

Resurfacing capitate pyrocarbon implant after proximal row carpectomy: A literature review

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Abstract

Up to a decade ago, to treat patients with chronic wrist pain due to advanced stages of arthritis, surgeons had four main solutions: partial or total wrist arthrodesis, total wrist prosthesis and proximal row carpectomy (PRC). Since 2010, a new technique has been described in literature using the Resurfacing Capitate Pyrocarbon Implant (RCPI), combined to PRC. The aim of this article is to review the literature and determine the indications, outcomes and complications associated with RCPI. An electronic literature research was carried out and pertinent articles were selected. Surgical technique, results and complications described in those articles are presented. From this review of the literature, authors conclude that Resurfacing Capitate Pyrocarbon Implant can be considered as a good alternative to arthrodesis and total wrist arthroplasty, at any ages, when proximal row carpectomy alone would not be indicated.

Introduction

Wrist osteoarthritis is a group of mechanical abnormalities resulting in joint destruction. These abnormalities include cartilaginous degeneration and hypertrophic bone changes, which can lead to swelling, diminution of range of motion (ROM), diminution of strength and pain. Hand surgeons frequently deals with osteoarthritis of the wrist, being one of the most common reason to refer to a specialist.^{1,2} Osteoarthritis of the wrist can be idiopathic, but it is mostly seen as a post-traumatic condition. There are different types of post-traumatic osteoarthritis. Scapholunate advanced collapse (SLAC) is the most common form, followed by scaphoid non-union advanced collapse (SNAC).³ Other, post-traumatic causes such as intra-articular fractures of the distal radius or ulna, even though less

common, can also lead to wrist osteoarthritis.

Some other causes of wrist arthritis and chronic pain are Kienböck's disease,⁴ an avascular necrosis with fragmentation and collapse of the lunate bone, and scaphoid chondrocalcinosis advanced collapse (SCAC).⁵

SLAC, SNAC and SCAC have a similar radiological classification:^{5,6}

Stage I: the osteoarthritis is only localized in the distal scaphoid and radial styloid.

Stage II: the osteoarthritis is localized in the entire radio-scaphoid joint.

Stage III: the osteoarthritis is localized in the entire radio-scaphoid joint with involvement of the capito-lunate joint.

Stage IV: the osteoarthritis is located in the entire radiocarpal joint and in the intercarpal joints. It also may involve the distal radio-ulnar joint (DRUJ).

Kienböck disease has its own classification first described by Litchman⁷ in 1977:

Stage I: Normal radiograph (possible lunate fracture).

Stage II: Sclerosis of the lunate without collapse. (Portions of the lunate begin to deteriorate. This shows as a white blemish on x-rays.)

Stage IIIA: Lunate collapse and fragmentation, in addition to proximal migration of the capitate.

Stage IIIB: Lunate collapse and fragmentation, in addition to proximal migration of the capitate. In addition, there is fixed flexion deformity of the scaphoid.

Stage IV: Changes up to and including fragmentation, with radiocarpal and midcarpal arthritic changes.

For all these pathologies, depending on type and stage, numerous different types of treatment have been and are frequently used such as proximal row carpectomy (PRC), four corner arthrodesis, total wrist arthroplasty and total wrist arthrodesis.^{6,8,9} Since 2010, a new technique has been described in the literature¹⁰ using the resurfacing capitate pyrocarbon implant (RCPI) (*Tornier, Montbonnot-Saint-Martin, France*). The implant is designed to replace the head of capitate, and used combined with PRC as a treatment option when articular surfaces of the capitate and radius are damaged, preserving a painless motion of the wrist.¹¹

Pyrocarbon¹² has been firstly developed in the 1950s for the nuclear industry. It is around 1969 that its use has been widened to medical field, thanks to its biocompatibility and tribological properties. It has been first used for mechanical heart valves, which remain one of its main use, and then, around 1979, in orthopaedics as an alternative to

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silicone in metacarpophalangeal joint implants.¹³ The RCPI used for capitate head resurfacing is a one-piece hemi-prosthesis with a truncated spherical head, tilted by 15°, mounted on an intramedullary stem press-fitted into the capitate (Figures 1 and 2).

