

# Resurfacing capitata pyrocarbon implant as salvage procedure in several serious outcomes of carpal injuries. Clinical experience and follow-up.

Augusto Marcuzzi<sup>1</sup>, Camillo Fulchignoni<sup>2</sup>, Julien Teodori<sup>1</sup>, Lorenzo Rocchi<sup>2</sup>

<sup>1</sup>Modena University Hospital, Department of Hand Surgery, Modena, Italy; <sup>2</sup>Hand Surgery and Orthopedics Unit, Department of Orthopaedics and Traumatology, Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome Italy – Università Cattolica del Sacro Cuore, Rome Italy

**Abstract.** *Background and aim:* Resurfacing Capitata Pyrocarbon Implant has been introduced in the surgical practice as an alternative method to restore wrist motion, strength and functions in patients suffering from wrist osteoarthritis. It has already been well described in the literature as a treatment for advanced stages of degenerative wrist diseases which follow scaphoid's and lunate's injuries such as scapho-lunate advanced collapse, scaphoid non-union advanced collapse, and advanced stages of Kienböck disease. Authors extended the use of RCPI to other selected cases of complicated wrist injuries, spreading out from the classic indications for which this device was designed. *Methods:* We discuss 8 cases with serious outcomes of carpal injuries treated with Resurfacing Capitata Pyrocarbon Implant as salvage procedure between 2005 and 2013 by the first author of this paper. *Results:* Among the eight particular selected cases, at a mean 4.3 years follow-up (range 2-11) only one was considered a failure and underwent a total wrist arthrodesis, resolving pain after all. The seven other cases reported good results. Range of Motion, Visual Analogue Scale for pain, subjective satisfaction and radiographical outcomes are reported. *Conclusions:* As a result of this heterogeneous clinical experience, validated by long-term follow-ups in most cases, we think that the use of a Resurfacing Capitata Pyrocarbon Implant can be suggested as an option in the outcomes of various carpal injuries.

**Key words:** Resurfacing Capitata Pyrocarbon Implant, RCPI, Wrist arthrosis, Carpal injuries.

## Introduction

Wrist osteoarthritis is a common long-term outcome of carpal injuries (1,2). In the surgical practice, many techniques have been developed along the years. Among those, the most frequently used - depending on patient conditions and demands, and surgeon preferences - are partial or total wrist arthrodesis (3,4), total wrist arthroplasty (5) and proximal row carpectomy (PRC) (6-8). Each of these techniques has its well-described indications, complications and limitations (9-12). Since the beginning of the 21<sup>st</sup> century, a new carpal implant, the resurfacing capitata pyrocarbon implant (RCPI) (*Tornier, Montbonnot-Saint-Martin, France*), has been introduced in the surgical practice

(13-16) as an alternative method to restore wrist motion, strength and functions. Associated with PRC, RCPI aims to avoid force loss in manual workers, to reduce complications, and to manage the advanced stages of degenerative wrist diseases which follow scaphoid's and lunate's injuries such as scapho-lunate advanced collapse (SLAC), scaphoid non-union advanced collapse (SNAC) (17), and advanced stages of Kienböck disease (18), when other techniques would not be recommended (19).

RCPI is made out of pyrocarbon (20), an inert material used in the medical field, in mechanical heart valves, since 1969. This material was then extended to the orthopaedic surgery, in metacarpophalangeal joint implants (21), at the end of the seventies because of its

tribological properties and its biocompatibility. In the following years, various carpal implants were developed. RCPI presents a truncated spherical head and a short stem designed to replace the head of capitate. It was designed to be used in combination with PRC when the radius' lunate fossa and/or the proximal pole of capitate are damaged, to prevent a painful motion of the wrist (22). Mid and long-term follow-up (14,16) are available in the literature reporting neither osteointegration nor soft tissue reaction to pyrocarbon. Few surgical technique details change from an author to another (19), such as the cutaneous incision and the joint approach, the option of partial wrist denervation, the capsulotomy technique or the capitate proximal pole preservation (23).

