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Radial head replacement with the MoPyC pyrocarbon prosthesis

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Background: Radial head fractures often pose therapeutic dilemmas. We present the early results of patients who underwent radial head replacement with the MoPyC prosthesis (Bioprofile, Tornier, Saint-Ismier, France).
Materials and methods: We re-evaluated patients who underwent post-traumatic radial head resection and implantation of the MoPyC prosthesis due to pain and motion restriction. All patients underwent radiographic evaluation. Clinical evaluation was performed using the Broberg-Morrey and the Mayo Elbow Performance Score (MEPS) scales.
Results: Thirty-two patients (20 men, 12 women; mean age, 54 years; 22 dominant upper limbs) were evaluated. Twenty had a comminuted radial head fracture (Mason IV, 15; Mason III, 5), 2 from radial head fracture malunion, and 10 had complex elbow injuries (comminuted radial head fractures with ligamentous ruptures with or without coronoid process fractures). Mean follow-up was 27 months (range, 21-46 months). The mean results at the latest follow-up were flexion–extension, 130° (range, 105°-150°); pronation, 74° (range, 60°-80°); and supination, 72° (range, 60°-80°). No laxity was evident during valgus and varus stress tests. Mean grip strength was 96% of the contralateral side. Broberg-Morrey scores were excellent in 33%, good in 44%, and fair in 23%. MEPS results were excellent in 80%, good in 17%, and fair in 3%. There were 6 cases of periprosthetic lucencies or osteolysis of the radius without any clinical signs of loosening.
Conclusions: Radial head replacement with the MoPyC pyrocarbon prosthesis (when performed in carefully selected patients) yields satisfactory results regarding range of motion and function of the elbow joint.
Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Radial head replacement; pyrocarbon

Fractures of the radial head and neck represent 1.7% to 5.4% of all fractures that necessitate treatment[23] and almost 33% of all elbow fractures.[25] This type of fracture was formerly treated mainly by immobilization when it was simple[8] and by radial head excision if displaced or comminuted.[19] The currently implied method of treatment is more or less clear for Mason type I and II radial head fractures. It is in the more severe cases of Mason type III (Figs. 1 and 4) fractures that the method of treatment is according to the surgeon's personal preference, and based on his or her experience, open reduction and internal

This study was approved by our institution's scientific research board.

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Figure 1 Anteroposterior radiograph of the elbow joint shows a Mason type III fracture of the radial head.

fixation or radial head resection and use of a prosthesis may be used.

Among the latest types of radial head prostheses that are currently being used is the modular pyrocarbon radial head prosthesis. Aim of this study is to present the clinical, functional, and radiographic midterm results in patients who sustained a radial head fracture and subsequently underwent treatment with the MoPyC pyrocarbon prosthesis (Bioprofile, Tornier, Saint-Ismier, France).

Patients and methods

This retrospective case-series study included patients who were treated operatively with replacement of the radial head with the MoPyC pyrocarbon prosthesis. The study enrolled 32 patients (20 men, 12 women) who were a mean age of 54 years (range, 32-68 years). The dominant side was affected in 22 patients. All patients complained of pain and restricted range of motion. The fractures were comminuted radial head fractures in 20 patients (5 patients had Mason type III and 15 patients had Mason type IV fractures), malunion of a radial head fracture in 2, and complex elbow injuries (ligamentous ruptures with comminuted radial head fractures with or without coronoid process fractures) in 10 (Table I).

The mean time between the fracture and the surgery was 2.1 days, excluding the 2 patients with malunion of the radial head who underwent operations 6 and 9 months after the fracture, respectively. In all patients, this was the first procedure for treating the fractured radial head.

The patient was positioned supine on the operating table under general anesthesia. A tourniquet was applied in all patients; although the tourniquet might not be used, it can be a useful adjunct in certain situations. After flexion of the affected elbow and pronation of the affected forearm, the patient's hand was secured on his or her draped chest or on the operating table. Pronation of the forearm was necessary to move the posterior interosseous nerve medially and to keep it away from the operative field.[14]

The posterolateral (Kocher) approach was used by the same surgeon in all patients. Only the annular ligament was divided, when needed, and resutured after the prosthesis was introduced. The radial head was reached between the anconeus and the extensor carpi ulnaris muscles and through the radiohumeral joint capsule. The radial head fragments were removed, and after a guided osteotomy of the radial neck with the saw, the radial head was fully excised. The osteotomy was performed at an angle of 15° to the plane of the articular surface of the radial head. The radial head was reassembled on the operating table to make sure that no fragments were left within the capsule and to determine the sizing of the head of the prosthesis.

