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Dorsal locked plate fixation in dorsally unstable distal radius fractures

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Abstract
Introduction: Distal radius fractures are common, and internal fixation for operative management of these injuries is widely accepted. Although use of the volar approach for plate fixation has become more popular, benefits of the dorsal surgical approach include the potential for direct reduction and assessment of articular alignment, evaluation and management of concomitant intrinsic intercarpal ligament injury, and initiation of early range of motion. For certain fracture patterns, dorsal plate fixation is the preferred surgical technique. Improvements in implant design, in particular the use of low-profile dorsal plates, has decreased the rate of complications seen previously with this technique.
Purpose of the study: We are trying into evaluate the functional outcome of distal radius fractures treated by open reduction internal fixation [ORIF] with precontoured low profile dorsal locking plates.
Material and Methods: We performed ORIF with dorsal plating in 40 patients (16 males and 24 females) for distal radius fractures according to our inclusion and exclusion criteria. Fractures were classified by AO classification. Patients were followed up at routine intervals and the functional outcome was evaluated by the Disabilities of the Arm, Shoulder, and Hand questionnaire, the Gartland and Werley scoring system and modified Green O' Brien score. All plates were low profile and stainless steel. Radiographic parameters, range of motion, and strength compared with the uninjured side were recorded.
Results: According to the AO classification system, there were 5 type A fractures, 6 type B fractures, and 29 type C fractures. The median preoperative dorsal angulation was 30°, and the median postoperative angulation was -4° volar. Twenty-six patients with fractures had an intra-articular step-off or gap, which were all corrected to neutral by the procedure. Seven patients with the fractures showed positive ulnar variance, all corrected to neutral at time of follow-up evaluation. The median patient age at surgery was 59 years. The median follow-up period was 18 months Compared with the contralateral side, the mean extension and flexion were 88% and 81%, respectively; pronation and supination were 89% and 87%, respectively; and grip strength and thumb pinch were 78% and 94%, respectively. The mean postoperative Disabilities of the Arm, Shoulder, and Hand questionnaire score was 15 points. 38 patients had Gartland and Werley scores of good or excellent. No patients needed to have their plates removed, and no extensor tendon rupture was reported. 1 patient lost reduction; 1 patient needed a tenolysis of the extensor pollicis longus tendon. Out of 40 patients, 31 patients had excellent results, 7 patients had good results and 1 had fair and only 1 patient had poor result, according to the modified Green O' Brien score. Average time to clinico-radiological union was 7 weeks. Average follow up time was 18 months.
Conclusion: Our study has demonstrated that dorsal plating is an effective method for management of dorsally unstable distal radius fractures.

Keywords: distal radius fracture, dorsal approach, locked plate fixation, low profile plating

1. Introduction
The effectiveness of dorsal plating for dorsally unstable fractures of the distal radius has been shown in a number of studies using numerous plate types and study designs [1–5]; however, controversy exists surrounding the complications associated with dorsal fixation [6–8]. Extensor tendon irritation, attrition, and rupture have been linked to dorsal fixation. Because of this unfavourable association with soft-tissue complications, a volar approach has been advocated for stabilizing most dorsally or volarly comminuted distal radius fractures [9, 10]. Low-profile dorsal plates were subsequently developed to specifically address these extensor tendon complications [11–13]. Thinner plates have been used in an attempt to reduce extensor tendon irritation and rupture, but few studies [13, 14] have described the effectiveness or the complications associated with these newer plates.

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One other retrospective study [15] has examined the plating system used in our work. The purpose of this study was to determine the functional and radiographic outcomes and any complications after low-profile dorsal plating for dorsally angulated distal radius fractures in a single-institution study. The results of this study were compared with those of similar low-profile plating studies. We believe that low-profile dorsal plating can effectively stabilize dorsally angulated distal radius fractures without extensor tendon complications. More modern implants have been designed to minimize the potential for attritional wear or rupture of the extensor tendons by incorporating features such as polished surfaces with tapered edges and low-profile locking screw heads. Plates are also precontoured and come in a variety of sizes to minimize the need to bend or cut the plates, which can result in sharp edges. Recent reports have documented favourable outcomes and minimal complications with these newer-generation implants. The use of locking screws can provide more stable fixation, even in patients with compromised bone stock, and may allow for the same benefit of early range of motion as volar plating.