Only few articles on the use of RCPI are published in literature, and no complete review have been done. The aim of this article is to determine the indications, outcomes and complications associated with RCPI combined to PRC.

Materials and Methods

An electronic literature research was carried out on PubMed, Google Scholars and Cochrane Library. To find relevant studies, the following search terms were used: "RCPI" AND (Scaphoid OR Capitate OR Kienböck OR Lunate OR Osteoarthritis OR Wrist); "Pyrocarbon" AND (Scaphoid OR Capitate OR Kienböck OR Lunate OR Osteoarthritis OR Wrist). Three authors

independently selected relevant articles and subsequently discussed those. The reference lists of all relevant publications were screened for additional pertinent articles. Searches were updated to January 2020. Five articles were finally selected (Table 1).

Results

Surgical technique

All surgical techniques described in the selected publication are very similar with very few differences (Table 2). Usually this surgery is performed under axillary block anaesthesia. Dorsal skin incision is made, and the fourth compartment is opened longitudinally. Capsulotomy is performed to expose the radiocarpal joint. Depending on the author, neurotomy of the dorsal interosseous nerve is done. A proximal row carpectomy is performed followed by a minimal osteotomy of the head of the capitate, parallel to the lunate fossa of the distal radius. Using a K-wire directed towards the base of third metacarpal bone, a hole is created in the medullary cavity of the capitate (Figures 3 and 4), by the mean of a bone perforator, curette and 14 mm or 16 mm rasps depending on the size, for the stem of RCPI, being careful not to damage the cortical bone of the capitate. Trial prosthesis can be tried (two sizes: 14 mm & 16 mm, depending on capitate size) and checked under fluoroscopy. If position and size fit, the trial prosthesis is replaced by the definitive pyrocarbon implant and a last fluoroscopic control is performed. Dorsal capsule and extensor retinaculum are

repaired and skin is sutured. At the end of surgery, a cast splint is made to immobilize the operated wrist, and will be kept from 4 days to 4 weeks according to author's preferences.

Outcomes

Although low quantity of available publications so far and the relative lack of evidence, optimistic results have been obtained (Table 3).

In 2010 first case report was published by Fernandes,¹⁰ regarding the use of RCPI in a 38 years old male with a stage IV Kienböck disease. He reported his results at a 12 months follow-up. The patient was satisfied with the procedure and had an improvement of VAS score for pain. An improvement of flexion of the wrist from 20° to 60° was achieved, and a 20° extension was maintained after surgery.

Successively Goubier *et al.*¹⁴ reported their results on 7 patients for the use of RCPI in radiocarpal osteoarthritis at an average 30 months follow up. VAS score improved from a mean of 7 to 4, grasp strength decreased



Figure 1. Resurfacing Capitate Pyrocarbon Implant (RCPI) (Tornier, Montbonnot-Saint-Martin, France).



Figure 2. Follow-up antero-posterior and lateral x-rays with RCPI implanted.

Table 1. Number of patients selected in each article, the diagnosis of those patients when specified, the sex, the mean age in years and mean follow-up in months.

Articles	Patients	SLAC	SNAC	SCAC	K	M	F	Age (range)	FU (range)
Fernandes ¹⁰ , 2010	1	0	0	0	1	1	0	38	12
Goubier ¹⁴ , 2011	7		NOT SPECIFIED			6	1	49 (37-63)	30 (6-72)
Szalay ¹¹ , 2012	5	4	1	0	0	3	2	40 (23-66)	54 (25-68)
Marcuzzi ¹⁵ , 2014	35	11	18	2	4	26	9	54 (22-81)	34 (12-91)
Giacalone ¹⁶ , 2017	25		NOT SPECIFIED			23	2	58 (25-80)	34 (24-89)

SLAC: scapholunate advanced collapse, SNAC: scaphoid non-union advanced collapse, SCAC: scaphoid chondrocalcinosis advanced collapse, K: Kienböck syndrome, M: male, F: female, FU: follow-up.

Table 2. Procedures details.

