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Short to midterm outcomes of one hundred and seventy one MoPyC radial head prostheses: meta-analysis

Pierre Laumonerie [1] · Meagan E. Tibbo [2] · Panagiotis Kerezoudis [3] · Marc Olivier Gauci [4] · Nicolas Reina [1] · Nicolas Bonnevialle [1] · Pierre Mansat [1]

Abstract

Background The MoPyC implant is an uncemented long-stemmed radial head prosthesis that obtains primary press-fit fixation via controlled expansion of the stem. Current literature regarding MoPyC implants appears promising; however, sample sizes in these studies are small. Our primary objective was to evaluate the short- to midterm clinical outcomes of a large sample of the MoPyC prostheses. The secondary objective was to determine the reasons for failure of the MoPyC devices.

Methods Four electronic databases were queried for literature published between January 2000 and March 2017. Articles describing clinical and radiographic outcomes as well as reasons for reoperation were included. A meta-analysis was performed to obtain range of motion, mean Mayo Elbow Performance score (MEPS), radiographic outcome, and reason for failure. **Results** A total of five articles describing 171 patients (82 males) with MoPyC implants were included. Mean patient age and follow-up were 52 years (18–79) and 3.1 years (1–9), respectively. Midterm clinical results were good or excellent (MEPS > 74) in 157 patients. Overall complication rate was low ($n = 22$), while periprosthetic osteolysis was reported in 78 patients. Nineteen patients returned to the operating room, with implant revision being required in ten patients. The two primary reasons for failure were (intra-)prosthetic dislocation ($n = 8$) followed by stiffness ($n = 7$); no painful loosening was described.

Conclusion Short- to midterm outcomes of MoPyC prostheses are satisfactory and complications associated are low. The use of stem auto-expansion as a mode of obtaining primary fixation in radial head arthroplasty appears to be an effective solution for reducing the risk of painful loosening.

Keywords Auto-expandable stem · Failure · MoPyC · Outcomes · Radial head arthroplasty · Radial head prosthesis · Survival

Introduction

One-third of fractures involving the elbow joint affect the radial head [29], and the treatment of Mason III fractures remains controversial [9, 10, 24, 38, 40, 41, 46, 50]. In cases of non-reconstructable radial head fractures, radial head resection yields satisfactory long-term results [4, 21, 25]. However, this procedure may result in progressive valgus instability, potential radial ascent, and secondary ulnocarpal injury, in addition to an alteration in elbow and forearm kinematics leading to a self-perpetuating cycle of degenerative changes [22–24, 47, 49, 50]. In the presence of associated ligamentous injury, superior functional results have been demonstrated with radial head arthroplasty (RHA) [26–28]. RHA is a therapeutic alternative that allows for maintenance of the integrity of the four columns of the elbow in cases of fractures that cannot be reconstructed via open reduction internal fixation (ORIF) [38, 40, 42]. Mid- and long-term functional results after RHA are good to excellent in 85% of cases (Mayo Elbow Performance (MEP) score > 74), according to a systematic review by Heijink et al. [21]. Nonetheless, it has been reported that tight-fitting radial head prostheses (RHP) may have inferior midterm survival than loose-fitting implants [2,

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5, 13, 15, 17, 21, 33–36, 38, 39]. Recently published data describe variable complication rates after RHA depending on the series [17, 21, 32]; re-operation rates ranged from 0 to 29% [21]. According to van Riet et al. [48], painful loosening is the primary reason for RHP removal.

The MoPyC implant is a monopolar device comprised of a titanium head, with a pyrocarbon neck and stem, allowing for 48 different prosthesis assembly combinations (Fig. 1). The uncemented long stem obtains primary press-fit fixation via an expansion device controlled by a dynamic screw. According to the current literature, midterm outcomes of this modular pyrocarbon prosthesis (Bioprofile Laboratory - Tornier, Grenoble, France) seem promising, with good overall patient function and low complication rates [1, 3, 16, 19, 31, 43, 45]. The series describing these devices, however, have small sample sizes [1, 16, 31, 43, 45].

The primary objective of the present study is to evaluate *the short to midterm* clinical outcomes of tight-fitting prostheses that use auto-expanding stem fixation. The primary hypothesis is that *short to midterm* clinical outcomes of MoPyC implants are satisfactory. The secondary objective is to determine the reasons for failure of the MoPyC devices. The secondary hypothesis is that painful loosening represents the primary reason for reoperation in RHP with auto-expanding stem fixation.

