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Causes for early and late surgical re-intervention after radial head arthroplasty

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Abstract

Purpose The primary objective was to describe the reasons for surgical re-intervention after radial head arthroplasty. The secondary objective was to analyze the radiographic and clinical outcomes after surgical re-intervention at the elbow with implant conservation.

Methods Among the 70 radial head arthroplasties with bipolar radial head implant performed between 2002 and 2014, 29 required surgical re-interventions. Reasons for surgical re-intervention were gathered from operative notes and follow-up documentation. Patients who underwent re-intervention with implant retention were reassessed via clinical and radiographic examinations by an independent reviewer.

Results Twenty nine re-operations were performed at a mean follow-up of 16 ± 11.7 months (0.2–36 months). The prosthesis was removed in 18 cases and retained in 11. There was a significant difference in mean time to re-intervention between the implant removal and preservation groups, 23.1 ± 8.3 months (7–36 months) and 4.4 ± 4.7 months (0.2–13 months), respectively ($p < 0.001$). The primary reason for surgical re-intervention was painful loosening (13 cases). Radiocapitellar instability was the most frequent reason for re-intervention with implant retention (5 cases). Midterm quickDASH and MEPS after surgical re-intervention with implant retention were 15.4 ± 5.4 and 82.27 ± 7.3, respectively. At least one degenerative lesion was reported in nine cases (81.8%) (i.e. 5 periprosthetic osteolysis, 5 capitellar wear, 5 periarticular heterotopic ossification).

Conclusions Painful loosening and capitellar instability are the primary reasons for surgical re-intervention with or without implant removal. Midterm clinical results are favourable despite an elevated rate of degenerative lesions after surgical re-intervention with implant retention.

Keywords Radial head · Prosthesis · Removal · Revision · Radial head fracture · Complication

Introduction

Proximal radius fractures are the most common traumatic injury, and represent about one third of all elbow fractures [1]. Radial head prostheses (RHP) are reserved for acute, non-reconstructable Mason III fractures as well as chronic lesions including pseudarthroses, neck malunions, post-traumatic arthrosis and patients who are symptomatic after radial head resection [2]. In the case of non-reconstructable radial head fractures, simple radial head resection results in progressive valgus instability, potential radial ascent, secondary ulnocarpal injury, in addition to an alteration in elbow and forearm kinematics leading to a self-perpetuating cycle of degenerative changes [3–8]. Radial head arthroplasty (RHA) is the therapeutic alternative when osteosynthesis is impossible, and allows for maintenance of the integrity of the four columns essential to frontal and horizontal forearm stability [2, 9, 10]. No prosthetic design to date has the capability to precisely reproduce the anatomy and biomechanical properties of the native radial head [11–14]. Although functional outcomes are promising, description and analysis of complications in the literature is sparse. The most commonly reported reason for implant failure is painful loosening [15–20].

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From 2002 to 2014, three radial head prosthesis designs were used to treat acute, non-reconstructable radial head fractures and their post-traumatic sequela in the department of orthopaedic surgery at our institution: GUEPAR® prosthesis (Aston Medical) (Saint-Etienne, France), Evolutive® prosthesis (Aston Medical) (Saint-Etienne, France), rHead® RECON prosthesis (Stryker-Small Bone Innovation [SBI]) (Morrisville, Pennsylvania, USA).

The primary objective was to describe the reasons for surgical re-intervention (SR) after radial head arthroplasty (RHA) with a bipolar radial head prosthesis (RHP). The secondary objective was to analyze the midterm clinical and radiographic outcomes of patients in whom the RHP was retained after SR.

Materials and methods

The present study is a continuous retrospective, single-center study performed in an academic department of orthopaedics and traumatology. The inclusion criteria were: radial head arthroplasty requiring re-operation between 2002 and 2014. Exclusion criteria were: monopolar design, age under 16 years, and follow-up less than 24 months for patients who underwent re-intervention with implant retention.

