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Original article

Long-term outcomes of proximal row carpectomy: A series of 62 cases

Devenir à long terme de la résection de la rangée proximale du carpe. À propos d'une série de 62 cas

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ABSTRACT

The aim of this study was to determine and analyze the functional and radiographic outcomes after proximal row carpectomy (PRC). We hypothesized that this surgery could restore wrist mobility and function in case of radiocarpal osteoarthritis or severe carpal trauma. Sixty-two patients who had undergone PRC were included in this study: 44 patients with wrist osteoarthritis (11 SNAC, 24 SLAC, 3 Kienböck's disease, 6 other) and 18 patients with severe carpal trauma. Each patient underwent clinical (pain, range of motion, grip strength, functional scores) and radiographic evaluations. At the latest evaluation after a mean of 11.8 years, 15 patients (24.2%) required revision total wrist arthrodesis surgery in a median of 2 months (range, 6–179) because of disabling pain and lack of strength. The failure was statistically correlated with being young and a manual laborer. The range of motion and strength of the operated wrist were 61.5% and 70%, respectively, compared to the contralateral side. PRC remains a reliable procedure for treating wrist arthritis and severe carpal trauma. However, manual activity and being under 50 years of age can lead to an early salvage procedure such as total arthrodesis of the wrist. In this subset of the population, another alternative must be considered.

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Mots clés :
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RÉSUMÉ

L'objectif de ce travail était d'analyser les résultats cliniques, fonctionnels et radiographiques après résection de la rangée proximale du carpe (RRPC) avec un recul minimum de 5 ans. Notre hypothèse était que cette intervention chirurgicale dans le cadre d'une arthrose radio-carpienne ou d'un traumatisme grave du carpe pouvait rendre un poignet mobile et fonctionnel de façon pérenne. Il s'agissait d'une série rétrospective multi-opérateur de 62 patients. Quarante-quatre patients présentaient une arthrose radio-carpienne (11 SNAC, 24 SLAC, 3 maladies de Kienböck, 6 autres) et, pour 18 cas, la RRPC était effectuée dans le cadre d'un traumatisme sévère du poignet sans traitement conservateur possible. Une évaluation clinique et radiographique a été réalisée pour chaque patient. Avec un recul moyen de 11,8 ans, 15 patients (24,2 %) ont nécessité une reprise chirurgicale par arthrodèse totale du poignet dans un délai médian de 22 mois (6 à 179) consécutive à des douleurs invalidantes et un manque de force. Cette reprise chirurgicale était statistiquement corrélée au statut de travailleur manuel et au jeune âge du patient. Les mobilités du poignet et la force de poigne étaient mesurées à 61,5 % et 70 %, respectivement, par rapport au côté opposé. Dans le traitement de l'arthrose du poignet et des traumatismes graves du carpe, la RRPC reste une procédure fiable. Cependant, une activité manuelle et un âge inférieur à 50 ans peuvent conduire à une reprise précoce par arthrodèse totale du poignet. Il est nécessaire dans cette population d'envisager une autre alternative.

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1. Introduction

Post-traumatic osteoarthritis of the wrist is rare, with 5% prevalence in the general population [1]. It is asymptomatic for a long time before decompensating and causing major functional disability. Treatment is first and foremost medical, and surgery should only be considered after failure of conservative treatment. The surgical methods used today are controversial and consensus has not been achieved [2]. The therapeutic armamentarium includes total wrist denervation, proximal row carpectomy (PRC), total or partial arthrodesis, interposition implants, and more recently, arthroplasty.

The aim of this study was to determine and analyze the long-term results of PRC at a minimum of 5 years after surgery. We hypothesized that in patients with radiocarpal osteoarthritis or severe carpal trauma, PRC can restore the wrist's range of motion and function. This study could validate this therapeutic option, which continues to be debated because of the appearance of arthritis between the capitate and the radius, particularly in young subjects and manual workers [3].

2. Patients and methods

2.1. Population

This was a retrospective, continuous, single-center, and multisurgeon study on patients operated between June 1994 and April 2009 (Table 1). We performed 62 PRC procedures on 14 females and 48 males who had a mean age of 46.5 ± 13 years (range, 22–73 years); there were 39 right wrists and 23 left wrists. Forty-one patients (66%) were operated on their dominant side. Thirty-eight patients had a manual occupation. Twenty-four patients took part in sports with significant radiocarpal loading (e.g., mountain biking). In 19 cases (31%), the operation was performed secondary to a work-related accident or an occupational disease.

2.2. Surgical indication

In this study, PRC was indicated for radiocarpal arthritis (44 cases) or perilunar dislocation of the carpus (18 cases) (Table 1). Arthritis was secondary to scaphoid nonunion advanced collapse (SNAC) in 11 cases, scapholunate advanced collapse (SLAC) in 24 cases, Kienböck's disease in 3 cases, fracture of the distal radius in 4 cases, and inflammatory disease in 2 cases. The main reason for consultation was pain. Preoperatively, using Watson's radiological classification [1], which could be applied to 35 of the 62 cases, we found 2 cases at stage 1, 24 at stage 2, and 9 at stage 3 (Fig. 1). Other than the trauma cases, the indication for PRC was retained for degenerative wrist that was painful, stiff, with loss of strength, and radiocarpal and/or intracarpal arthritis. When arthritis of the lunate fossa of the radius or capitolunate osteoarthritis demonstrated, we performed the procedure described by Salomon and Eaton (41 cases) (Fig. 2) [4].

