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Original article

Mason type III radial head fractures treated by anatomic radial head arthroplasty: Is this a safe treatment option?

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ABSTRACT

Background: Radial head fractures make up approximately 3% of all fractures and they are the most common elbow fracture in adults. Replacement through arthroplasty is the recommended treatment in the context of unstable elbow injury and comminuted radial head fracture. The midterm clinical, functional, and radiographic results in patients treated with anatomic radial head arthroplasty for a Mason type III radial head fracture are presented.
Material and methods: We performed a retrospective search of our facility's prospective trauma database to identify all skeletally mature patients who were treated by primary radial head replacement or open reduction and internal fixation following an acute radial head fracture. Inclusion criteria were Mason type III fractures and anatomic radial head arthroplasty (RHA). All the patients included were evaluated using a standard postoperative protocol including clinical and radiographic evaluation at 1, 3 and 12 months of follow-up. All the patients were reviewed clinically at an average of 30 months' follow-up.
Results: Forty-one subjects (32 Mason type III and 9 Mason IV fractures) were treated with anatomic RHA (Acumed, Hillsboro, OR, USA). Of these, two patients (1 Mason type III and 1 Mason type IV) were excluded from the analysis because severe cognitive impairment. Moreover, we decided to exclude the subjects with a Mason type IV fracture to obtain a more homogeneous sample. Therefore, 31 patients with a Mason type III fracture were included in this study. Based on the Mayo Elbow Performance Score, excellent results were obtained in 24 (77%) patients, good in 3 (10%) and fair in 4 (13%) patients. Heterotopic ossification was reported in 8 patients (26% of cases). The final elbow flexion-extension range of motion was of 112°, with a mean flexion of 125°. The final forearm rotational range of motion was 134° with a mean pronation of 68° and a mean supination of 66°.
Discussion: Anatomic radial head replacement leads to a good functional recovery, even in the presence of severe instability, such as coronoid fractures and LUCL injury. However, patients should be informed of the high number of adverse events (mainly heterotopic ossification) following this treatment.
Level of evidence: Therapeutic IV.

1. Introduction

Radial head fractures make up approximately 3% of all fractures and they are the most common type of elbow fracture in adults [1,2]. These fractures usually result from a fall on an outstretched arm with the forearm pronated; they range from simple fractures to those associated with complex elbow instability [3]. Normally, most radial head fractures without associated fractures or ligament injuries are inherently stable, even when displaced more than 2 mm [4]. Displacement of 2 or 3 mm has been cited as a criterion for surgical treatment, but this magnitude of displacement can happen with a stable fracture [3,5,6]. Surgical management options for displaced fractures with associated elbow instability include open reduction and internal fixation (ORIF) and radial head arthroplasty (RHA) [3,7,8].

Fragmentation and instability are two factors that can influence the outcomes of ORIF [9]. Fractures with more than three fragments treated with ORIF have dissatisfaction rates of 54% [3]. These kinds of fractures are usually not fixed and are better treated with RHA [10,11]. Dou et al. performed a meta-analysis comparing the clinical efficacy of RHA versus ORIF for Mason type III radial head fractures. They found a significantly higher postoperative rate of excellent and good outcomes, better Bromberg–Morrey elbow scores, and a lower postoperative complication rate in patients treated with RHA [12]. Bain et al. suggest that RHA is indicated when more than 30%

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of the articular surface is involved [13]. RHA is also indicated for displaced, unstable, fragmented fractures of the radial head that occur during elbow fracture-dislocation [14].

The aim of this study was to present the midterm clinical, functional, and radiographic results in patients who sustained a Mason type III radial head fracture and subsequently were treated with anatomic RHA.

2. Material and methods

2.1. Study cohort

We performed a retrospective search of our facility's prospective trauma database to identify all skeletally mature patients who were treated by primary radial head replacement or ORIF because of an acute radial head fracture. Fractures were classified based on Mason's classification [1], as modified by Johnston [15]. Inclusion criteria were Mason type III fractures and anatomic RHA. Patients under 18 years of age, with severe cognitive impairment, and with less than 12 months' follow-up were excluded.

