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Original Research

## Radiographic Outcomes of Dorsal Spanning Plate for Treatment of Comminuted Distal Radius Fractures in Non-Elderly Patients

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**Purpose:** Multifragmentary fractures of the distal radius with articular and metaphyseal comminution (AO 23-C3) represent challenging injuries to manage. Distal fracture lines, articular comminution, and limited distal bone stock may preclude stable fixation with a volar locking plate. The use of a dorsal spanning plate (DSP) offers an alternative treatment option in this setting. We examined the radiographic outcomes of a consecutive series of patients with comminuted intra-articular distal radius fractures not amenable to volar locked plating, who were treated with a DSP.

**Methods:** We reviewed all distal radius fractures treated with a dorsal spanning plate at our institution between October, 2014 and March, 2018. Patients with AO 23-C3 fractures treated with dorsal spanning plate fixation were included in this study. Demographic data, time from plate placement to removal, and postoperative radiographic outcomes were examined.

**Results:** We identified 24 patients, mean age 41 years (range, 19–62 years). Mean follow-up was 19.5 weeks (range, 12–35 weeks) from the time of plate placement. Plates were removed at a mean of 87 days (range, 40–215 days) after surgery. All patients achieved radiographic union. Mean radial height at the time of union was 11.1 mm (SD,  $\pm 3.7$  mm; range, 6–18 mm), radial inclination was 19.7° (SD,  $\pm 5.4^\circ$ ; range, 9° to 30°), ulnar variance was 1.0 mm (SD,  $\pm 2.4$  mm; range, –3 to 6 mm), and volar tilt was 1.4° (SD,  $\pm 5.2^\circ$ ; range, –10° to 14°). Mean articular displacement was 1.7 mm (SD,  $\pm 1.7$  mm; range, 0–6 mm). Malalignment of at least one of these radiographic parameters was identified in 16 of 24 patients at the time of union.

**Conclusions:** Dorsal spanning plate fixation offers an alternative treatment option for comminuted intra-articular distal radius fractures (AO 23-C3). Although this technique presents a straightforward means for fixation of complex distal radius fractures, radiographic outcomes may be inferior relative to less complex fractures treated with standard volar plating techniques.

**Type of study/level of evidence:** Therapeutic IV.

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Treatment of intra-articular distal radius fractures centers on restoring length and alignment and obtaining congruency of the articular surface. A variety of techniques are available, from closed reduction to percutaneous, external, and internal fixation. Although comparative studies have not unequivocally demonstrated superiority of one of these techniques, volar locked plating has become a

preferred means of internal fixation of intra-articular distal radius fractures. Despite the popularity of this technique, certain fractures may not be well-suited to volar locked plating alone, including dorsal shearing fractures<sup>1</sup> and complex articular fracture patterns.<sup>2</sup> Highly comminuted articular fractures provide a challenge in that standard volar plating options may not capture key articular fragments or provide sufficient stability to maintain alignment during healing. Higher complication rates with volar plate fixation have been noted in more complex fractures (AO 23-C3), including loss of reduction and inferior radiographic outcomes.<sup>3</sup>

Traditionally, external fixation has been considered for highly comminuted fractures to restore overall length and stability.<sup>4,5</sup> More recently, wrist dorsal wrist spanning plate (DSP) fixation,

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also referred to as internal distraction plating, has been recognized as a potential treatment option to restore length and alignment.<sup>6–10</sup> Potential advantages of the DSP include avoidance of pin-site infections and pin migration seen with external fixators, construct stability sufficient to allow early digital motion and light functional use, and a more aesthetically appearing construct.<sup>6–10</sup> Disadvantages include the need for an additional surgical procedure for plate removal as well as the potential lack of control of articular fragments. Several studies have assessed the use of such plates for osteoporotic fractures in the elderly population.<sup>6–10</sup> However, scarce literature exists on the radiographic outcomes of the DSP for treatment of complex intra-articular distal radius fractures in a younger cohort of patients. The purpose of this study was to examine the radiographic outcomes of a consecutive series of patients aged less than 65 years with multifragmentary articular distal radius fractures treated with a DSP.