After the radial shaft was prepared and the stem of the prosthesis was sized with the corresponding trial rasps, the prosthesis stem was introduced into the radius. Care was taken regarding the height of the prosthesis (Fig. 2). Ideal positioning necessitates a distance of 1 to 2 mm between the prosthesis and the humerus (capitellum) when the elbow joint is at 90° of flexion.

As mentioned, the size of the stem is determined by the rasps, which correspond to the 3 stem sizes of the prosthesis, whereas the neck size determines the height of the prosthesis because there are 4 sizes. After the prosthesis was placed, the elbow was evaluated for instability and ligament integrity through varus and valgus tests and the ligaments were restored, if needed (Table I).

Postoperatively, an arm sling was used for resting the arm, and physiotherapy with passive mobilization was initiated on the second day. From postoperative day 10 and up to 3 to 4 weeks, active assisted exercises were performed, and strengthening exercises were performed from the week 6 and on.

Results

To have accurate results, several parameters were evaluated. The patients were first evaluated with a visual analog scale regarding the pain. Range of motion (flexion, extension, pronation and supination) and results of the grip-strength and the varus and valgus stress tests of the affected elbow were recorded. Detailed radiographic evaluation was performed to assess the osteointegration of the stem and the appearance of the humerocapitellum cartilage and the distal radioulnar joint. Patients were further evaluated with the Broberg-Morrey score[2] and the Mayo Clinic Elbow Performance Score (MEPS), which evaluates dressing, grooming, eating, and personal hygiene.[26] The mean follow-up time of our study was 27 months (range, 21-46 months).

The mean flexion–extension arc of motion was 130° (range, 105°-150°), the mean pronation was 74° (range, 60°-80°), and the mean supination was 72° (range, 60°-80°). No clinically apparent laxity was noted in any patient while performing the valgus and varus stress tests, and the mean grip-strength was 96% of the contralateral side. As

Table I Patients and treatment

No. of patients (N = 32)	Type of injury	Treatment	Complication	Additional treatment
2	Malunion 1 patient: 6 months postfracture 1 patient: 9 months postfracture	Radial head excision and replacement	1 patient: extension lag of 30° 1 patient: radiographic signs of heterotopic ossification without clinical manifestation, but with ossification of the LCL	Column technique was performed as described by Mansat and Morrey[21] for release of the anterior joint capsule in the patient with the extension lag.
5	Radial head fracture Mason type III	Radial head excision and replacement	1 patient: radiographic signs of heterotopic ossification without clinical manifestation, but with ossification of the LCL	
15	Radial head fracture Mason type IV	Radial head excision and replacement	1 patient: radiographic signs of heterotopic ossification without clinical manifestation, but with ossification of the LCL	
5	Radial head fracture with fracture of the coronoid process and rupture of the MCL	Radial head excision and replacement	1 patient: radiographic signs of heterotopic ossification without clinical manifestation	
3	Radial head fracture and rupture of the MCL	Radial head excision and replacement	2 patients: radiographic signs of heterotopic ossification without clinical manifestation	
2	Radial head fracture and rupture of the LCL	1 patient: Radial head excision and replacement and suturing of the stubs of the torn LCL 1 patient: Radial head excision and replacement and reconsruction of the LCL with Palmaris longus tendon auto graft.	1 patient: radiographic signs of heterotopic ossification without clinical manifestation	

LCL, lateral collateral ligament; *MCL,* medial collateral ligament.

determined by the Broberg-Morrey score, results were excellent in 33% of the patients, good in 44%, fair in 23%; and bad in 0%. Results according to the MEPS score were excellent in 80%; good in 17%; fair in 3%, and bad in 0% (Table II).

Two patients presented with periprosthetic lucencies of the radius; however, when these 2 patients were clinically assessed, no signs of loosening were apparent. In another 4 patients, there were radiographic signs of stress-shielding osteolysis under the neck of the radius, but again, without any clinical signs assessed at the latest follow-up visit. The mean size of the stress-shielded area was 4 mm (range, 1-8 mm) and appeared during the first 4 to 8 months postoperatively, with no progression until the latest follow-up visit. Radiographic signs of heterotopic ossification were also noted in 7 patients; however, none of the patients had clinical manifestation or limited range of motion. Three of those patients showed ossification of the lateral collateral ligament. Because there was no clinical evidence, no treatment was administered.