Materials and Methods
The patient records, surgical reports, and radiographs of 34 consecutive patients from 2015 to 2018 who had isolated dorsal plating for unstable, dorsally angulated (10°) fractures of the distal radius at our institution were retrospectively analysed for this study. All of these patients had intra-articular or extra-articular fractures for which initial closed reduction and splinting had failed. Patients with fewer than 12 months of follow-up evaluation were excluded from the study. Patients who had been treated with concomitant volar plating or external fixation in addition to dorsal plating or those with bilateral wrist injuries also were excluded. All patients were called back for final functional evaluations. Of the 44 consecutive patients who met our inclusion/exclusion criteria, 3 were lost to follow-up evaluation and 1 declined to participate. The study cohort comprised the remaining 40 patients. Research protocols were approved by the institutional review board at our institution. The study group consisted of 16 men and 24 women with a median age of 59 years (range, 27–86 y). The median duration of follow-up evaluation was 18 months (range, 12–28 mo). Twelve patients had surgery on the dominant hand. The most common mechanism of injury was a fall from a standing height (34 patients). In addition, 1 patient fell down a flight of stairs, 1 fell off a table, 1 fell from a height of approximately 3 m, 2 sustained a sports-related injury, and 1 was the victim of an assault. All patients were treated initially with closed reduction and splinting in the emergency room. If this conservative reduction failed radiographically (10° dorsal angulation), the patients subsequently had open reduction and internal fixation by a single fellowship-trained orthopaedic surgeon. All plates were anatomically designed, low profile (1.2-mm thick), and stainless steel. The thickness of the low-profile plate used in this study was defined by technical monographs provided by the manufacturer. When seated fully into the plate, the screws sit below the outer surface of the plate rather than elevated above the plate surface. The true thickness of the implant (i.e., plate and screws combined), therefore, was determined to be the thickness of the plate. The implant size was determined by the operating surgeon. All patients had definitive fixation within 10 days after injury.

Surgical Technique
The surgical technique is a dorsal approach through a 7-cm skin incision just ulnar to Lister's tubercle. The extensor retinaculum is incised over the third dorsal extensor compartment of the wrist, and the extensor pollicis longus tendon is retracted radially. The dorsal aspect of the radius is exposed subperiosteally between the second and fourth extensor compartments, and Lister's tubercle is removed. The plate is placed directly over the dorsum of the radius after intra-articular and extra-articular fracture reduction. Screws were placed across the distal and proximal aspects of the plate, respectively. Allograft bone chips are packed into any metaphyseal defects in the distal radius fracture site after reduction. The extensor retinaculum of all patients then is repaired with nonabsorbable 2-0 polyester braided sutures. If the extensor retinaculum is too tight to close primarily after plate fixation, relaxing incisions are made on the radial and ulnar sides of the retinaculum to achieve proper retinacular closure. The extensor pollicis longus tendon is left dorsal to the extensor retinaculum. Dorsal short-arm splinting was used after surgery to ensure adequate wrist stabilization and to still allow full flexion of all 5 fingers. Patients were advised to begin active and passive finger motion early in the second postoperative day. Two weeks after surgery the sutures were removed and the wrist was placed in a custom-made thermoplastic volar splint. Active and active-assisted wrist motion was started at that time. Passive wrist motion and grip-strengthening exercises were started at 4 weeks. Based on evidence of radiographic fracture healing, light weight-bearing and static progressive/dynamic wrist strengthening exercises were begun at 4 to 5 weeks.

Outcomes Evaluation
Because cataloguing complications was central to our study, we carefully recorded any postoperative complications, including loss of reduction, non-union, infection, pain, plate removal, hardware removal, neuropathy, and extensor tendon irritation or rupture. Palpation for extensor tendon tenderness also was performed. At the time of the final evaluation, the range of motion (ROM) of the injured wrist was evaluated by recording the arcs of flexion– extension, pronation–supination, and radial– ulnar deviation with a standard goniometer, and these were compared with those of the contralateral side. Grip strength and thumb pinch were measured with a dynamometer and thumb press, respectively, and were compared with those of the contralateral side. Radiographic data were evaluated by independent reviewers for angulation, articular congruity, and radial height (ulnar variance) at the time of the final evaluation. According to the AO classification system, there were 5 type A fractures (1 type A2, 3 type A3), 6 type B fractures (2 type B1, 3 type B2), and 29 type C fractures (8 type C1, 9 type C2, 4 type C3). Radiographic healing was defined as proper union of the fracture within 6 months. Patients were examined at the time of the final evaluation, and activities of daily living and quality of life were assessed with the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, the Gartland and Werley clinical scoring system and modified Green O' Brien score. Continuous variables were assessed for normality by the Kolmogorov-Smirnov goodness-of-fit test to identify skewness and to determine the appropriate choice of statistical methods. Radiographic parameters did not follow a normal distribution and therefore were presented as medians and ranges and compared with respect to preoperative and follow-up values by the Wilcoxon signed-rank test. Correlation and multiple linear regression analysis were used to test which variables were predictive of DASH and Gartland and Werley