Articles	Anaesthesia	Surgical access	Interosseous denervation	Capsulotomy technique	Splint
Fernandes ¹⁰ , 2010	brachial plexus block	dorsal and radial incision	no	in ">"	3 w
Goubier ¹⁴ , 2011	brachial plexus block	dorsal approach	yes	NOT SPECIFIED	1 w
Szalay ¹¹ , 2012	brachial plexus block	dorsal approach	yes	NOT SPECIFIED	4 w
Marcuzzi ¹⁵ , 2014	brachial plexus block	dorsal approach	yes	proximal base capsular flap	4 d (+3 w at night)
Giacalone ¹⁶ , 2017	brachial plexus block	dorsal approach	no	radial-based "ligament-splitting"	3 w (+3 m at night)

w: weeks, d: days, m: months.

from 19 kg pre-operatively to 16 kg after surgery, and mean flexion-extension of the wrist went from 36-0-33° to 20-0-30°. Six out of seven patients were satisfied with surgery.

Szalay¹¹ has up to now published the longest follow-up with an average of 54 months. He reported extensive results on 4 SLAC and 1 SNAC cases he treated with RCPI combined to PRC. He had excellent results in terms of pain resolution with mean VAS decreasing from 6.1 to 1.4, good results in terms of wrist ROM improvement (from 23-0-30° to 37-0-42° for flexion-extension

and from 8-0-20° to 7-0-25° for radio-ular deviation), strength (increasing from 70% to 88% of the contralateral wrist), and daily activities score (mean DASH improving from 50 before surgery to 8 after surgery). All patients were satisfied with surgery.

In 2014, Marcuzzi *et al.*¹⁵ published the largest study with results of 35 patients (18 SNAC, 11 SLAC, 2 SCAC and 4 Kienböck) who had RCPI implanted. At an average 34 months follow-up mean VAS score decreased from 8.4 to 1.4, wrist ROM improved in flexion-extension (from 25-0-25° to 33-0-34°) and radio-ular deviation

(from 4.7-0-12° to 12-0-19°), DASH went from a mean 56.9 score before surgery to 11.4 after surgery, and grip strength at Jamar test increased from 10.1 kg to 16.5 kg. Marcuzzi *et al.* also evaluated if there were any differences between White-collar and Blue-collar workers, without any statistical differences. Thirty-two out of 35 patients were satisfied with the surgery.

Recently, Giacalone *et al.*¹⁶ published a comparative study analysing outcomes of patients who underwent PRC alone and patient who had RCPI implanted. In this second group of 25 patients, at an average 34



Figure 3. Intraoperative antero-posterior and lateral fluoroscopies with K-wire in the capitate and base of the third metacarpal to guide the rasping of capitate.



Figure 4. Intraoperative picture of capitate after rasping, with k-wire *in situ*.

Table 3. Results before and after surgery.

Articles	f-e PRE	f-e POST	r-u PRE	r-u POST	vas PRE	vas POST	gs POST	gs POST	dash PRE	dash POST	S
Fernandes ¹⁰ , 2010	20-20	60-20	n.a.	n.a.	n.a.	better	n.a.	n.a.	n.a.	n.a.	1/1
Goubier ¹⁴ , 2011	36-33	20-30	n.a.	n.a.	7	4	19 kg	16 kg	n.a.	n.a.	6/7
Szalay ¹¹ , 2012	23-30	37-42	8-20	7-25	6,1	1,4	70%	88%	50	8	5/5
Marcuzzi ¹⁵ , 2014	25-25	33-34	4-12	5-19	8,4	1,4	10,1 kg	16,5 kg	56,9	11,4	32/35
Giacalone ¹⁶ , 2017	n.a.	27-33	n.a.	12-27	n.a.	2	n.a.	54%	n.a.	20	23/25

PRE: before surgery, POST: after surgery; f-e: flewion-extension in °, r-u: radioulnar deviation in °, vas: visual analog scale for pain, gs: grasp strength at Jamar dynamometer (when in %, gs is compared to contralateral side), dash: disabilities of the arm, shoulder and hand score, S: number of patients satisfied with the surgical procedure, n.a.: not available.

Table 4. Clinical complications, number of cases requiring reintervention (among which arthrodesis), and radiological complications.