Fig. 1 Image depicting the MoPyC radial head prosthesis with a titanium head, and a pyrocarbon neck and stem (Bioprofile Laboratory Tornier, Grenoble, France)

Materials and methods

Literature search strategy

A literature search was performed using Ovid Medline, Ovid Embase, Scopus, Cochrane Library, and the Medical Subject Headings vocabulary. The search was limited to English language literature; terms used were combined with "AND" and "OR": "radial head," "arthroplasty," "prosthesis," "radial head prosthesis," and "radial head arthroplasty." The reference lists in each study were reviewed in order to identify additional articles fulfilling the selection criteria.

Selection criteria

Articles were eligible for this review if they were original studies, published between January 2000 and March 2017, and if they reported clinical and radiographic outcomes as well as failure rates of MoPyC implants. Exclusion criteria were inadequate study design (meta-analysis; review of the literature, case report, and abstract for meetings), comparative study between RHA and another treatment method (e.g., open reduction and internal fixation, excision of the radial head), biomechanical or anatomic studies, and series including implants other than MoPyC devices or with a minimum follow-up less than 12 months.

Data extraction and critical appraisal

Data were extracted from manuscripts, tables, and figures. Two investigators (P.L. and N.R.) independently reviewed the full text of all eligible articles. When information was incomplete, the corresponding authors of the articles were contacted (Table 1).

Gathering of comprehensive data from each study (age, sex, hand dominance, associated injury, total number of RHA, RHA in an acute or delayed setting, and duration of follow-up after RHA) allowed for meta-analysis of the multiple patient cohorts as a single group. Clinical (range of motion and Mayo Elbow Performance score (MEPS)) and radiographic outcomes (periprosthetic osteolysis, loosening, heterotopic ossification, capitellar wear, overstuffing) of MoPyC implants were analyzed in order to test the first hypothesis. We also abstracted the presence of stiffness following RHA, which was defined as limited active and passive range of elbow movement [34]. Reasons for failure of RHA (re-operation with (or without) implant removal and mean time to re-operation) were assessed in order to test the secondary hypothesis.

Table 1 Patient demographics among articles reporting outcomes of MoPyC implants

	Abdulla et al. [1]	Gauci et al. [16]	Sarris et al. [44]	Ricón et al. [42]	Lamas et al. [31]	Overall
Country	Australia	France	Greece	Spain	Spain	
Year of publication	2015	2016	2013	2012	2010	2017
Study design	Retrospective Single center	Retrospective Single center	Retrospective Single center	Retrospective Single center	Retrospective Single center	Meta analysis
Patients' characteristics	21	43	32	28	47	171
Men, *n* (%)	9 (42.9%)	24 (55.8%)	20 (62.5%)	11 (39.3%)	18 (38.3%)	82 (47.9%)
Age (mean (range))	47 (18 79)	54,4 (22 77%)	54 (32 68)	54 (24 79)	51 (34 70)	52,1 (18 79)
Dominant upper limb, *n* (%)	12 (57.1%)	28 (65.1%)	22 (68.7%)	15 (53.6%)	32 (68.1%)	109 (63.7%)
Mean follow up in years (range)	1.8 (1 2)	3.8 (2 9)	2.2 (1.7 3.8)	2.7 (1 5.2)	4 (1 5)	3.1 (1 9)
Acute	21 (100%)	26 (60.5%)	30 (93.7%)	28 (100%)	47 (100%)	152 (88.9%)
Isolated Mason type III (M III)	15 (71.4%)	0	5 (15.6%)	0	27 (57.4%)	47 (27.5%)
M III + LCL and/or MCL	0	1 (2.3%)	5 (15.6%)	7 (25%)	3 (6.4%)	16 (9.6%)
M III + ulnohumeral dislocation	0	2 (4.6%)	15 (46.9%)	6 (21.4%)	10 (21.3%)	33 (19.3%)
Essex Lopresti	0	2 (4.6%)	0	0	2 (4.2%)	4 (2.3%)
M III + Monteggia	0	3 (7%)	0	6 (21.4%)	5 (10.6%)	14 (8.2%)
M III + ulnohumeral (no dislocation and no Monteggia)	0	1 (2.3%)	0	2 (7.1%)	0	3 (1.7%)
Terrible triad	6	17 (39.5%)	5 (16.7%)	7 (25%)	0	35 (20.5%)
Delayed	0	17 (39.5%)	2 (6.2%)	0	0	19 (11.1%)
Failure of fixation	0	6 (13.9%)	0	0	0	6 (3.5%)
Stiffness after fixation	0	5 (11.6%)	0	0	0	5 (2.9%)
Post traumatic sequelae	0	6 (13.9%)	2 (6.2%)	0	0	8 (4.7%)

