal in this study.

Low numbers of patients, the retrospective design, and the lack of a control group limited our study. It was also a heterogeneous group of patients given the associated injuries particularly in the same limb and delay in surgery or revision procedures. Unfortunately in these high-energy injuries it is expected to not only cause a complex multi-fragmentary distal radius fracture but also injuries to adjacent bones and joints. Some of the operations were delayed or revisions so could be classified as nonunion or malunion surgery, despite this it demonstrates that this technique can be utilized in these situations. We believe, due to the low complication rates and satisfactory functional outcomes, that this reproducible approach to treatment is a reasonable option for these devastating injuries.

Note

Our local ethical board was contacted prior to evaluating the patients and felt ethical approval wasn't required because assessment was no different to our normal clinical assessment. Patients signed consent forms following an informed consent process for their operation.

Conflict of Interest

None.

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