scores by examining the following covariates: age, gender, surgery of dominant hand, AO classification, duration of follow up evaluation, ROM variables on the injured side, and radiographic parameters. Statistical analysis was performed using statistical software. Power analysis indicated that a sample size of 40 patients would provide 90% power to detect a statistically significant radiographic reduction of 10° in dorsal angulation between preoperative and follow-up measurements using the nonparametric Wilcoxon test for paired data

Results
Complications were catalogued throughout the course of the study period and at follow-up evaluation. There was no malunion, plate breakage, early or late infection, or compression neuropathy during the study period. No plates were removed for soft-tissue complications, and there were no extensor tendon ruptures. No patients experienced residual motor or neurologic deficits. One patient lost reduction and reported fair functional outcome at 25 months. Initial radiographic parameters for this patient were as follows: 36° dorsal angulation with a notable component of both volar and dorsal comminution. Follow-up angulation for this patient was 34° volar. No other patients lost reduction of the fracture. At the time of the final evaluation, the mean ROM of the

wrist consisted of 53° (range, 34°–71°) of extension, 48° (range, 30°–70°) of flexion, 71° (range, 40°–90°) of pronation, and 71° (range, 55°– 115°) of supination. (Table 1 for ROM as compared with the contralateral uninjured side). The mean grip strength was 23 kg (range, 4–46 kg), and the mean thumb pinch was 6 kg (range, 3–12 kg). Results of preoperative and postoperative radiographic analyses (Fig. 1) for angulation, step-off, gap, and radial height/ulnar variance are presented in (Table 2). The postoperative angulation was defined in reference to the preoperative dorsal angulation (i.e., dorsal [+], volar [-]). According to established radiographic criteria [14, 16], satisfactory radiographic reduction (defined as within 10° of dorsal angulation, 20° of volar angulation, 5 mm of positive ulnar variance, 1 mm of articular incongruity) was achieved for all but 1 of the 40 fractures at the time of surgical fixation (p <.001; Fig. 2, Fig 3). The mean score on the DASH questionnaire was 15 points (range, 0–55 points; maximum possible score, 100 points). According to the Gartland and Werley scoring system, 26 patients had an excellent outcome, 12 had a good outcome, and 2 had a fair outcome (mean score, 4; range, 0–16). Out of 40 patients, 31 patients had excellent results, 7 patients had good results and 1 had fair and only 1 patient had poor result, according to the modified Green O' Brien score. (Table 3).

(A) Extra-articular and intra-articular dorsally angulated fractures before surgery