Risk of bias assessment

Risk of bias was assessed using the criteria described by the Newcastle-Ottawa Quality Assessment Scale [39, 52] for observational studies. Stars were placed on the fulfilling criteria as is indicated in the Newcastle-Ottawa Quality Assessment Scale guidelines: clear definition of study population, clear definition of outcomes and outcome assessment, independent assessment of outcome parameters, sufficient duration of follow-up time, selective loss during follow-up, and the identification of important confounders and prognostic factors included in the study design.

Statistical analysis

We present continuous variables with means and standard deviations and categorical variables with frequencies and proportions. MEP scores between acute and delayed injuries were compared using Pearson's chi-square test; comparison of ROM was not feasible because standard deviations were not available in the original studies. The I^2 statistic was used to determine the percentage of total variation across studies secondary to heterogeneity rather than chance, with values greater than 50% representing substantial heterogeneity [18]. In the present meta-analysis, the DerSimonian and Laird random-effects model was utilized in order to take into account the clinical diversity between studies [12]. Specific analyses considering confounding factors were not possible because raw data were not available. Statistical analysis was conducted using an open-source software (OpenMetaAnalyst) [51]. Level of statistical significance was set at 0.05.

Results

Quality of studies

Our electronic search strategy yielded a total of 1312 studies. After exclusion of duplicates and irrelevant articles, 339 eligible articles remained. After detailed evaluation of the articles, five observational studies were included in the analysis. A summary of the search strategy is outlined in Fig. 2.

Population characteristics

A total of 171 patients were included in the current review. There were 82 males and 89 females with a mean age of 52 years (range, 18 to 79). The dominant hand was involved in 109 cases. One hundred fifty-two RHAs were performed acutely, and 19 for chronic radial head injuries or post-traumatic sequelae. Among the acute RHAs, there were 47