2.2. Surgical technique

The posterolateral (Kocher) approach between the extensor carpi ulnaris and anconeus was used in all patients. Radial head fracture fragments were removed and used to determine the diameter of the radial head prosthesis needed. We prefer to use a slightly smaller diameter, based on the fracture fragments, to implant a radial head prosthesis that is more like the bony part of the native radial head, excluding the cartilage component. This allows us to more closely reproduce the native radial head size on X-rays.

The correct prosthetic collar height was evaluated by placing the elbow in 90° flexion and forcing the olecranon against the distal trochlea; this reduces the elbow joint and prevents overestimation due to a concomitant lateral ulnar collateral ligament (LUCL) injury [16]. In all patients, the Acumed anatomic radial head system (Acumed, Hillsboro, OR, USA) was used. We prefer this design to nonanatomic implants, since we believe this prosthesis provides greater radiocapitellar joint stability, in the absence of the tip of the coronoid process, especially in cases of posterolateral elbow dislocation characterized by posterior displacement of the radial head relative to the capitellum, associated with LUCL injury.

When the LUCL was injured, it was repaired using either bone tunnels (in case of complete tear) or suture anchors (in case of partial tear). Tunnels were drilled at the isometric point of the lateral epicondyle and at the LUCL's insertion on the ulna. If instability persisted at this point, we also repaired the coronoid process and subsequently explored the medial collateral ligament (MCL). In this cohort, complete elbow stability in flexion-extension was achieved without needing to repair the coronoid or MCL.

In the event of an Essex-Lopresti fracture-dislocation, after the radial head was replaced, the triangular fibrocartilage complex was repaired and reattached to the ulnar head with suture anchors to restore the correct ulnar variance and distal radio-ulnar joint stability (Fig. 1A–C).

Postoperatively, patients were immobilized with a posterior cast in 90° flexion and neutral forearm rotation. On postoperative day 2, active gradual flexion-extension movements were allowed with the use of an articulated elbow brace. Starting in 2012, celecoxib (Celebrex, Pfizer Inc., New York, NY, USA) therapy (200 mg bid) was recommended for 2 weeks' post-surgery.

2.3. Clinical and radiographic assessment

The preoperative imaging assessment included standard anteroposterior and lateral X-rays of the injured elbow and ipsilateral wrist to evaluate the possibility of an Essex-Lopresti fracture-dislocation. A CT scan was performed in 12 of the 31 patients.

All the patients were evaluated in the postoperative period using a standardized protocol including clinical examination and X-rays at 1, 3 and 12 months of follow-up. Some patients had a longer radiographic and clinical follow-up, depending on the surgeon's inclinations or patient's needs. Between May and June 2015, all patients were invited back to the clinical for an additional clinical evaluation at an average of 30 months of follow-up (range 12 months to 7 years).