2.3. Surgical technique and treatment protocol

The proximal row was exposed through a longitudinal or transversal dorsal cutaneous approach, followed by opening of the fourth extensor compartment, and then quadrangular capsulotomy preserving a distal hinge. The posterior interosseous nerve was resected in 36 cases (58%) to relieve pain. When cartilage lesions were present in the lunate fossa of the radius and the capitate head, we also performed the Eaton technique (41 cases) with interposition of a capsular flap attached to the anterior capsule (30 cases) or associated with partial capitate resection (11 cases) (Fig. 2) [4]. Styloidectomy of the radius was performed in 10 cases. In the 21 cases for which the Eaton procedure was not performed, the capsule was closed very loosely so as not to compromise range of motion in flexion. After skin closure and bandaging, the wrist was immobilized in a cast, except for five patients who received intermittent immobilization with an orthosis so that functional rehabilitation could begin immediately. The cast was left in place for 27.5 ± 11.4 days (range, 7–45 days). The mean hospital stay was 1.9 ± 2.2 days (range, 0–11 days). Four patients underwent outpatient surgery.

Functional rehabilitation with a physical therapist began systematically on the 1st postoperative day with active and passive mobilization of the fingers, and then of the wrist, as soon as possible. Rehabilitation lasted a mean of 7.3 ± 5.2 months (range, 0–24 months) with a minimum of two sessions per week.

2.4. Evaluation

The patients underwent clinical and radiographic assessments. To avoid bias, the clinical examination was conducted by a clinician who was not involved in the surgery and the X-rays were read by two specialists. The patients were either seen in-person (48 cases) by an independent examiner (CBB) or they filled out a questionnaire and sent in their X-rays (14 cases). At the last follow-up, various clinical parameters were collected (Table 2) to better define the population. Comparative range of motion of the two wrists was measured in degrees with a goniometer. Grip and pinch strength were measured with a Jamar digital hand dynamometer. The functional results were assessed using the Patient-Rated Wrist Evaluation (PRWE) score [5], the QuickDASH score [6], and the Mayo Wrist score [7] (Table 2). Satisfaction was assessed on a scale of 1 to 4 (dissatisfied, disappointed, satisfied, very satisfied) and pain was evaluated using a visual analog scale (VAS 0–10).

The radiological results were assessed using X-rays of the wrist (AP and lateral) to describe the stage of radiocapitate arthritis of the new joint using the Culp and Jebson classification [8,9] (Fig. 1). A subgroup analysis was performed for the Eaton technique cases, cases with more or less than 10 years of follow-up, and cases with perilunar dislocations of the carpus.

Failure of the PRC procedure was defined as surgical revision with total arthrodesis of the wrist; these patients were not seen clinically for this study. We evaluated the impact of loss of strength, stiffness, and pain on the wrist's function relative to the follow-up duration.

2.5. Statistical methods

In this study, descriptive statistical tools were used for the initial analyses. The quantitative parameters were evaluated for

Table 1
Preoperative demographic data.

		Gender		Side				Surgical indication				
Patients	Age (years)	Female	Male	Right	Left	Dominant side affected	Manual laborer	SNAC	SLAC	Kienböck	Injury	Other
$n = 62$	46.5 ± 13 (22–73)	14	48	39	23	43 66%	38 61%	11	24	3	22	2

SLAC: scapholunate advanced collapse; SNAC: scaphoid nonunion advanced collapse.

