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The acute bipolar radial head replacement for isolated unreconstructable fractures of the radial head

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Abstract For the acute treatment of radial head fractures, radial head arthroplasty can be considered if open reduction and internal fixation is not technically possible and if simple radial head resection is contraindicated. We report our experience with a bipolar Judet radial head prosthesis. After a mean follow-up of 41.7 months, 16 patients were assessed following radial head replacement. The outcome was assessed clinically, functionally, and radiographically. Outcome was satisfactory in 87.5% of cases. The mean post-operative ranges of motion were greater than the functional arcs both in flexion–extension and in pronation-supination, and the results did not appear to be influenced in a significant way by the type of original lesion. All elbows were stable. The main complication was the development of heterotopic ossifications. Bipolar radial head prosthesis represents a suitable option for acute treatment of unreconstructable radial head fractures, either isolated or associated with elbow dislocation and in the absence of other bony lesions.

Keywords Elbow Joint · Radial head fracture · Elbow dislocation · Bipolar radial head

Introduction

Fractures of the radial head usually result from a fall on an outstretched hand with the elbow partially flexed and pronated; they account for about 1.7–5.4% of all fractures and 33% of elbow fractures, and in 85% of cases, they involve adults between 20 and 60 years of age, with a mean age of 30–40 years [1].

Fractures of radial head and neck are most commonly classified according to the system developed by Mason [2] and subsequently modified by Johnston [3].

For acute treatment of type II and type III radial head fractures, when technically possible, open reduction and internal fixation is the treatment of choice, otherwise if the radial head fracture is unreconstructable, the alternative is between radial head resection and radial head arthroplasty [1, 4, 5].

Simple resection can be considered if the elbow is stable, but this is contraindicated if the radial head fracture is associated with destabilizing lesions that make the elbow unstable [6, 7]: in such cases, radial head arthroplasty represents a suitable option for restoring elbow stability [8–12].

The aim of the current study is to report the results obtained in our experience after radial head replacement with a bipolar radial head prosthesis for isolated radial head fractures, analysing the advantages and disadvantages of this implant design.

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Materials and methods

The bipolar radial head prosthesis (designed by T. Judet in the early 1990s and developed by Tornier Implants Chirurgicaux s.a.s., Saint Ismier Cedex, France) is a bipolar implant consisting of two components (Fig. 1): a radial cup, made of a cobalt–chrome coat enclosing a high-density polyethylene core, which articulates with the second component, a cemented cobalt–chrome intramedullary stem with a neck-shaft angle of 15°, reproducing the normal supination curvature of the radius [13]. The articulation between the two prosthetic components is semiconstrained and gives the radial cup a double range of movement, allowing free rotation of 180° and an arc of 35° of uniplanar movement in any direction (Fig. 2), thus providing great mobility while guaranteeing maximum contact between the prosthetic cup and both the capitulum humeri and the lesser sigmoid notch of the ulna throughout the arc of movement [14].

Fig. 1 CRF II (Cupule Radiale Flottante) is the bipolar radial head prosthesis used by authors

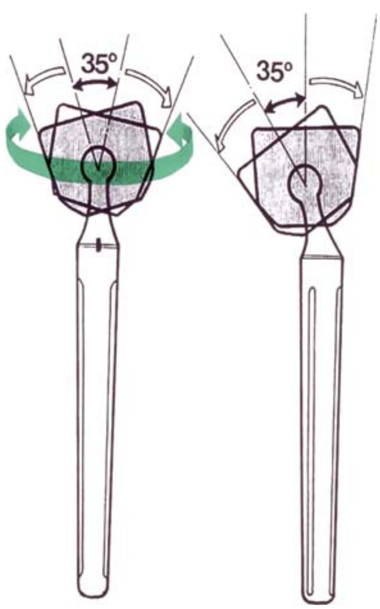

Fig. 2 The semiconstrained articulation between the radial cup and the stem gives the radial cup free rotation of 180° and an arc of 35° of uniplanar movement in any direction

Native radial heads exhibit great anatomical variability, so the implant is modular, with different component sizes interchangeable in order to choose the implant size that best substitutes the native radial head. Two cup sizes are available (with diameters of 19 mm and 22 mm, respectively), two stem sizes (60 mm × 8 mm and 55 mm × 6.5 mm), and two neck lengths (short and regular).

