Long-Term Outcome and Secondary Operations after Proximal Row Carpectomy or Four-Corner Arthrodesis

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Abstract

Background Proximal row carpectomy (PRC) and four-corner arthrodesis (FCA) are common surgical procedures used to treat degenerative wrist conditions; however, complications and failures can occur.

Purpose This study aimed to investigate and compare the long-term rate of secondary surgeries including conversion to total wrist arthrodesis in patients who underwent PRC or FCA.

Materials and Methods A retrospective chart review of all patients who underwent PRC or FCA in the past 20 years at a tertiary referral institution and associated Veterans Affairs (VA) hospital was performed. Patient demographics, comorbidities, surgical indications, and associated complications were tabulated. Patients were contacted via phone to obtain additional follow-up information regarding any additional surgeries, 10-point visual analog scale (VAS) for pain, quick Disabilities of the Arm, Shoulder, and Hand (quickDASH) scores, hand dominance, and occupational data.

Results A total of 123 wrists made up the final dataset. Sixty-two wrists treated with PRC and 61 wrists treated with FCA were reviewed at a mean follow-up of 8.2 years. We did not find a significant difference in the rate of conversion to total wrist arthrodesis between the PRC (14.5%) and FCA (19.5%, $p = 0.51$) cohorts. Secondary operations were significantly greater in the FCA group (34.4%) compared with the PRC group (16.1%, $p = 0.02$). Females were 2.6 times more likely than males to undergo secondary operations when controlling for surgical procedure and smoking status ($p = 0.04$). We did not detect a significant difference in VAS pain or in quickDASH scores between the two groups ($p = 0.35, 0.48$, respectively).

Conclusion PRC and FCA have comparable patient reported outcomes and wrist arthrodesis conversion rates at a mean follow-up of 8.2 years. In contrast, the FCA patient group had a significantly higher rate of secondary operations, including those for nonunion, symptomatic hardware, and other implant-related issues, when combined with wrist arthrodesis conversion.

Level of Evidence Level IV, therapeutic study.

Keywords

- wrist
- arthritis
- proximal row carpectomy
- four-corner arthrodesis

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Both proximal row carpectomy (PRC) and four-corner arthrodesis (FCA) are motion-sparing surgical procedures commonly used to treat certain painful, degenerative wrist conditions. PRC, which dates to Stamm's description in 1944, converts the complex link joint of the wrist to a simple ball-and-socket joint.¹ FCA traditionally involves scaphoidectomy with fusion of the lunate, capitate, triquetrum, and hamate. These procedures have been commonly described in the treatment of scaphoid nonunion advanced collapse (SNAC) and scapholunate advance collapse (SLAC) patterns of arthritis, Kienbock's disease, and in chronic perilunate injuries.²⁻⁶

The choice of procedure between FCA and PRC is often influenced by several factors, including patient age, sex, and occupation, as well as evaluation of the cartilage on the proximal pole of the capitate.⁷ A relative contraindication to PRC is degenerative change of the cartilage surface of the proximal pole of the capitate (as in type 3 SNAC and SLAC wrists), and both procedures are typically avoided when there is degeneration of the cartilage in the lunate fossa of the distal radius.⁸

In many cases, however, both PRC and FCA remain surgical options based on carpal anatomy. In this scenario, controversy exists over which of these operations provide the best outcome for patients. Both procedures have shown acceptable results in short term in relatively small cohorts of patients.^{3,6,9-16} PRC is considered to be a technically simpler operation that avoids the risks of nonunion or symptomatic hardware associated with FCA and may lead to better wrist motion.^{15,17} FCA may offer greater grip strength and a lower predisposition to the development of radiocarpal arthritis when compared with PRC, although this benefit is unclear.^{11,13} Overall, the published differences between PRC and FCA outcomes with regard to wrist motion and grip strength appear small and of questionable clinical significance.^{15,18,19}

Despite overall good early results, there are a number of patients who undergo PRC or FCA and develop persistent pain or have other complications, which lead to an undesirable outcome. In the setting of a failed PRC or FCA, total wrist arthrodesis is a commonly accepted surgical salvage option.²⁰ Given the apparent relative equivalence of the clinical outcomes between PRC and FCA, the conversion rate to total wrist arthrodesis is arguably paramount when the choice between the two procedures is being made.