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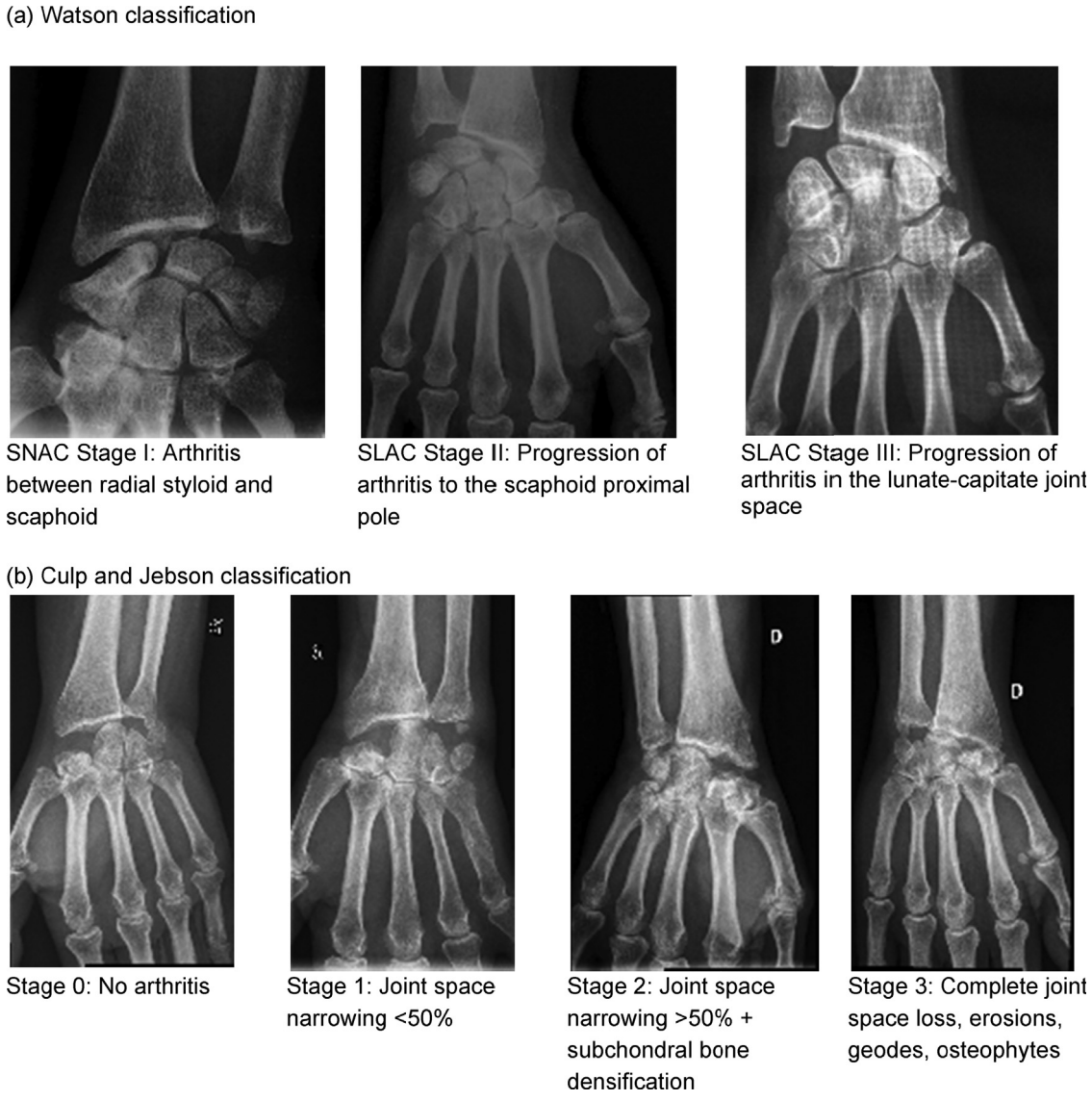

Fig. 1. Radiological classification of preoperative arthritis according to Watson [1] (a) and postoperative arthritis according to Culp et al. [9] and Jebson et al. [10] (b).

normal distribution using the Shapiro-Wilk test. When these parameters were normally distributed, they were described by the mean and standard deviation. Otherwise, they were described by the median and the 25th and 75th percentiles. The qualitative parameters were expressed as counts and percentages. The correlations were evaluated with the Pearson correlation coefficient. Student's *t*-test was used to compare means. The nonparametric Mann-Whitney U test was used when the conditions needed to apply Student's *t*-test were not present. An ANOVA test was used to show the absence of a difference between two parameters. The nonparametric Kruskal-Wallis test was used when the conditions required for the ANOVA were not present. Significance was set at $P < 0.05$. This analysis was done with R software (version 3.1.0).

3. Results

The study included 62 patients who had undergone PRC. Forty-eight patients were examined in-person and 14 of the 15 total arthrodesis patients were contacted by telephone by the independent examiner; they had a mean follow-up of 142.6 ± 55.2 months (range, 69–249.6 months).

3.1. Outcomes

Fifteen patients (24.2%) required surgical revision with total arthrodesis of the wrist within a median 22 months (range, 6–179 months) due to debilitating pain and lack of strength. Of these 15 failures, 12 had undergone an Eaton procedure (Fig. 3). None of these patients was able to return to work after PRC. These 15 patients were significantly younger than the 47 others ($P < 0.05$) with a mean age of 41.6 ± 11.4 years (range, 27–65 years) versus 47.9 ± 13.2 years (range, 22–73 years). Moreover, 86% (13/15) of these patients were manual workers versus 53% (25/47) for those who did not undergo arthrodesis ($P = 0.049$). Half the patients under 40 years of age underwent revision with total arthrodesis, whether or not they were manual workers. All the patients except three who underwent revision were less than 50 years old.