Patients

Ninety-four patients underwent RHA between 2002 and 2014. Fifty-two patients were excluded: seven RHAs with monopolar implants (rHead® STANDARD), four patients with less than 24 months of follow-up, 41 did not undergo surgical re-intervention. Of the remaining patients, 13 were lost to follow-up. In total, 29 patients having bipolar RHP required a surgery associated with RHA (Fig. 1). These included 22 males and seven females with a mean age of 50.4 ± 11.2 years (20–73 years). The dominant hand was involved in 19 cases. There were 27 Mason III fractures and two neck fractures. Nineteen cases consisted of isolated radial head fractures and ten were associated with one or multiple other lesions. The associated injuries included 13 terrible triads, one Essex-Lopresti, one ulnar diaphyseal fracture and five trans-olecranon fracture-dislocations.

RHA was performed acutely in 18 cases, and for traumatic sequela in 11 cases (10 after open and 1 after closed reduction). At this institution, a call for tenders was performed for each radial head prosthesis model; the orthopaedic surgery department preselected one type of implant to be used for all RHAs for a limited period of time. The implant received by each patient was dependent on the institution's implant preference at the time of surgery. No randomization implants were performed as there was only one implant choice at the time of surgery for each patient in this study. The 23 prostheses (15 GUEPAR® and 8 Evolutive®) were bipolar prostheses with long (30 mm), cobalt-chrome, smooth stems that allowed for cement fixation. The six rHead® Recon prostheses were bipolar devices with short (16–22 mm), roughened stems that allowed for press-fit fixation; cementing (6) was deemed necessary intraoperatively in order to obtain satisfactory stability in the case of an insufficient press-fit (Fig. 2).

Evaluation method

Reasons for surgical re intervention

Pre-operative clinical and radiographic data, as well as surgical intervention data was gathered from consultation, hospitalization, and operative documentation for all 29 patients in the series. This information allowed for analysis of the cause and timing of re-intervention (with or without RHA conservation). Subgroups were created to facilitate further analysis based on timing of RHA (acute vs delayed), type of initial injury (isolated radial head fracture vs those with associated lesions), as well as prosthesis design.

Pre-operative proximal radial forearm pain according to O'Driscoll's definition [19] and a loose implant confirmed by the quality of prosthetic seating (described in the operative report) were used to identify painful loosening.

Analysis of the clinical and radiographic outcomes after re intervention in patients with RHA

An independent reviewer re-analyzed clinical and radiographic (AP and lateral views) data for those patients who underwent re-intervention with prosthesis retention.

Radiographic examination An analysis of degenerative lesions was performed using lateral elbow radiographs. Signs of periprosthetic osteolysis (Fig. 3), heterotopic ossification according to the Brooker classification system, and capitellar wear were evaluated at each post-operative follow-up visit until the final visit specifically for study purposes.

Clinical evaluation Analysis was possible in 11 cases where patients had retained their RHA at time of last follow-up. Range of motion of the operative elbow was compared to the contralateral side and measured by goniometer. Flexion and extension force was also compared to the contralateral side and measured by Kinedyn® dynamometer. Results were evaluated according to the Mayo Elbow Performance Score (MEPS) [21]. Functional evaluation was assessed using patient-completed surveys to calculate the Quick Disabilities of the Arm, Shoulder and Hand Score (quickDASH) [22]. If a re-intervention was required, the reasons behind it were also reported.