This study aimed to quantify and compare the long-term rate of conversion to total wrist arthrodesis for each of these operations. Secondly, this study quantified the associated complications and secondary operations associated with each of the operations, as well as patient reported outcomes including VAS pain and quickDASH scores. We hypothesize that PRC may have a greater conversion to total wrist arthrodesis while four-corner arthrodesis may have a higher rate of postoperative complications necessitating additional secondary operations.

Materials and Methods

This was a nonrandomized, retrospective cohort study. Following Institutional Review Board (IRB) approval, all patients treated with a PRC or FCA at a tertiary referral institution and associated Veteran Affairs (VA) hospital between January 1,

1995 and January 1, 2015 were identified from the medical record using Current Procedure Terminology (CPT) codes and considered eligible for the study. Medical records and radiographs were reviewed by the research team to confirm study eligibility. Eligible candidates (42 wrists in 40 patients at the VA, and 187 wrists in 182 patients at the University medical center) were identified through this process. Pediatric patients, vulnerable patient populations, deceased patients, and patients with less than 1-year follow-up were excluded from the study.

We attempted to contact all eligible patients by phone to obtain patient reported outcomes including a VAS for pain and the quickDASH scores.²¹ In addition, phone conversations and medical records were employed to gather information about the patient cohort including time of index procedure, employment status, handedness, and medical comorbidities. The incidence of perioperative complications and secondary operations were also compiled, and a review of the medical record including radiographs and operative reports was performed to classify the preoperative grade of SLAC or SNAC arthritis.

The primary outcome was conversion to total wrist arthrodesis after PRC or FCA. Median time to the primary outcome was calculated. Secondary outcomes included VAS, quickDASH scores, and any additional operations after the index procedure.

Based on a priori power analysis, we determined that the study would need 60 wrists in each group to adequately power the study to detect a 10% difference in conversion to wrist arthrodesis between the patient groups. The difference in both fusion and secondary operation rates between the cohorts was compared using a log-rank test. We compared patient characteristics (age, sex, labor activity, handedness) and comorbidities (smoking, diabetes, body mass index [BMI]) to index procedure failure rates using a Cox's proportional hazards model. Each predictor was compared separately (univariate models) and together (multivariate model). Kaplan-Meier survival plots were created for index procedure failure and secondary operation rates. Significance was evaluated at $p < 0.05$ level.

PRC and FCA were performed using methods previously described in published reports.²²⁻²⁵ Use and source of bone graft was dependent on surgeon preference, and fixation for FCA variably included Kirschner wires, headless compression screws, circular plates, and other FCA-specific plates. All FCA patients were placed in below elbow splint for 7 to 14 days with transition to cast or splint immobilization at that time for 6 to 8 weeks, with mobilization and activity restrictions modified based on surgeon preference. After initial postoperative splinting in a below elbow splint for 2 weeks, PRC patients were immobilized based on surgeon preference with either a below elbow cast or splint and instructed to avoid any weight bearing postoperatively for a minimum of 4 weeks.

Results

A total of 123 wrists (61 in the FCA group and 62 in the PRC group) in 116 patients were contacted and consented for inclusion in the study. Patient demographics and cohort characteristics are summarized in **Table 1**. Of the seven bilateral patients included in the study, four of these patients underwent