3.2. Complications of proximal row carpectomy

Nine complications were found. Six patients had type 2 complex regional pain syndrome and three patients had a surgical site infection. These infections occurred in high-risk patients (one case

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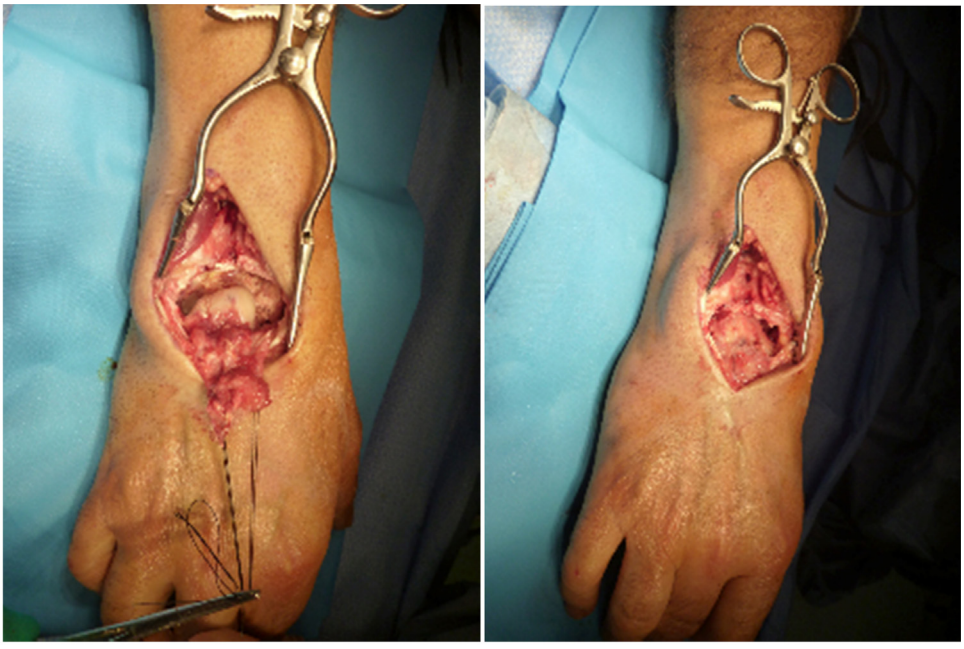

Fig. 2. Capsular interposition according to the Eaton technique (capsular interposition arthroplasty). Before capsular interposition arthroplasty (a): proximal row carpectomy performed, distal hinge capsular flap on pull-through sutures. After capsular interposition arthroplasty (b): re-draping of capsular flap on the capitate head attached to the anterior capsule.

of rheumatoid arthritis and two cases of open, infected perilunar dislocation of the carpus).

3.3. Analysis of the 47 patients who did not require total arthrodesis of the wrist

3.3.1. Pain, strength, and range of motion

At the last follow-up, the VAS pain score was 0.8 ± 1.6 (range, 0–7) (Table 3). Range of motion in flexion–extension was 75° ± 17.8 (range, 25–105°) on the operated side and 116.3° ± 20.6 (range, 65–160°) on the healthy side ($P < 0.05$). Range of motion in radial–ulnar deviation was 34.1° ± 11.1 (range, 10–55°) on the operated side and 61° ± 16.5 (range, 20–90°) on the healthy side ($P < 0.05$). Grip strength was 24.3 kg ± 11.6 (range, 4–52 kg) on the operated side and 34.5 kg ± 11.5 (range, 12–64 kg) on the healthy side ($P < 0.05$). The wrist with the PRC had 61.5% of the range of motion and 70% of the strength of the opposite healthy side.

3.3.2. Subjective functional assessment

The mean value of the PRWE score was 23.5 ± 1.9 (range, 0–83) (Fig. 4). The mean value of the QuickDASH score was 26 ± 26.6 (range, 0–75) (Fig. 4). The mean Mayo Wrist score was 66.6 ± 18.1 (range, 15–100) (Table 2). The PRWE and QuickDASH scores were correlated with pain (Pearson = 0.7 [0.54; 0.81] and $P = 0$). The PRWE and QuickDASH scores were weakly correlated with strength (Pearson = 0.34 [0.05; 0.57] and $P = 0.02$). The PRWE and QuickDASH scores were not correlated with wrist range of motion (Pearson = 0.25 [−0.07; 0.52] and $P = 0.13$).

Twenty-five patients were very satisfied 17 were satisfied; three patients were disappointed and two were dissatisfied. Seven patients needed to wear an elastic wrist band daily. Sixteen patients reported occasional level I analgesic use and seven of them also took a level II analgesic.

The mean sick leave duration was 8.1 ± 7.5 months (range, 2–36 months). At the end of the sick leave, 21 patients were able to resume their occupation with the same job, six had their workstation adapted, three patients had to take on a new position with the company, and six patients could not return to work and were put on disability. Heavy-manual workers returned to work significantly later (11 months) than non-manual or light-manual workers (6 months) ($P < 0.05$).

Table 2
Functional scores.

	PRWE score	QuickDASH score	Mayo Wrist score
Information considered	Pain Function	Pain Function	Pain Function Range of motion Strength
Values	0–100	0–100	0–100
Interpretation	Best score 0	Best score 0	100–90 Excellent 90–80 Good 80–60 Satisfactory < 60 Poor
References	Voche [4]	Hudak [5]	Amadio [6]

PRWE: Patient-Rated Wrist Evaluation.