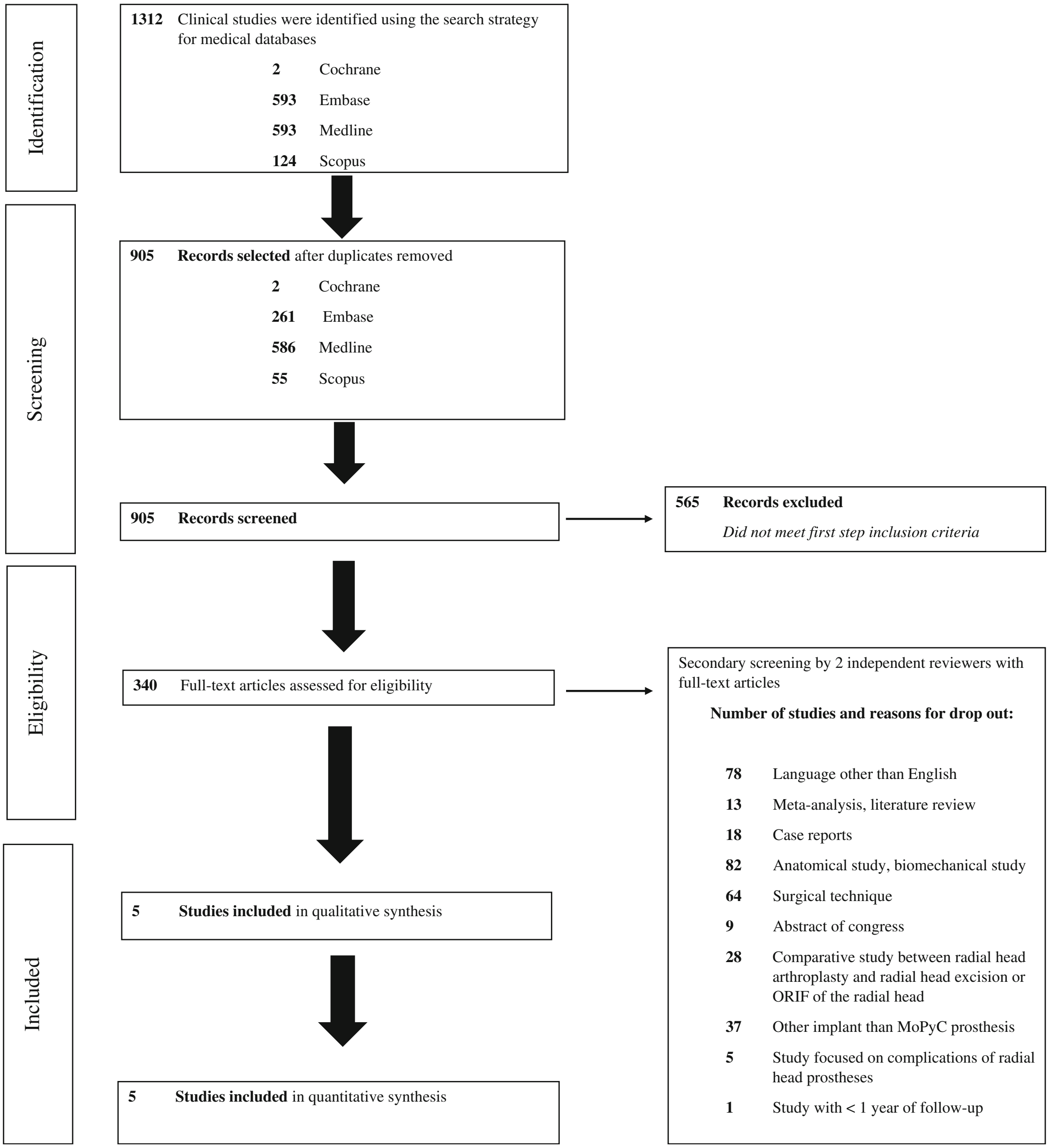

Fig. 2 Summary of search strategy (PRISMA flow chart) for relevant studies on outcomes of MoPyC implants and their reasons for surgical re intervention

isolated radial head fractures and 105 fractures associated with one or multiple other lesions. The mean follow-up for the entire cohort was 3.1 years (range 1 to 9). Population characteristics are reported in Table 2.

Reported percentages of RHA performed for acute injury in the literature ranged from 60.5 to 100% (pooled proportion 93%, [95% CI] = 86 to 99.8%, $I^2 = 99\%$), while chronic injuries comprised 0 to 39.5% (pooled proportion 7%, [95% CI] = 0.2 to 14%, $I^2 = 99\%$) of cases. Isolated radial head injury rates in the cohort ranged from 0 to 71.4% (pooled proportion 28%, [95% CI] = 9 to 47%, $I^2 = 99\%$), and additional lesion rates ranged from 28.6 to 100% (pooled proportion 72%, [95% CI] = 53 to 91%; $I^2 = 99\%$), respectively.

Clinical and radiographic outcomes

Clinical outcomes, including ROM and MEP scores, are shown in Table 2. The mean MEP score was 91.5 (range, 50–100). MEP scores were excellent or good in 140/152 cases (92%) undergoing acute RHA, and in 17/19 cases (89%) undergoing RHA in a delayed fashion. Statistical significance calculations could not be performed due to the significant variability in the sample sizes and lack of raw data from the individual contributing studies. Periprosthetic osteolysis ($n = 72$; 42.1%) was the primary adverse radiographic finding, located primarily around the radial neck ($n = 57$; 33.3%) (Fig. 3). Radiographic results are reported in Table 3.

Table 2 Clinical outcomes of RHA according to timing of treatment: acute or delayed

	Acute RHA *N* = 152	Delayed RHA *N* = 19	*P* value	Abdulla et al. [1]	Gauci et al. [16]	Sarris et al. [44]	Ricón et al. [42]	Lamas et al. [31]	Overall
Range of motion (ROM)									
Flexion extension arc	122.7	127.1		115.5	127	130	105	136	124.7
Pronation	75.3	74.2	N/A	81	71	74	80	81	77.0
Supination	73.56	72.26		77	76	72	85	76	76.8
MEP score									
Excellent or good (> 74)	140 (92.1%)	17 (89.5%)		16 (76.2%)	42 (97.7%)	31 (96.9%)	26 (92.9%)	42 (89.4%)	157 (91.8%)
Fair (60 73)	10 (6.6%)	2 (10.5%)	0.89	5 (23.8%)	1 (2.3%)	1 (3.1%)	2 (7.1%)	3 (6.4%)	12 (7.0%)
Poor (< 60)	2 (1.3%)	0		0	0	0	0	2 (4.2%)	2 (1.2%)