Table 1 Characteristics of patients in the study

Variables	PRC	FCA	p-Value
Study participants (n)	62	61	–
Follow-up, median, y; (IQR)	6.0 (2.4–9.6)	7.9 (2.2–11.4)	0.35 ^b
Age at surgery (y), mean (SD)	52 (13)	52 (13)	0.99 ^a
Sex, n (%)			0.01 ^b
Male	44 (71)	55 (90)	
Female	18 (29)	6 (10)	
Smoking status, n (%)			0.02 ^b
Yes	18 (29)	7 (11)	
Diabetes, n (%)			0.59 ^b
Yes	9 (15)	11 (18)	
BMI, mean (SD)	29.96 (7.7)	30.08 (6.6)	0.93 ^a
Dominant hand, n (%)	32 (52)	35 (57)	0.52 ^b
Manual labor preoperation			0.05 ^b
Yes	19 (31%)	29 (48%)	
No	43 (69%)	32 (52%)	
Surgical indication, n (%)			0.08 ^c
SLAC	37 (60)	39 (64)	
SNAC	12 (19)	16 (26)	
Perilunate	1 (2)	3 (5)	
Kienbock's	5 (8)	0 (0)	
Other	7 (11)	3 (5)	
SLAC/SNAC type, n (%)			<0.01 ^c
I	1 (3%)	0 (0%)	
II	33 (97)	15 (37)	
III	0 (0)	26 (63)	
QuickDASH score (at final follow-up)			
Mean (SD)	24.4 (18.9)	27.1 (23.2)	0.48 ^a
VAS pain (at final follow-up)			
Median (IQR)	1 (0–4)	1 (0–4)	0.35 ^d

Abbreviations: BMI, body mass index; FCA, four-corner arthrodesis; IQR, interquartile range; PRC, proximal row carpectomy; QuickDASH, quick Disabilities of the Arm, Shoulder, and Hand; SD, standard deviation; SLAC, scapholunate advance collapse; SNAC, scaphoid nonunion advanced collapse.

^aTwo sample *t*-test.

^bChi-square test.

^cFisher's exact test.

^dWilcoxon–Mann–Whitney test.

bilateral FCA, two patients underwent bilateral PRC, and one patient underwent both a PRC (nondominant wrist) and FCA (dominant wrist). Median follow-up was 6.0 years in the PRC

group and 7.9 years in the FCA group. The mean follow-up was longer for both groups at 8.7 years in the FCA group and 7.7 years in the PRC group and was a result of several outliers with very long-term follow-up within the study cohort.

At final follow-up, 9 wrists (14.5%) in the PRC group and 12 wrists (19.5%) in the FCA had undergone conversion to total wrist arthrodesis, a difference that was not statistically significant ($p = 0.51$). Mean time to wrist arthrodesis was 27 months (range: 4–81 months) in the PRC group and 36 months (range: 2–126 months) in the FCA group. Kaplan–Meier survival curves comparing PRC and FCA wrist arthrodesis conversion rates are shown in ►Fig. 1. In addition, 2-, 5-, and 10-year survival rates with respect to the primary outcome of conversion to wrist arthrodesis for PRC and FCA are shown in ►Table 2. Two patients in the PRC group and two patients in the FCA group underwent wrist arthrodesis beyond 30 months postoperatively.

Excluding total wrist arthrodesis procedures, one wrist (1.6%) in the PRC group underwent a secondary operation for scar revision and tenolysis at 4 months postoperatively. In the FCA group, nine wrists (14.8%) underwent other secondary surgeries (excluding wrist arthrodesis) at an average of 16.6 months postoperatively. Of these secondary operations, three were for nonunion, four for symptomatic hardware with impingement, one for ulnar impaction, and one for pin site infection. Excluding wrist arthrodesis, one patient in the FCA cohort (63 months for removal of hardware) and no patient in the PRC cohort underwent a secondary operation beyond 30 months.

When comparing all secondary operations including wrist arthrodesis, there was a significantly higher rate of secondary operations in the FCA group when compared with the PRC group ($p = 0.02$). Kaplan–Meier survival curves for secondary operations after PRC and FCA, including conversion to total wrist arthrodesis, are displayed in ►Fig. 2. Survival rates for PRC and FCA at the 2, 5, and 10-year timeline are presented in ►Table 3.

