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Original article

Factors influencing the mid-term radiological and functional outcomes of 41 post-fracture bipolar radial head arthroplasty cases at a mean follow-up of 87 months

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Study approved by the ethics committee of our institution

Abstract

Introduction

When treating comminuted radial head fractures that cannot be adequately fixed, the next option is arthroplasty (radial head replacement). We hypothesized that the radiological and functional outcomes of bipolar mobile cup radial head arthroplasty is not influenced by the length of follow-up but instead by the correct positioning of the implant intraoperatively and by the presence of associated bone or ligament injuries.

Patients and Methods

Between May 1998 and December 2016, 82 cases of radial head arthroplasty were performed at our hospital. The mean age of patients at the time of arthroplasty was 53 years (22–81). Ligament or bone injuries complicated the radial head fractures in 70% of patients.

Results

For the final assessment, 41 patients were reviewed and included in the statistical analysis with a mean of 82 months (12–228). The mean MEPS at the final assessment was 88.7 (61–100). There were 23 excellent, 9 good, 9 average and 0 poor results. The average DASH score was 18.7 (0–55). The average VAS for pain was 1.0 (0–5). Five patients (12%) required surgical revision, including one implant change. Our statistical analysis found no relationship between follow-up time and functional outcomes. The appearance of periprosthetic radiolucent lines was not affected by the length of follow-up. Associated bone or ligament injuries significantly increased the probability of periprosthetic radiolucent lines, humeroulnar joint degeneration and decentering of the implanted cup. Radiological evidence of a suspended implant was associated with significantly worse functional outcomes.

Conclusion

This study confirms the long-term stability of the clinical outcomes of radial head arthroplasty. There was no relationship between worsening radiological appearance of the implant and the clinical outcomes. It is critical that this implant not be oversized or suspended, as this can trigger premature capitellar erosion and painful stiffness of the operated elbow.

Level of evidence: IV ; systematic retrospective analysis

Keywords: radial head fracture, cemented implant, bipolar, functional evaluation, X-ray evaluation, mid-term outcomes

Introduction

Fractures of the radial head (RH) make up one-third of all elbow fractures [1] and mainly affected a younger population with a mean age of 45 years [2, 3]. In instances where a comminuted RH fracture cannot be adequately fixed, arthroplasty is recommended [4-7] to ensure elbow stability and healing of associated ligament injuries [3, 7, 8]. In fact, RH fractures rarely occur in isolation; in 75% of cases, they occur simultaneously with other elbow fractures or injuries to periarticular tissues [2, 7, 9]. At this point, the surgeon must decide which type of implant to use. There are two competing biomechanical theories that come into play when choosing the implant. Monoblock implants stabilize the damaged elbow the best [10-12]. On the other hand, bipolar implants—thanks to their mobile radial cups—distribute the loads better, thereby reducing high joint stresses [13, 14]. Thus bipolar implants stabilize the joint while reducing the excessive pressure on the lateral condyle, and therefore the risks of arthritic degeneration in the humeroulnar and humeroradial joints [15].

We hypothesized that the radiological and functional outcomes of bipolar mobile cup RH arthroplasty is not influenced by the length of follow-up but by the correct positioning of the implant intraoperatively and by the presence of associated bone or ligament injuries. The primary endpoint of this study was the functional outcomes at the longest follow-up represented by the MEPS and DASH scores relative to the radiological position of the RH arthroplasty. The secondary endpoints at the longest follow-up were:

- Functional outcomes (MEPS and DASH scores) and grip strength in the operated side relative to the contralateral side
- Patient satisfaction
- Pain in the operated elbow evaluated on a visual analog scale (VAS)
- Outcomes of the arthroplasty relative to associated injuries at the time of fracture.

Materials and Methods

Study overview

This was a multisurgeon retrospective study of cases done at our orthopedics and trauma surgery department between May 1998 and December 2016. The inclusion criteria were primary RH arthroplasty in the context of acute elbow trauma, at least 1 year of follow-up, patient at least 18 years of age, patients available for final clinical and radiographic assessment. The exclusion criteria were secondary RH arthroplasty (more than 15 days after the initial fracture event) and implant inserted in the context of total elbow replacement. All the patients included in our statistical analysis were reviewed in person by a single examiner for the final assessment. This study was approved by our institutional review board on January 30, 2018 (number 243-2018-09).

Surgical procedure and postoperative course

Several surgeons were involved in these cases. The implant was a Judet-type RH prosthesis with floating cup (CRF®, Tornier, France) and a long, cemented stem. The procedure was done under general or regional anesthesia. The patient's position was supine with the operated arm on an arm board and a tourniquet in place. The surgical approach was selected based on the presence of associated injuries. It could be either posterolateral (Cadenat approach), lateral (Kaplan approach), posterior when ulnar fracture fixation was required (Boyd approach) or a combination of approaches (lateral + posteroulnar, lateral + medial).

The postoperative care did not follow a set protocol. The need for postoperative immobilization and its type was based on the associated injuries encountered. The same goes for the need for postoperative rehabilitation, which could either be immediate or delayed, either by a physiotherapist or self-directed.

Patients

Between May 1998 and December 2016, 92 arthroplasty procedures were done with the CRF implant in 91 patients immediately following a RH fracture. There were 37 men (41%) and 54 women (59%). The left side was involved in 53 cases (58%) and the right side in 39 (42%). The fracture was in the dominant arm in 34 patients. The mean age at the time of RH arthroplasty was 53 years (22–81). At the time of the injury, 47 patients were considered as sedentary or retired (52%), 29 did light manual labor (32%) and 15 did heavy manual labor (16%).