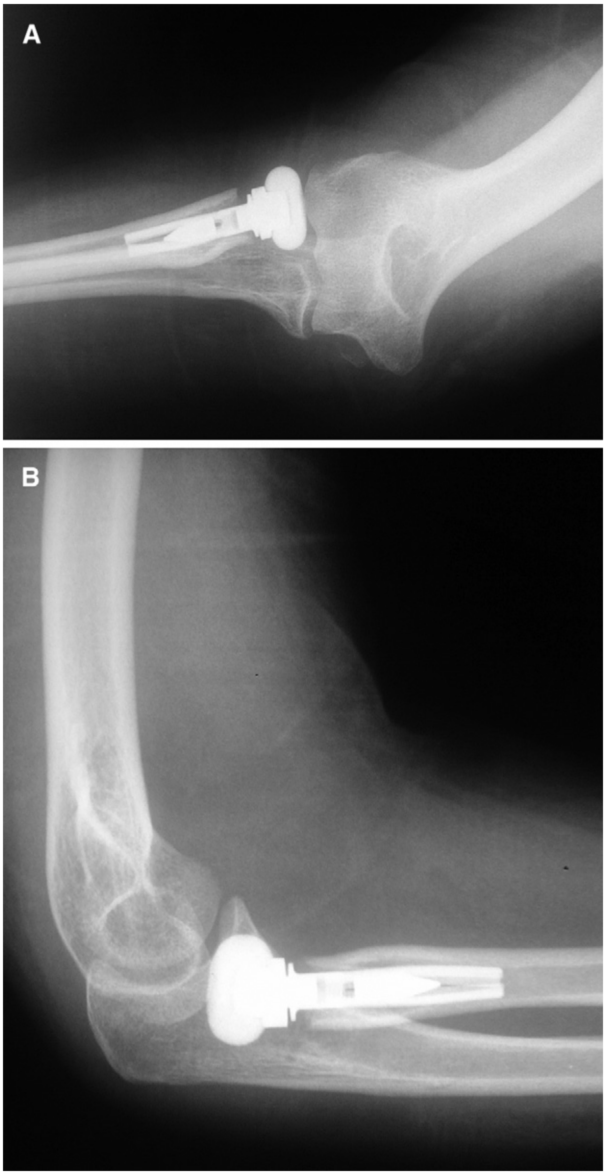

Figure 2 (**A**) Anteroposterior and (**B**) laterolateral radiographs of the elbow show the postoperative result after radial head replacement with MoPyC prosthesis.

Complications included 2 patients with stem–neck dissociation (Fig. 3), both of which occurred 5 weeks postoperatively, and were treated by surgical removal of the pyrocarbon head under local anesthesia (Fig. 4). This complication may have been caused because the surface of the taper had not been thoroughly cleaned and dried before the final impaction.

Also, the strength applied for the impaction is insufficient, but the manufacturers announced that a new direct impactor is under validation to facilitate impaction, therefore resolving this problem. However, until this impactor is validated, the method we used was to impact the radial head with a reversed trial radial head as a direct impactor.

One patient treated for radial head malunion postoperatively had extension of the elbow up to 35° and was therefore treated surgically according to the column procedure for release of the anterior capsule, as described by Morrey et al.[21] The elbow extension at the latest follow-up was 10°.

Discussion

The decision on how to treat a Mason type III radial head fracture may be a difficult task. Open reduction and internal fixation (when possible) should always be the first choice, and only if that is impossible should radial head resection and prosthetic insertion be done. Although radial head resection after fracture has yielded satisfactory long-term results[17] in the past and was thought to be the treatment of choice (when reconstruction was not possible),[24] treatment with placement of a radial head prosthesis seems more appealing nowadays, mainly due to the instability of the elbow that develops after the excision of the radial head.[15,27] Another reason that favors the placement of radial head prosthesis is that with Mason type III or IV fractures, the surrounding soft tissue has also sustained damage, therefore rendering the elbow joint unstable. Furthermore, displaced and unstable fractures of the radial head and neck are usually associated with other fractures and ligament injuries that create instability to the elbow.[7]

Indications for radial head replacement have been set nowadays. Ring et al[31] reports that radial head fractures with 3 or more fragments should be removed and replaced by a prosthesis. Harrington et al[12] showed that radial head excision is still a valid option in an otherwise stable elbow, whereas head replacement should be performed if the elbow joint is unstable after the radial head resection. Hall et al[11] described a series of patients with posterolateral rotator instability of the elbow after radial head resection. Nevertheless, recent studies[13,16,29] report that even if the ligaments and interosseous membrane are intact, radial head excision may lead to pain, instability, proximal radial migration, decreased grip strength, osteoarthrosis, and cubitus valgus.

The main goal of the radial head prosthesis is to provide satisfactory results with respect to 4 important functional parameters: stability, motion, pain, and strength. Many types of radial head prostheses were developed throughout the years.