## Materials and Methods

We obtained institutional review board approval for this study. All patients whom the senior author treated operatively for distal radius fractures were identified using our institution's surgical database between October, 2014 and March, 2018. All cases were further reviewed to identify patients who were treated with DSP fixation. Two independent observers examined and classified injury radiographs using the AO classification system. Patients with multifragmentary articular and metaphyseal fracture patterns, AO type 23-C3, were identified. We included all such patients who underwent both placement and removal of the DSP at our institution. Patients who underwent supplementary volar or dorsal plating were excluded from analysis.

### Operative technique

Indications for DSP fixation in this cohort included (1) articular comminution that was thought to be too severe to be adequately secured with a volar plate and (2) fracture lines distal to the footprint of a standard volar plate. After the induction of anesthesia, manual reduction of the distal radius was performed. We have found intraoperative traction fluoroscopic views to be a helpful adjunct to preoperative imaging in selecting fixation. For fractures with insufficient distal bone stock owing to articular comminution or distal fracture lines, but which were reducible by closed or percutaneous means, we proceeded with DSP fixation. A longitudinal incision was made on the dorsal aspect of the hand overlying the second metacarpal. The extensor tendons were retracted and the dorsal surface of the metacarpal was exposed. A second incision was made in the dorsoradial forearm overlying the radius, proximal to the fracture site. The deep fascia was incised longitudinally, typically just proximal to the abductor pollicis longus muscle, and the radial wrist extensors were retracted to expose the radius. A 2.4-mm DSP (DePuy-Synthes, West Chester, PA) was then introduced into the distal wound and slid in retrograde fashion through the second dorsal compartment into the proximal wound. The plate was then secured distally to the second metacarpal. A distraction force was applied to the wrist to restore radial length with the forearm in neutral rotation and the plate was provisionally clamped to the radius. Fluoroscopic images were obtained to assess reduction and confirm the absence of overdistracted at the radiocarpal and midcarpal joints (defined as joint space in excess of 5 mm). The digits were assessed to confirm full passive flexion. Once satisfactory reduction was confirmed, the remaining proximal and distal screws were placed. When deemed necessary by the operative surgeon, supplemental K-wires were placed to facilitate articular

reduction and augment fixation of key articular fragments, in particular the radial styloid.

After surgery, digital motion exercises were initiated immediately. Patients were allowed functional use of the affected extremity after surgery with a weight-bearing restriction of 5 lb or less until plate removal. Patients were evaluated in the clinic at 2 weeks, and then at monthly intervals. When used, K-wires were left in place for 4 to 6 weeks. Plate removal was planned between 8 and 10 weeks after placement, depending on clinical and radiographic healing and patient adherence to scheduled follow-up appointments.

Patient demographics, injury characteristics, the interval between the injury and surgery, and the interval between surgery and plate removal were recorded. Radiographic outcomes were measured by an independent observer not involved in the care of the patients immediately after surgery and on final follow-up radiographs. In 3 patients, this was at the time of plate removal. We also compared final radiographic alignment with that obtained at the time of surgery, to examine whether reduction achieved operatively was maintained through fracture healing. Radiographic parameters including radial height, radial inclination, ulnar variance, articular stepoff, and volar tilt at final x-ray before DSP removal were obtained for all patients. Several studies examined acceptable radiographic parameters after open or closed treatment of distal radius fractures.<sup>11,12</sup> We defined acceptable reduction parameters as articular tilt greater than  $-5^\circ$  volar (also known as  $5^\circ$  dorsal), ulnar variance less than 3 mm, radial height greater than 8 mm, articular stepoff 2 mm or less, and radial inclination greater than  $15^\circ$ . Mean values for each parameter were determined, as well as the proportion of patients whose alignment fell outside each of these parameters. Any treatment-related complications or adverse events were also recorded.

## Results

We identified 30 patients treated with DSP fixation for fractures of the distal radius during the study period. We excluded 2 patients who had combined fixation with a volar plate and DSP, and another 3 who underwent DSP for treatment of AO 23-C2 distal radius fractures. One patient underwent plate removal at a different institution and was subsequently lost to follow-up. The 24 patients who underwent both plate placement and removal at our institution for treatment of AO 23-C3 fractures were included in our study. [Table 1](#) lists demographic information. Average age was 41 years (range, 19–62 years). There were 22 closed and 2 open fractures (one grade 1 and one grade 2 Gustilo—Anderson). The mechanism of injury was 4 motor vehicle accidents, 2 motorcycle accidents, 3 ground-level falls, 1 assault, and 14 falls from a height (range, 4–20 ft). Of the 24 patients, 3 sustained other injuries to the ipsilateral upper extremity: one experienced a complex elbow dislocation requiring a radial head arthroplasty and lateral ulnar collateral ligament repair, one had a supracondylar distal humerus fracture requiring open reduction internal fixation, and one sustained a metacarpal shaft fracture that was managed nonsurgically. Average time from injury to placement of the DSP was 11.1 days (range, 0–25 days). Mean follow-up was 19.5 weeks (range, 12–35 weeks) from the time of plate placement. In 3 patients, fixation was augmented with percutaneous K-wires. No patients underwent open reduction of the fracture site.