N/A not available

There were a total of 22 (12.9%) complications including 3 (1.7%) intra-operative complications and 19 (11.1%) re-operations. Nine patients (5.3%) underwent re-operation with implant retention and ten implants (5.8%) were revised. No re-operations for painful loosening were reported. These results are depicted in Table 4.

Risk of bias

Risk of bias was found to be low across all five studies (Supplemental Table 1).

Discussion

Our findings demonstrate satisfactory *short to midterm* results with a modular pyrocarbon implant and corroborate excellent outcomes of RHA recently published in the literature [5, 13, 17, 20, 35]. Although functional outcomes are promising, the description and analysis of results of MoPyC implants in the literature is scarce [1, 16, 31, 43]. Furthermore, this implant design is not currently available for use in the USA. According to Heijink et al. [21], midterm clinical results after RHA vary significantly according to design; monopolar pyrocarbon prostheses with auto-expanding stems, and bipolar cobalt chrome, press-fit implants, significantly outperform their counterparts with respect to clinical outcomes. Our meta-analysis, demonstrating excellent *short to midterm* survivorship and clinical results (MEP score > 74) for 157 (91.8%) of patients undergoing RHA with a MoPyC implant, confirms the aforementioned findings (Tables 3 and 4).

The rate of complications was low at 12.9% and consisted of three (1.7%) intra-operative complications as well as 19

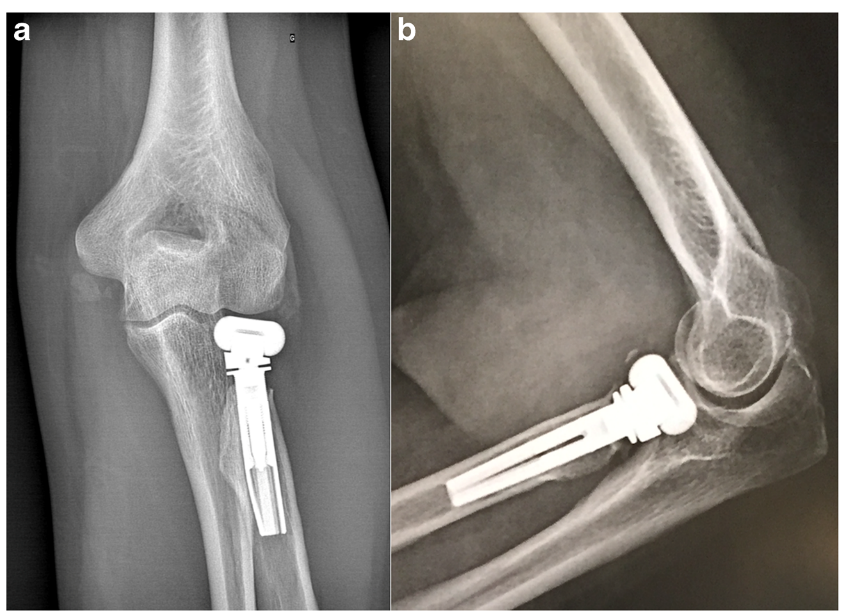

Fig. 3 Anteroposterior (AP) (**a**) and lateral (**b**) radiographs of the elbow demonstrating stress shielding around a MoPyC radial head prosthesis

Table 3 Radiographic outcomes of MoPyC implants in each study

	Abdulla et al. [1]	Gauci et al. [16]	Sarris et al. [44]	Ricón et al. [42]	Lamas et al. [31]	Overall
Periprosthetic osteolysis						
Neck	0	42 (97.7%)	4 (12.5%)	11 (39.3%)	0	57 (33.3%)
Stem	6 (28.6%)	0	2 (6.2%)	0	7 (14.9%)	15 (8.8%)
Loosening	0	0	0	0	4 (8.5%)	4 (2.3%)
Heterotopic ossification	12 (57.1%)	0	7 (13.5%)	5 (17.9%)	3 (6.4%)	27 (15.8%)
Capitellar wear	11 (52.4%)	9 (20.9%)	0	0	0	20 (11.7%)
Overstuffing (equivalent oversizing)	3 (14.3%)	14 (32.6%)	N/A	3 (10.7%)	0	20 (11.7%)