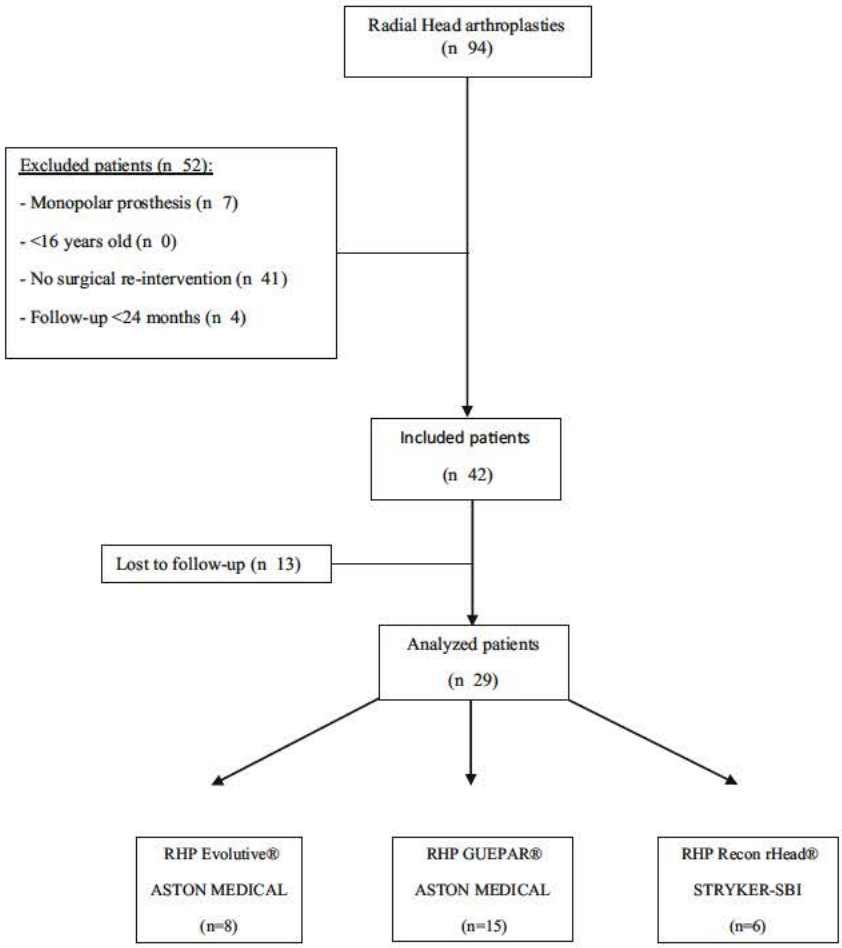

Fig. 1 Flowchart displaying the distribution of different models of prostheses (short and long stemmed implants) in the patient cohort

Statistical analysis

Statistical analyses of the data were carried out using Microsoft Excel® (Microsoft, Redmond, Washington, USA) and PASW® Statistics 17.0 (Addinsoft, SARL, Paris, Ile de France, France).

The objective was to describe the distribution of reasons for reoperation in patients having undergone arthroplasty with

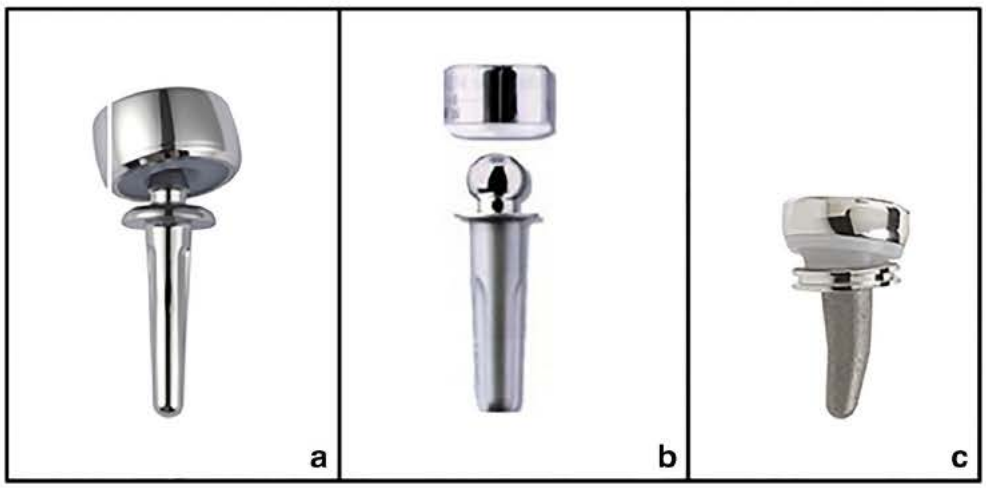

Fig. 2 Three bipolar radial head prostheses: Guepar® (**a**) (Aston Medical, Saint Etienne, France) and Evolutive® (**b**) (Aston Medical, Saint Etienne, France) are implants with long, cemented stems anchored beyond the neck (Guepar® (**a**) and Evolutive® (**b**) prostheses); rHead® Recon implant (**c**) (Stryker Small Bone Innovation, Morrisville, Pennsylvania, USA) has a short, press fit stem for high neck fixation and eventually cementation if stability is not obtained