### Radiographic outcomes

[Table 2](#) lists radiographic outcomes. Mean duration of radiographic follow-up was 19.5 weeks. All patients achieved radiographic union before removal of the DSP. Average time from plate

**Table 1**  
Demographics and Mechanism of Injury for All 24 Patients in Cohort

Patient	Age, y	Sex	Body Mass Index	Comorbidity	Tobacco	Mechanism of injury	Open/Closed Injury	Side
1	19	M	28	None	No	Fall from 20 ft	Open, grade 1	Right
2	60	F	27	Hypothyroidism	No	MVA	Closed	Right
3	36	F	25	None	0.5 PPD	MVA	Closed	Left
4	41	F	33	Osteopenia	1 PPD	Ground-level fall	Closed	Left
5	46	M	44	None	No	Motorcycle accident	Open, grade II	Right
6	30	F	28	None	No	MVA	Closed	Left
7	53	M	28	None	No	Fall from 20 ft	Closed	Left
8	52	F	28	None	No	Ground-level fall	Closed	Left
9	50	M	34	None	No	Fall from 6-ft ladder	Closed	Right
10	30	M	27	None	No	Fall from 10-ft tree	Closed	Left
11	53	M	33	None	No	Assault	Closed	Left
12	27	M	21	None	No	Fall from 6 ft	Closed	Right
13	60	M	23	None	0.5 PPD	Fall from 15 ft	Closed	Right
14	49	F	26	None	No	Fall down 8 ft	Closed	Left
15	36	M	25	None	No	Fall from 15 ft	Closed	Right
16	32	M	26	None	No	Fall from 11 ft	Closed	Right
17	32	M	23	None	No	Fall from 4 ft	Closed	Right
18	47	M	35	None	No	Fall from 4 ft	Closed	Left
19	62	F	31	Diabetes mellitus, hyperlipidemia, osteoporosis	No	Ground-level fall	Closed	Left
20	29	M	26	None	No	Fall from 10 ft	Closed	Left
21	35	M	31	None	No	MVA	Closed	Right
22	47	M	28	None	No	Fall from 15 ft	Closed	Left
23	39	M	25	None	No	Motorcycle accident	Closed	Right
24	35	M	32	None	No	Fall from 6 ft	Closed	Left
Average ± SD (range)	41.2 ± 11.7 (19–62)		28.7 ± 5 (21–44)					

MVA, Motor vehicle accident; PPD, packs per day.

**Table 2**  
Days Between Injury and DSP Placement, and Between DSP Placement and Removal, and Radiographic Outcomes of All 24 Patients