(B) At 8 weeks after satisfactory fixation with low-profile dorsal plating

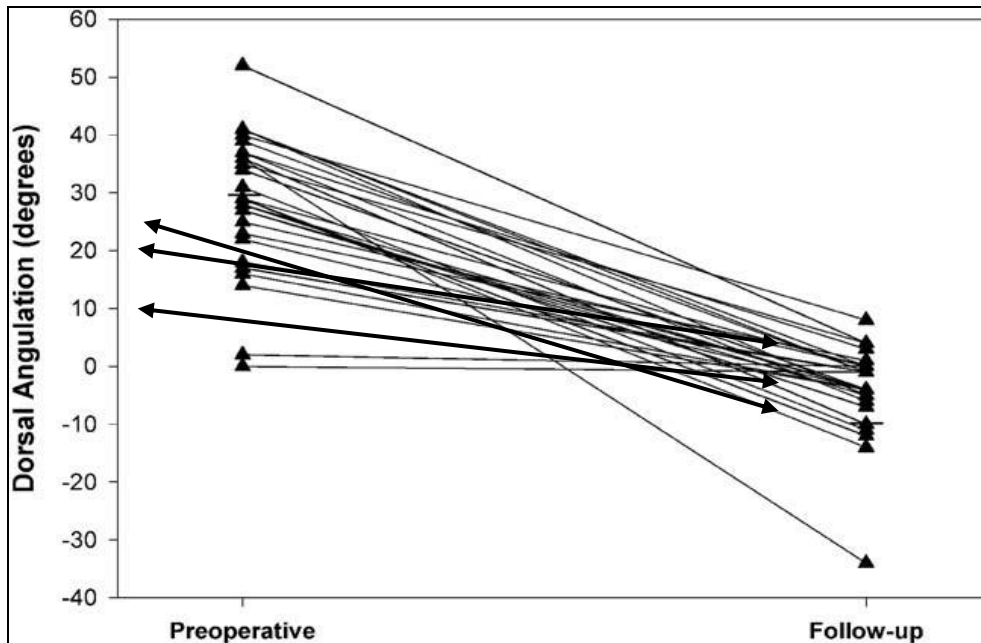**Fig 1:** Range of Motion Compared With

Fig 2: Preoperative and follow-up (range, 12–28 mo) dorsal angulation.
Horizontal lines indicate mean values at preoperative (30° dorsal) and follow-up (-4° volar) time points. *P*<.001, Wilcoxon test.

Fig 3: Postoperative Follow up

Table 1: Range of Motion Compared with Contralateral Side

ROM Variable	Mean%	95% Confidence Interval %
Extension	88	81-96
Flexion	81	75-86
Pronation	89	85-94
Supination	87	84-91
Grip strength	78	71-85
Thumb pinch	94	85-97

Table 2: Changes in Radiographic Parameters

Radiographic Parameter	Before Surgery	Follow Up	P- value
Dorsal tilt, °(Degree)	40 (0-52)	-4 (-34 to 8)	<.001*
Step-off, mm	0 (0-2)	0 (0-2)	.007
Gap, mm	0 (0-6)	0 (0-0)	<.050*
Radial height/ulnar variance, mm	0 (0-10)	0 (-2 to 2)	<.050*

*Statistically Insignificant

Table 3: Modified Green O' Brien score

Prognosis	Total (n= 40)
Excellent	31
Good	7
Fair	1
Poor	1

Discussion

The controversy still exists regarding the advantage of dorsal plating over volar plating for distal radius fractures. Our study aimed at evaluating the functional outcome of dorsal plating, specifically in dorsally unstable distal radius fractures. Traditionally, dorsally comminuted distal radius fractures were treated with dorsal plating. The dorsal aspect of radius is subcutaneous and easy to access. This approach allows direct fracture reduction, evaluation of articular congruity and restoration of injured intrinsic inter-carpal ligament stability [16]. Since most distal radius fractures are dorsally displaced, the dorsal surface is the most appropriate surface for buttress plating, as it counteracts the deforming forces, which is rational for the plate to be applied dorsally.

The dorsal aspect of the distal radius is not the ideal surface for a plate fixation, because of the convex nature of the dorsal aspect of radius, presence of Lister's tubercle and the fact that there is only minimum soft-tissue cover and the proximity of the plate with the extensor tendons leading to tendon irritation, resulting in tenosynovitis and later rupture, particularly with the more bulky implants or those which required intra-operative cutting the plate for better fit and contouring to the shape of the bone [17].

The size and thickness of the plate is directly proportional to the extensor tendon complication. This required a smaller plate, pre contoured to the dorsal rim like in our study which could engage the subchondral bone for efficient fixation and stabilization. Over the past few years, volar fixation for dorsally angulated fractures has received much attention. Although the volar approach avoids extensor tendon complications to a great extent, the surgeon may not be able to visualise the articular surface. Also, this plating approach faces the problem of an inadequate buttress effect and subsequent high bending loads on the plate. In a study by Orbay and Fernandez, with volar plating, the majority of fractures were not complex, and the average follow-up period was approximately 16 months. Three plates in their study needed to be removed, including 1 for extensor tendon irritation caused by improper screw placement on the volar surface of the plate. [18, 19]. After the introduction of the small fragment T plate by Mathys in 1973, the design of low-profile anatomically contoured plates reduced the complication of tendon irritation and rupture to negligible level [20]. The use of dorsal plate at the periarticular subchondral bone also provides angular and axial stability of the construct thereby avoiding the need for bone grafting for the metaphyseal defects and ensured the radial length restored at surgery was maintained till fracture healing occurs. The head of the locking screw locks into the plate and as a result the screws are flush with the plate which avoids the chance of extensor tendon irritation and rupture, by a good deal [21].