Articles	Clinical complications	Reintervention (arthrodesis)	X-ray complications
Fernandes ¹⁰ , 2010	1 hypertrophic scar	0 (0)	1 bone reabsorption
Goubier ¹⁴ , 2011	none	0 (0)	none
Szalay ¹¹ , 2012	none	0 (0)	2 loosening around the implant
Marcuzzi ¹⁵ , 2014	10 unspecific ulnar-sided pain	3 (1)	13 medial translation, 1 mild sinking
Giacalone ¹⁶ , 2017	1 persistent pain, 1 dislocation	2 (1)	1 mild sinking

months follow-up post-operative ROM was 27-0-33° for flexion-extension and 12-0-27° for radio-ulnar deviation, VAS score was 2, grip strength was 55% of contralateral limb, DASH score was 20, and PRWE was 28. Twenty-three out of 25 patients were satisfied with the outcomes. The main difference between the groups was a higher degree of post-operative wrist extension in PRC group, although this result might be linked to the fact that patients enrolled for RCPI were at a higher stage of pathology.

Complications

Although most of the patients are satisfied with RCPI, and none of the studies included in this review reported any complications during the surgery, this procedure is not complication free (Table 4).

Fernandes¹⁰ referred a hypertrophic scar on the dorsum of the hand and described bone reabsorption between implant and bone seen on the one year follow-up x-ray.

No intra- or post-operative complications are described by Goubier¹⁴ on any patient of his series.

Szalay¹¹ described mild sign of loosening around the implant at the latest x-ray in two out of five patients, but patients were satisfied with surgery results and pain free so no reintervention was needed.

Out of 35 patients in Marcuzzi's¹⁵ publication, 10 patients had nonspecific ulnar-sided wrist pain. Of these patients, one had a dynamic distal radio-ulnar joint (DRUJ) instability diagnosed after surgery and underwent synovectomy and DRUJ stabilization; another had radial styloidectomy for pain on the radial styloid due to stylo-trapezoid impingement. One patient had a total wrist arthrodesis due to persistent pain. At last x-ray follow-up 13 patients had a slight medial translation from the lunate fossa of the implant without any functional related outcome, and one patient had a mild sinking of the RCPI into the capitate but patient was pain free and no reintervention was required.

In Giacalone's comparative study¹⁶, in the group of patients who underwent surgery with RCPI combined to PRC, one patient had a volar dislocation of the implant one week after surgery and necessitated surgery for implant reduction and joint stabilization with a Kirschner wire; long term results for this patient were comparable to those of other patients. Another patient of this group required total wrist arthrodesis one year after the first surgery for poor grip strength and persistent pain. With the exception of one asymptomatic case, with mild sinking of the implant into the capitate (not needing reintervention), the radiographic examination showed good implant

adaptation, no loosening, no ruptures, and no bone resorption or fracture.

Discussion and Conclusions

Patients of both sexes and any age with wrist osteoarthritis mainly refer to hand surgeon because of pain and ROM limitation. In this review patients were mainly male (59 vs. 14; 81%) and mostly young with a mean age of 56 years old (range 22-80). Up to a decade ago, to please patients' requests, surgeons had four main solutions: partial or total wrist arthrodesis, total wrist arthroplasty and PRC. The four-corner arthrodesis^{17,18} is a validated technique that reduces pain, preserves ROM and provides sufficient grip strength. However this procedure is burdened by a non-negligible complication rate, as in the literature many cases of painful radial dorsal impingement, reduction of ROM, and pseudarthrosis are reported. Furthermore, mid-term radio-lunate arthrosis, due to functional overload on the lunate fossa, has been proved.¹⁹⁻²¹ Total wrist arthrodesis,²¹⁻²³ resolves pain, allows a good recovery of grip strength, but causes a major loss of function blocking all movements. This condition also involves the frequent development of arthropathies of the elbow and shoulder.²³

To preserve motion, total wrist prosthesis^{24,25} have been developed, with results not as satisfying as expected, and complications such as implant failure due to early periprosthetic bone resorption.^{26,27} Moreover, the indication to these prostheses, born for the treatment of rheumatoid arthritis, remains limited to subjects who do not need to perform intense manual activities and fatigue.^{24,28} The PRC^{9,29,30} is an ancient and reliable surgical procedure whose goal is the simplification of the complex carpal joint. It is a good option to decrease pain and maintain ROM, but it is limited to cases of radio-scaphoid joint degeneration with well-preserved capitate and of the radius cartilaginous surfaces (condition identifiable as SNAC/SLAC 1 and 2). The use of this technique in case of more advanced arthrosis is contraindicated, as it is doomed to a rapid failure, because of the degeneration of the radio-capitate articular aspects.