Patient	Days Between Injury and DSP Placement	Days Between DSP Placement and Removal	Radial Height, mm	Radial Inclination (degrees)	Ulnar Variance, mm	Volar Tilt, mm*	Articular Steppoff, mm	Radiographic Parameters Outside Acceptable Range, n (out of 5) <sup>†</sup>
1	1	215	18	25	<b>3</b>	3	1	1
2	12	70	<b>5</b>	<b>9</b>	<b>3</b>	0	<b>3</b>	4
3	18	175	11	<b>14</b>	<b>3</b>	8	<b>3</b>	3
4	25	102	<b>8</b>	<b>11</b>	-2	<b>-5</b>	<b>4</b>	4
5	5	61	16	30	0	14	<b>4</b>	1
6	4	68	13	26	0	2	1	0
7	7	136	18	27	2	0	2	0
8	19	76	11	20	0	0	0	0
9	9	40	10	19	<b>3</b>	<b>-6</b>	<b>3</b>	3
10	20	84	18	25	0	2	<b>3</b>	1
11	0	66	10	23	<b>6</b>	0	0	1
12	1	63	9	<b>15</b>	0	0	0	1
13	2	62	<b>8</b>	<b>14</b>	<b>6</b>	0	1	3
14	18	62	11	23	0	3	0	0
15	2	80	10	20	<b>4</b>	0	0	1
16	9	84	12	20	-1	0	1	0
17	13	66	12	24	-3	3	1	0
18	25	54	11	20	0	7	1	0
19	11	84	<b>7</b>	17	1	-1	1	1
20	14	77	<b>6</b>	<b>12</b>	0	<b>-5</b>	<b>3</b>	4
21	7	53	9	18	-3	2	0	0
22	16	82	12	20	0	9	<b>5</b>	1
23	4	130	<b>8</b>	<b>15</b>	2	<b>8</b>	<b>6</b>	3
24	24	118	15	26	0	<b>-10</b>	0	1
Average ± SD (range)	11.1 ± 8 (0–25)	87.0 ± 39.0 (40–215)	11.1 ± 3.7 (6–18)	19.7 ± 5.4 (9–30)	+1 ± 2.4 (-3 to 6)	1.4 ± 5.2 (-10 to 14)	1.7 ± 1.7 (0–6)	1.4 ± 1.4 (0–4)

\* Negative volar tilt signifies dorsal tilt.

<sup>†</sup> Bold numbers indicate numbers that fell outside the acceptable radiographic parameters for each respective category: radial height greater than 8 mm, radial inclination greater than 15°, ulnar variance less than 3 mm, volar tilt greater than -5°, and articular steppoff 2 mm or less.

placement to plate removal was 87 days (range, 40–215 days). One patient demonstrated a loss of reduction during fracture healing (Fig. 1). Mean radial height at time of final follow-up was 11.1 mm (SD, ±3.7 mm, range, 6–18 mm). Five patients healed with a radial

height less than 8 mm. Average radial inclination was 19.7° (SD, ±5.4°, range, 9° to 30°). Seven patients had radial inclination less than 15°. Average volar tilt was 1.4° (SD, ±5.2°, range, -10° to 14°). Four patients had volar tilt less than -5° (dorsal tilt, greater than 5°).



**Figure 1.** A, B Radiographs of a 36-year-old man with a right comminuted distal radius fracture after a fall off a 15-ft roof. C, D Fluoroscopic images of patient, who underwent treatment with a DSP 2 days later. E, F Radiographs were taken at 10 weeks after DSP placement. Final postoperative x-rays met acceptable criteria in 2 of 5 radiographic parameters (radial height and ulnar variance) with loss of sagittal alignment.

Average ulnar variance was 1.0 mm (SD,  $\pm 2.4$  mm, range,  $-3$  to 6 mm). Seven patients had ulnar variance greater than 3 mm. Mean articular displacement was 1.7 mm (SD,  $\pm 1.7$  mm, range, 0–6 mm). Eight patients had articular displacement greater than 2 mm.

#### Complications

There were 3 complications in the case series. One patient developed tenosynovitis of the first dorsal compartment after

DSP removal, which required first dorsal compartment release at 6 months after surgery with resolution of symptoms. One patient developed carpal tunnel syndrome after placement of DSP and underwent carpal tunnel release concurrently with DSP removal. One patient who was lost to follow-up after DSP placement returned with a fractured plate at 9 months after surgery. The fracture had healed with satisfactory alignment and the broken plate was removed without complication. There were no cases of radial sensory nerve injury or neuritis.



**Figure 2.** A, B Radiographs of a 48-year-old man with a comminuted right distal radius fracture who sustained a ground-level fall. C, D Fluoroscopic images of patient, who underwent treatment with DSP 4 weeks after the day of injury. E, F Radiographs were taken 6 weeks after DSP placement. Final postoperative x-rays reveal appropriate alignment in all 5 radiographic parameters.

