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HANDSURGERY

Comparative study of the closed reduction percutaneous cannulated screw fixation and open reduction palmar locking plate fixation in the treatment of AO type A2 distal radius fractures

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Abstract
Introduction The present study was designed to demonstrate the efficacy of standard 4.0 mm cannulated screw fixation by comparing it with palmar locking plate fixation in the treatment of acute, unstable, simple extra-articular distal radius fractures.
Materials and methods We prospectively collected and retrospectively analyzed outcomes data for 65 patients aged between 18 and 60 with AO type A2 fractures treated with closed reduction, percutaneous cannulated screw fixation (CRPCS $n = 34$) or open reduction palmar locking plate fixation (ORPLP $n = 31$). Range of motion, grip strength, Gartland–Werley and QuickDASH scores were compared at 2 months after surgery, and final follow-up (mean 32 months, range 12–90). Deterioration in radiographic parameters were measured and compared. Operative time and return to preinjury activity were evaluated.
Results Parameters did not differ significantly between the groups at either time point with respect to grip strength or range of motion, except pronation and supination; they were better in the CRPCS group ($p = 0.005$ and 0.025, respectively) at 2 month follow-up. The Gartland–Werley and QuickDASH scores obtained at final follow-up were similar for each group and lacked statistical significance. Group comparison for the deterioration of radiologic parameters showed no significant difference. CRPCS group had significantly shorter operative time ($p = 0.001$) and there was no significant differences between the groups regarding the return to preinjury activity ($p = 0.129$).
Conclusions CRPCS group was found to be as successful as ORPLP group and it may be suitable in the case of young, active individuals with AO type A2 distal radius fractures.

Keywords Distal radius · Fracture · Cannulated screw · Percutaneous fixation

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Introduction

Because of the intrinsic variabilities, there is no single treatment method available to fix all type of distal radius fractures. These variabilities are including age, bone quality, patient demands and difference in fracture patterns. Of these fracture patterns, the treatment of unstable extra-articular fracture of distal radius is potentially the most controversial, since the opinions often differ as to what type of fixation is most appropriate. Historically, closed reduction with percutaneous pin fixation has been the most common treatment method for these fractures [1, 2]. However, specific limitations and complications such as lack of rigidity, need for restrictive immobilization, skin irritation and interfering with daily activities of patients have decreased its popularity over time [3, 4]. These disadvantages may have contributed to the reported trend toward palmar plate fixation in surgical techniques for distal radius fracture [5]. While simpler fracture patterns may be suitable to simpler and inexpensive techniques, the use of the palmar locking plate became a popular treatment method for most fracture patterns with significant soft tissue dissection, moderate complication rate, and longer operative time [6–8].

However, there are different options available for fixation of distal radius, especially for extra-articular fractures without the risks of open surgery. Cannulated screw

technology is one of these options and is applicable to distal radius fractures [9, 10]. The present study was designed to demonstrate the efficacy of standard 4.0 mm cannulated screw fixation by comparing it with palmar locking plate fixation. Our hypothesis was that functional and radiologic outcomes would not differ between the patients treated with CRPCS fixation or ORPLP fixation after an acute, unstable, simple extra-articular (AO type A2) distal radius fracture.

Patients and methods

The study was approved by our university institutional review board. We prospectively enrolled and collected the data for patients with distal radius fractures who were treated either with cannulated screw or palmar locking plate fixation between January 2005 and April 2012. The patients aged between 18 and 60 with AO type A2 fractures treated with closed reduction, percutaneous cannulated screw fixation (CRPCS) or open reduction palmar locking plate fixation (ORPLP) were eligible for inclusion and the patients with complex or articular fractures, late injury more than a week, prior surgery for the same fracture and concomitant upper extremity injuries were excluded from consideration. The inclusion and exclusion criteria are summarized in Table 1. We were able to pair-match 36 patients treated with CRPCS to 36 patients treated with ORPLP on the basis of age (±15 years), sex (difference between the groups maximum 15 %), time from injury to surgery (±1.5 days) and dominant extremity injury (difference between the groups maximum 1.2 %). One patient refused to participate. Thus, seventy-one patients met the criteria and we retrospectively analyzed the prospectively collected data for these 71 patients. Six patients were excluded because of insufficient data, lived out of city or would not be available for the final follow-up. The remaining 65 patients formed the study group. Of these 65 patients, 34 were treated with CRPCS fixation and 31 were treated with ORPLP fixation.