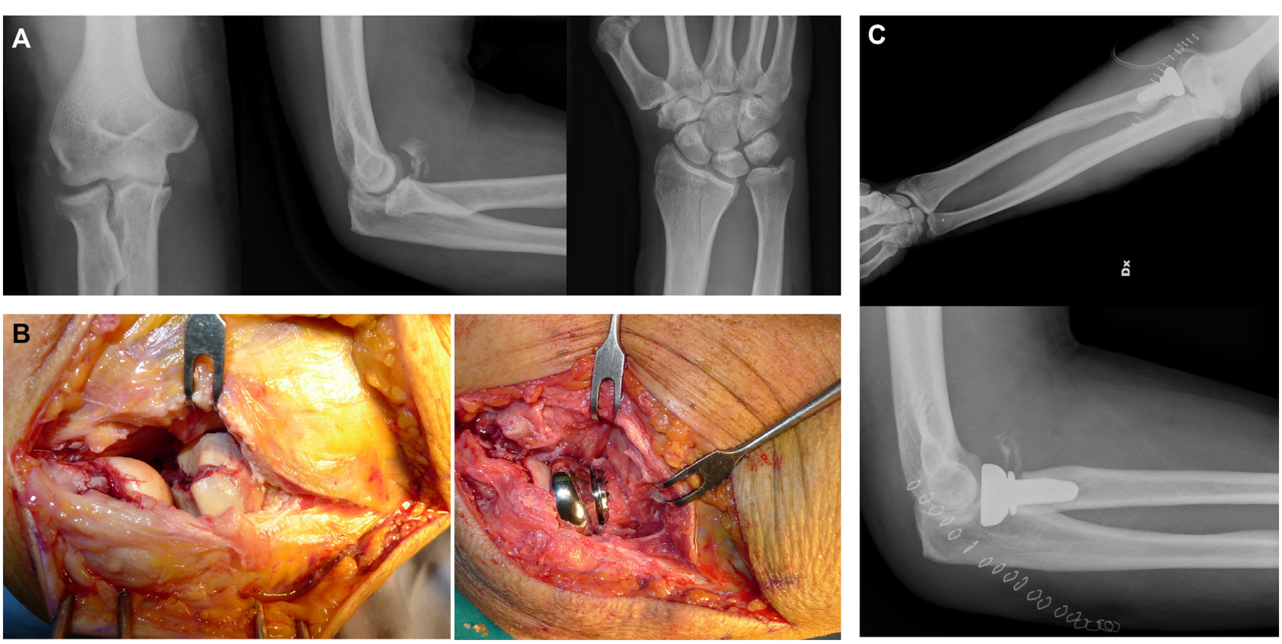

Fig. 1. A. X-rays showing an Essex-Lopresti fracture-dislocation. B. Intraoperative view of a radial head fracture and radial head replacement. C. Postoperative X-rays showing the radial head replacement with anatomic implant and the presence of an anchor on the ulnar head, with restoration of the correct ulnar variance.

The postoperative clinical evaluation included analysis of passive range of motion (ROM), radiological assessment, functional results using the Mayo Elbow Performance Score (MEPS) [17] and complications. Passive elbow flexion-extension and forearm pronation-supination ROM were measured with a goniometer. X-rays included standard anteroposterior and lateral views of the injured elbow.

Radiographs of the elbow were evaluated for signs of osteolysis around the implanted stem, prominence of the radial head implant, and periarticular ossifications. All measurements were performed on a picture archiving and communication system (PACS, Fuji Synapse software). One senior orthopedic resident and one orthopedic surgeon reviewed all the images for description, measurement and classification purposes. Per Doornberg et al. [18], radial head prominence was evaluated by measuring the longitudinal distances between the margin of the coronoid process and the center of proximal surface of the metallic head on the anteroposterior view. Heterotopic ossification (HO) was identified on postoperative radiographs and graded according to the classification of Hastings and Graham [19]. This classification distinguishes three grades of HO. Patients with class I have HO that does not cause functional limitation. Patients with class II HO have a functional limitation that blocks motion: class IIA represents an elbow flexion contracture of 30° or greater and limited flexion of less than 130°, class IIB represents limited forearm rotation of less than 50° pronation or less than 50° supination, and class IIC represents heterotopic bone causing limitation in both planes of motion. Patients with Class III HO have ankylosis that prevents elbow motion (Class IIIA), forearm rotation (Class IIIB), or both (Class IIIC).

2.4. Data analysis

Continuous data were expressed as mean ± standard deviation. The Shapiro–Wilk test for normality [20] was used to determine whether the variables were normally distributed: in cases of normal distribution, continuous variables were tested with Student's *t*-test; for non-normal distributions, two-sample tests were performed using the Wilcoxon rank-sum test. The functional outcomes of patients with and without associated injuries (LUCL lesion or LUCL lesion plus coronoid fracture) were compared using the Kruskal–Wallis test for 3 groups. MedCalc version 11.5.1 (MedCalc Software, Mariakerke, Belgium) was used for the analysis and significance was set at $P < 0.05$.