Between 2000 and 2007, 73 bipolar radial head prostheses were implanted consecutively at our institution for the treatment of both acute and chronic lesions, and sixteen bipolar Judet radial head prostheses were implanted for the acute treatment of unreconstructable radial head fractures without concurrent fractures of the coronoid process. After informed consent, all these 16 patients agreed to participate in this retrospective review study, with mean follow-up of 41.7 months (range: 12.3–86.3 months) (Table 1).

The group comprised 11 men (68.8%) and 5 women (31.2%), with mean age of 46.1 years (SD 13.9; range: 27–74 years) at the time of the trauma.

The prosthesis was implanted a mean of 9.1 days after the trauma (SD 5.3; range: 0–20 days), and it involved the right side in 9 cases and the left side in 7 cases; in 9 cases (56.3%), it involved the dominant arm.

According to the Mason-Johnston classification, the original lesions were type III in 9 cases (56.3%) and type IV (fracture-dislocations) in 7 cases (43.7%), with an elbow dislocation associated with an unreconstructable radial head fracture; in all cases, the radial head fracture was the only bone lesion, and there were no other associated fractures involving ulna or humerus. Any Essex-Lopresti lesion was included in this group of study.

Intraoperative evaluation confirmed with fluoroscopic examination, established insufficiency of the lateral collateral ligament (LCL), also; at the end of the surgical procedure, LCL repair was performed using 2 number 5 non-absorbable sutures, fixed to the condyle through bony tunnels.

The same surgical approach was followed in all cases, using lateral Kocher approach to the proximal radius.

Assessment of patients

The review of patients consisted of physical and radiographic examinations and an interview with questionnaires; the clinical and radiographic evaluations were performed by an independent orthopaedic surgeon not involved in the surgical procedures.

The elbow range of motion (ROM) in flexion–extension and pronation-supination was measured with a goniometer. Based on the recovered ROM, the results were then divided into three categories: patients who recovered both functional arcs of motion, patients who recovered one functional arc of

Table 1 Our complete case series with post-operative results

Case number	Sex (M/F)	Age (years)	Side dominant (±)	Mason-Johnston classification	Concurrent elbow dislocation (Y/N)	Follow-up (months)	MEPS (pt.)	DASH (pt.)	Flexion (°)	Extension (°)	Pronation (°)	Supination (°)	Complications
01	M	58	R+	III	N	12.7	50	36.6	80	80	0	0	Ankylosis
02	M	39	R+	IV	Y	49.3	90	8.0	145	0	0	0	Proximal radio-ulnar synostosis
03	F	31	R+	III	N	26.0	100	5.6	145	0	80	90	–
04	M	42	R+	III	N	12.3	50	36.6	70	70	0	0	Ankylosis
05	M	27	R+	III	N	33.6	80	5.2	115	15	80	90	Slight capitellar erosion
06	M	68	L–	III	N	86.3	100	0	145	0	80	90	–
07	F	60	L–	IV	Y	83.8	100	0.9	145	0	80	90	–
08	M	39	L–	III	N	84.3	100	4.5	145	0	80	20	–
09	M	51	L–	III	N	23.8	95	9.3	115	15	80	85	–
10	M	32	R+	IV	Y	27.6	100	9.8	140	0	80	90	–
11	M	49	R+	IV	Y	13.0	100	5.6	145	0	65	60	–
12	F	53	L–	IV	Y	43.8	95	13.4	145	0	80	90	–
13	F	29	L–	III	N	19.3	85	19.0	145	0	80	90	–
14	M	33	L–	IV	Y	14.6	90	18.3	105	0	0	0	Proximal radio-ulnar synostosis
15	M	74	R+	IV	Y	74.2	95	7.4	145	0	75	90	–
16	F	53	R+	III	N	63.0	100	2.7	145	25	80	90	Capitellar erosion

motion (only flexion–extension or only pronation-supination), and patients who recovered none of the functional arcs of motion. We used the Morrey's definition of the functional arc [15] necessary to perform most of the activities of daily living. The physical examination then included an evaluation of elbow stability under the varus-valgus stress and lateral pivot shift test described by O'Driscoll for postero-lateral rotatory instability [16] associated with the fluoroscopy examinations to assess the implant. Wrist motion was also examined along with the presence of pain or anatomical alterations involving distal radio-ulnar joint.