Satisfied with their own results and supported by the good reports of the literature, authors extended the use of RCPI to selected cases of complicated wrist injuries, spreading out from the classic indications for which this device was designed. The aim of this article is to describe those particular cases and to discuss the possibility to widen indications for the use of this pyrocarbon implant.

## Material and methods

We discuss 8 cases with serious outcomes of carpal injuries treated with RCPI as salvage procedure between 2005 and 2013 by the first author of this paper. All cases are assessed measuring wrist range of mo-

tion (ROM) in degrees, functionality and strength in kilograms (kg) using a Jamar dynamometer, and Visual Analogue Scale (VAS) for pain. All procedures were performed following written informed patient consent and in accordance with the ethical standards of the institutional and/or national research committee and the 1964 Declaration of Helsinki and its subsequent amendments or comparable ethical standards.

## Results

(Table 1)

Case n.1, *Transcavo-Transcapitate Perilunate Fracture-Dislocation Outcomes*. (Fig. 1)

C.L. 22 years old (y.o.), workman and martial art practitioner. The patient suffered a road accident with head trauma, with subsequent treatment in intensive care unit for 30 days. At initial injury assessment, the patient presented a transcavo-transcapitate perilunate fracture-dislocation of the left wrist, treated in another orthopedic service by reduction of the dislocation and fractures fixation using K-wires. The patient came to us one year after the first surgical treatment reporting left wrist severe ankylosis and pain (VAS=7). On clinical and radiological assessment, the following elements were reported: capitate proximal pole necrosis, scaphoid pseudarthrosis, pancarpal arthritis with sclerotic and lytic areas.

The patient was treated surgically 14 months after the traumatic event and underwent PRC, with resection of

**Table 1.** Age, results and follow-up for each case.

	Age	E-F ROM pre	E-F ROM post	U-R ROM pre	U-R ROM post	Strength pre	Strength post	VAS pre	VAS post	Follow-up
Case 1	22	0	50-60	0	35-0	4.1	18.2	7	0	11
Case 2	60	15-10	15-10	0	0	4.6	5.0	7	8	2
Case 3	51	40-40	45-40	30-5	30-10	6.8	20.5	7	1	6
Case 4	51	20-25	35-40	35-10	40-15	7.6	13.2	6	0	5
Case 4 bis	51	15-20	30-40	20-5	35-10	6.4	12.5	4	0	2
Case 5	65	0-0 (flexed at 25°)	0-0 (neutral position)	0-0	0-0	9.6	12.4	0	0	6
Case 6	63	20-25	50-45	25-10	40-15	6.9	18.7	7	1	3
Case 7	39	0-0 (flexed at 40°)	40-45	0-0	30-10	5	17.3	8	0	2
Case 8	39	60-50	65-60	30-10	40-15	8.1	19.6	6	1	2

Age in years, ROM in degrees, Strength in kilograms, Follow-up in years. E-F = extension-flexion; ROM = range of motion; PRE = before RCPI implantation; POST = at last follow-up; U-R = ulnar-radial; VAS = Visual analogic scale.

necrotic capitate pole, radial stiloidectomy and RCPI implantation.

The last clinical and functional assessment, 11 years after last surgical treatment, showed the following results:

- Wrist ROM: extension 50°, flexion 60°, ulnar deviation 35°, radial deviation 0°
- Pre-operative strength: 4.1 kg; post-operative strength: 18.2 kg
- VAS: 0
- Radiographic examination showed correct articular alignment and regular RCPI implantation with no signs of bone resorption.

#### Case n.2, *Lunate Dislocation Outcomes.* (Fig. 2)

V.F. 60 y.o., retired and Red Cross volunteer. The patient reported a history of chronic pain following lunate dislocation (about 25 years before) treated by reduction and surgical fixation, with no signs of lunate necrosis.