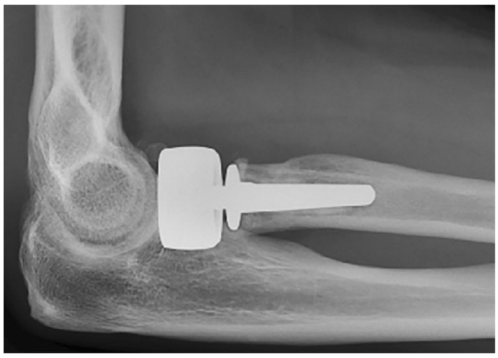

Fig. 3 Lateral radiograph of the elbow showing a radial head prosthesis (EVOLUTIVE® Aston Medical) with periprosthetic osteolysis

radial head prostheses. The reasons for re-intervention were described according to their absolute value and percentage (with respect to the appropriate subgroup). Fischer and Kruskal Wallis tests were used to perform the subgroup analyses with respect to reasons for surgical re-intervention (i.e. acute vs delayed, isolated vs non-isolated radial head fracture). The chi-square test was used to analyze the rates of re-intervention for each implant type and the rates of painful loosening according to the stem length (e.g., short vs long stemmed implants). The small sample size did not allow for statistical analysis of results by implant type for each subgroup. The Mann–Whitney U-test was used to assess the time to surgical re-intervention (with or without implant retention) after RHA.

The second objective was descriptive analysis of the clinical and radiographic outcomes of patients receiving surgical re-intervention with implant retention. Clinical results were described according to their means and standard deviations; radiographic results were described according to their absolute value and percentage (with respect to the appropriate subgroup). The Mann–Whitney U-test, Kruskall Wallis and Fisher tests were used to perform clinical and radiographic subgroup analyses.

Confidence intervals were fixed at 95%. Results were considered statistically significant if the p value was less than 0.05.

Results

Surgical re-intervention

Twenty-nine patients underwent re-operation during the study period. The overall mean time to re-intervention was 16 ± 11.7 months (0.2–36 months); there was no significant difference with respect to implant type ($p = 0.35$). Time to re-intervention was not statistically different in RHA performed in an acute versus delayed setting (9.9 ± 9.8 months vs 19.8 ± 11.3 months, $p = 0.14$), nor for those performed in cases of isolated radial head fracture versus those associated with other lesions (14 ± 10.6 months vs 17.1 ± 12.4 months, $p = 0.5$). Radial head fractures with one or multiple associated lesions were statistically significantly more numerous (19 [65.5%] vs 10 [34.5%], $p = 0.03$) than isolated fractures. The rates of RHA utilized in delayed (18 [62.1%]) and acute (11 [37.9%]) fashions were not significantly different in this series ($p = 0.11$). Painful loosening was the reason for 44.8% of all surgical re-interventions and 72% of all implant removals (Fig. 4); the rate of painful loosening of short-stemmed implants was significantly higher than that of RHP with long stem (6 [34.8%] vs 5 [83.3%], $p = 0.03$). The remaining reasons for surgical re-intervention are reported in Tables 1 and 2.

Eighteen RHP were removed at a mean follow-up of 23.1 ± 8.3 months (7–36 months) from initial RHA. The rates of RHA performed in a delayed fashion (6 [33.3%] vs 5 [45.4%], $p = 0.7$), and of radial head fracture with associated fracture (11 [61.1%] vs 8 [72.72%], $p = 0.7$) were not significantly different between the implant removal and conservation groups.

Eleven surgical re-interventions with RHP retention were performed at a mean of 4.4 ± 4.7 months (0.2–13 months) from initial RHA; the time to re-intervention was significantly shorter than the time to removal (4.4 ± 4.7 months versus 23.2 ± 8.3 months, $p < 0.001$). Radiocapitellar instability (5) was confirmed by the posterolateral rotatory apprehension test and treated using reconstruction of the capsule and lateral ligamentous complex. Ulnar neuropathy (3), stiffness secondary to Complex Regional Pain Syndrome (CPRS) (1) or humero-radial conflict (2), and radial cup dissociation (1) were treated with neurolysis, arthrolysis, conservative pain management, and re-implantation with re-tensioning of the lateral capsule and ligamentous complex, respectively.