3. Results

Between January 2007 and December 2014, a total of 153 patients were identified. Among these patients, 112 (98 Mason type II and 14 Mason type III fractures) were treated with ORIF (using pins or mini-screws) and 41 (32 Mason type III and 9 Mason IV fractures) were treated with anatomic RHA. Of these, two patients (1 Mason type III and 1 Mason type IV) were not included in the analysis because of severe cognitive impairment. We decided to exclude patients with a Mason type IV fracture to obtain a more homogeneous sample. Therefore, 31 patients with a Mason type III fracture (Fig. 2A–C) were included in this study. The patients were operated an average of 4 days after the injury (2–8 days). Thirteen patients were female and 26 were male; the mean age was 49 years. The males had a mean age of 47 years (range 27–74). Women were older with an average age of 53 years (range 24–80). The mechanisms of injury ranged from simple falls to motor vehicle accidents and sports activities. The injury site was the right arm in 26 cases and left arm in 13. Associated injuries consisted of LUCL tear in 11 cases and LUCL tear plus coronoid fracture in 6 cases (Table 1). At an average of 30 months' follow-up (range 12 months to 7 years), the mean elbow flexion-extension ROM was 112° with a mean flexion of 125° (range 95°–150°); the mean forearm rotation ROM was 134° with a mean pronation of 68° and a mean supination of 66° (Table 1).

Heterotopic ossification was found in 8 patients: 3 patients with Class I, 2 with Class IIA, 2 with Class IIB, and 1 with Class IIC (Table 1). In two cases, HO developed in patients in whom an iatrogenic fracture on the cortical surface of the neck occurred during stem insertion. It is worth noting that in these two cases, no stem loosening was found, only heterotopic ossification around the neck (Fig. 3). Ossification was observed over the anterior and lateral margins of the radial neck and prosthetic head in 5 cases, near the medial collateral ligament in 2 cases, and near the LUCL in 1 case. Based on the MEPS, excellent results were obtained in 24 (77%) patients, good results in 3 (10%) and fair in 4 (13%) cases (Table 1). More specifically, patients who developed HO reported excellent results in 4 cases (3 Class I and 1 Class IIA), good in 1 case (Class IIA) and fair in 3 cases (2 Class IIB and 1 Class IIC). The remaining case of a fair MEPS score was a patient in which signs of osteolysis around the prosthetic stem were found at 4 months of follow-up (Fig. 4).

When the groups of patients with and without postoperative complications (heterotopic ossification or osteolysis around the prosthetic stem) were compared, the patients without complications had significantly higher MEPS scores ($P = 0.010$), whereas no statistically significant differences were found in the ROM (Table 2).

The correlation between subjects with and without concomitant associated injuries (LUCL tear or LUCL tear plus coronoid fracture) and the functional score is given in Table 3. The only parameter that reached significance ($P = 0.07$) was the degree of elbow flexion, suggesting that the presence of an isolated LUCL tear could negatively affect flexion ROM.

The final follow-up images showed an intact radial head implant. However, in two cases there were radiolucent lines around the prosthetic stem, probably due to a stress shielding effect (Fig. 4). No signs of instability were found, and no radial head subluxation was observed. The distance between the parallel planes at the proximal surface of the metallic head and the lateral edge of the coronoid process averaged 1.9 ± 0.8 mm (range 0.3–3.2).

4. Discussion

In a recent review, Giannicola et al. described the various types and designs of radial head implants available. The implants can be classified as anatomic or nonanatomic; one-piece or modular; unipolar or bipolar; and intentionally loose, press-fit, or cemented [21].

The anatomic radial head implant used in our study had an anatomically shaped radial head designed to mimic the radiocapitellar joint contact pattern of a native radial head [22], which may reduce cartilage erosion and capitellum wear over time relative to nonanatomic implants [23,24].

Sahu et al. examined how the contact pressure differed between various radial head implant designs: anatomic radial head, circular radial head system (RHS) with the floating articulation locked (monopolar), and the circular RHS radial head system with the floating articulation unaltered (bipolar). They showed that the design of the anatomic radial head implant, which includes a 2.3-mm dish and variable radius of curvature, effectively created a more conforming articulating surface and better contact area with the capitellum [24]. It is likely that peak pressures in nonanatomic RHS implants cause long-term cartilage damage [24]. Mimicking the anatomic features of the radial head in a radial prosthesis can result in more favorable joint contact characteristics and thus could reduce the occurrence of long-term capitellum damage [24]. The

Table 1
Demographics, associated injuries, clinical outcome and complications in the study cohort.