3.3.3. Radiographic assessment

Forty X-rays were available at the last follow-up and were assessed using the Culp and Jebson classification [8,9] (Fig. 2). Eight patients had no arthritis, 6 patients had stage 1 (< 50% joint space narrowing), 14 patients had stage 2 (> 50% joint space narrowing, sclerosis), and 12 patients had stage 3 (geodes, complete joint space loss, erosions, osteophytes). We found no significant difference in the PRWE or QuickDASH scores between the different stages on the Culp and Jebson classification. There was no significant correlation between the clinical result and the degenerative progression of the new joint.

The Eaton procedure was not protective or harmful relative to deterioration of the radio-capital joint space at follow-up. This remained true after adjusting for age, manual work, and etiology.

The morphology of the radiocapitate joint was altered over time. In the sagittal plane, we observed deepening in the lunate

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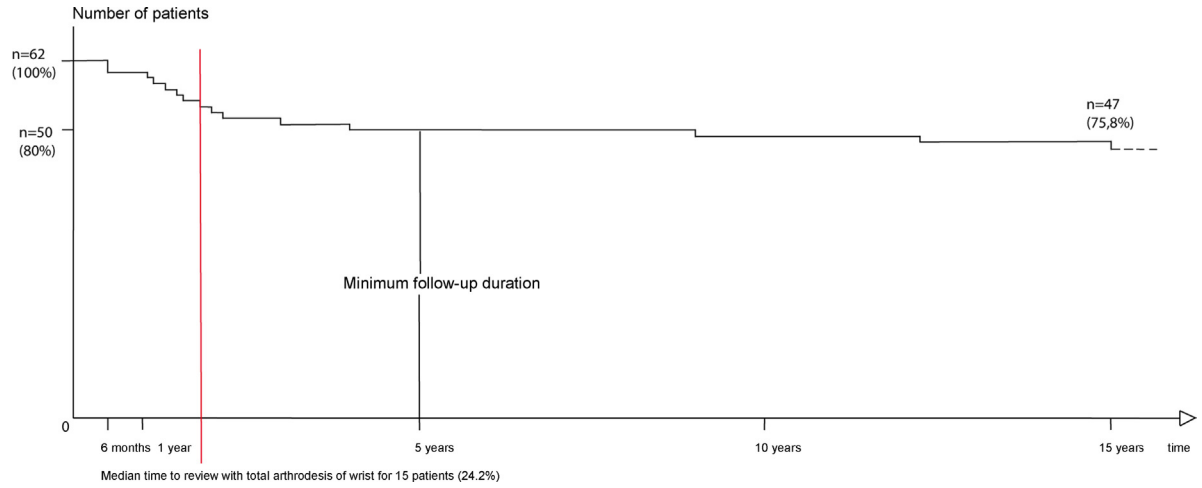

Fig. 3. Kaplan-Meier survival curve for proximal row carpectomy.

fossa of the radius: its radius was 11.4 mm preoperatively (r1) and 10 mm at follow-up (r2). Similarly, flattening of the capitate head was observed: its radius was 8.2 mm preoperatively (r3) and 8.4 mm at follow-up (r4). The mean ratio between the radius of curvature of the capitate and the carpal joint surface of the radius was 0.736 immediately after surgery (r3/r1) and it increased to 0.82 at the last follow-up (r4/r2) (Fig. 5). There was a statistically significant correlation between the differential ratio (r4/r2–r3/r1), indicating that the joint surfaces have adapted over time ($r = 0.44$; $P = 0.005$).

3.4. 3.4. Subgroup analysis of changes in outcomes over time

The subjective functional assessment (PRWE, DASH, Mayo Wrist score) was stable before and after 10 years of follow-up (Table 4).

3.5. Subgroup analysis of the Eaton procedure

Forty-one Eaton procedures were carried out in this cohort (Table 4). The subjective function scores in this subgroup were not different from the remainder of the cohort. Through a detailed analysis of the objective clinical results (range of motion, strength, time to return to work) we found a significantly higher grip force (26.6 kg versus 20.7 kg) in cases of Eaton capsuloplasty ($P < 0.05$).

3.6. Perilunar dislocation of the carpus with no conservative treatment possible

Functional assessment of PRCs after perilunar dislocation of the carpus was carried out (Table 4). There was no significant difference between emergency versus differed treatment (inveterate dislocation). On the other hand, the QuickDASH score was significantly worse when the PRC was performed for perilunar dislocation than for a degenerative etiology.

4. Discussion

In this study, PRC failed in 24.2% of the patients (15/62). These patients required revision total arthrodesis of the wrist within a median 22 months. PRC transforms a complex joint into an ellipsoid-type joint. This is an anatomical simplification first described by Stamm in 1944 [10]. This new radiocapitellar joint is relatively incongruent and non-physiological. The kinematics and potential factors responsible for failure are demographic (age, manual labor activity, residual mobility) or morphologic (radio-capitellar congruence, arthritis). In this study, manual labor and being under 50 years of age were the major determinants of PRC failure.