Surgery type was significantly associated with an increased rate of reoperation even after controlling for sex and smoking status, as Cox's proportional hazard regression demonstrated a hazard ratio of 3.46 for FCA when compared with PRC ($p = 0.003$). After controlling for surgery type and smoking status, female patients were significantly more likely to undergo secondary operation with a hazard ratio of 2.61 ($p = 0.04$) than males. Smoking status did not show a statistically significant difference in the hazard ratio for risk of secondary operation when controlling for sex or surgery type ($p = 0.08$).

There was no statistically significant difference detected in either the VAS pain score or the quickDASH scores between the two groups at final follow-up (►Table 1). Thirty patients (48.4%) in the PRC group and 27 patients (44.3%) in the FCA group reported a pain score of 0.

Discussion

The management of the degenerative wrist presents persistent clinical challenges. While effective in relieving pain,

Fig. 1 Kaplan-Meier survival curves for conversion to wrist arthrodesis. FCA, four-corner arthrodesis; PRC, proximal row carpectomy.

total wrist arthrodesis has been shown to impact long-term upper extremity function as well as general measures of health.²⁶ In a small study of 22 wrist arthrodesis patients, 20 of these patients, when given the option, would have preferred a motion-sparing procedure.²⁶ While various alternative procedures such as total wrist arthroplasty and denervation procedures are options in the surgical management of the degenerative wrist, the mainstay of motion-sparing surgical treatment remains either PRC or intercarpal fusion such as FCA.

Multiple prior comparisons between PRC and FCA have been published. A recent systematic review concluded that short-term patient reported outcomes were not significantly different between PRC and FCA with regard to both pain and function.¹³ Similarly, patient satisfaction scores did not appear to be significantly different between the two surgeries.⁶ Other meaningful differences between the two procedures have been identified. For example, FCA carries with it the risks associated with attempted limited arthrodesis, most notably nonunion, symptomatic hardware, infection, and a more prolonged postoperative immobilization.¹⁵ Nonunion has been reported to range from 3 to 10% in most studies, although there have been other studies with higher nonunion rates, up to 63%.^{3,11–13,16,27,28} PRC has been reported to lead to higher rates of osteoarthritis progression radiographically, though most patients with progression may be asymptomatic.¹³

Table 2 Survival rates for each procedure for avoiding wrist arthrodesis

Follow-Up	PRC	FCA
	Survival (95% CI)	Survival (95% CI)
2 y	92% (85–98)	85% (76–94)
5 y	86% (76–95)	83% (74–93)
10 y	83% (72–93)	80% (69–91)

Abbreviations: CI, confidence interval; FCA, four-corner arthrodesis; PRC, proximal row carpectomy.

Based on the published literature to date, it therefore appears that both PRC and FCA lead to similar acceptable short-term functional outcomes, such as range of motion, strength, and pain relief. Given this, there are several studies that have focused on the rate of conversion of FCA and/or PRC to total wrist arthrodesis. In a cohort of 47 patients, Dacho et al reported a total wrist arthrodesis conversion rate of 12% after PRC and 3.3% after FCA with stage 2 SLAC or SNAC wrists and a mean follow-up of 27 to 42 months.¹¹ Krakauer showed failure rates of 8.7 and 17% for PRC and FCA, respectively, in a cohort of 51 patients with a 50-month mean follow-up.⁵ In a smaller but long-term study of 22 wrists with a 17-year follow-up, Berkhout et al showed that 7 and 27% of PRC and FCA patients, respectively, underwent wrist arthrodesis.¹⁵ In a systematic review by Mulford et al, the authors reported that 3.9 and 2.9% of PRC and FCA patients underwent total wrist arthrodesis, a finding that was not statistically significant.¹³

This study describes the clinical outcomes of PRC and FCA in a cohort of 122 patients at a mean follow-up of 8.2 years, with particular focus on the rate of conversion to wrist arthrodesis. The main finding of this study was that no significant difference in wrist arthrodesis conversion rate between the PRC cohort (14.5%) and the FCA cohort (19.5%) was detected ($p = 0.51$). Consistent with previous investigation, this study did not demonstrate significant differences between the two surgeries with regard to VAS pain scores or quickDASH scores, but did demonstrate a statistically significant increase in the rate of secondary surgeries in the FCA cohort compared with the PRC cohort ($p = 0.02$).