Midterm clinical and radiographic outcomes after surgical re-intervention with implant retention

There were 11 patients who underwent surgical re-intervention with implant retention at a mean time to re-operation of 71.4 ± 35.5 months (24–107 months). There were no significant differences in this group with respect to timing of initial RHA: acute 70 ± 47.4 months (24–102 months) versus delayed 72.14 ± 46.7 months (29–107 months) ($p = 0.39$), or isolated versus non-isolated radial head fracture (78.3 ± 49.3 months [24–104 months] vs 63 ± 41.9 months [24–107 months], $p = 0.21$). Midterm clinical and radiographic outcomes are reported in Table 3.

Mean maximal motion about the elbow joint was 120.9 ± 15.6° (range, 100–150°) of flexion, −13.2 ± 12.7° of extension, 74.1 ± 7° of pronation, and 70 ± 7.42° of supination. Mean elbow flexion and extension force in the operative extremity were 87.7 ± 9.8% and 75.4 ± 7.6%, respectively, compared to the contralateral side. Mean quickDASH and MEPS were

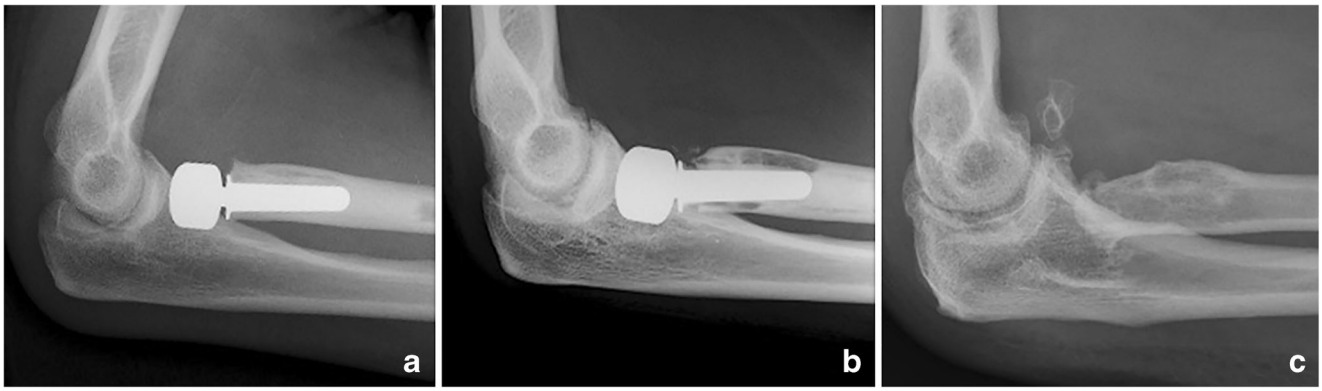

Fig. 4 Three sequential lateral radiographs of the elbow showing progressive loosening of a radial head prosthesis (Guepar®, Aston Medical, Saint Etienne, France), at follow up intervals of 0.7 and 1.6 years (**a**, **b** respectively). The implant had to be removed two years after the initial arthroplasty (**c**)

15.4 ± 5.4 points and 82.3 ± 7.3 points, respectively. No second surgical re-interventions were reported.

We identified degenerative lesions in nine (81.8%) patients. Lesions included five (45.5%) cases of periprosthetic osteolysis (Fig. 4), one case of early capitellar wear, and five cases of heterotopic ossification (four Brooker Grade I and one Grade II). There were no statistically significant differences in clinical or radiographic outcomes between the acute and delayed subgroups, nor between the isolated radial fractures and those with one or more associated lesions ($p > 0.05$).

Discussion

Radial head arthroplasty is the procedure of choice for acute, irreducible radial head fractures or traumatic sequela secondary to the same [10, 23–27]. Several radial head prosthesis (RHP) designs are currently available. Bipolar implants allow for more movement of the cup with respect to the capitellum, despite suboptimal reproduction of anatomic and biomechanical properties [14, 28, 29]. However, studies analyzing implant characteristics have demonstrated no significant difference in clinical outcomes and report high satisfaction for various designs at both short- and long-term post-operative follow-up [30–33].