On clinical assessment, the following elements were noted: pan-carpal arthritis, with a carpal ulnar deviation, minimal ROM and severe pain (VAS 7).

The patient was surgically treated and underwent PRC, radial stiloidectomy and RCPI implantation.

Clinical and functional follow-up at 2 years showed the following results:

- Wrist ROM: extension 15°, flexion 10°, no ulnar and radial deviation.
- Pre-operative strength: 4.6 kg; post-operative strength: 5.0 kg
- VAS: 8
- Radiographic examination showed severe ulnar instability of the carpus with RCPI in conflict with caput ulnae

Considering the procedure failure, a surgical revision with conversion to total wrist arthrodesis was performed. The last clinical and functional assessment 2 years after the last surgical treatment showed no residual pain (VAS: 0), good grip strength (18.4 kg) and good patient satisfaction.

#### Case n.3, *Scapholunate Ligament Reconstruction Failure.* (Fig. 3)

M.F. 51 y.o., workman. The patient was treated for traumatic scapholunate dissociation by double ac-

cess and ligament reconstruction with bone-anchors. In the following months he reported an unbearable wrist pain, therefore a resection of the proximal carpal row was suggested to the patient and subsequently performed. At the clinical assessment 6 years later, the patient reported again the onset of painful symptoms,



**Figure 1.** radiographies before (a,b) and after (c,d) RCPI implantation in case 1.



**Figure 2.** radiographies before (a,b) and after (c,d) RCPI implantation, and after total wrist arthrodesis (e,f) in case 2.

and radiograms showed severe arthrosis of the radio-capitate joint with the following clinical results:

- Wrist ROM: extension 40°, flexion 40°, ulnar deviation 30°, radial deviation 5°
- Strength: 6.8 kg
- VAS: 7

The patient therefore underwent surgical treatment with capitate proximal pole replacement by RCPI implant. The last clinical and functional assessment 6 years later, showed the following results:

- Wrist ROM: extension 45°, flexion 40°, ulnar deviation 30°, radial deviation 10°
- Strength: 20.5 kg
- VAS: 1, good patient satisfaction
- Radiographic examination showed correct articular alignment and regular RCPI implantation with no signs of bone resorption.

#### Case n.4, RCPI peri-prosthetic infection. (Fig. 4)

A.C. 51 y.o., housekeeper. This patient firstly came to our attention for a SLAC lesion stage III of the right wrist, with low grip strength (7.6 kg) and pain (VAS=6). The wrist ROM was: extension 20°, flexion 25°, ulnar deviation 35°, radial deviation 10°.

The patient was surgically treated and underwent resection of the proximal carpal row, radial stiloidec-

tomy and RCPI implantation.

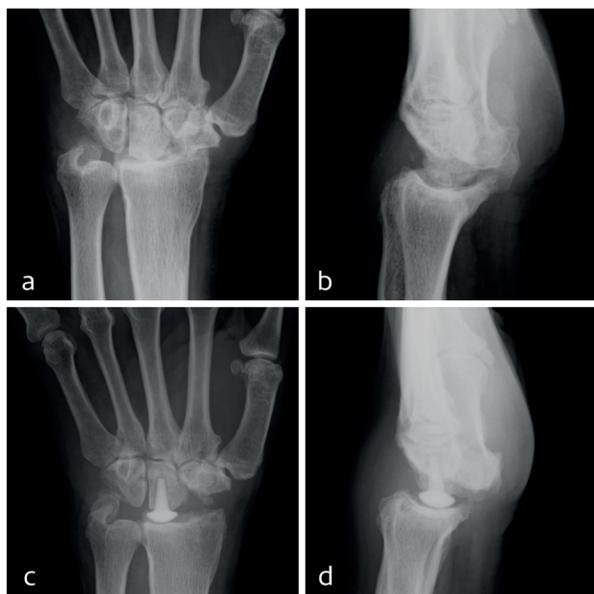
The 5 years follow up showed:

- Wrist ROM: extension 35°, flexion 40°, ulnar deviation 40°, radial deviation 15°
- Grip strength: 13.2 kg
- VAS: 0, good patient satisfaction
- correct articular alignment and regular prosthetic implantation

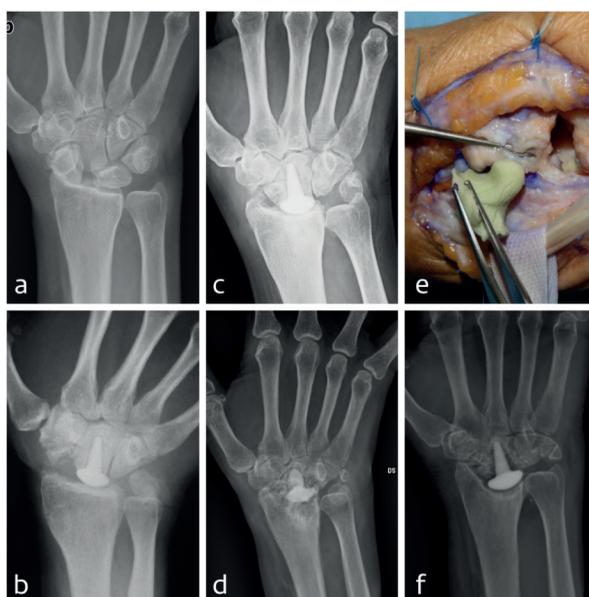
Two years later, the patient came back to our observation for a peri-prosthetic infection, confirmed by scintigraphy with marked leukocytes. The functional results were:

- Wrist ROM: extension 15°, flexion 20°, ulnar deviation 20°, radial deviation 5°
- Grip strength: 6.4 kg
- VAS: 4

The patient underwent surgical revision with RCPI removal and placement of an antibiotic spacer molded on the lunate fossa. Fifteen months later, spacer removal and a new RCPI implant (a larger size) were performed, filling the reabsorbed lunate fossa area with a cancellous bone graft. The last clinical and functional assessment 22 months later, showed the following results:



**Figure 3.** radiographies before (a,b) and after (c,d) RCPI implantation in case 3.



**Figure 4.** radiographies before (a) and after (b,c) first RCPI implantation, after custom made-spacer implantation (d) and after second RCPI (f) implantation in case 4. (e): intra-operative picture of custom made-spacer implantation.

- Wrist ROM: extension 30°, flexion 40°, ulnar deviation 35°, radial deviation 10°
- Grip strength: 12.5 kg
- VAS: 0, good patient satisfaction
- Radiographic examination showed correct articular alignment and regular RCPI implantation with signs of minimal bone resorption, due to the previous infection.

Case n.5, *Spontaneous Total Wrist Arthrodesis in Gout Arthritis*. (Fig. 5)

C.G. 65 y.o., retired, affected by gout. At first clinical assessment, the patient presented:

- a spontaneous total wrist arthrodesis
- Wrist flexed at 25° with no residual ROM
- Grip strength: 9.6 kg
- VAS: 0

The patient complained about a high functional limitation and was therefore surgically treated with resection of the proximal carpal row, radial styloidectomy and RCPI implantation. Postoperatively patient recovered a moderate wrist ROM that, however, was lost at further follow-ups.

The last clinical and functional assessment 6 years later, showed the following results:

- recurrence of spontaneous arthrodesis, in neutral position



**Figure 5.** radiographies before (a,b) and after (c,d) RCPI implantation in case 5.

- Post-operative strength: 12.4 kg
- VAS: 0
- good patient satisfaction for aesthetic and functional outcome with neutral wrist position
- Radiographic examination showed correct articular alignment and regular RCPI implantation with no signs of resorption.