ROM									
Sex	Age	Side	Associated injuries	Flexion (°)	Extension deficit (°)	Pronation (°)	Supination (°)	MEPS	Complications
M	38	R		110	0	80	80	95	
M	41	R	LUCL	135	10	90	80	100	
F	74	R	LUCL	140	0	60	75	94	
M	63	L		100	20	55	40	65	HO class 2B
M	55	R	LUCL + coronoid	135	25	80	65	98	
F	32	R	LUCL + coronoid	115	0	50	70	93	Osteolysis stem
F	48	L		120	35	90	60	91	
M	37	L	LUCL	135	15	65	50	97	
M	71	L		120	40	60	65	90	HO class 2A
M	29	R		130	5	85	60	100	
M	42	R	LUCL + coronoid	95	35	60	55	84	HO class 2A
F	52	R	LUCL	135	0	60	75	100	
M	44	R	LUCL	150	0	55	60	78	
M	71	L		115	0	90	90	98	
F	80	R		110	10	80	90	96	
M	74	R	LUCL	135	30	55	40	93	
F	58	L		145	25	40	40	68	HO class IIC
F	44	L	LUCL + coronoid	120	15	75	80	95	
M	58	R		115	0	90	75	100	
M	63	R	LUCL	140	20	85	75	92	HO class I
M	41	L		120	0	45	70	100	
F	55	R	LUCL + coronoid	120	0	35	60	70	HO class 2B
M	35	R		115	0	75	45	73	
M	70	R	LUCL	120	15	60	75	100	
F	57	L	LUCL	130	30	80	55	81	
M	31	R		150	0	70	85	98	HO class I
M	56	L	LUCL	125	25	65	50	98	
M	65	R		125	30	70	65	93	
F	41	R	LUCL + coronoid	130	25	70	55	97	Osteolysis stem
M	46	L		100	0	90	85	95	HO class I
M	38	R	LUCL	145	0	50	75	100	

%	Mean ± SD	%	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	%
68% M 32% F	52 ± 14.4	65% R 35% L	125 ± 14.4	13 ± 13.6	68 ± 15.9	66 ± 14.7	91 ± 10.3	26% HO 6% Osteolysis

ROM: range of motion: MEPS: Mayo Elbow Performance Score; M: male; F: female; R: right; L: left; HO: heterotopic ossification; LUCL: lateral ulnar collateral ligament.

Table 2
Comparison of functional outcomes between patients with (C) and without (NC) postoperative complications.

	Group C $n = 10$ (mean ± SD)	Group NC $n = 21$ (mean ± SD)	Test for normal distribution (*P*)	Correlation (*P*)
Flexion (°)	121.5 ± 19.6	126.9 ± 11.3	< 0.05[a]	0.335[b]
Extension deficit (°)	16.5 ± 15.5	11.7 ± 12.7	0.932[a]	0.478[c]
Pronation (°)	61.5 ± 17.8	71.4 ± 14.2	< 0.05[a]	0.106[b]
Supination (°)	63.0 ± 16.2	67.4 ± 14.1	< 0.05[a]	0.448[b]
MEPS	85.2 ± 12.8	94.3 ± 7.7	0.918[a]	0.010[c]

Group C: patients with postoperative complication (heterotopic ossification or osteolysis around the stem); group NC: patients without any postoperative complication: MEPS: Mayo Elbow Performance Score.

[a] Shapiro–Wilk test.

[b] Student's *t*-test.

[c] Wilcoxon test.

Table 3
Comparison of functional outcomes between patients with and without associated injuries (LUCL tear or LUCL tear plus coronoid fracture).