The present series reports a high rate of re-intervention (41.4%), without significant differences according to implant type ($p = 0.3$). Recent publications report variable complication rates for RHP (i.e., rate of surgical re-intervention with implant removal ranged from 0 to 29% among studies) [15, 32, 34, 35]. Our study included a large proportion of devices implanted in a delayed fashion (37.9%) and a large proportion of radial head fractures with associated lesions (65.5%) treated by bipolar implants; this was compounded by variable

Table 1 Causes of surgical re intervention with respect to each implant

Parameter	Overall ($N = 29$)	Evolutive® ASTON medical ($N = 8$)	rHead® RECON SBI Stryker ($N = 6$)	GUEPAR® ASTON medical ($N = 15$)	*P* value
Mean time to surgical re intervention	16 ± 11.7 months (0.2 36 months)	9.5 ± 9.5 months (0.2 24 months)	21.2 ± 8.1 months (12 33 months)	17.5 ± 12.8 months (0.3 36 months)	0.35
* No implant removal	4.4 ± 4.7 months (0.2 13 months)	2.9 ± 2.4 months (0.2 6.8 months)	13 months	4 ± 5 3 months (0.3 12.6 months)	
* Implant removal	23.1 ± 8.3 months (7 36 months)	20.3 ± 4.7 months (15 24 months)	22.8 ± 7.8 months (12 33 months)	24.2 ± 9.7 months (7 36 months)	
Surgical re intervention with implant removal	18 (62%)	3 (37.5%)	5 (83.3%)	10 (66.7%)	0.19
Painful loosening	13 (44.8%)	1 (12.5%)	5 (83.3%)	7 (46.7%)	
Humero radial conflict	4 (13.79%)	2 (25%)	0	2 (13.3%)	
Radiocapitellar instability	1 (3.4%)	0	0	1 (6.7%)	
Surgical re intervention with implant retention	11 (61.1%)	5 (62.5%)	1 (16.6%)	5 (33.3%)	0.19
Radiocapitellar instability	5 (17.2%)	2 (25%)	1 (16.6%)	2 (13.3%)	
Ulnar neuritis	3 (10.3%)	2 (25%)	0	1 (6.7%)	
Humero radial conflict	1 (3.4%)	0	0	1 (6.7%)	

Table 2 Causes of re operation per patients demographics

Parameter	Early application ($N = 18$)	Delayed application ($N = 11$)	P value	Radial head fracture without associated lesion ($N = 10$)	Radial head fracture with associated lesion(s) ($N = 19$)	P value	Mean time to re intervention (months)
Surgical re intervention with implant removal	12 (66.7%)	6 (54.5%)	0.70	7 (70%)	11 (57.9%)	1	23.2 ± 8.3
Painful loosening	8 (44.4%)	5 (27.3%)	0.68	6 (50%)	7 (36.8%)	1	24.8 ± 7.5
Humero radial conflict	3 (16.7%)	1 (9.1%)	1	1 (10%)	3 (15.8%)	1	17.5 ± 9.5
Radiocapitellar instability	0	1 (9.1%)	0 38	0	1 (5.3%)	1	26
Surgical re intervention with implant retention	6 (33.3%)	5 (45.4%)	0.70	3 (30%)	8 (42.1%)	0.69	4.4 ± 4.7
Radiocapitellar instability	2 (11.1%)	3 (27.3%)	0 33	1 (10%)	4 (21%)	0.63	4.1 ± 6
Ulnar neuritis	2 (11.1%)	1 (9%)	1	0	3 (15.8%)	0 53	1.6 ± 1.3
Humero radial conflict	1 (5.6%)	0	1	1 (10%)	0	0 34	5.7
Stiffness after complex regional pain syndrome	1 (5.6%)	0	1	1 (10%)	0	0 34	8.8
Complete dissociation of the implant	0	1 (9%)	0 37	0	1 (5.3%)	1	10.6

experience levels (specifically with RHA) of each treating surgeon at our institution. We speculate that these factors may account for the high rate of re-intervention in our cohort [15, 17, 32, 34, 35].

According to Neuhaus et al. [17], 50% of RHP removals occur during the first year after surgery with a mean time to removal of 23 ± 42.25 months (0.5–144 months) [17]. Our study demonstrated that it may be possible to distinguish between two periods when following results of RHA within the first three years after implantation ($p < 0.001$). Early on (4.4 ± 4.7 months [0.2–13 months]), there are re-interventions with implant retention, and later (23.2 ± 8.3 months [7–36 months]) re-interventions involve implant removal. RHA performed in a delayed setting or in the case of fracture with additional associated lesions did not affect the time to surgical re-intervention ($p > 0.05$).