Fracture

All 92 RH fractures were classified as Mason type 3 according to the Mason classification as modified by Broberg-Morrey [16]. Among these 92 fractures, 29 were considered as isolated (31.5%). These isolated fractures were treated by resection-arthroplasty, with no additional procedures. Forty-one fractures (44%) were associated with ligament or other soft tissue injuries. Eighteen fracture (20%) had other bones fractured such as the olecranon, ulnar metaphysis or shaft, humeral condyles or distal humerus, while four fractures (4%) had combined ligament and bone damage. In these cases, resection-arthroplasty was combined with:

- suture repair of the lateral collateral (18 cases) and/or medial collateral ligaments (3 cases)
- anterior capsulorrhaphy by reinsertion on the coronoid (12 cases)
- fixation of coronoid fracture (7 cases)
- fixation of ulna fracture (19 cases)
- fixation of lateral condyle fracture (2 cases)
- fixation of proximal radius fracture (1 case).

Only the patients who were reviewed in person for the final assessment were included in our statistical analysis. Our study design is summarized in **Figure 1**. All the patients were evaluated at the last follow-up visit by an independent surgeon. The radiological analysis was done by an independent radiologist.

Clinical assessment, satisfaction, and functional outcome scores

Pain at the final assessment was evaluated using a visual analog scale (VAS) from 0 to 10. The patient's satisfaction was determined by asking the patient whether they were "very satisfied", "satisfied", "somewhat satisfied", "not satisfied" or "dissatisfied" with the procedure. The elbow's range of motion was measured with a goniometer. The elbow's mobility was considered as functional when flexion was greater than 130° and the extension deficit less than 30°. Elbow stability was evaluated based on subjective criteria (patient's feeling of instability) and objective criteria (examiner looking for posterolateral instability through a pivot shift) [17]. Maximum grip strength was evaluated over three successive trials using a Jamar dynamometer. The ratio between the operated and non-operated side was calculated. The functional outcome scores used were the Mayo Clinic Performance score (MEPS)[18] and the Disability of Arm-Shoulder-Hand (DASH)[19]. The MEPS was considered excellent if it was between 90 and 100, good if between 75 and 89, average if between 60 and 74, and poor if below 60.

Radiological outcomes

The radiological workup consisted of an AP view of the elbow in extension and a lateral view of the elbow in 90° flexion. These x-rays were used to look for radiolucent lines suggestive of periprosthetic loosening as described by Popovic et al. [20] (**Figure 2a**), suspended implant as evidenced by asymmetry in the humeroulnar joint (river delta sign) [21] (**Figure 2b**), decentering of the radial cup (radial shaft axis does not pass through center of capitellum –

equal to Storen's line) (**Figure 2c**), arthritic degeneration of the humeroulnar joint according to the Broberg-Morrey classification and graded as present or absent in our study [22] (**Figure 2d**), demineralization of the lateral condyle graded as present or absent in our study [23] and heterotopic ossification graded as present or absent in our study [24] (**Figure 2d**).

Statistical analysis

Results of the quantitative variables are given as mean \pm standard deviation, minimum, maximum, and median values; those of qualitative variables are expressed as counts and percentages. For the qualitative variables, the Chi² test was used according to the Monté Carlo method to estimate the value of a small p . To determine if two quantitative variables were related, a correlation analysis by linear regression was done and the statistical significance estimated with the Pearson test.

To compare quantitative variables, the Mann Whitney was used according to the Monté Carlo' method to estimate the values of a small p . To compare groups based on quantitative variables, the non-parametric Mann-Whitney or Kruskal Wallis test was used. In every case, the value of the small p was estimated with a Monté Carlo method with 5000 iterations and a 95% confidence interval. Significance threshold was $p < 0.05$.

Results

The population for analysis consisted of 41 fractures in 41 patients who were reviewed in person with a mean follow-up of 86.9 months (range, 12–228). There were 14 men (34%) and 27 women (66%). Their mean age at the time of arthroplasty was 59 years (24–81). Among these 41 fractures, 11 were considered as isolated (27%), 20 were associated with ligament injuries (49%) and 10 were associated with both ligament and bone injuries (24%).

Complications and surgical revisions

There were 10 postoperative complications (29%). The characteristics used for comparison are shown in **Table 1**. There was one case of posterior interosseous nerve palsy that developed immediately postoperative; it resolved in 10 months.

Clinical outcomes at final assessment (Table 2)

The mean MEPS was 88.7 (min 61, max 100). The mean DASH score was 18.7 (min 0, max 55). Three patients had to change jobs (7%). The grip strength in the operated arm was 87% (min 20%, max 189%) of the contralateral arm. The mean pain on VAS was 0.78 (min 0, max 5). Twenty-six patients (63%) had an average residual extension deficit of 13° (min 0, max 60°), although only three patients (7%) had non-functional range of motion. Seven patients (17%) had incomplete pronation–supination arc: one (2%) had no pronation-supination at all due to concurrent fracture of the distal ulna and radius; two patients (5%) had isolated supination deficit (50° and 45° supination, respectively), four patients (10%) had both pronation and supination deficits. One patient reported a feeling of elbow instability, but this was not associated with objective findings. No patients had objective signs of elbow instability.

Radiological outcomes at final assessment

The radiological results are reported in **Table 2**. **Figure 3** shows the radiological findings in a patient in whom the implant was positioned too high, with decentering of the radial cup, demineralization of the lateral condyle and humeroulnar osteoarthritis.