We were somewhat surprised to find that only two patients both in the PRC and FCA groups underwent fusion beyond 30 months postoperatively. Similarly, secondary operations showed a similar temporal pattern, with one patient in the FCA cohort (63 months for removal of hardware) and none in the PRC cohort undergoing an operation beyond 30 months. It appears that once patients' wrists survive the initial 30 months postoperatively, their chance of conversion to wrist arthrodesis and/or secondary surgery diminishes, at

Fig. 2 Kaplan-Meier survival curves for any additional secondary operations. FCA, four-corner arthrodesis; PRC, proximal row carpectomy.

least temporarily. In addition, female sex appeared to be an independent risk factor for secondary operation in the pooled cohort analysis, but the reasons for this finding are unclear.

Limitations of this study are several, and include most notably the differences between the two patient cohorts. There was a statistically significant difference between our patient cohorts with regard to both sex and smoking status, with males and nonsmokers more likely to have received a FCA. This is likely to be a result of surgeon bias given the perceived association of smoking with nonunion, as well as prior studies and traditions promoting FCA for its potentially increased grip strength, particularly in male manual laborers.^{11,29} Cohort matching is an inherent problem in retrospective studies of FCA and PRC, as the noted biases are prevalent in this and prior investigations, and are difficult to overcome.

Similarly, the choice between PRC and FCA is not, at times, available due to the status of the carpal anatomy and in particular the status of the cartilage on the proximal pole of the capitate or the integrity of the lunate. This is a limitation that has been well recognized and is also present in majority of prior investigations comparing the two procedures.^{5,13,15} In this study, 63% of patients who received a FCA for SLAC or SNAC arthritis were not candidates for PRC based on the

presence of capitate arthrosis (SLAC or SNAC type 3), biasing FCA patient selection. It is possible that patients who are not candidates for PRC (and therefore receive a FCA) exhibit characteristics that influence the secondary operation rates we report here. Despite these limitations, we feel that this study is consistent with majority of the prior published literature comparing PRC to FCA, and a large cohort adds to our understanding of failure rates of these procedures and secondary surgeries in long-term follow-up.

In addition, of the 237 wrists eligible for study, we were only able to include 123 wrists in the study leading to potential reporting bias. The heterogeneous nature of the patient population studied, the different wrist conditions for which surgeries were performed, and the variety of surgical techniques and postoperative protocols employed also introduce variability into this study.

In conclusion, this study demonstrates that both PRC and FCA are viable options in the surgical treatment of selected degenerative wrist conditions, providing comparable patient reported outcomes and similar rates of conversion to wrist arthrodesis in long-term follow-up. For patients undergoing FCA, preoperative counseling regarding the significantly higher rate of secondary operations is likely appropriate. Due to the significantly higher rate of reoperation and the otherwise relatively equivalent clinical outcomes, we prefer to perform PRC for appropriately selected patients. Further prospective or retrospective study with matched cohorts would possibly aid our understanding of the optimal selection of surgical procedure for patients with painful degenerative wrist conditions.

Note

This study protocol was approved by our institution's IRB.

Conflict of Interest

None.

Table 3 Survival rates for each procedure for avoiding any secondary operation

Follow-Up	PRC	FCA
	Survival (95% CI)	Survival (95% CI)
2 y	90% (83–98)	72% (61–83)
5 y	84% (74–94)	70% (59–82)
10 y	81% (70–92)	64% (51–78)

Abbreviations: CI, confidence interval; FCA, four-corner arthrodesis; PRC, proximal row carpectomy.

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