According to Van Riet et al., the four main reasons for re-operation in RHA are painful loosening, stiffness, instability and surgical site infection [20]. Our series found that loosening was the primary reason for failure of bipolar RHP (13 [44.8%] cases of surgical re-intervention) (Tables 1 and 2, Fig. 4). According to O'Driscoll, insertion force, as well as diameter and length of the stem determine the risk of loosening [36, 37]; this is consistent with the increased rate of painful loosening for the short-stemmed implants of the present study ($p = 0.03$). O'Driscoll found that the risk of loosening can be determined using the cantilever quotient (CQ) which can be calculated using the length of the radial head (R) and dividing by the total length of the implant (T) (Fig. 5). An elevated CQ (>0.4) increases the initial risk of instability and micromotion [36]. rHead® Recon implants with short stems (16–22 mm), high neck anchors, and radial head heights identical to other models, have a theoretically increased risk of initial instability compared to Evolutive® and GUEPAR® devices with 30-mm stems. Additionally, rHead® RECON devices were all found to have insufficient intra-operative stability after press-fit and required cementing to obtain satisfactory initial fixation. The ability to add cement to the interface means that the diameter of these prostheses was always less than the maximal diameter needed. According to Moon and colleagues, prostheses of sub-maximal size had micromotion (>250 μm) that exceed the threshold for bone ingrowth and initial stem stability [37]. We speculate that difficulties in obtaining satisfactory stability of rHead® Recon prostheses may predispose the surgeon to favour stability over implant positioning.

The results of this series have identified radiocapitellar instability in bipolar RHP (45%) as the most frequent reason for early re-operation (first year post-operatively) (Table 2) [29, 38]. Radial head fractures associated with one or multiple additional lesions had an elevated rate of radocapitellar instability (26.3%) when compared to isolated radial head fractures (7.1%; this confirms the importance of appropriate management of associated injuries [38]). Lack of fixation of a coronoid fracture and lateral collateral ligament incompetence are two main causes of radiocapitellar instability [15, 38, 39]. Repeated posterolateral dislocations increase the risk of hypermobility of the cup secondary to radiocapitellar instability and may lead to complete dissociation of the cup from the stem [15, 26]. Monopolar prostheses are the implants of choice in cases with associated ligamentous injury because they allow for superior radiocapitellar stability thanks to increased concave compression of the implants [28, 29]. Tissue integrity did not affect implant choice for each patient

Table 3 Midterm clinical and radiographic outcomes after surgical re intervention with conservation of the radial head arthroplasty

Variable	Radial head fracture with associated lesion(s) ($N = 5$)	Radial head fracture without associated lesion ($N = 6$)	P value	Early application ($N = 4$)	Delayed application ($N = 7$)	P value	Evolutive® ASTON medical ($N = 5$)	rHead® RECON SBI Stryker ($N = 1$)	GUEPAR® ASTON medical ($N = 5$)
Periprosthetic osteolysis (absolute values (%))	3 (60%)	4 (66.7%)	0.82	4 (100%)	3 (42%)	0.19	3 (60%)	1 (100%)	4 (80%)
Stem	3 (60%)	4 (66.7%)	0.82	4 (100%)	3 (42%)	0.19	3 (60%)	1 (100%)	3 (60%)
Neck	1 (20%)	1 (16.7%)	0.89	1 (25%)	1 (14.3%)	0.66	0	1 (100%)	1 (20%)
Capitellar wear (absolute values)	3 (60%)	2 (33.3%)	0.57	1 (25%)	4 (57.1%)	0.54	2 (40%)	0	3 (60%)
Brooker classification (mean values)	0.7 ± 0.9	0.3 ± 0.5	0.78	0.8 ± 1	0.2 ± 0.4	0.91	0.2 ± 0.4	0.7	0.7 ± 0.9
Range of motion (degrees)									
Flexion	121 ± 18.2	120.8 ± 15	0.55	128.8 ± 10.3	116.4 ± 17	0.47	132 ± 13	110	112 ± 12.5
Extension	16 ± 15.2	10.8 ± 11.1	0.73	12.5 ± 12.6	13.6 ± 13.6	0.61	6 ± 8.9	15	20 ± 14.1
Pronation	71 ± 2.2	76.7 ± 8.8	0.98	77.5 ± 6.4	72.1 ± 7	0.91	76 ± 6.5	60	75 ± 5
Supination	69.2 ± 6.7	71 ± 8.9	0.33	75 ± 4.1	67.1 ± 7.6	0.95	69 ± 8.9	65	72 ± 6.7
Force compared to contralateral unaffected side (%)									
Flexion	80.9 ± 4.9	96 ± 7.4	0.009*	93.7 ± 10.3	84.3 ± 8.4	0.94	73 ± 5.3%	75	88 ± 9.7%
Extension	75 ± 7.8	76 ± 8.2	0.50	77.5 ± 5	74.3 ± 8.9	0.70	72 ± 7.6%	70%	80.3 ± 6.1%
Mean MEPS score (points)	80.5 ± 8.90	84.4 ± 4.9	0.33	87.2 ± 5.9	81 ± 7.7	0.94	80.4 ± 9.9	81	84.4 ± 4.9
Mean QuickDASH score (points)	17 ± 4.90	13.6 ± 5.9	0.86	13.76 ± 5.7	16.4 ± 5.4	0.22	18.4 ± 5.5	12	13.2 ± 4.7