Laulan et al. [11] defined the ideal candidate for PRC as a patient who is sedentary or a light-manual worker, not too young, and who still has mobility despite degenerative lesions secondary to SLAC or SNAC. Yazaki et al. [12] recently validated the research of Viegas [13,14] on the anatomical variations between the lunate and the capitate. When the lunate is Viegas type II, a V-shaped capitate is systematically found. These observations were reviewed by Imbriglia et al. [15] in a CT study and by Hawkins-Rivers et al. [16] on MRI. They found approximately 60% congruence between the capitate head and the lunate fossa of the radius. After PRC, the contact surface between the radius and the capitate greatly decreases, thereby increasing pressure [17]. Hogan et al. [18] found a 280% increase in these stresses. From a clinical point of view, the studies of Jebson et al. [9] and Balk and Imbriglia [19] at 10 and 9 years of follow-up, respectively, showed relative adaptation between the shape of the radius and the capitate on X-rays, without proving that this was due to remodeling or arthritis. We

Table 3
Summary of the entire series.

Cohort ($n = 62$) Failure ($n = 15$; 24.2%)		Wrist range of motion						Grip strength				
		Flexion–extension range of motion										
Analyzed patients ($n = 47$)	Pain	Operated side	Compared to contralateral side	Flexion	Extension	Radial deviation	Ulnar deviation	Operated side	Compared to contralateral side	Quick DASH	PRWE	MWS
Mean	0.8/10	75°	61.5%	35°	40°	7°	27°	24.3 kg	70%	26	23.5	66

MWS: Mayo Wrist score; PRWE: Patient-Rated Wrist Evaluation score.

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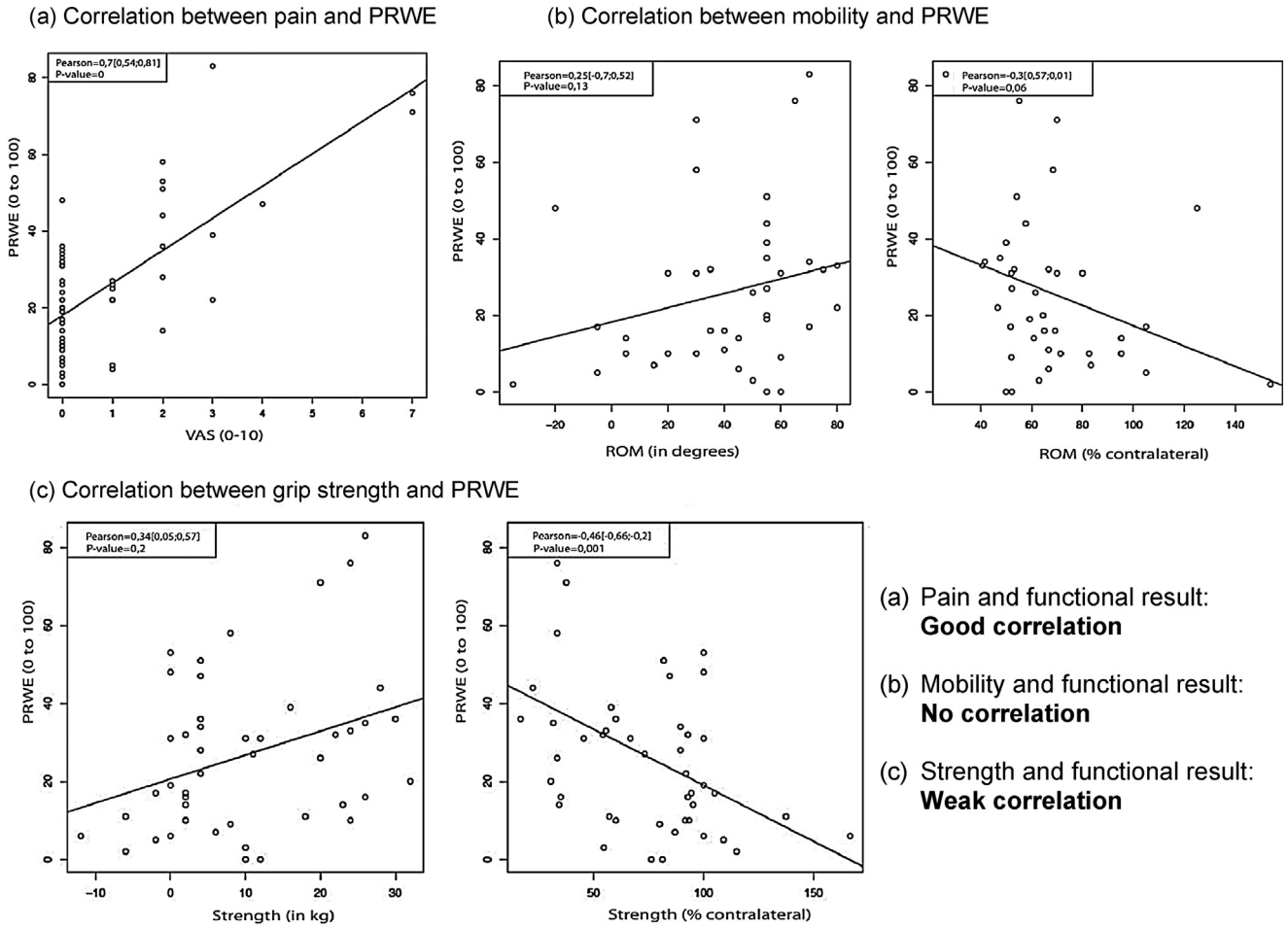

Fig. 4. Correlations between pain (a), range of motion (b) or grip strength (c) and the PRWE functional score.