Surgical technique

The fracture is judged to be unstable and skeletal fixation is performed if it is not possible to maintain the stable position after closed reduction, initial dorsal angulation >20°, initial shortening >5 mm, dorsal comminution >50 % and an associated ulnar fracture [1, 11]. All the operations were performed after a satisfactory level of anesthesia had been achieved, a pneumatic tourniquet had been applied and the upper extremity had been sterilely prepared in the operating room. Operative time was reviewed and compared in both groups. Procedure selection was determined by surgeon or patient preference and availability of implants at the time of injury.

Closed reduction and cannulated screw fixation

The affected hand is suspended in fingertraps with 2–4 kg of countertraction applied across the upper arm. Closed reduction under fluoroscopic guidance with ligamentotaxis is then performed. Once anatomic alignment is achieved, a guiding wire placement is done with horizontal fingertrap traction on the operating table. Under fluoroscopic guidance, a guiding wire is inserted through the radial styloid just dorsal from the first dorsal compartment. The wire is then advanced through the ulnar cortex in a distal to proximal and radial to ulnar direction. A second guiding wire is next inserted, crossing to the first wire in a proximal to distal and radial to ulnar direction from the proximal radial side of the radius and advanced through the palmar ulnar corner. Incisions of 1 cm in length are made around the pins, and care is taken to avoid injury to the tendinous tissue and cutaneous branch of the radial nerve. After measurement for screw length, the near cortex is drilled with a sleeve to protect the soft tissue. A 4.0-mm cannulated long threaded screw (Synthes, Paoli, US) is inserted over the guide wire under fluoroscopic guidance. Screws are placed close to the palmar cortex, which is located in a more favorable biomechanical position, in order to increase bone

Table 1 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
18–60 years of age	Prior surgery for the same fracture
Good bone quality	Late injury more than a week
Unstable displaced simple extra-articular fracture requiring surgical fixation (AO type A2)	Concomitant upper extremity injuries
Independent function	Multiple trauma
	Bilateral fractures
	Complex or articular fractures
	Open fractures
	Associated neurovascular injury
	Patients who rely on others for basic activities