as only one design was available at the time of surgery for all patients in this series. We recognize this is an inherent limitation in our study as the bipolar is clearly used only when there is malignment of the proximal radius with the capitellum [28, 29].

Despite an elevated rate of degenerative lesions (9 cases, 81.8%) in the multiply-operated elbow (i.e. periprosthetic osteolysis, peri-articular heterotopic ossification), early re-intervention with implant conservation does not compromise

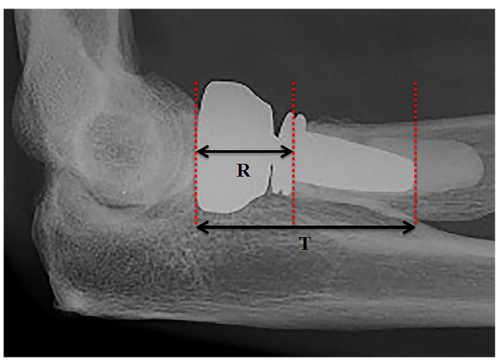

Fig. 5 The CQ ratio, describing the head length (R) divided by total implant length (T) of a prosthesis (lateral radiograph of rHead® RECON prosthesis), and exceeding 0.4. The risk of instability is significantly higher secondary to increased micromotion of this short stemmed implant

predicted midterm functional outcomes. The current series confirms excellent outcomes of RHA (mean quickDASH and MEPS of 15.4 ± 5.4 points and 82.27 ± 7.3 points, respectively), consistent with the results reported in the recent literature on non-reoperated RHP [9, 26, 40–44]. Considering the elevated rate of degenerative lesions in patients having undergone multiple operations, we speculate that surgical re-intervention after RHA, with or without implant removal, alters the midterm radiographic outcomes [31, 41, 42, 44].

The limitations of our study are related to its retrospective, single-center nature and the sample size. The study design is retrospective, which is inherently more susceptible to bias and to data loss secondary to issues with follow-up. The small number of patients did not allow for demonstration of statistically significant differences by subgroup. Additionally, the analysis did not take into account the impact of associated injuries on clinical results or failure of the arthroplasty. Meta-analyses with a larger sample sizes will be necessary in avoiding bias and providing a secure foundation for statistical analysis, especially with respect to defining specific mean times to removal and revision of RHPs. We analyzed a heterogeneous data set with long and short stemmed prostheses and a variety of associated lesions that were not accounted by comparative analysis in the follow-up period. The

difference in group sizes (acute or delayed application, and radial head fracture with or without associated lesions) did not allow for reliable comparative subgroup analysis.

Conclusion

Painful loosening is the primary reason for surgical re-intervention with implant removal, whereas capitellar instability was the most common reason for revision with implant retention. Two distinct periods within the first three years after implantation were identified, one included early re-intervention with RHA conservation and a second, later period involved implant removal. Midterm clinical results are favourable despite an elevated rate of degenerative lesions after surgical re-intervention with implant retention.

Compliance with ethical standards

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Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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