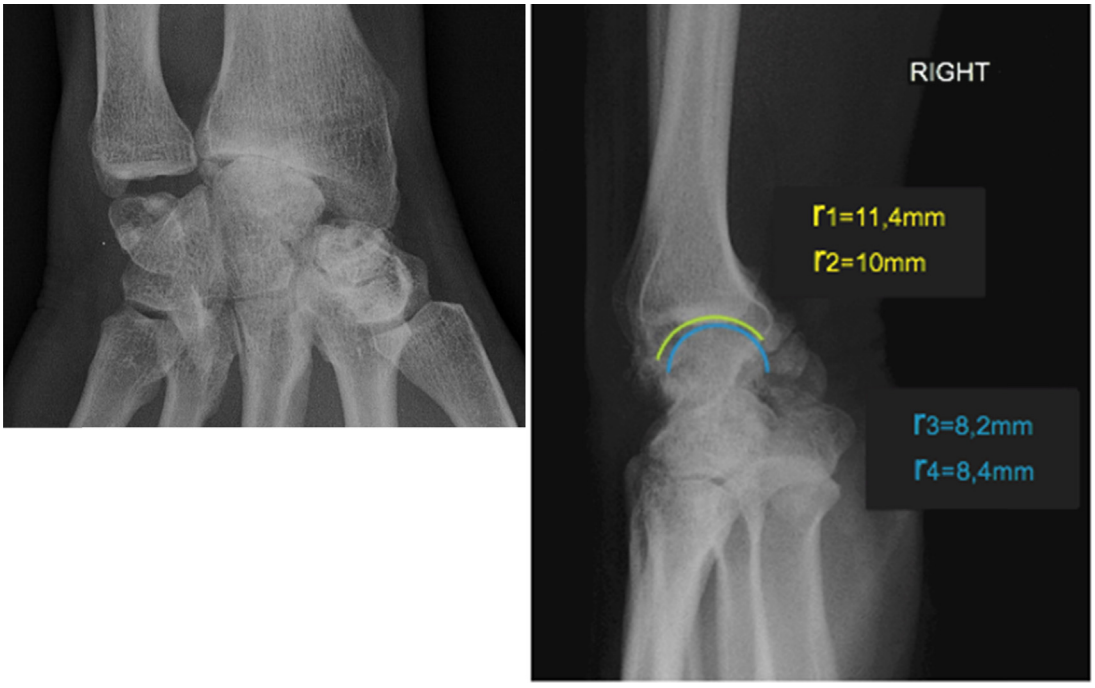

Fig. 5. Morphology of the radiocapitellar joint. The mean ratio between the radius of curvature of the capitate and the radial glenoid is 0.736 immediately after surgery (r3/r1) and increased to 0.82 at the last follow-up (r4/r2). Joint congruence increases over time due to remodeling or arthritis progression.

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Table 4
Subgroup analysis.

Mean values	PRC failure (= revision with total arthrodesis)	Quick DASH	PRWE	MWS
Capsular interposition arthroplasty with Eaton technique				
Yes (n = 41)	12	24.9	23.3	68.5
No (n = 21)	3	31.5	27.6	62.8
Follow-up after surgery				
< 10 years	–	27.9	30.0	67
> 10 years	–	19.3	21.0	66.2
Perilunar dislocation of the carpus				
Emergency (n = 7)	1	28.5	23.4	67.5
Chronic (n = 11)	3	27.7	26.5	63.8

MWS: Mayo Wrist score; PRWE: Patient-Rated Wrist Evaluation score.

Table 5
Recent published studies on the outcomes of proximal row carpectomy.

Mean values	No. of patients	Follow-up (months)	Revision rate for total arthrodesis (time to revision)	Age (years)	Range of motion F + E (degrees)	Strength (% of contralateral)	Quick DASH	PRWE	MWS
Ali [21]	61	235	19.6% (35 months)	41	69	48	–	32.2	61.8
Richou [26]	24	116	12% (30 months)	36	76	78	–	20	–
Jebson [8]	20	157	10% (34 months)	43	77	83	–	–	–
Croog [22]	21	120	14% (23 months)	38	105	87	12	17	84
DiDonna [23]	15	168	18% (64 months)	36	72	91	9	–	–
Wall [24]	17	288	35% (11 years)	36	68	72	16	26	–
Our study	62	142	24.2% (22 months)	46.5	75	70	26	23.5	66

E: extension; F: flexion; MWS: Mayo Wrist score; PRWE: Patient-Rated Wrist Evaluation score.

were able to verify this increase in joint congruence in our study, with notably a mean radius of 0.736 between the sagittal radius of curvature of the capitate and the proximal row surface of the radius immediately after surgery (r3/r1) and 0.82 at the last follow-up (r4/r2) (Fig. 5). This joint surface adaptation can be explained by a recess in the lunate fossa of the radius and flattening of the capitate, which was statistically correlated with time after PRC in our study ($r = 0.44$; $P = 0.005$).