All the patients were asked about their overall satisfaction using the VAS Score [17].

All patients underwent antero-posterior and lateral radiography of the elbow, and evaluations were established for the correct setting of the implant, the evidence of ulno-humeral dislocation or subluxation and the presence of periprosthetic loosening, prosthetic disassembly or rupture, heterotopic ossification, capitellar erosion, and ulno-humeral osteoarthrosis.

Elbow performance was assessed using both the Mayo Elbow Performance Score (MEPS), which evaluates four parameters: pain, arc of motion, elbow stability, and ability to perform daily activities [18], and the Disabilities of the Arm, Shoulder and Hand (DASH) score, which includes 30 questions investigating disability resulting from elbow problems [19].

Elbow pain was assessed using a visual analogue scale graduated from 0 (no pain) to 10 (maximum pain).

Data were statistically analysed with SPSS®15.0 for Windows and Microsoft Office Excel 2007®, using Student's *t* test.

Results

MEPS-score and percentage of success

The mean Mayo Elbow Performance Score after surgery was 89.4 points (SD 16.0; range: 50–100 points). According to the MEPS-score, 12 "excellent" (75%), 2 "good" (12.5%), and 2 "poor" (12.5%) results were achieved, and so the results can be considered satisfactory in 14 cases (87.5%).

The mean DASH-score was 11.4 points (SD 10.9; range: 0–36.61 points).

Recovery of functional arcs of motion

A total of 12 patients (75%) recovered the functional arcs of motion for both flexion–extension and pronation-supination. Two patients (12.5%) recovered the functional arc only for flexion–extension, and 2 patients (12.5%) did not recover either the flexion–extension or the pronation-supination arc.

On the whole, the mean range of motion at the follow-up was 117° in flexion–extension (SD 47.2°) and 120° in pronation-supination (SD 71.6°), whereas in the group of patients who recovered both the functional arcs of motion, the mean arcs of motion were 135.0° in flexion–extension (SD 17.8°) and 160° in pronation-supination (SD 22.7°).

Type of lesion versus results

Of the 9 patients who had isolated unreconstructable radial head fractures without elbow dislocations (Mason-type III), 7 cases (77.8%) achieved recovery of the functional arcs of motion both in flexion–extension and in pronation-supination, and 2 cases (28.6%) achieved recovery of the functional arcs of motion either in flexion–extension or in pronation-supination; the mean range of motion in this group was 100.0° in flexion–extension (SD 59.7°) and 123.9° in pronation-supination (SD 73.8°).

Of the 7 patients who had unreconstructable radial head fractures associated with elbow dislocations (Mason-type IV), 5 cases (71.4%) achieved recovery of the functional arcs of motion both in flexion–extension and in pronation-supination, and 2 cases (28.6%) achieved recovery of the functional arc of motion only in flexion–extension; the mean range of motion in this group was 138.6° in flexion–extension (SD 14.9°) and 114.3° in pronation-supination (SD 79.7°).

The differences between the mean arcs of motion in patients with an isolated unreconstructable radial head fracture (Mason-type III) and in patients with a concurrent elbow dislocation (Mason-type IV) were not significant both for flexion–extension and for pronation-supination.

Pain

The mean pain intensity at follow-up was 1.38 at rest (SD 1.83) and 2.25 (SD 2.75) after work or physical activity.

Articular stability

Both the clinical examination associated with the fluoroscopy exams and the radiographic assessment demonstrated complete elbow stability in all patients, with no cases of valgus instability, postero-lateral rotatory instability, or ulno-humeral subluxation.