(11.1%) reoperations. Recently published complication rates after RHA ranged from 0 to 29% depending on the study; failure rates did not differ according to prostheses polarity, material, or fixation method [21]. The primary reason for failure of most RHA remains painful loosening [11, 14, 30, 32, 33, 50]; additionally, tight-fitting implants may be more prone to painful loosening [21, 33]. However, the two main failure modes affecting MoPyC implants are (intra)prosthetic dislocation (9; 5.3%) (Fig. 4) and stiffness (7; 4.1%) (Table 4). The former is unique to this implant, differentiating it from other designs in which this failure mode rarely occurs. Pyrocarbon head fracture and stem fracture are two additional failure modes specific to the MoPyC prosthesis [19]. The absence of painful loosening among 171 implants at *short to midterm* follow-up also appears to be unique to the MoPyC device; however, Lamas et al. [31] did report proximal migration of four implants without diagnostic confirmation of painful loosening. O'Driscoll and colleagues [35, 48] found that the best fixation strength in press-fit RHPs was achieved by the maximum diameter and length of prosthetic stem within the intramedullary canal. With this in mind, a long stem whose diameter expands automatically to fill the canal would seem to be an ideal design choice to achieve satisfactory stability in a tight-fitting implant. We also report an elevated rate of periprosthetic osteolysis around the neck (63 patients; 36.8%) consistent with stress shielding. According to Chanlalit et al. [8], stress shielding is common, typically minor, and unaffected by stem design; however, no auto-expanding stem systems were included in their analysis. Although a long-term study is certainly needed, we speculate that the rigidity of fixation obtained with the use of auto-expanding stem systems may explain both the significant stress shielding and the low rate of painful loosening compared to other prosthetic fixation methods [6, 19, 35, 48].

The most frequent reason of re-operation was stiffness (n = 7; 4.1%) after radial head arthroplasty [34]. According to a recent meta-analysis [34], a statistically higher rate of re-operation for stiffness was found with monopolar implants. However, the causes of stiffness are multifactorial and constitute a confounding bias which was not accounted for in our study. Post-operative stiffness can be affected by the severity of the initial injury, heterotopic ossification, complex regional pain, degenerative changes, and/or malpositioning of the implant [30, 34, 50].

Table 4 Complications and reoperations of radial head arthroplasty, among articles published between January 2011 and March 2017

	Abdulla et al. [1]	Gauci et al. [16]	Sarris et al. [44]	Ricón et al. [42]	Lamas et al. [31]	Overall
Intra operative complications	0	0	0	2 (7.1%)	0	3 (1.7%)
Neck fracture	0	1 (2.3%)	0	1 (3.6%)	0	2 (1.2%)
Intraprosthetic dislocation	0	0	0	1 (3.6%)	0	1 (0.6%)
Reason for revision	0	0	2 (6.2%)	3 (10.7%)	5 (10.6%)	10 (5.8%)
Intraprosthetic dislocation	0	0	2 (6.2%)	0	1 (2.1%)	3 (1.7%)
Implant dislocation (or posterior subluxation tendency)	0	0	0	3 (10.7%)	2 (4.2%)	5 (2.9%)
Stem fracture	0	0	0	0	1 (2.1%)	1 (0.6%)
Stiffness (arthrofibrosis)	0	0	0	0	1 (2.1%)	1 (0.6%)
Reason for re operation with implant retention	0	7 (16.3%)	0	2 (7.1%)	0	9 (5 3%)
Ulnar nerve palsy	0	1 (2.3%)	0	1 (3.6%)	0	2 (1.2%)
Radiocapitellar incongruity (MCL and/or LCL repair)	0	0	0	2 (7.1%)	0	2 (1.2%)
Stiffness (arthrofibrosis)	0	6 (13.9%)	0	0	0	6 (3.5%)