Case n.6, *Articular Chondrocalcinosis*. (Fig. 6)

Z.L. 63 y.o., retired. On clinical assessment, the patient presented:

- a Scaphoid Chondrocalcinosis Advanced Collapse (SCAC) (24) stage IV of the right wrist with severe radiocarpal and midcarpal arthrosis and a massive radial cyst
- Wrist ROM: extension 20°, flexion 25°, ulnar deviation 25°, radial deviation 10°
- Grip strength: 6.9 kg
- VAS: 7

The patient was surgically treated and underwent proximal row carpectomy, filling of the cystic area with cancellous bone taken from the resected carpal bones and RCPI implantation.

The last clinical and functional assessment 3 years later, showed the following results:

- Wrist ROM: extension 50°, flexion 45°, ulnar deviation 40°, radial deviation 15°



**Figure 6.** CT scans before RCPI implantation (a,b) and radiographies after RCPI implantation (c,d) in case 6.

- Grip strength: 18.7 kg
- VAS: 1
- Radiographic examination showed correct articular alignment and regular RCPI implantation. No signs of bone resorption.

Case n.7, *Infection and Algodystrophy post- Trans-Scafo Perilunate Fracture-Dislocation Surgery.* (Fig. 7)

S.G. 39 y.o., workman. The patient reported a fall down the stairs resulting in a complex trauma with a trans-scafo perilunate fracture-dislocation treated in another hospital by scaphoid screw fixation and ligament stabilization with K-wires. After treatment, the patient reported an infectious complication and a subsequent algodystrophic evolution.

On clinical assessment, the following results were observed:

- Wrist flexed at 40° with no residual ROM
- Grip strength: 5 kg
- VAS: 8

The patient was surgically treated and underwent resection of the proximal carpal row, radial stiloidectomy and RCPI implantation.

The last clinical and functional assessment, 2 years later, showed the following results:

- Wrist ROM: extension 40°, flexion 45°, ulnar deviation 30°, radial deviation 10°



**Figure 7.** radiographies before (a) and after (b,c) RCPI implantation in case 7.

- Grip strength: 17.3 kg
- VAS: 0
- Radiographic examination showed correct articular alignment and regular RCPI implantation. Signs of moderate bone resorption, probably due to the previous infection.

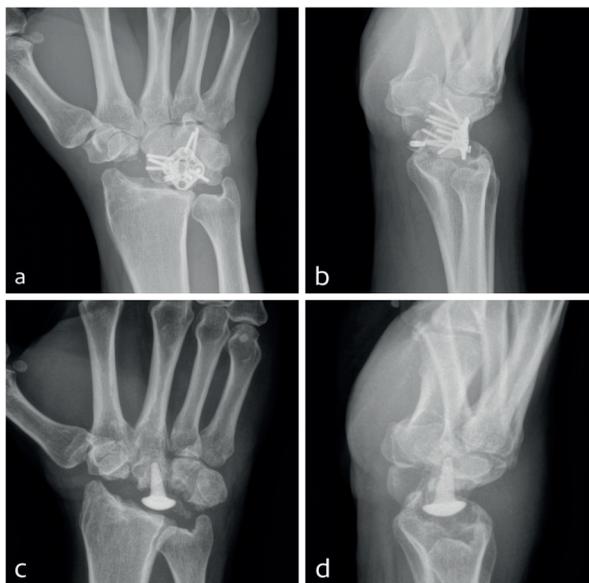
Case n.8, *Painful Pseudarthrosis in Four Corners Arthrodesis.* (Fig. 8)

C.M. 39 y.o., businessman. The patient had a history of previous trauma with scapholunate dissociation treated in another hospital with surgical stabilization according to Brunelli's capsulo-ligamento-plasty (25). A year later he underwent a subsequent revision surgery with conversion into four corners arthrodesis.