Clinical outcome as a function of follow-up time

Figures 4, 5 and 6 show the functional scores and grip strength relative to contralateral side as a function of the follow-up time. There was no statistical relationship between the MEPS,

DASH, grip strength ratio and the follow-up after RH arthroplasty ($p = 0.09$, $p = 0.7$, $p = 0.9$ respectively).

Radiological findings relative to follow-up time

Radiolucent lines suggestive of loosening were found around 10 implants (24%). The mean follow-up for these implants was 80 months (min 17, max 218). The 31 implants with no radiolucent lines had a mean follow-up of 82 months (min 12, max 228). There was no statistical relationship between the appearance of periprosthetic radiolucent lines and the time elapsed after RH arthroplasty ($p = 0.8$).

Impact of associated injuries at time of RH fracture (Tables 3,4)

The presence of associated ligament or bone injuries at the time of the RH fracture significantly increased the risk of periprosthetic radiolucent lines, radiological deterioration of the humeroulnar joint and decentering of the radial cup ($p = 0.03$, $p < 0.0001$ and $p = 0.03$, respectively). There was no statistical relationship between the presence of associated ligament or bone injuries and the functional outcomes (MEPS, DASH, and grip strength) ($p = 0.3$, $p = 0.3$, $p = 0.2$, respectively)

Functional outcomes relative to radiological findings

The radiological findings of cup decentering, periprosthetic calcifications and lateral condyle demineralization had no impact on the functional outcomes at the final assessment, nor the grip strength relative to the contralateral side (**Table 5**).

A suspended implant was associated with significantly worse functional outcomes (MEPS, DASH and grip strength, respectively: $p = 0.04$, 0.05 , 0.04) (**Table 5**). In 86% of cases, a suspended implant caused an extension deficit in the elbow (**Table 6**). However, our statistical analysis did not reveal a relationship between a suspended RH implant and extension deficit. There was also no statistical relationship between an implant being

suspended and the appearance of periprosthetic radiolucent lines or arthritic degeneration in the humeroulnar joint (**Table 6**).

Discussion

Our study found a strong relationship between the functional outcomes of mobile cup bipolar RH arthroplasty and the implant's positioning on radiographs. To improve the functional outcomes and reduce the risk of radiological degeneration, good implant positioning is critical [2, 25-27]. The aim is to reduce the initial length of the radius. If the radius is too short, there is a risk of secondary ulnar-carpal impingement[26]. Conversely, if the radius is too long, then there is a risk of causing arthritic degeneration of the lateral condyle and the humeroulnar joint [2, 28]. There should be no contact between the implant and the lateral condyle, both in flexion and extension [25]. It is also important not to overstuff the radial cup to limit the space taken up by the implanted cup. This size must be either the same as or slightly less than the original radial cup.

Our study also confirms that functional outcomes are stable in the medium term after performing RH arthroplasty with CRF® bipolar mobile cup for an acute elbow fracture. At a mean follow-up of 80 months, we found a mean MEPS of 89 and 78% good and excellent results. These functional outcomes are comparable to other published studies with the CRF® implant. The mean MEPS ranges from 87 to 96 in published studies with mostly good or excellent results (**Table 7**). This is confirmed by the DASH score, which was 18.7 on average in our study and is similar to the score reported by Laum et al. at 67 months' follow-up [7]. This type of arthroplasty also helps patients regain satisfactory grip strength, which was 87% of the contralateral side. This result within the range of that reported in other studies with the same type of implant (**Table 7**). Thus using a CRF® bipolar radial cup with cemented stem

restores good function in the operated limb, while allowing associated ligament injuries in the elbow and forearm to heal [7, 15, 29].

When we looked at the radiographs made during the final assessment, 24% had radiolucent lines around the stem. This incidence ranges from 0% to 53% in other published studies [20]. Chanlalit et al. reported a high loosening rate (65%) independent of the type of fixation (cemented vs press-fit) for the RH implant and the stem design, although the loosening had no major clinical consequences and did not get worse over time [10]. In their meta-analysis, Delclaux et al. concluded that the percentage of radiolucent lines was the same whether the stem was cemented or not [30]. In his meta-analysis of revision RH arthroplasty, Kachooei found no superiority of one implant over the other in terms of longevity and revision rate [31]. Moreover, the literature, like our study, does not find a relationship between the appearance of radiolucent lines around the stem and alteration in functional outcomes at the final assessment [10, 32].

Arthritic degeneration of the capitellum and demineralization of the lateral condyle has frequently been reported in the literature following RH arthroplasty [33]. Our study found that 54% of elbows had radiographic evidence of lateral condyle demineralization. However, a bipolar mobile cup appears to be better able to adapt its articulation with the lateral condyle, which helps to reduce the excess pressure over the lateral condyle and thereby to reduce the likelihood of arthritic degeneration [15, 29, 33]. Some authors advocate using a cementless stem to allow the implant to adapt its position relative to the lateral condyle, which would reduce the pressure on the lateral condyle. However, this is theoretical since many surgeons do not recommend using the bipolar implant in a press-fit configuration and instead recommend using a cemented stem [33, 34]. When it comes to choosing between unipolar and bipolar implants, Chytas et al. concluded that unipolar metal RH implants were

more likely to cause capitellum degradation and thus to trigger stiffness in the operated elbow [15]. However, the clinical study by Marsh et al. of 33 patients who received unipolar implants found that only 22% of them had lateral condyle demineralization at a mean follow-up of 8 years, which is lower than what we found with a bipolar implant [35]. Our study did not allow us to establish a link at the final assessment between lateral condyle demineralization and worse functional outcomes in our patients. Several other studies confirm this observation, no matter which implant was used [20, 36].