	LUCL $n = 9$ (mean ± SD)	LUCL + coronoid $n = 8$ (mean ± SD)	None $n = 14$ (mean ± SD)	Correlation (*P*)
Flexion (°)	137.8 ± 7.1	120.6 ± 12.4	119.6 ± 14.5	0.007[a]
Extension deficit (°)	11.1 ± 11.9	18.1 ± 13.1	11.8 ± 15.0	0.783[a]
Pronation (°)	65.0 ± 13.7	63.8 ± 15.8	72.9 ± 17.1	0.281[a]
Supination (°)	64.4 ± 14.7	64.4 ± 9.8	67.9 ± 17.5	0.719[a]
MEPS	94.7 ± 7.0	89.8 ± 10.4	90.1 ± 12.2	0.530[a]

LUCL: lateral ulnar collateral ligament: MEPS: Mayo Elbow Performance Score.

[a] Kruskal–Wallis test.

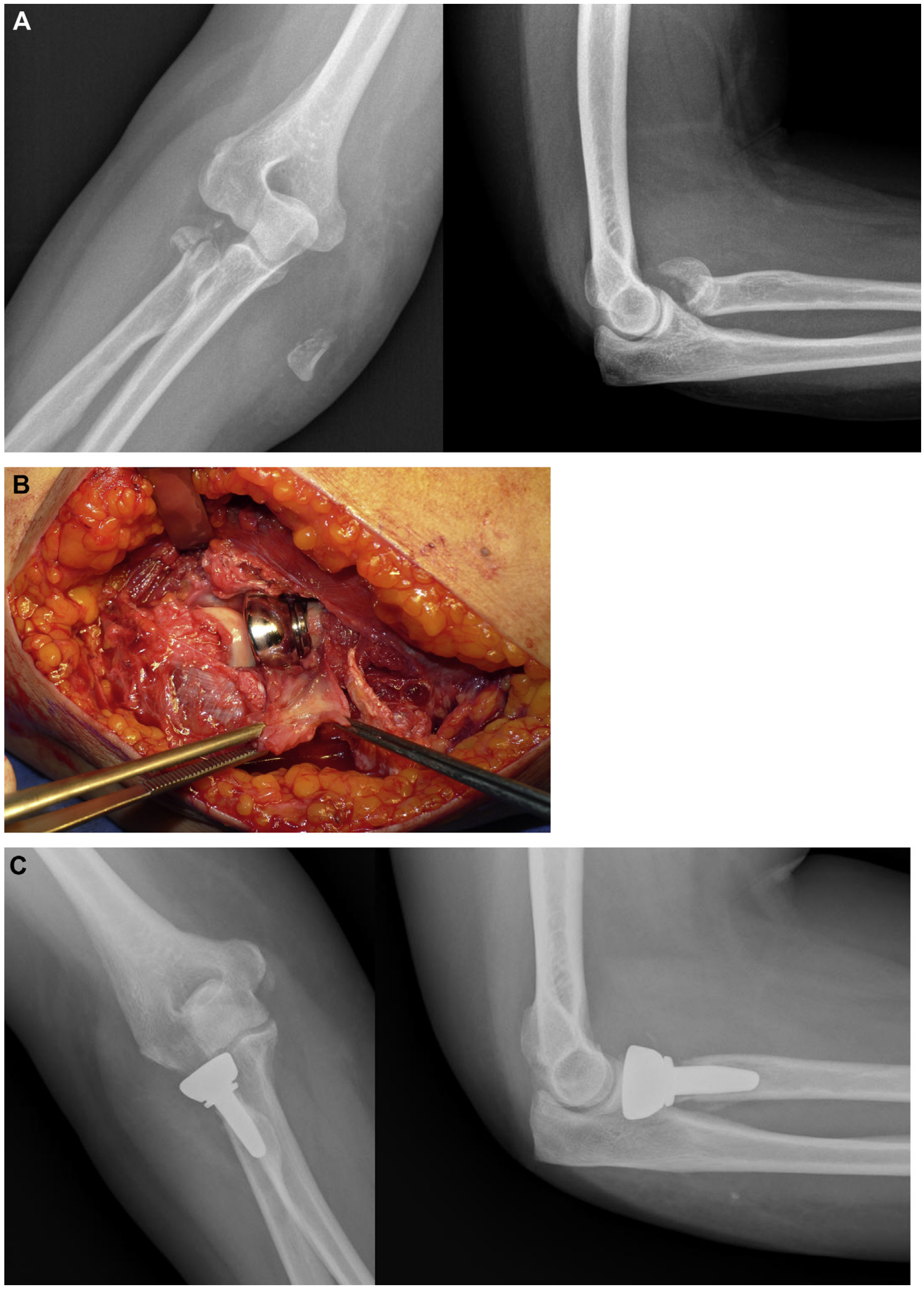

Fig. 2. A. X-rays showing fracture of the radial head with dislocation of fragments. B. Intraoperative view of the anatomical radial head implant and the lateral ulnar collateral ligament (LUCL) ligament detached from its condylar insertion. C. X-rays at 6 months after surgery showing minimal stress shielding around the neck.

anatomic radial head has also been shown to improve radiocapitellar stability because of its deeper dish [25].

A recent systematic review and meta-analysis compared the complication and satisfaction rate between ORIF and RHA in the treatment of Mason type III radial head fractures [11]. This study revealed a higher complication rate for ORIF than RHA for Mason Type III radial head fractures (58.1% versus 13.9%). The satisfaction rate was lower for ORIF than RHA for Mason Type III radial head fractures (51.6% versus 91.7%).