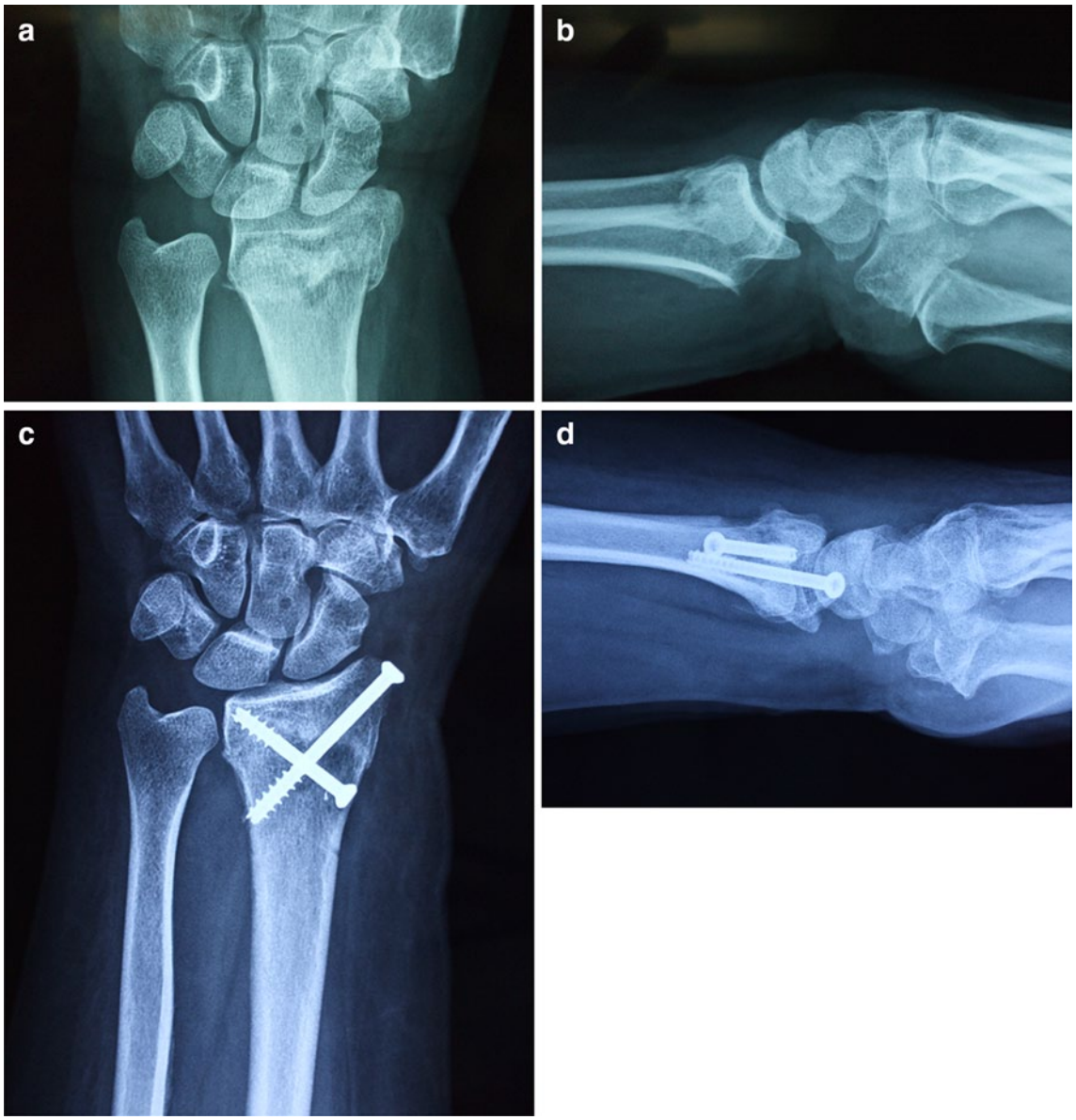

Fig. 1 Preoperative anteroposterior (**a**) and lateral (**b**) radiographs of a patient with an unstable, displaced simple extra-articular fracture of the distal radius (AO type A2). Postoperative 2 months anteroposterior (**c**) and lateral (**d**) radiographs showing stable fixation of the fracture and bony healing after closed reduction and percutaneous cannulated screw fixation. Wrist motion at the 2 month follow-up (**e**, **f**). Anteroposterior (**g**) and lateral (**h**) radiographs at final follow-up evaluation

contact and support the far cortex, thereby increasing stability [12]. Care is taken to avoid soft tissue damage and articular penetration by use of a fluoroscopy. Screws are slightly buried into the bone to prevent tendon irritation. An additional screw can be inserted in a similar fashion in order to increase stability (Fig. 1).

Open reduction and palmar locking plate fixation

Open reduction and palmar locking plate fixation was performed with use of a standard palmar approach of Henry [13]. The palmar fixed angle locking plate (Acumed, Beaverton, US or Synthes, Paoli, US) was placed directly and the distal screws were placed immediately below the subchondral plate to provide subchondral buttress effect [1, 2].

Postoperative rehabilitation

The wrist was immobilized in a short arm cast postoperatively to control edema for all patients. Active and passive finger motion was encouraged in the immediate postoperative period. After the cast removal, all patients were

Fig. 1 continued

referred for a standardized outpatient range of motion therapy program with removable protecting splint. Active and active-assisted motion of the wrist joint was started at that time. Patients were encouraged to use their hand, and resistive exercises were initiated 4–6 weeks after surgery. Passive stretching and strengthening of the wrist was started at 6 weeks in patients in whom there was radiographic evidence of fracture healing. Heavy labor was permitted after 3 months.