As for arthritic degeneration of the humeroulnar joint, our study found a 63% incidence of osteoarthritis at a mean follow-up of 80 months. This is comparable to the 64% incidence found by Moghaddam et al, who used a monoblock modular implant [37]. Based on the current literature, this implant also does not appear to affect the arthritic progression of the humeroulnar joint over the long term [3, 37].

The treatment of comminuted RH fractures requires an extensive preoperative assessment to make sure none of the associated injuries are missed. A preoperative CT scan is often needed to classify the RH fracture and to look for a coronoid fracture [7]. Moreover, it is essential to look for associated ligament damage in the context of a terrible triad elbow injury or Essex-Lopresti injury. In fact, surgical repair of these lesions is essential to reducing the risk of poor radiological and functional outcomes after RH arthroplasty [3]. According to Vannabouathong et al., the type of implant used is of secondary importance; the priority is making the correct diagnosis and treating the associated ligament injuries properly [3]. Consequently, no published studies has been able to demonstrate that one implant is superior to the others [6,22–27]. As for the stability of the operated elbow, Yian et al. showed in an *in vitro* study that bipolar implants restore elbow stability as well as monoblock implants, while providing better joint congruency and thereby theoretically

reducing the risk of implant subluxation [38]. Pomianowski et al. also showed that bipolar implants were as effective against valgus instability as monoblock implants [39]. Several other studies have corroborated this observation [28, 40]. However, other studies have contradicted these findings. Thus, certain authors feel that bipolar implants do not restore joint stability in a satisfactory manner. Monoblock implants are more effective at addressing an unstable elbow, for example in the context of a terrible triad injury [26, 31, 39].

Our study is one of the most important published studies on the CRF® implant, given the number of patient and length of follow-up (**Table 7**). To limit bias in this study, the functional outcomes were determined at the review point by an experienced physician who was not involved in the patient's surgical care. The radiographs were evaluated by an independent radiologist. Nevertheless, this study has the typically limitations associated with a retrospective study. Many patients were lost to follow-up. The functional scores were only evaluated at the final assessment; since we did not have this data preoperatively, we could not assess how function changed over time.

Conclusion

Our study found very good results when doing RH arthroplasty with a CRF® bipolar mobile cup in the context of comminuted RH fractures. Because of the elbow stability conferred by this implant, the radiological and functional outcomes were highly satisfactory in the medium term. However, to achieve good results, it is essential to properly analyze the fracture and associated injuries preoperatively. It is also critical to find any associated ligament lesions intraoperatively in order to treat them. The radiological and functional outcomes of RH arthroplasty after RH fracture are correlated with appropriate care of these associated lesions and good intraoperative positioning of the implant.

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Author contributions:

PSM, CC designed the study, collected data, did the statistical analysis, wrote the manuscript
GV, JH, CM, JLC provided critical review of the manuscript

Figures and Tables

Figure 1: Study flow chart

Figure 2: Radiographic findings

2a: Radiological appearance of periprosthetic radiolucent line

2b: Radiological appearance of suspended implant (river delta sign)

2c: Postoperative radiological appearance of non-centered radial cup in an implant that is too high

2D: Radiological appearance of early humeroulnar osteoarthritis and periprosthetic calcifications

Figure 3: In Patient 31, the implant was too high with off-centered radial cup, lateral condyle demineralization and humeroulnar osteoarthritis.

Figure 4: MEPS relative to follow-up after radial head arthroplasty

Figure 5: DASH score relative to follow-up after radial head arthroplasty

Figure 6: Grip strength relative to contralateral side as a function of follow-up after radial head arthroplasty

Table 1: Complications documented at final assessment

Table 2: Clinical and radiological outcomes at final assessment

Table 3: Impact of associated lesions on radiological findings

Table 4: Impact of associated lesions on clinical outcomes

Table 5: Functional outcomes based on presence of implant loosening, periprosthetic calcifications, off-centered cup, lateral condyle demineralization or incorrect implant positioning

Table 6: Effect of implant positioning on radiological findings and extension deficit

Table 7: Comparison of our findings with those of other published studies on the CRF® implant

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Figure 1:

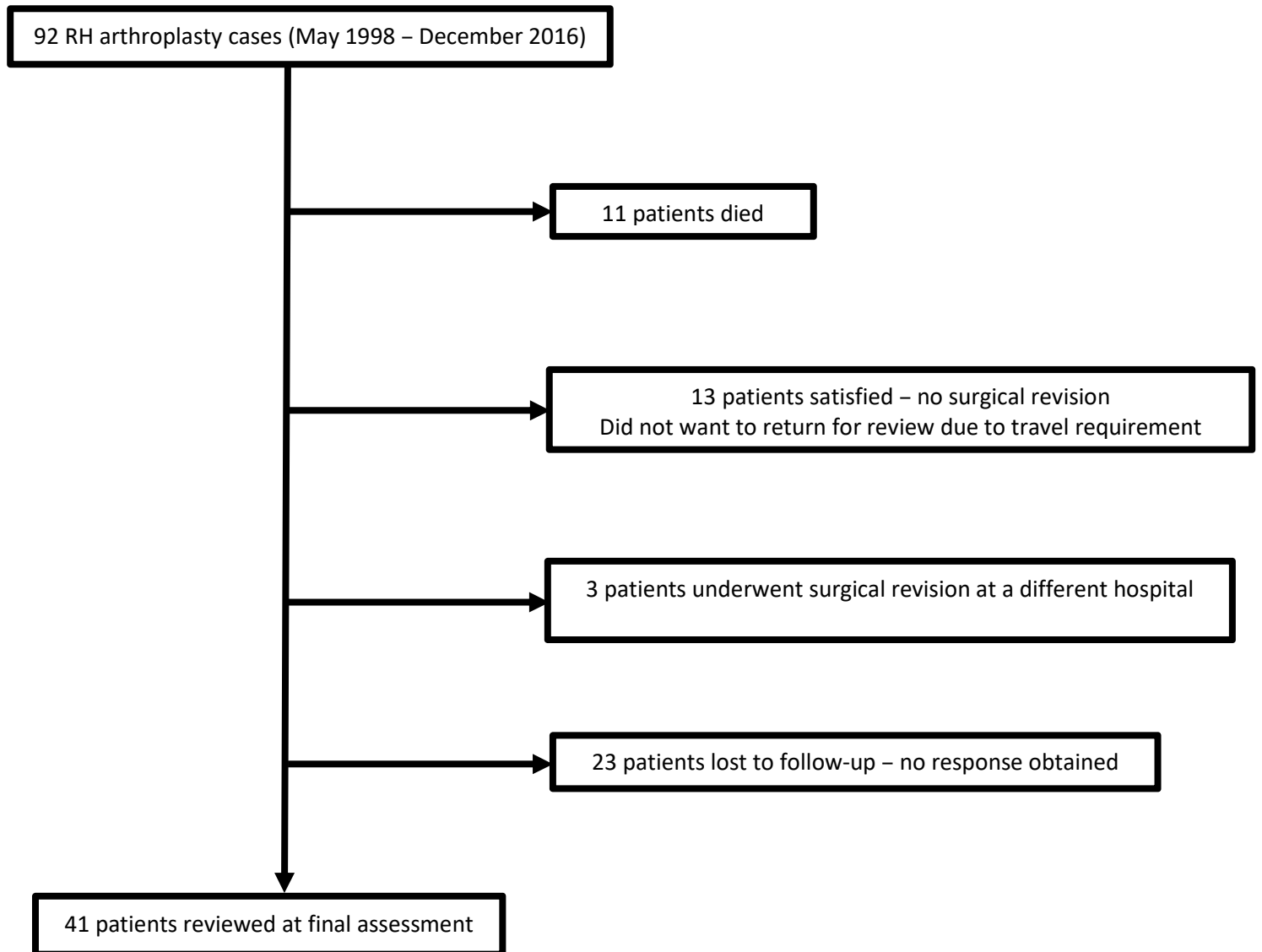


Figure 2 :



Figure 3 :