Complications

The main complication observed in our experience was the development of heterotopic ossifications that led, according to the Hastings and Graham classification [20], to complete

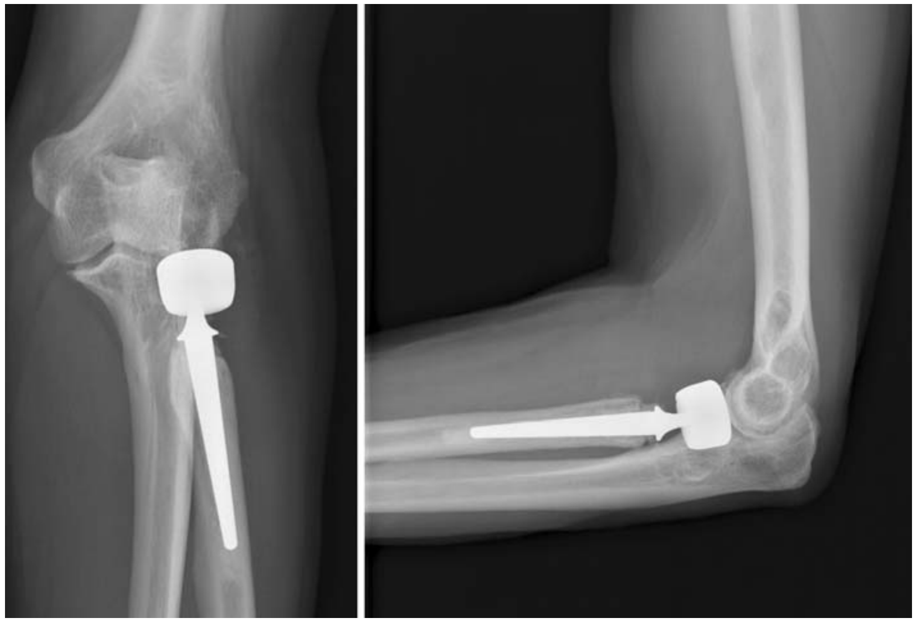

Fig. 3 Case nr. 06: A–P and L–L radiography after a follow-up of 86.3 months showed proximal bone resorption while the distal end of the stem remained well fixed

ankylosis in 2 cases (12.5%) and to proximal radio-ulnar synostosis in 2 cases (12.5%).

In 2 cases (12.5%), the radiographic assessment revealed signs of capitellar erosion (slight in one case), suggesting an overstuffing of the prosthesis on the capitulum humeri.

One case (Fig. 3) showed proximal bone resorption while the distal end of the stem remained fixed in the cement.

No cases of infection, breakage or disassembly, periprosthetic loosening, proximal radial migration, posterior interosseous nerve palsy, or ulnar neuropathy were identified.

Patients' overall satisfaction

At the follow-up, 12 patients (75.0%) declared they were fully satisfied with the results, whereas 2 patients (12.5%) were not fully satisfied, and 2 patients (12.5%) were not satisfied because of the development of heterotopic ossifications compromising elbow ROM.

Discussion

When a radial head is irreparable, the radial head prosthesis is useful to restore elbow and forearm stability both in acute and in chronic lesions [21, 22].

Two different prosthesis designs have been proposed: monoblock or unipolar implants and bipolar models, which have a mobile cup articulated to a fixed stem.

Over the last 12 years, various small series of radial head replacements with bipolar prosthesis have been reported. We extrapolated the results achieved in the acute treatment of unreconstructable radial head fractures not associated with other concurrent fractures, as these lesions being analogous to those reported in the present study.

In 1996, Judet et al. [13] reported their experience using a floating radial head prosthesis on 4 patients assessed after a mean average follow-up of 55.3 months, and according to the Broberg and Morrey score, they obtained two "excellent" and two "good" results.

In 2000, Smets et al. [23] performed a multicentric study on 5 patients, evaluated after an average follow-up of 25.6 months, and according to the Mayo Elbow Performance Score, the results were classified as "excellent" in one case, "good" in one, "adequate" in two, and "poor" in one.

In 2007, Popovic et al. [24] published a study on 51 comminuted fractures treated using the bipolar radial head replacement. Eighteen patients had an elbow dislocation with isolated radial head fracture, and according to the MEPS-score, they achieved an average of 83 points in the entire group of patients.