Outcome evaluations

The surgeon was not involved in the outcome measurements and evaluations. Data were analyzed for postoperative 2 months and the final follow-up with an average 32 (range 12–90) months. Two-month follow-up data included wrist flexion, extension, ulnar–radial deviations, forearm supination–pronation and grip strength. The final follow-up data included wrist flexion, extension, ulnar–radial deviations, forearm supination–pronation, grip strength, Gartland–Werley score and Disabilities of the Arm, Shoulder and Hand score [14–18]. Wrist range of motion was measured by a standard goniometer and grip strength was measured by a dynamometer (Jamar, Preston, US). When grip strength was calculated, an adjustment in the calculation was made to reflect the fact that the dominant hand is shown to be 10 % stronger than the nondominant hand for right handed patients. For left handed patients, grip strength

was considered equivalent in both hands [19]. Cast removal time, and from a patient's perspective, return to independent function and preinjury activity level were assessed as an indicator of general postoperative quality of life [20].

Radiographic assessment was made on the standard anteroposterior and lateral projection as described by Gilula [21]. Immediate postoperative and final radiographs were analyzed and alignment was compared. Difference in palmar tilt, radial height, radial inclination and ulnar variance were determined for each patient and the average loss in each parameter was compared between the groups. Complications following the surgical treatment were reviewed.

Statistical analysis

Statistical analysis was performed by a statistician. The material was processed and analyzed using Number Cruncher Statistical System (NCSS) 2007 and Power Analysis and Sample Size(PASS) 2008 Statistical Software (Utah, US) packages. Measures were reported as the mean and the ranges. Variables were tested for normality using the Kolmogorov–Smirnov test. Parametric variables were compared using Student's t test and, the Mann–Whitney U test was applied to non-parametric variables for inter-group comparisons. For in-group comparisons, Paired samples test were used for parametric variables and Wilcoxon signed-rank test for non-parametric variables. Yates continuity correction test was used for comparison of qualitative data. A difference was considered to be statistically significant when $p < 0.05$ and $p < 0.01$. To determine statistical power, the primary outcome variable was the pronation value. The present study was designed to determine an 8.8 point mean difference in the pronation values between the two groups with a standard deviation of 9.2 points. A power analysis indicated that a sample size of 25 patients in each group would provide 80 % statistical power (α error probability of 0.01, β error probability of 0.20).

Results

Group comparison

Both groups were compared to ensure that the patients had similar demographic characteristics. There were no statistically significant difference detected between the groups with regard to age ($p = 0.347$), sex ($p = 0.705$) and dominant extremity injury ($p = 1.000$). There was no statistically significant differences between the groups in terms of follow-up period ($p = 0.606$), but ORPLP group has longer follow-up owing to changing trends in the treatment methods. There was no statistically significant differences between the groups regarding the time from injury to surgery ($p = 0.104$). CRPCS group had significantly shorter operative time ($p = 0.001$). The characteristics for each group are summarized in Table 2.

Table 2 The characteristics of the groups

	CRPCS ($n = 34$)	ORPLP ($n = 31$)	p
Age[a]	41 (18–60)	44 (18–60)	0.347
Sex[c]			
Female	18	14	0.705
Male	16	17	
Dominant extremity injury[c]	15	14	1.000
Time from injury to surgery (days)[b]	0.9 (0–6)	1.1 (0–6)	0.104
Operative time (min)[a]	53 (40–80)	77.7 (60–90)	**0.001****
Follow–up (months)[b]	29.2 (12–65)	35 (12–90)	0.606

The values are given as the mean and ranges. Significant value is denoted in bold

** $p < 0.01$

[a] Student t test

[b] Mann–Whitney U test

[c] Yates Continuity Correction

Clinical outcomes

Two-month follow-up data are available for 27 of 31 patients in ORPLP group and all patients in CRPCS group. There were no significant differences between the groups with respect to grip strength or range of motion, except pronation and supination; they were better in the CRPCS group ($p = 0.005$ and 0.025, respectively). Final follow-up data are available for all patients in both groups. The range of motion, grip strength, Gartland–Werley and QuickDASH scores obtained at final follow-up were similar for each group and lacked statistical significance. Range of motion, grip strength values, objective and subjective scores are showed in Table 3.