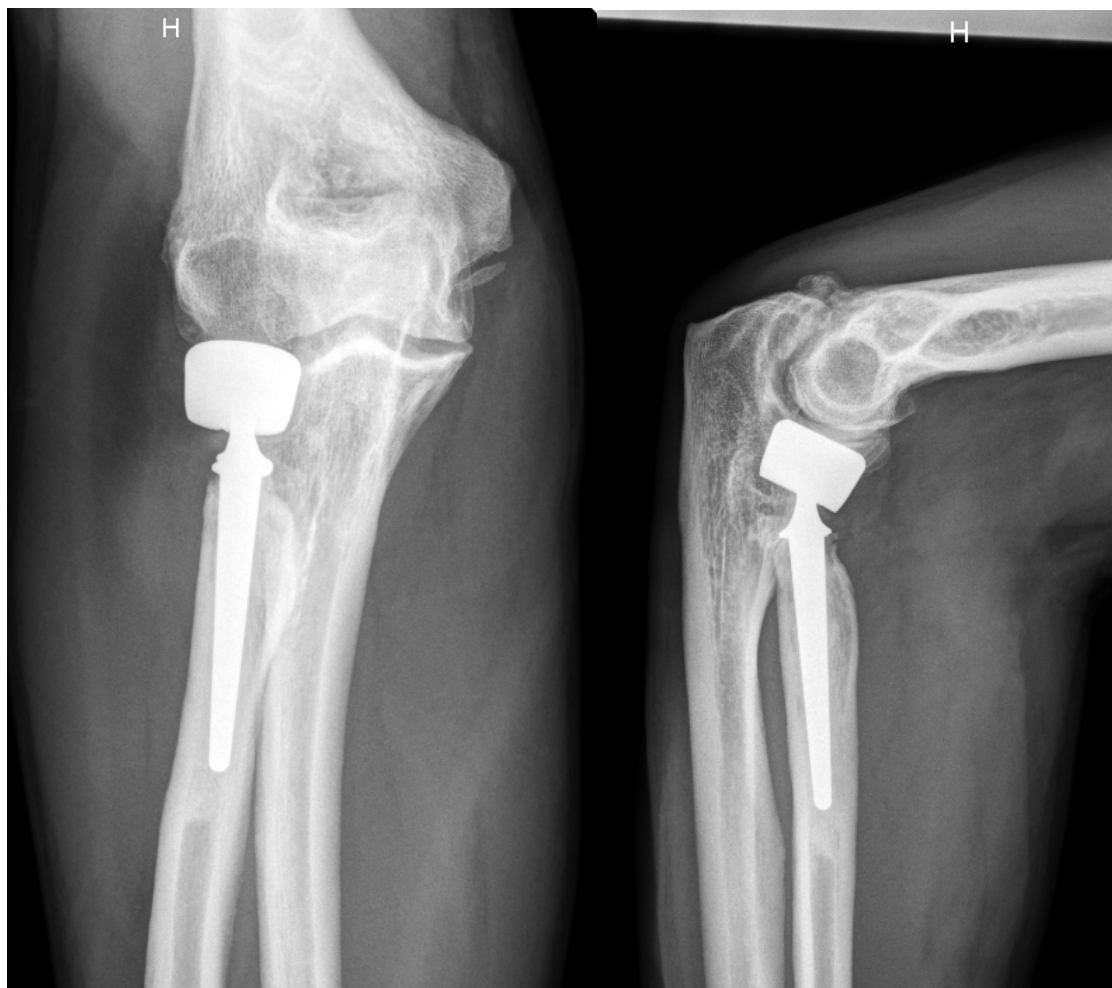
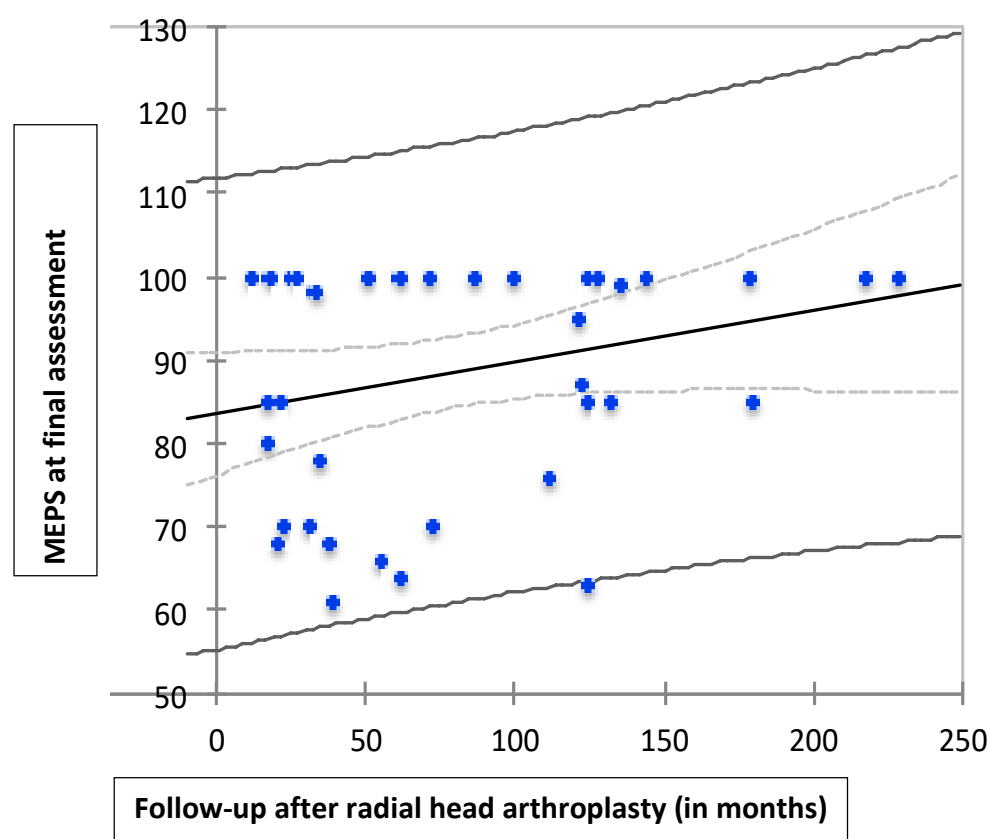


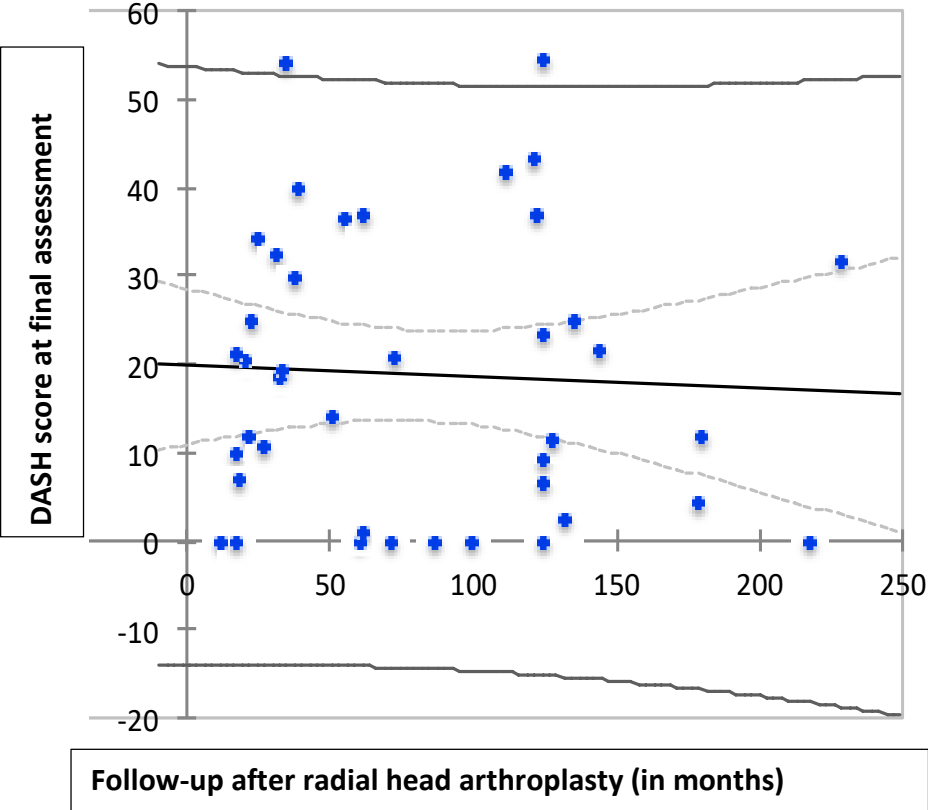
Figure 4:



MEPS

Significance of correlation	
p (Pearson) =	0.093
R ² =	0.071

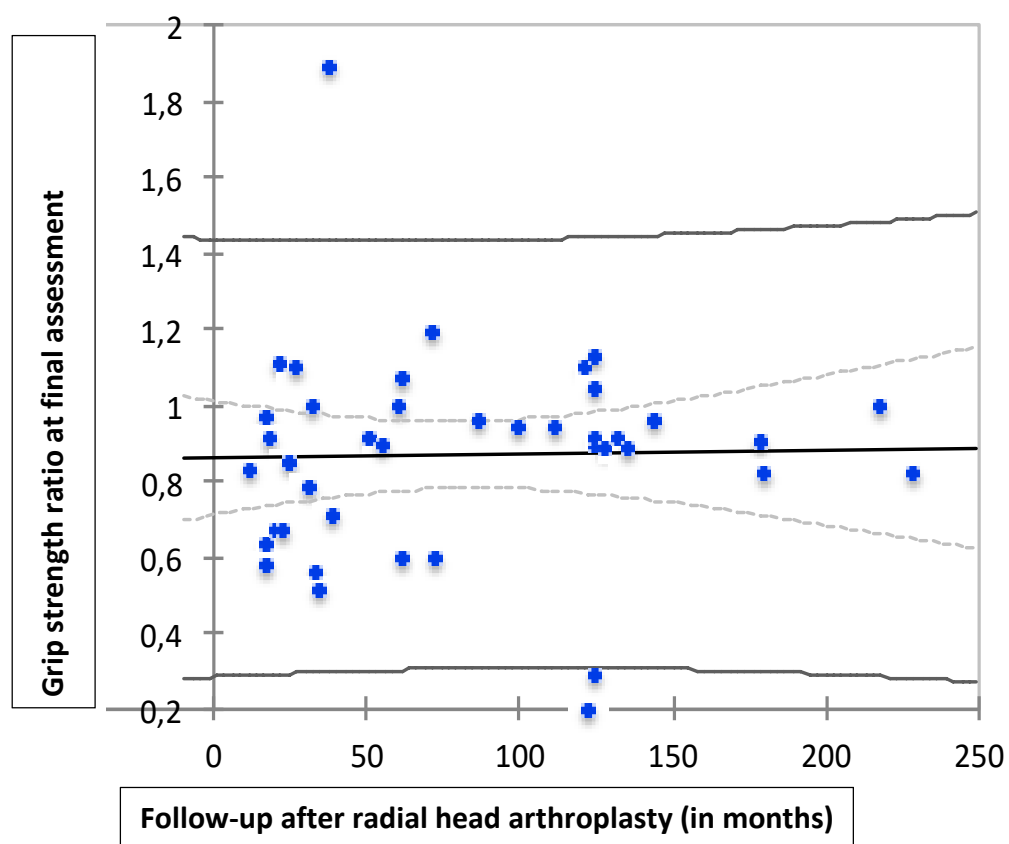
Figure 5:



DASH score:

Significance of correlation	
p (Pearson) =	0.762
R ² =	0.002

Figure 6:



Grip strength ratio:

Significance of correlation	
p (Pearson) =	0.886
R ² =	0.001

Table 1:

Complications, n (%)	10 (24.4%)
Complication without surgical revision: <ul style="list-style-type: none"> - Type 1 complex regional pain syndrome - Transient posterior interosseous nerve palsy 	5 (12.2%) 4 (9.8%) 1 (2.4%)
Complication with surgical revision: <ul style="list-style-type: none"> - Surgical revision without implant change <ul style="list-style-type: none"> ▪ Elbow arthrolysis ▪ Persistent humeroulnar subluxation ▪ Revision of other fracture fixation devices - Surgical revision with implant change 	5 (12.2%) 4 (9.8%) 1 1 (implantation of external fixator) 2 (1 removal of ulnar plate, 1 decortication-graft of proximal ulna) 1 (2.4%) (one suspended implant: implant change)

Table 2:

Last follow-up	Number of patients analyzed (n = 41)
Clinical outcomes	
Mean MEPS (min-max)	88.7 (61-100)
Excellent result (%)	23 (56%)
Good result (%)	9 (22%)
Mediocre result (%)	9 (22%)
Poor result (%)	0 (0%)
Patient satisfaction	
Very satisfied (%)	25 (61%)
Satisfied (%)	16 (39%)
Mean VAS for pain (min-max)	0.78 (0-5)
Range of motion (°)	
Flexion (min-max)	139.3° (120°-140°)
Extension (min-max)	-13° (0°- -60°)
Pronation (min-max)	69° (50°-70°)
Supination (min-max)	78.4° (45°-80°)
Radiological outcomes	
Radiolucent line around stem (%)	10 (24%)
Decentering of radial cup (%)	15 (37%)
Suspended implant (%), asymmetric humeroulnar joint space	7 (17%)
	26 (63%)
Alteration humeroulnar joint space (%)	24 (59%)
Peri-articular calcifications (%)	22 (54%)
Lateral condyle demineralization (%)	

Table 3:

	Periprosthetic radiolucent line			Humeroulnar joint degeneration			Cup decentered		
	No	Yes	p (Chi ²) = 0.03	Yes	No	p (Chi ²) = 0.0001	Yes	No	p (Chi ²) = 0.03
RH	11	0		1	10		10	1	
RH+LL	15	5		15	4		10	9	
RH+LL+BL	5	5		10	0		5	5	

RH: Isolated radial head fracture (stable elbow)