In our cohort, flexion-extension (112°) and forearm rotation (135°) ranges were like those reported in other studies [13,26]. Based on the MEPS score, excellent results were obtained in 24 (77%) patients; good in 3 (10%) and fair in 4 (13%) cases. Lamas et al. evaluated 47 patients (27 type III fractures and 10 type IV fractures), treated with a pyrocarbon radial head implant. Based on the MEPS, 42 patients had good/excellent results, with three fair and two poor outcomes [27]. Comparable results were reported by Sarris et al., who evaluated 32 patients who underwent radial head replacement with the MoPyC prosthesis, and found excellent MEPS results in 80%, good in 17%, and fair in 3%, at a mean follow-up of 27 months [28].

Several studies suggest that overstuffing the radiocapitellar joint can bring on pain, loss of elbow flexion, capitellar erosions, lateral elbow joint hinging, and early-onset arthritis [29–32]. It has been demonstrated that 2.5-mm of overlengthening or more can alter elbow joint kinematics and radiocapitellar joint pressures [31]. In our study, the mean axial height of the RHA, as measured by Doornberg et al. [18], was 1.9 ± 0.8 mm and was less than 3.2 mm in

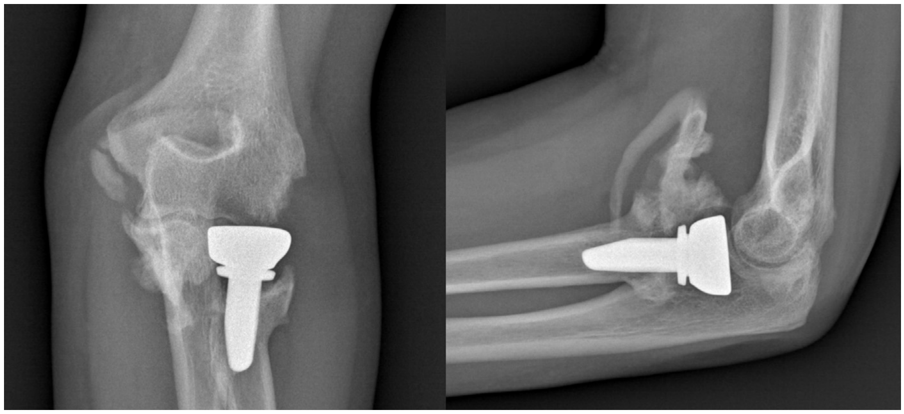

Fig. 3. X-rays showing heterotopic ossification at 3 years' postoperative.

all implants. This is consistent with the results of a previous study in which the prominence of the radial head implant was compared to the contralateral elbow, and was found to be less than 3.7 mm in all implants [33].