Return to independent function

Patients stated that they were able to return to their preinjury activity level at an average of 2.5 (range 1.5–5) months in the CRPCS group and 2.2 (range 1–4) months in the ORPLP group postoperatively. There was no significant differences between the groups ($p = 0.129$). Cast was removed with an average 2.7 (range 2–3) weeks in the CRPCS group and 1.7 (range 1–3) weeks in the ORPLP group. Althuogh, ORPLP group has significantly shorter cast removal time ($p = 0.001$), it was no longer than 3 weeks in both groups.

Table 3 Clinical outcomes at 2-months and the final follow-up

Clinical outcome	CRPCS	ORPLP	*p*
Two-month follow-up	$n = 34$	$n = 27$	
Flexion (°)[a]	51 (20–80)	53 (30–70)	0.643
Extension (°)[a]	50 (20–80)	49 (20–70)	0.779
Pronation (°)[a]	66 (30–90)	58 (40–70)	**0.005***
Supination (°)[a]	59 (50–80)	51 (30–70)	**0.025***
Ulnar deviation (°)[a]	17 (0–30)	18 (10–30)	0.598
Radial deviation (°)[b]	6 (0–15)	6.1 (0–15)	0.634
Grip strength (kg)[b]	9 (2–30)	8 (0–20)	0.750
Final follow-up	$n = 34$	$n = 31$	
Flexion (°)[a]	70 (50–90)	68 (45–80)	0.573
Extension (°)[a]	67 (50–80)	69 (45–90)	0.612
Pronation (°)[a]	72 (50–90)	72 (50–90)	0.069
Supination (°)[a]	69 (50–85)	69 (30–90)	0.935
Ulnar deviation (°)[a]	26 (15–40)	27 (15–35)	0.461
Radial deviation (°)[a]	14 (0–20)	15 (5–20)	0.222
Grip strength (kg)[a]	20 (5–45)	19 (5–40)	0.717
Gartland–Werley score[b]	1.4 (0–5)	1.3 (0–6)	1.00
QuickDASH score[b]	3.8 (0–16)	3.2 (0–15)	0.960

The values are given as the mean and ranges. Significant values are denoted in bold

* $p < 0.05$

[a] Student *t* test

[b] Mann–Whitney *U* test

Radiologic outcomes

In the CRPCS group, the mean loss in palmar tilt, radial height, radial inclination and the change in ulnar variance were smaller, but these differences reached significance ($p = 0.032$; 0.004; 0.024 and 0.001, respectively). In the ORPLP group, the mean loss in palmar tilt ($p = 0.001$), radial height ($p = 0.001$), radial inclination ($p = 0.001$) and the change in ulnar variance ($p = 0.004$) were smaller, but reached significance between the early postoperative and final follow-up measurements. Group comparison for the deterioration of radiologic parameters showed no significant difference. Values were close to anatomic parameters and the alignment was maintained at the final follow-up in both groups. Radiographic measurements are presented in Tables 4 and 5.

Complications

Tendon irritation was detected in one patient in each group. In the CRPCS group, one patient presented with first dorsal compartment irritation caused by a prominent screw. In the ORPLP group, flexor carpi radialis tendon was irritated by the plate. Implants were removed at an average 9 (range 6–12) months postsurgery. All patients reported total improvement in their symptoms after removal. There were no cases of infection or nerve irritation in both groups.