In 2002, Holmenschlager et al. [25] reported their experience on 8 patients, evaluated with minimum follow-up of 12 months, and according to the Broberg and Morrey score, all the results were classified as "good".

In 2003, Frosch et al. [26] published the results of 5 prostheses after an average follow-up of 5 years, obtaining according to the Broberg and Morrey score, one "excellent", two "good", and two "poor" results.

The present study demonstrates that bipolar radial head prosthesis allowed 75% of patients with an unreconstructable radial head fracture to recover the functional arcs of motion both in flexion–extension and in pronation-supination. The prosthesis enabled achievement of mean ranges of motion greater than the functional arcs of flexion–extension and pronation-supination, both in patients with an isolated unreconstructable radial head fracture (Mason-type III) and in patients with a concurrent elbow dislocation (Mason-type IV). The differences between the results in these two groups of lesions were not significant, which suggests that the effectiveness of bipolar radial head prosthesis is not compromised to a relevant extent by the concurrent presence of an elbow dislocation.

The bipolar radial head prosthesis usually provides a satisfying ROM and restores joint stability, allowing early mobilization that reduces the risk of post-traumatic elbow stiffness.

As concerns elbow pain, the implant of a bipolar radial head prosthesis gives good results, with a very low mean pain intensity indicated by patients.

As regards complications, the most frequent and most important is the development of heterotopic ossifications, which can have negative functional consequences preventing the recovery of the functional arcs of motion. We believe this is not due to a defect in the prosthesis but instead to an elbow feature, and indeed the elbow is known as the body joint at highest risk of post-traumatic stiffness and the highest incidence of heterotopic ossification, the aetiology of which is still unclear and not understood [27, 28].

No correlation in this series was found between the time of the surgical procedures and the development of heterotopic ossifications.

The absence of breakage or disassembly and periprosthetic loosening demonstrates that this implant is strong enough to tolerate the high physiological loads developing across the elbow, and it can prevent proximal radial migration as biomechanical study showed to be adequate and comparable to unipolar models [29].

We observed in one case the proximal bone resorption without loosening of the cemented stem; this can be related to the polyethylene wear that can lead to the osteolysis and bone loss. The polyethylene debris comes from the radial head made of polyethylene enclosed in cobalt–chrome cap that articulates with the cemented stem.

Consequently, we believe that the majority of complications arise not from incorrect design of the prosthesis, but rather are due to implant surgical technique [30–32].

The good results obtained with the implant of the radial head prosthesis are confirmed by the high scores achieved according to MEPS and DASH and by the high levels of overall patient satisfaction.

On the basis of our experience using the bipolar design, we believe that its major advantage is improved adaptation to both the lesser sigmoid cavity and the capitulum humeri: the double range of movement on the stem enables the radial cup to maintain contact with both these articular surfaces during the full arc of motion in flexion–extension and in pronation-supination, in this way reducing stress on the ulno-humeral joint and cartilaginous erosion, and preventing ulno-humeral arthrosis.

Another advantage is that the rotation in prono-supination of this implant design is inside the prosthesis between the head and the neck, and this can improve the range of motion.

The main disadvantage of the bipolar design as reported in literature is a risk of posterolateral rotatory instability (PLRI) of the elbow [14]. We checked the stability of the implant for PLRI using the Pivot shift test and the stability in varus and valgus using the varus-valgus test associated with the fluoroscopic exams.

No patients in the study reported this complication, leading to the conclusion that repair and retensioning of the LCL and a correct surgical implant of the prosthesis can avoid this complication [14, 30].

At present, no radial head implant is available that works as well as a native radial head. However, a bipolar radial head prosthesis is a suitable option for acute treatment of unreconstructable radial head fractures, either isolated or associated with elbow dislocation. When correctly positioned, the bipolar radial head prosthesis allows recovery of a mean ROM greater than the functional arcs of motion both in flexion–extension and in pronation-supination and contributes to restoring elbow stability while the bone and soft tissues heal. Further studies are required to assess results after a long-term follow-up.

Conflict of interest None.

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