The 2.7 locking plate with angular stability could engage the dorsal rim, dorso ulnar corner and the radial styloid fragments to provide a mechanically stable dorsal construct which would allow early range of movements at the wrist. Dorsal plating is mechanically suitable for correction of dorsal tilt and displacement. Structural stability of the construct is enhanced since the locking screw engage the subchondral bone of the volar rim which is the strongest part of the distal radius [22].

Multiple case series have shown that articular alignment and joint congruity could be restored reliably with dorsal approach, even with complex AO-type C2 and C3 fractures [23-26]. In our study, the mode of injury was road traffic accident in 18 patients (47%), fall in 22 patients (53%). Similar results were obtained in the study by Kilic et al. as he had road traffic accidents in 13 patients (48.1%) and low energy falls in 14 patients (51.9%) while in study done by Chung et al. he found 42 patients (48.3%) with road traffic accidents and 45 patients (51.7%) with low energy falls [23,24].

In our study, 57.89% had excellent outcome, 31.59% had good outcome, 5.26% had fair functional outcome and only 5.26% had poor functional outcome, according modified Green O' Brien scoring criteria, which is considered a more stringent criteria than scoring system by Gartland and Werley. Our study is in concurrent with the study done by Simic et al. who evaluated 51 distal radius fractures for functional and radiographic outcome after internal fixation of displaced and unstable distal radius fractures with low profile dorsal plating. They reported no cases of tendon irritation or rupture, infection or CRPS. Hardware removal was performed for only one patient who experienced dorsal wrist pain. All patients had an excellent (31 patients) or good (19 patients) result according to the scoring system of Gartland and Werley [21].

Campbell also described a series of 25 patients treated with dorsal plating, 21 of them being AO C3 type fractures. He found 15 good and excellent results according to Gartland and Werley scoring. Thirteen fractures had no articular step off, seven had 1 mm step off, and only one fracture had 2 mm of articular step off at final follow-up radiograph. Three of his study patients needed plate removal and one patient had extensor digitorum longus tendon rupture [29].

There are studies which support volar plate fixation in dorsally unstable fractures. In a multicentric, retrospective study involving three hospitals situated in Spain, Switzerland, and the United States, 97 patients with 101 intra-articular distal radius fractures, including 13 volarly displaced and 88 dorsally angulated fractures underwent volar distal radius lock plating, between January 2000 and March 2006. Over 80% were C2/C3 fractures, based on the AO classification. In their, series they had 16 open fractures. With an average follow-up of 28 months, the Disabilities of the Arm, Shoulder, and Hand (DASH) score was 8. The complications rate was < 5%, including loss of reduction in two patients. All fractures healed by 3 months post injury. They concluded that irrespective of the direction and amount of initial displacement, majority of intra-articular fractures of the distal radius can be managed with a fixed angle volar plate through a single volar approach [30].

Orbay et al. study also used volar approach to avoid the soft tissue problems associated with dorsal plating. He had a consecutive series of 29 patients with dorsally displaced, unstable distal radial fractures with fixed-angle internal fixation device. At a minimal follow-up time of 12 months the volar fractures had healed with highly satisfactory radiographic and functional results. The overall outcome according to the Gartland and Werley scales showed 19 excellent and 12 good results. They also concluded that stable internal fixation with the preservation of the dorsal soft tissues resulted in rapid fracture healing, reduced need for bone grafting, and low incidence of tendon problems [31].

David et al. did a comparison study of the functional outcomes of volar and dorsal plating in 34 patients with volar plating done in 14 patients and dorsal plating in 20 patients.

According to the AO classification there were fifteen C3 and five C2 fractures in the dorsal plating group and ten C3 and four C2 fractures in the volar plating group. Volar plating resulted in a significantly better Gartland-Werley score compared to dorsal plating. There were no significant differences in the DASH score. Volar collapse was documented in 5 patients of dorsal plating group and no collapse occurred in the volar plating group. Dorsal plating was associated with ruptured extensor indicis tendon in 1 patient and secondary surgical procedures were required in 4 patients (tenolysis and radial styloidectomy). Volar plating was associated with median nerve neuropathy in 2 patients and intersection syndrome in one. In addition, there was a higher rate of volar collapse and late complications in the dorsal plating group compared with the volar plating group [32].

Conclusion

From our study we are concluding that stable fixation and good functional outcome can be consistently achieved by dorsal plating for dorsally unstable distal radial fractures.

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