Speed[33] published the first series of ferrule caps for the radial head. An acrylic prosthesis was introduced by Cherry[4] and a silicone implant by Swanson et al,[34] which remained popular for many years even though its use was accompanied by several complications (implant breakage, silicone–associated giant cell synovitis).[9,28,35,36,37] Carn et al[3] showed that silicone implants deformed under stress and did not support the radius on the capitellum.

Table II Results

Pt	Type of injury	Flexion- Extension (deg)	Pronation (deg)	Supination (deg)	Grip strength (%)	Assessment scale	
						Broberg-Morrey	MEPS
1	Malunion	130	80	76	94	Excellent	Excellent
2	Malunion	105	62	60	90	Fair	Fair
3	Mason III	140	78	70	98	Excellent	Excellent
4	Mason III	140	78	74	100	Excellent	Excellent
5	Mason III	135	76	74	100	Good	Excellent
6	Mason III	135	74	70	100	Good	Excellent
7	Mason III	140	76	74	98	Excellent	Excellent
8	Mason IV	135	74	70	96	Good	Excellent
9	Mason IV	125	68	66	92	Fair	Good
10	Mason IV	130	70	70	96	Good	Excellent
11	Mason IV	120	70	70	96	Fair	Excellent
12	Mason IV	130	72	70	100	Good	Excellent
13	Mason IV	135	76	76	98	Excellent	Excellent
14	Mason IV	135	76	76	94	Good	Excellent
15	Mason IV	120	72	68	92	Fair	Excellent
16	Mason IV	135	78	74	96	Excellent	Excellent
17	Mason IV	135	76	72	96	Excellent	Excellent
18	Mason IV	130	74	72	98	Good	Excellent
19	Mason IV	120	68	68	92	Fair	Good
20	Mason IV	135	78	76	98	Excellent	Excellent
21	Mason IV	125	70	70	96	Fair	Excellent
22	Mason IV	135	78	76	98	Excellent	Excellent
23	Radial head, coronoid MCL	130	74	74	96	Good	Excellent
24	Radial head, coronoid MCL	125	66	68	94	Good	Excellent
25	Radial head, coronoid MCL	135	76	74	96	Good	Excellent
26	Radial head, coronoid MCL	120	68	68	94	Fair	Good
27	Radial head, coronoid MCL	130	76	76	96	Good	Excellent
28	Radial head, MCL	135	78	76	98	Excellent	Excellent
29	Radial head, MCL	135	78	74	98	Excellent	Excellent
30	Radial head, MCL	130	76	74	96	Good	Excellent
31	Radial head, LCL	135	76	74	92	Good	Excellent
32	Radial head, LCL	125	76	74	94	Good	Excellent
Mean score		130	74	72	96		

LCL, lateral collateral ligament; *MCL*, medial collateral ligament; *MEPS*, Mayo Elbow Performance Score.

These complications, in addition to the evolution of the knee and hip total arthroplasty implants, led to the introduction of the metallic radial head prostheses that are currently and widely being used. However, these prostheses as well are accompanied by several complications and problems:

- The Vitallium prosthesis (Howmedica, London, UK), is associated with loosening and poor results.[20]
- The Judet bipolar prosthesis[18] (Tornier, Saint-Ismier, France) has 2 main disadvantages: (1) the radial head will tilt under any unbalanced or eccentric load across it, and (2) the head has the potential to disassociate from the stem.[30]
- Moro et al[22] revealed that the metal radial head implant is safe and effective for severely comminuted radial head fractures, but postoperative arthrosis developed in 20% of the patients treated.
- In another recent study, Grewal et al[10] restored 26 comminuted radial head fractures with a modular metallic prosthesis with very satisfactory results, even though osteoarthritic changes developed in 5 patients. One of the points they made was the ease of placement of the prosthesis due to its modularity.

Shore et al[32] reviewed 32 metallic radial head implants and concluded that metallic implants appeared to be safe and stable at 8 years postoperatively and that no implant required revision.

One of the latest designs of radial head implants is the modular pyrocarbon (MoPyC) radial head prosthesis (Bioprofile, Tornier, Saint-Ismier, France) that consists of a radial head made of pyrolytic carbon, an anatomic neck with an angulation of 15°, and a stem, both made of

Figure 3 A postoperative anteroposterior radiograph shows dissociation of the pyrocarbon radial head from the prosthesis neck at 6 weeks.