At our clinical and radiographic evaluation, one year later, the patient showed four corners pseudarthrosis with pain (VAS: 6) and low grip strength (8.1 kg). The patient therefore underwent implant removal, resection of the residual proximal row carpal bones and RCPI implantation.

The last clinical and functional assessment 23 months later, showed the following results:

- Wrist ROM: extension 65°, flexion 60°, ulnar deviation 40°, radial deviation 15°
- Grip strength: 19.6 kg
- VAS: 1



**Figure 8.** radiographies before (a,b) and after (c,d) RCPI implantation in case 8.

- Radiographic examination showed correct articular alignment and regular RCPI implantation. No signs of bone resorption.

## Discussion

Conceived to support the proximal row carpectomy in the treatment of chronic degenerative conditions like SNAC/SLAC lesions and Kienböck disease, the resurfacing capitate pyrocarbon implant may feature as a useful surgical tool in all conditions in which the midcarpal joint is compromised. There are only a few reports in the literature about the use of RCPI in post-traumatic occurrences other than those for which the device was designed.

Three authors report the use of RCPI in capitate diseases. In 2010 Dereudre et al. (26) presented a case of avascular necrosis of the capitate in a young woman, treated with RCPI, not performing a PRC. It resulted in good results concerning daily activities and pain release, but a decreased range of motion was observed. In 2013 we presented two cases in which a chronic Fenton's syndrome (a scapho-capitate fracture accompanied by 180° rotation of the head of capitate and associated perilunate dislocation) was treated with the same method, with good final outcomes concerning pain and ROM (27). In these cases, however, we found it very challenging to perform surgery, because of the limited space to implant the prosthesis between scaphoid and hamate. In 2020 Ruijs et al. (28) reported two more cases of RCPI implanted for comminuted fracture of the capitate. In both cases, (a Fenton's lesion and an isolated comminuted fracture of the capitate pole), to perform the implant without PRC, authors used a spanning external fixator to provide temporary distraction, for a quite long time (three months and one month and a half respectively). Their clinical results, which were rather good, are reported at 21- and 29-months follow-up respectively, witnessing a long period of rehabilitation needed.

In our opinion, since the RCPI was designed to resurface the capitate after proximal row carpectomy, in case of proximal row preservation care should be taken to choose the proper implant. In fact, other appropriate implants have been produced in recent years (20).

Analyzing our case history, the use of the RCPI made it possible to manage various complex clinical conditions, for which other surgical procedures and devices could involve a failure (as a proximal row carpectomy alone), greater risks of complications (total wrist implants) or worse results from a functional point of view (total arthrodesis). In case n.1, a transscafo-transcapitate perilunate fracture-dislocation was probably undertreated, resulting in a capitate pole necrosis and an atrophic non-union of the scaphoid, with severe wrist ankylosis and pain. The PRC, associated with the capitate proximal pole replacement by RCPI, led to a complete solution of pain and a satisfying ROM and strength restoration at long term follow-up. In case n.2, a lunate dislocation long-term outcome led to a pan-arthritis, and was treated with a PRC/RCPI procedure. In this case a severe ulnar instability of the carpus led to the failure of surgery, because of the implant conflict with caput ulnae. In this case a surgical revision with conversion to total wrist arthrodesis was necessary, finally achieving the resolution of pain, a good restoration of strength, but the loss of wrist ROM. This case allows to consider RCPI a valid solution in complicated wrist disorder maintaining available a further salvage procedure such as total wrist arthrodesis. In case n.3, a surgical reconstruction for scapholunate dissociation failed and a PRC was performed. Six years later, onset of midcarpal joint painful arthritis compromised the result. The patient underwent surgical treatment with capitate proximal pole replacement with RCPI, saving wrist ROM, strength and achieving the almost absence of pain. In cases like this, in which a PRC has already been performed, the RCPI implantation in the capitate is more challenging, due to the shortening of the capsular wall and ligaments. However, implantation is still possible, allowing to resolve the secondary radio-carpal conflict. In case n.4, a peri-prosthetic RCPI infection was observed in a patient successfully treated 7 years before for a SLAC wrist. In this case the implant was removed and infection was managed by placement of an antibiotic spacer molded on the lunate fossa. A new prosthetic implant was afterwards performed implanting a larger size RCPI, obtaining final good results on mobility, functionality and pain relief. In case n.5, a spontaneous wrist arthrodesis in an arthritic patient