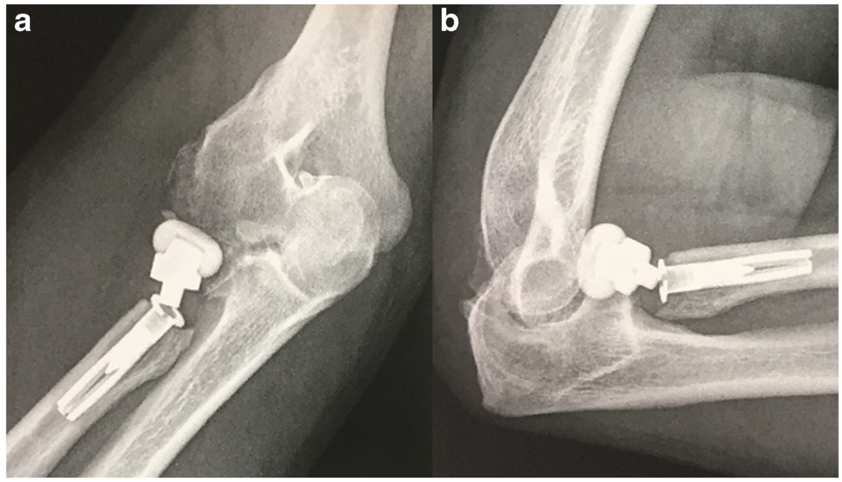

Fig. 4 Anteroposterior (**a**) and lateral (**b**) radiographs of the elbow depicting an intraprosthetic dislocation of the MoPyC radial head prosthesis

Biomechanical studies have demonstrated a significantly higher rate of instability among bipolar implants; this tendency was reaffirmed by clinical studies, though they lacked associated statistical evidence [6, 36, 44]. According to Moon et al. [37], the superior radiocapitellar stability of monopolar devices can be explained by increased concave compression of the implants, making monopolar prostheses the implants of choice in patients with associated ligamentous injury [6, 7, 37]. Despite the fact that MoPyC is a monopolar implant, radiocapitellar instability (9; 5.3%) was the primary reason for revision; this included intraprosthetic (4; 2.3%) and radiocapitellar (5; 2.9%) dislocation. Despite the seemingly low rate (2.3%), intraprosthetic dislocation accounted for 40% of the dislocations in our series and is extremely rare among other RHA designs. We hypothesize that the increased constraint at both the head-neck and head-capitellum junctions associated with expanding stem fixation lead to the elevated rate of intraprosthetic dislocation (Fig. 4) and stress shielding (Fig. 3) in our series.

Limitations associated with the retrospective, single-centre study design are the potential lack of heterogeneity in the sample, loss to follow-up, and confounding bias. The 171 cases of RHA with a MoPyC implant were gathered from five single-centre retrospective series [1, 16, 31, 43, 45], which could certainly allow for a single centre to bias the distribution of results (Tables 2, 3, and 4). The determination of reasons for failure constitutes a bias inherent in research performed using a posteriori consensus between two reviewers (P.L. and N.R.). The difference in group size between RHAs performed in an acute and delayed fashion did not allow for reliable comparative sub-group analysis of radiographic results. We analyzed a homogeneous series with respect to prosthesis type; however, there were a variety of associated lesions that could not be accounted for via comparative analysis during the follow-up period. The follow-up duration of each study should also be taken into account when interpreting results; only one study with a minimum follow-up greater than three years allows for satisfactory assessment of the true complication rate after RHA [34]. The lack of available data did not allow for adjustment based on injuries associated with radial head fractures. Malalignment of the proximal radius with respect to the capitellum was not taken into account during assessment of radiocapitellar instability among MoPyC devices. Furthermore, overstuffing, which plays an important role in radiocapitellar instability (posterior subluxation tendency), could not be determined [33, 47]. The influence of implant malposition, particularly overstuffing, on the rate of radiocapitellar instability could not be assessed in the present study. A comparative analysis needs to be carried out to help further our understanding of specific results among RHP fixation modes. Finally, although beyond the scope of the current work, future studies should also provide insights into the mid- and long-term outcomes following revision of RHA (including the MoPyC implant), such as improvement of stiffness.

Conclusions

In conclusion, short- to mid-term outcomes of MoPyC implants are satisfactory and complications associated with the devices are low. Fixation obtained via an auto-expanding stem seems to reduce the rate of early painful loosening. Additional long-term studies are needed to determine the specific risk of failure associated with each stem fixation method.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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