RH+LL: Radial head fracture + ligament lesions (unstable elbow)

RH+LL+BL: Radial head fracture + ligament lesions + other bone lesions (unstable elbow)

Table 4:

Variable	Number	Mean	Standard Deviation	p (Kruskal-Wallis)	95% CI
MEPS RH	11	91.5	14.5	0.3	0.280; 0.304
MEPS RH + LL	20	89.2	13.3		
MEPS RH + LL + BL	10	84.6	14.6		
DASH RH	11	13.2	15.9	0.3	0.250; 0.273
DASH RH + LL	20	19.7	16.6		
DASH RH + LL + BL	10	22.6	14.6		
Grip strength ratio RH	11	1	0.3	0.2	0.141; 0.159
Grip strength ratio RH + LL	20	0.8	0.3		
Grip strength ratio RH + LL + BL	10	0.9	0.2		

RH: Isolated radial head fracture (stable elbow)

RH+LL: Radial head fracture + ligament lesions (unstable elbow)

RH+LL+BL: Radial head fracture + ligament lesions + other bone lesions (unstable elbow)

Table 5:

Implant loosening	Number	Mean (min; max)	Standard Deviation	p (Mann-Whitney)	99% CI
MEPS No	31	89 (63-100)	14.027	0.482	0.464; 0.500
MEPS Yes	10	87 (61-100)	13.630		
DASH No	31	18 (0-55)	16.921	0.298	0.281; 0.314
DASH Yes	10	22 (0-40)	12.697		
Grip strength ratio No	31	0.8 (0.2-1.9)	0.267	0.092	0.081; 0.102
Grip strength ratio Yes	10	0.7 (0.2-1.1)	0.260		
Periprosthetic calcification					
MEPS No	17	86 (61-100)	15.645	0.356	0.338; 0.373
MEPS Yes	24	90 (63-100)	12.443		
DASH No	17	18 (0-42)	14.789	0.954	0.947; 0.962
DASH Yes	24	19 (0-55)	17.069		
Grip strength ratio No	17	0.9 (0.5-1.9)	0.289	0.424	0.406; 0.442
Grip strength ratio Yes	24	0.8 (0.2-1.2)	0.256		
Decentered cup					
MEPS No	25	87 (61-100)	14.580	0.657	0.640; 0.674
MEPS Yes	15	90 (66-100)	12.906		
DASH No	25	19 (0-55)	17.201	0.630	0.613; 0.648
DASH Yes	15	16 (0-44)	13.953		
Grip strength ratio No	25	0.8 (0.2-1.9)	0.328	0.343	0.326; 0.360
Grip strength ratio Yes	15	0.9 (0.6-1.2)	0.148		
Lateral condyle demineralization					
MEPS No	18	89 (61-100)	14.626	0.690	0.673; 0.707
MEPS Yes	22	87 (64-100)	13.486		
DASH No	18	14 (0-55)	15.457	0.067	0.058; 0.076
DASH Yes	22	22 (0-55)	15.706		
Grip strength ratio No	18	0.9 (0.2-1.9)	0.323	0.679	0.662; 0.696
Grip strength ratio Yes	22	0.8 (0.2-1.2)	0.233		
Implant positioning					
MEPS Correct	33	90 (61-100)	13.343	0.039*	0.032; 0.046
MEPS suspended	7	79 (63-100)	13.636		
DASH Correct	33	16 (0-42)	13.501	0.053*	0.045; 0.061
DASH Suspended	7	31 (0-55)	21.131		
Grip strength ratio Correct	33	0.9 (0.2-1.9)	0.267	0.038*	0.031; 0.045
Grip strength ratio Suspended	7	0.7 (0.2-1.1)	0.254		

Table 6:

Positioning of RH implant	Periprosthetic radiolucent line		p (Chi ²) = 0.67	Humeroulnar joint degeneration		p (Chi ²) = 0.4	Extension deficit		p (Chi ²) = 0.2
	No	Yes		Yes	No		Yes	No	
Correct	25	8		20	13		19	14	
Suspended	6	1		6	1		6	1	

Table 7:

	Number of patients	Age	Follow-up (months)	MEPS	DASH	Grip strength	Extension deficit	Implant change
Our study	41	53	81.6	88.7 Excellent: 23 Good: 9 Mediocre: 9	18.7	87%	13°	2
Burkhart et al. 2010 [36]	9	43	110	92.4 Excellent: 3 Good: 6	9.3	/	20°	1
Celli et al. 2010 [41]	16	46.1	41.7	89.4 Excellent: 12 Good: 2 Poor: 2	11.4	/	13°	0
Popovic et al. 2007 [20]	51	51	100.8	83	/	85.3%	15°	0
Dotzis et al. 2006 [42]	12	44.8	63	87.1 Excellent: 6 Good: 4 Mediocre: 1 Poor: 1	23.9	89.9%	13.7°	0
Holmenschlager et al. 2002 [43]	16	/	19	Excellent: 2 Good: 12 Mediocre: 1 Poor: 1	/	90%	5°	/
Smets et al. 2000 [44]	13	/	25.2	Excellent: 7 Good: 3 Mediocre: 1 Poor: 2	/	/	/	1
Judet et al. 1996 [13]	5	43	49	Excellent: 2 Good: 3	/	/	6°	/
Laum et al. 2019 [7]	45	49.9	67	90.3 Excellent: 26 Good: 10 Poor: 1	18.6	91.8%	12.5°	1
Heijink et al. 2016 [45]	25	55	50	89.6 Excellent: 14 Good: 7 Mediocre: 3 Poor: 1	/	91.8%	6°	1