Table 4 Radiographic measurements in the early postoperative period and at the final follow-up

Radiographic outcomes	Early postoperative	Final follow-up	*p*
CRPCS ($n = 34$)			
Palmar tilt (°)	+4.2 (−10, +15)	+3.4 (−10, +30)	**0.032***
Radial height (mm)	11.8 (9.15)	11.4 (8.15)	**0.004****
Radial inclination (°)	20.9 (16.25)	20.5 (15.25)	**0.024***
Ulnar variance (mm)	+0.2 (−4, +4)	+1 (−3, +7)	**0.001****
ORPLP ($n = 31$)			
Palmar tilt (°)	+6.7 (0, +15)	+4.9 (−7, +11)	**0.001****
Radial height (mm)	11.7 (6.15)	11.2 (6.15)	**0.001****
Radial inclination (°)	21.2 (12.28)	20.6 (12.28)	**0.001****
Ulnar variance (mm)	−0.2 (−7, +3)	+0.4 (−5, +3)	**0.004****

The values are given as the mean and ranges. Significant values are denoted in bold

mm millimeter

Paired samples test: * $p < 0.05$; ** $p < 0.01$

Discussion

The options for the skeletal fixation after an acute extra-articular distal radius fracture include, percutaneous pinning, external fixation, internal fixation or any combination of these. Among them, closed reduction with percutaneous pin fixation has been the most common treatment method [22]. However, specific limitations and complications have decreased its popularity. Lack of rigidity, need for restrictive immobilization and skin irritation may limit the success of the postoperative rehabilitation period. Pin migration, pin breakage, pin track infection, fracture malunion, and nerve injury are common complications and may develop with reported rates as high as 44 % [3, 4]. These are possible reasons why surgeons have shifted from percutaneous fixation to plate fixation. Today, many surgeons believe that ORPLP fixation provides a more stable fixation and allows earlier and comfortable motion than percutaneous fixation [5].

Reported good results may also contribute to this dramatic shift [23]. Recent meta-analysis has suggested that there is some evidence supporting the use of open reduction and internal fixation for unstable distal radius fractures [24–26]. In different clinical studies, functional outcomes

Table 5 The mean loss of palmar tilt, radial height, radial inclination and change in ulnar variance between the early postoperative period and the final follow-up

	CRPCS ($n = 34$)	ORPLP ($n = 31$)	p
Palmar tilt (°)	1.7 (0–15)	1.7 (0–7)	0.175
Radial height (mm)	0.4 (0–3)	0.4 (0–2)	0.403
Radial inclination (°)	0.4 (0–5)	0.5 (0–2)	0.156
Ulnar variance (mm)	0.8 (0–4)	0.7 (0–3)	0.787

The values are given as the mean and ranges. The mean change was calculated for each patient, and the mean of these individual changes was then calculated

mm millimeter

Mann–Whitney *U* test

of patients, who had been managed with open reduction and palmar plate fixation were compared. McFadyen et al. [27] specifically focused on the extra-articular distal radial fractures and reported superior functional and radiological outcomes at 2 and 6 months postinjury in injuries treated within locked plate fixation when comparing with percutaneous pinning. Others [28–30] have reported better outcomes in association with ORPLP fixation in comparison with external or percutaneous fixation particularly in the early postoperative period which is critical for patients demanding a faster return to function after the injury.

Despite the positive results of palmar locking plating, the optimal treatment of extra-articular distal radius fractures remains without a consensus of opinion [31]. Downing and Karantana [32] reported that there was no clear statement as to which fractures would benefit from ORPLP fixation. Herein, CRPCS fixation may be a good option for simple extra-articular distal radius fractures. The present study demonstrated similar range of motion and grip strength at the 2-month follow-up and CRPCS fixation was found to be as successful as ORPLP fixation in the early postoperative period. Moreover, forearm rotation was found better in the CRPCS group. A possible explanation could be the detachment of pronator quadratus in open surgery can cause muscle contracture and may restrict forearm rotation in ORPLP group in the early postoperative period. The cannulated screw fixation appears to provide effective fixation in the early postoperative period and allows early range of motion. At the final follow-up, objective and subjective parameters were equivalent with improved outcomes indicated in the in vivo stability of the cannulated screw fixation in simple extra-articular fractures.