Pyrocarbon implants are more and more used in hand surgery¹². The clinical series reported by the articles selected for this study, were composed of patients with advanced wrist osteoarthritis, identifiable with advanced stages of SLAC, SNAC, SCAC or Kienböck disease, where a proximal row carpectomy alone would not be indicated any more. VAS score for pain

improved in all studies after surgery, ROM of the wrist was maintained if not improved, DASH score decreased when measured, and except in Goubier's¹⁴ series, grip strength improved after surgery. Another important result is that 67 out of 73 patients (91.7%) included in those articles were satisfied with their surgery at a mean 34,6 months follow-up. All these parameters seem encouraging, compared to pathological conditions that, until a few years ago, would have required more demanding surgical procedures. Concerning complications and failures, very few clinical complications were described (less than 18% of cases), and of those, most have to be considered as minor (hypertrophic scar and pain resolved without reintervention). In 5 cases (6.8% of total cases), a second operative procedure was required, being in 3 cases (4.1%) a resort to surgery for manageable post-operative complications, and 2 cases (2.7%) of total wrist arthrodesis for not solvable persisting pain. We can therefore consider the percentage of major complications or failures lower than 3% of the sample. Furthermore, no wound infections have been described on 73 cases. Concerning the follow-up x-rays, 18 cases showed alterations such as bone reabsorption with minimal loosening around the RCPI, medial translation and mild sinking of the implant, but none of these needed reinterventions, as these conditions were not correlated with a clinical outcome.

Most of the authors, describing the surgical procedure, recommended to be careful when rasping the carpal bone to avoid capitate or third metacarpal cortical damage or fracture. However, none reported such intra-operative complications.

The longevity of this prosthesis is not questioned, as Pyrocarbon has been used as prosthetic cardiac valves for 20 years, with no complication related to the material up to now.¹⁴ Furthermore, longest follow-up of this review was asymptomatic, without any implant failure at 91 months.¹⁶

This literature review allows to identify the advantages of RCPI compared to traditional treatments. Patients who undergo four-corner arthrodesis are more likely to have a persistent and/or worsened pain at mid-term follow-ups due to the higher risk to have complication such as failed arthrodesis or radio-lunate arthrosis.¹⁹ In the same way, patients treated with total arthrodesis, a more demanding surgery, are more likely exposed to complications linked to the failure of the arthrodesis and arthropathy of nearby articulations, in addition to an important decrease of ROM that leads to a secondary invalidity.^{22,31,32} Those complications make total arthrodesis

a technique that should be considered only as a “rescue surgery”. Total prosthesis,²⁵ beyond being a more challenging surgery, presents often significant bone reabsorption and implant loosening, leading in most cases to a prosthesis revision after 10-12 years.³²⁻³⁴ Proximal row carpectomy is a less complicated surgery, and presents comparable results to RCPI,¹⁶ but it is not indicated in higher stages of SNAC/SLAC/SCAC/Kiembock.²⁹

In spite of the small number of articles published on the use of RCPI combined with PRC in advanced stage of wrist osteoarthritis and Kienböck syndrome, the short follow up of some of the patients included in those articles, and the non-uniformity of methods for collecting results in the different publications, we can conclude that Resurfacing Capitate Pyrocarbon Implant can be considered as a good alternative, at any ages, when proximal row carpectomy alone would not be indicated. Furthermore, RCPI allows to spare those patients from surgeries that are more invasive and complex, burdened by a greater number of complications and possibly with less predictable outcomes. Moreover, the RCPI implant doesn't prevent the possibility to perform more complex surgeries as implant of total wrist prosthesis or total wrist arthrodesis in a later time.

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