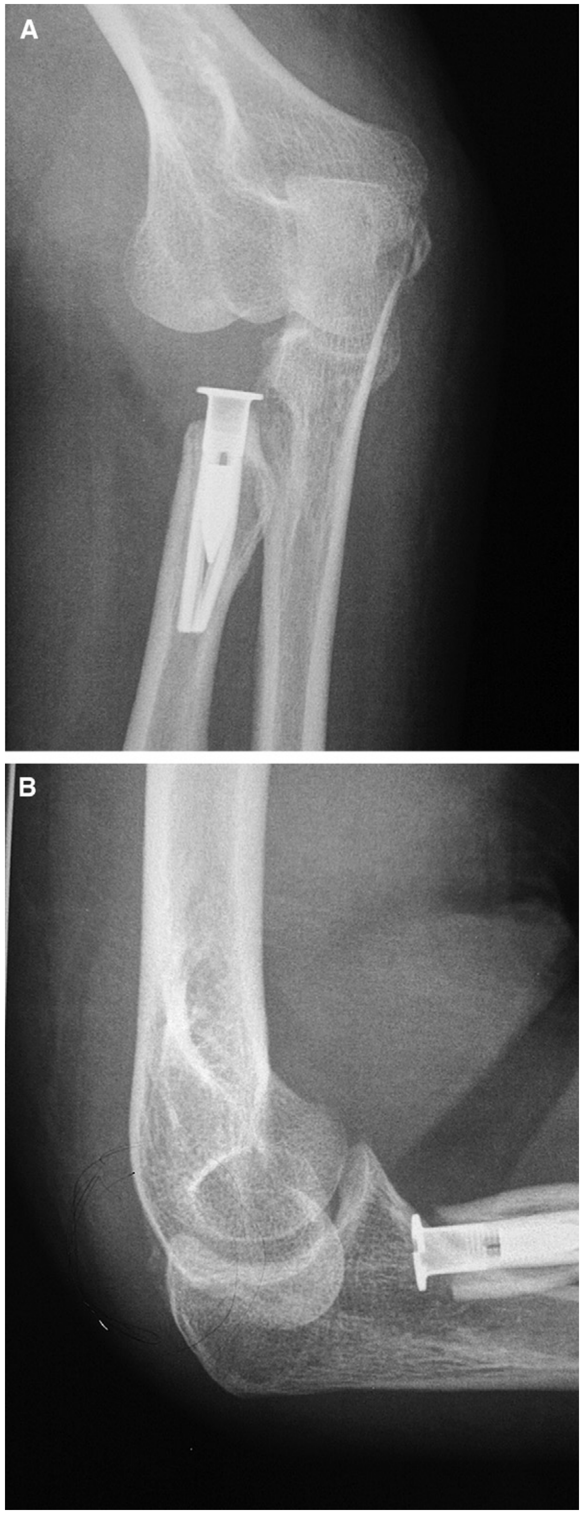

Figure 4 (**A**) Anteroposterior and (**B**) laterolateral radiographs show the elbow after the removal of the dissociated radial head of the prosthesis.

titanium alloy. There are 3 radial head sizes, 4 neck sizes, and 3 stem sizes.

Pyrolytic carbon is formed by the pyrolysis of hydrocarbon gas and is deposited as a coating onto a graphite substrate. The biocompatibility of this material is well known: it has been in use in artificial heart valves since 1969. In orthopedics it has been used in metacarpophalangeal and interphalangeal arthroplasties as well as in scaphoid implants. Pyrocarbon and bone have almost the same mechanical properties, and therefore, the former is expected to behave in a way very similar to the way the latter does. Its elasticity modulus is very close to that of the bone, hence allowing a good transmission of mechanical strength between bone and the implant, without any modification of the bone or the implant.

Apart from being very biocompatible and mechanically similar to the bone, pyrocarbon has also high wear resistance. Its polishing is superior to other materials that are used in implants, allowing in this way the capitellum to glide without wear. These characteristics of pyrocarbon were verified when 3 types of femoral head replacement implants were used (cobalt-chrome, titanium, and pyrocarbon) in 45 dogs for 2 to 18 months.[5,6] The results of the pyrocarbon implants were superior to the metal ones: the joint cartilage showed 92% survival with pyrocarbon but only 20% survival with the other implants.

Among the limitations of this study are that it is retrospective, a limited number of patients were included, and the follow-up time was relatively short.

Conclusion

Our results are in accordance with the only similar article in the literature[1] and show that the pyrocarbon implant is a very promising one. Still, care has to be taken in a few points. The 2 cases of impaction between the stem and the neck of the implant address this. The new direct impactor that is under validation by the manufacturers to facilitate better impaction may resolve this problem. More studies are certainly needed to find out whether these very satisfactory midterm results will stand the test of time.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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