## Discussion

Severely comminuted intra-articular distal radius fractures pose major challenges. Distal fracture lines, limited bone stock, and articular comminution challenge precise articular reconstruction and may preclude stable internal fixation with standard volar or dorsal locking plates. At times, indirect reduction

using ligamentotaxis may be preferable to maintain skeletal length and improve fracture alignment. Although external fixation may achieve these goals, limitations include high complications rates and poor functional outcomes associated with pin-site infections, fracture subsidence, digital stiffness, patient dissatisfaction, and potential delays in mobilization and functional use.<sup>4,5</sup> Dorsal wrist spanning plate fixation offers an





**Figure 3.** A, B Radiographs of a 39-year-old man with a left comminuted distal radius fracture after a motorcycle accident. C, D Fluoroscopic images of patient, who underwent treatment with DSP placement 12 days after the injury. E, F Radiographs were taken 6 weeks after DSP removal. Final postoperative x-rays reveal malalignment in 3 of the 5 radiographic parameters (radial height, radial inclination, and articular stepoff).

alternative surgical option that may avoid some of the drawbacks of external fixation.

In this study, we found that DSP fixation maintained fracture alignment through bony union with a low complication rate. Radiographic outcomes demonstrated mean values across the cohort that fell within acceptable parameters for radial length, inclination, volar tilt, ulnar variance, and articular displacement.

However, most patients demonstrated mal-reduction in at least one radiographic parameter at the time of fracture fixation that persisted through fracture healing.

Burke and Singer<sup>6</sup> initially described use of a DSP as an alternative to external fixation for comminuted unstable distal radius fractures. Hanel et al<sup>13</sup> and Ruch et al<sup>14</sup> applied this technique to distal radius fractures with metaphyseal-diaphyseal extension.

Later reports described the use of DSP fixation of comminuted, osteoporotic fractures in elderly patients.<sup>15</sup> Richard et al<sup>15</sup> reviewed 33 elderly patients, mean age 70 years, who were treated with distraction plating for comminuted osteoporotic distal radius fractures. All fractures healed and radiographs demonstrated a mean volar tilt of 5°, ulnar variance of 0.6 mm, and radial inclination of 20°. Mean values for wrist flexion and extension were 46° and 50°, respectively and pronation and supination were 79° and 77°, respectively. The authors concluded that distraction plating represents an effective method for restoring functional range of motion and acceptable radiographic alignment. However, mean Disabilities of the Arm, Shoulder, and Hand (DASH) score of 32 at mean 47-week follow-up revealed some persistent limitations in function.

Jain and Mavani<sup>10</sup> prospectively evaluated 20 patients, mean age 62 years, with comminuted distal radius fractures treated with DSP fixation. Radiographic outcomes included a mean volar tilt of 7°, ulnar variance of 0.5 mm, radial inclination of 18°, and average loss of 2 mm of radial height. In that study, mean wrist range of motion was 46° flexion, 50° extension, 79° pronation, and 77° supination. At final follow-up, mean DASH score was 32.<sup>10</sup> The current study included a population of patients younger than in those studies (mean age, 41 years) and focused exclusively on AO type C3 comminuted articular fractures of the distal radius. Mean radial height at the time of union was 11.1 mm, radial inclination was 19.7°, volar tilt was 1.4°, ulnar variance 1.0 was mm, and articular displacement was 1.7 mm.

We further examined radiographic outcomes to determine the proportion of fractures that did not achieve satisfactory restoration of distal radius anatomy. In this way, we identified outliers in which radiographic malunion in one or more radiographic parameters were evident despite acceptable mean values across the cohort. We found that 6 patients healed with a radial height of 8 mm or less, 7 had radial inclination of 15° or less, 4 had volar tilt of -5° or less (dorsal tilt of 5° or greater), 7 had ulnar variance of 3 mm or greater, and 9 had articular displacement of greater than 2 mm. Only 8 of 24 patients had acceptable alignment in all parameters (Fig. 2). Of those remaining, 9 patients demonstrated malalignment in one parameter, 4 patients in 3 parameters, and 3 patients in 4 parameters (Fig. 3). Articular incongruity greater than 2 mm was the most common residual deformity after DSP fixation in our series, observed in 8 of 24 patients.

One of the primary limitations of DSP fixation from a technical perspective is that all reduction is indirect. Although manipulative reduction may improve alignment before the plate is inserted, ultimately the plate itself allows distraction only across the wrist and fracture site. As was evident in our series, this technique is limited in the quality of reduction achievable in these complex fractures. Supplemental K-wire fixation may aid reduction of radial styloid fragments that do not reduce with plate application. However, we were not able to capture the volar lunate facet reliably with K-wires and residual displacement or rotation of this fragment accounted for most of the articular displacement observed in the 8 patients in our series. Whether it is better to accept some degree of malalignment and avoid opening the fracture or to pursue anatomic reduction aggressively with additional open volar and/or dorsal exposures and supplemental plating remains unclear. For the current study, we excluded patients who had supplemental fixation aside from K-wires because we thought this better defined the capabilities and limitations of the DSP technique.