was treated. The patient complained irreducible flexion of the wrist, which was treated with the resection of the proximal carpal row, associates with radial stiloidectomy and RCPI implantation. Grip strength, aesthetic and functional outcome improved with a neutral wrist position gained, even though the patient did not recover any wrist mobility. We believe, according to the obtained results, that in this kind of patients, although it was worthful to attempt to save wrist ROM, an arthrodesis to correct the position of the wrist could have been considered since the beginning. In case n.6, outcomes of an articular chondrocalcinosis led to a severe wrist arthrosis with a massive radial cyst. The patient presented severe pain and decreased strength and motion. Cancellous bone from the resected carpal bones was usefully exploited to fill the distal radius cystic space and a RCPI allowed to restore a not painful articular joint with increased strength and motion. In case n.7, a post-operative wrist infectious complication and a subsequent algodystrophic evolution, led to a stiff and flexed joint, accompanied with chronic pain and grip strength decrease. The PRC/RCPI surgery led to a satisfying ROM and strength restoration and pain disappearance. In this case, as in Case n.4, bone resorption was present at last follow-up radiography, due to bone remodeling probably correlated to the previous infection. However, the bone resorption did not compromise the pyrocarbon implant function and results, as RCPI is a loose fit implant that, differently from other prosthesis, does not necessitate an appropriate bone stock or regular surfaces. In case n.8, a painful nonunion in a four-corner arthrodesis was treated by implant removal, resection of the residual proximal carpal row and RCPI. After this revision surgery patient reported no residual pain, good grip strength and motion and overall satisfaction. We believe, although it is not described in the literature (29), that in case of four-corner arthrodesis complications (pain or pseudoarthrosis), RCPI can be considered a valid alternative to total wrist arthrodesis.

We present a series of heterogeneous complex cases of carpal injuries outcomes. This paper could be a point of reflection on the use of this pyrocarbon implant as a salvage procedure in complex conditions that otherwise would have been more difficult to treat or more disabling for the patients. Among the considera-

tions about this series, in addition to the almost constant resolution of pain and average good recovery of motion and strength, there are the radiographic results. In all cases except the one with severe ulnar instability of the carpus, the radiological examinations at mid- and long-term follow-ups (mean of 4.3 years in this series) showed correct articular alignment and stable device implantation, sustained over time. Furthermore, no signs of bone resorption related to pyrocarbon were observed in any case at last follow-up. Pyrocarbon implants are more and more used in hand surgery (19,20). The longevity of the implant is not questioned, as pyrocarbon has been used as prosthetic cardiac valves since 1969, with no complication related to the material up to now (14).

As a result of this heterogeneous clinical experience, validated by long-term follow-ups in most cases, we think that the use of a resurfacing capitate pyrocarbon implant can be suggested as an option in the outcomes of various carpal injuries, which seriously involve the midcarpal and/or the radiocarpal joint. In case of failure, a secondary wrist arthrodesis can still be performed.

**Conflict of interest:** Each author declares that he has no commercial associations that might pose a conflict of interest in connection with the submitted article. Institutional Review Board approval was not required for this retrospective observational study.

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Received: 15 November 2021

Accepted: 23 December 2021

Correspondence:

Camillo Fulchignoni, MD

Hand Surgery and Orthopedics Unit, Department of Orthopaedics and Traumatology, Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome Italy

Largo A. Gemelli, 8. 00168 Rome, Italy.

Phone: +39 3317880630

Email : camillo.fulchignoni@gmail.com