Patient's demand to an early return to independent function and preinjury activity level is an increasingly important determinant of the overall success rate in the treatment of distal radius fractures. From a patient's perspective, an early return to independent function may be the most important effect of internal fixation of these fractures [20]. The present study suggests that ORPLP fixation provides no advantage over CRPCS fixation in terms of early return to preinjury activity level. Our data demonstrate less restrictive immobilization time among patients managed with ORPLP fixation. However, we can infer that, cannulated screw fixation provided early independent function with a meaningful reduction of restrictive immobilization time. Studies have shown that, for patients treated with percutaneous pin fixation, average cast removal time was 3–4 weeks and pin removal time was 6–8 weeks [27–30, 33, 34]. In comparison with the percutaneous pin fixation, cannulated screw fixation demonstrates less restriction in the early postoperative period. Absence of the skin irritation caused by the pins and stability provided by the cannulated screws can be considered as possible reasons. Comparative studies focused on the extra-articular and simple intra-articular distal radius fractures reported the outcomes of patients who had been managed with percutaneous pin fixation. Rozental et al. [30] reported that average flexion was 26° and extension was 16° at 6 weeks postoperatively. McFadyen et al. [27] reported 28 % complication rate in the pin fixation group including pin-site infections, painful migrated pins and loss of fracture reduction. The current study suggested that CRPCS fixation achieves a superior outcome in comparison with the percutaneous pin fixation without the pin-specific complications in the early postoperative period. Biomechanical studies have demonstrated that palmar locking plates provide superior stiffness and axial loading strength than percutaneous techniques [35, 36]. As a result, the ability of palmar locking plates to maintain fracture reduction has previously been demonstrated in clinical studies [7, 23, 37]. Despite our early motion protocol, radiographic distal radial alignment was maintained at the final follow-up and a smaller, but similar deterioration with time in fracture position was seen in both groups. It seems that, fixation of unstable simple extra-articular distal radius fractures with the cannulated screws provide sufficient stability as the palmar locking plates with a minimal loss of reduction.

The palmar locking plating is not free from complications. Besides the risks of significant soft tissue dissection, studies of distal radial fractures that were treated with ORPLP demonstrated a complication rate of 27 %, including the damage to both the flexor and extensor tendons and the median nerve [6, 28, 38, 39]. In the present study, similar complications were seen in both groups. They were minor tendon irritations in one patient in each group and were resolved with implant removal. The lower complication rate in this study may be the result of the strict inclusion/exclusion criteria as well as the increasing familiarity with these techniques. Also, a relatively small number of patients in this study may be responsible for the lower

complication rate but, despite this, we have come to the conclusion that it still reflects the safety and reliability of cannulated screw fixation in the operative management of simple extra-articular distal radius fractures.

Shyamalan et al. [8] reported that the applying a palmar locking plate took 216 % longer time than percutaneous fixation. The present study showed a similar result with an average 24 min shorter operation time in the CRPCS group. Our study suggests that CRPCS fixation provides an advantage over ORPLP fixation in a significantly reduced operative time.

The present study had several limitations. In an effort to homogenize the study cohort, we included a defined age group of patients with similar type of distal radius fracture treated with specific fixation methods. The strict inclusion/exclusion criteria reduced the number of patients and the power of the study. Evaluation was performed by an investigator, who was not involved in treatment plan. However, the presence of surgical scars may introduce bias. Prospective data were gathered at a center with expertise in both techniques. Our assessment was conducted through a retrospective comparison and choice of procedure was not controlled. A blinded, randomized, prospective study would be necessary to better understand differences or similarities between both methods of treatment.

Despite these shortcomings, the present study suggests that ORPLP fixation provides no clear advantage over CRPCS fixation in the treatment of simple extra-articular distal radius fractures. Cannulated screw fixation provides shorter operative time and internal fixation without open surgery. It appears to be an effective means of allowing early range of motion of the wrist. This results in a rapid and comfortable functional recovery while maintaining alignment to bone healing similar to palmar plating (Fig. 1). It may be suitable in the case of young, active individuals with simple extra-articular distal radius fracture.

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Conflict of interest All the authors hereby declare that they have no conflicts of interest to disclose.

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