The difference in the radius of curvature between the capitate and the proximal row joint surface of the radius was not implicated, both in terms of the clinical outcome and the onset of arthritis [20]. Imbriglia et al. [15] showed the capitate articulates with the radius both as a hinge in rotation [21] and in translation, thus displacing the center of rotation [10]. This probably results in dissipation of stresses, thereby preserving the joint [15]. We are more reserved on this point, like many authors [2,3,9,22–26] who systematically note deterioration due to arthritis of the radio-capitellar joint space, as we did, without this finding being correlated with the clinical outcome. It can also be noted that this arthritis begins 2–3 years after surgery, when most failures are observed [2,3,9,22–26]. The median time to revision in our study was also early, which is why arthritis did not seem to be the main factor for the failure of PRC, because the indications for surgical revision were made before arthritis appeared.

Most authors [2,11,15,27] agree that PRC is contraindicated in the presence of arthritis of the lunate fossa of the radius and/or the capitate head. In stages II and III of the Watson classification [1], we performed capsular interposition arthroplasty using the Eaton technique [4]. This technical modification seems effective in clinical terms, since no significant difference was found in the functional scores, strength, or pain when there was radiocarpal or midcarpal arthritis. These results are in agreement with those found on the series reported by Salomon and Eaton [4]. In advanced midcarpal and Watson stage III radiocarpal arthritis, Marcuzzi et al. [28] proposed combining PRC with resurfacing of the capitate head using a pyrocarbon interposition implant. The majority of the failures occurred in the first 2 or 3 years after surgery. Beyond this time, the outcome seems stable. In our study, the functional PRWE, QuickDASH, and subjective assessment scores did not differ statistically between the subgroups with more or less than 10 years of follow-up. In the literature [9,23,24,26], no long-term deterioration of the outcome has been reported.

Pain disappears after surgery for 80–100% of the patients in other published studies [15,29]. In our study, only 60% of patients had a completely pain-free wrist. However, 90% of the patients had a VAS pain score lower than or equal to 2/10. For the entire cohort, 68% of the patients (42/62) were very satisfied or satisfied with the result. In the meta-analysis performed by Mulford et al. [27], range of motion in flexion–extension was 75° (Table 5). The mean range of motion was 75° ± 17.8 (range, 25–105°) in our study; if lateral deviations are also considered, overall range of motion of the operated wrist reached 61.5% of the contralateral wrist. The same holds true for grip strength, which is reduced to 70% of the strength of the opposite side; this supports the notion that PRC may be better suited for patients who do not engage in heavy-manual labor [30,31]. From a functional viewpoint, the results reported herein (QuickDASH, PRWE, subjective satisfaction score) were correlated with pain, had a weak correlation with strength, and had no correlation with range of motion values. These observations are in agreement with the degree of perceived disability [32]. Adams et al. believe that preserving the range of motion is not the primary objective for this surgery because there is no difference between a partial or complete limitation in wrist range of motion on the clinical outcome. The duration of postoperative immobilization varied in our study (range, 0–45 days). No difference was found on the postoperative functional outcome. Edouard et al. [33] reported the advantage of an immediate functional rehabilitation protocol with no immobilization, which led to faster recovery in a series of 13 patients.

In the context of radiocarpal and/or midcarpal arthritis, the preferred treatment was PRC in our study. Another option is partial proximal row arthrodesis, including the Watson procedure in cases of Watson stage II arthritis. These procedures have similar results

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in terms of pain relief and satisfaction. The complication rate is higher for partial arthrodesis, which can require revision to total arthrodesis in as many as 36% of cases [34,35]. Nevertheless, strength was better (75% of the opposite side) with a lower risk of radius-proximal row arthritis [27] and good long-term results. Given the PRC failure rate in our study, which was significantly higher in young patients and manual workers, partial proximal row arthrodesis should be preferred to PRC in this population [31].

5. Conclusion

PRC for treating wrist arthritis and serious injury to the proximal row has a low complication rate for patients who wish to preserve wrist range of motion. Even if the results in terms of preserving range of motion and strength are good, this study reminds us that long-term satisfaction may be low. The high revision rate in this study for young patients and manual workers suggests that an alternative should be sought in this population. The problems and complications during arthrodesis and arthroplasty make PRC a simple and effective first-line solution when the patients are selected carefully.

Disclosure of interest

The authors declare that they have no competing interest.

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