The long-term effects of malunion and the relative influence of specific radiographic parameters on pain, function, and development of symptomatic arthritis after distal radius fracture remain the subject of debate. In a long-term follow-up study, Ali et al<sup>16</sup> found that patients with malunion of a distal radius fracture

(defined as dorsal angulation greater than 10°, ulnar variance greater than 3 mm, or radial inclination less than 15°) sustained at age 18 to 65 years reported significantly worse DASH scores, pain scores, activity limitation, and dissatisfaction compared with patients without malunion. Our study was limited by a short follow-up and a lack of patient-reported outcomes. Therefore, the long-term functional implications of the radiographic malalignment observed in the relatively young patients in the current series is unknown.

Optimal treatment options for comminuted articular fractures of the distal radius remain unclear. Although our results demonstrate that radiographic outcomes may be suboptimal in complex fracture patterns stabilized with a DSP, available literature suggests similar limitations with alternate plating techniques. Volar plate fixation remains a preferred fixation option for most displaced intra-articular fractures. However, complications with this technique have become increasingly recognized.<sup>17,18</sup> Several authors noted higher complications rates in more complex fractures, including loss of reduction<sup>2</sup> and inferior radiographic outcomes.<sup>19</sup> In a retrospective analysis of complications and radiographic outcomes in a series of 392 patients treated with volar plate fixation of distal radius fractures, Quadlbauer et al<sup>20</sup> reported 51 early (13%) and 17 late (4%) complications. The authors noted that 73% of all complications occurred in AO type C fractures. Esenwein et al<sup>21</sup> reviewed 665 cases of volar plate fixation of radius fractures and reported an overall complication rate of 11.3% (75 complications) and a revision surgery rate of 10% (65 patients). The authors found that complications were most frequent in AO C3 fractures, which were present in 20% of cases.<sup>21</sup>

In a review of radiographic outcomes after volar plate fixation of 185 distal radius fractures, Mignemi et al<sup>19</sup> found that volar locked plating achieved an average correction of radiographic measurements within acceptable functional values in 88% of patients, defined as less than 20° of dorsal angulation, greater than 10° of radial inclination, and less than 5 mm of ulnar variance. However, the authors noted that restoration of anatomic norms for volar tilt, radial inclination, and ulnar variance was achieved in less than 50% of fractures. In particular, they reported that more complex, intra-articular fractures were less likely to achieve or maintain normal ulnar variance and volar tilt through fracture healing.

How volar plating compares with DSP fixation for AO C3 fractures in terms of restoration of radiographic alignment remains unclear. For complex articular fractures with sufficient distal bone stock and articular fragments large enough to accept fixation, our current preferred surgical option remains volar plate fixation, acknowledging that a combined approach with supplemental dorsal fragment-specific plating may also be required. However, although not the first-line option for fractures that are otherwise amenable to standard plating techniques, we think that DSP remains a useful technique for select complex distal radius fractures. In particular, for fractures with a highly comminuted articular surface that cannot be directly reconstructed or with fracture lines that are more distal than a volar plate may capture, distraction plating offers a technically simple alternative to restore gross alignment with a low incidence of reduction loss and implant-related complications. Further comparative studies are needed to elucidate the optimal method of fixation.

There are several limitations to this study. Our study had problems associated with retrospective studies, including loss to follow-up and inconsistent evaluation of surgical results in patient follow-up appointments. Some patients did not return for the post-DSP placement scheduled follow-up appointments and were scheduled for DSP plate removal later than they otherwise would have had. Because this study focused only on short-term radiographic outcomes, we are unable to draw conclusions regarding

long-term clinical outcomes or the extent to which the malalignment identified in the cohort influenced long term radiographic or functional outcomes.

Dorsal spanning plate fixation offers a straightforward technique to stabilize multifragmentary articular fractures of the distal radius. All fractures in this series achieved bony union. However, restoration of anatomic alignment was less reliable; only 8 of the 24 patients met all 5 radiographic criteria at the time of union. Further study is necessary to determine long-term functional outcomes with this technique and to evaluate the optimal method of fixation for these challenging injuries.

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