The main complication reported in our cohort was HO in 26% of cases. The onset of HO is a well-documented complication after elbow fracture, with a reported overall incidence of 15–37% [34,35]. Hong et al., investigated the prevalence and risk factors for clinically relevant HO after elbow fracture surgery in 122 patients (124 elbows treated) [36]. HO developed in 30.6% and clinically relevant HO in 21% of the surgically treated elbows. The prevalence of HO was highest in floating elbow injury cases, followed by combined olecranon and radial head fractures, terrible triad injuries, and isolated radial head fractures. Several studies have shown that delayed surgery and longer immobilization are risk factors for developing HO [34,37–39].

Our results are consistent with a recent study conducted by Marsh et al., reporting a 36% HO rate among 55 patients at a minimum 5 years of radiographic follow-up after RHA with a smooth-stemmed modular metallic implant for the treatment of acute radial head fractures [26]. By analyzing the factors that may have influenced the onset of HO in our study, we found a higher HO rate (33%) in the 18 patients operated before 2012 without primary prophylaxis with NSAIDs compared with a 15% rate in the 13 patients that received celecoxib therapy (200 mg bid) for 2 weeks after surgery.

Moreover, there were two cases (6%) of osteolysis around the prosthetic stem documented by plain X-rays. This rate appears lower than in other studies; however, those studies had a longer radiological follow-up [40,41]. Nevertheless, the appearance of radiolucent lines around the implant is not usually associated with the presence of symptoms [42–44].

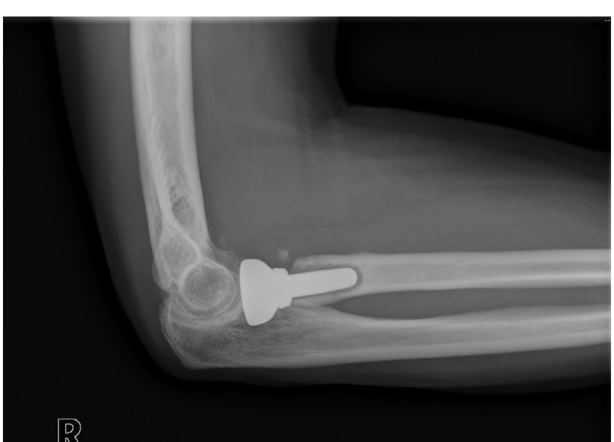

Fig. 4. Signs of osteolysis around the prosthetic stem at 4 months' follow-up.

This anatomic implant required press-fit of the stem into the medullary canal of the radius, conferring good stability, with radiocapitellar dislocation being infrequent [40], and avoiding the possibility of disassembly, which has occasionally been reported with bipolar designs [45].

Our study found that postoperative complications (i.e., heterotopic ossification or osteolysis around the prosthetic stem) negatively influenced the MEPS scores, even if no substantial differences in the ROM were observed. Several studies confirm that the onset of HO can trigger pain, stiffness, loss of elbow ROM, and functional impairments [36,46]. This study also found that the presence of a concomitant isolated LUCL tear can reduce the flexion ROM. However, this result should be interpreted with caution since it appears unlikely that flexion ROM is affected by an isolated LUCL tear, rather than a LUCL lesion plus coronoid fracture; therefore further studies are needed to better understand this finding.

The strengths of this study are the homogeneity of the injury pattern included (all Mason type III fractures) and the use of the same cementless anatomic radial head implant in all patients. The major limitations are the absence of a comparator group and relatively short follow-up (average 30 months).

5. Conclusion

Use of an anatomic radial head implant leads to a good functional recovery, even in the presence of severe instability, such as cases of coronoid fracture and LUCL injury. Moreover, it has proven effective in preserving elbow motion and maintaining the relative length of the radius. However, patients should be informed of the high number of adverse events (mainly HO) following this treatment.

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None.

Ethics committee approval

Policlinico di Modena – University of Modena and Reggio Emilia, protocol No. 871/C.E.

Disclosure of interest

The authors declare that they have no competing interest.

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