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Original article

Factors affecting outcome of partial radial head fractures: A Retrospective Cohort Study

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ABSTRACT

Background: The purpose of this study is to evaluate which factors will affect range of motion (ROM) and function in partial radial head fractures. The hypothesis is that conservative treatment yields better outcomes.
Materials and Methods: This retrospective comparative cohort study included 43 adult volunteers with partial radial head fracture, a minimum 1-year follow up, separated into a surgical and non-surgical group. Risk factors were: associated injury, heterotopic ossification, worker's compensation, and proximal radio ulnar joint (PRUJ) implication. Outcomes included radiographic ROM measurement, demographic data, and quality of life questionnaires (PREE, Q-DASH, MEPS).
Results: Mean follow up was 3.5 years (1–7 years). Thirty patients (70%) had associated injuries with decreased elbow extension (-11°, $p = 0.004$) and total ROM (-14°, $p = 0.002$) compared to the other group. Heterotopic ossification was associated with decreased elbow flexion (-9.00°, $p = 0.001$) and fractures involved the PRUJ in 88% of patients. Only worker's compensation was associated with worse scores. There was no difference in terms of function and outcome between patients treated non-surgically or surgically.
Discussion: We found that associated injuries, worker's compensation and the presence of heterotopic ossification were the only factors correlated with a worse prognosis in this cohort of patients. Given these results, the authors reiterate the importance of being vigilant to associated injuries.
Level of evidence: IV, Retrospective study.

1. Introduction

Radial head fractures are relatively common, representing approximately one-third of all elbow fractures [1–3]. However, despite their high incidence, few studies focused on this subject in the literature. Treatment algorithms are usually guided by the modified Mason classification, and range from nonoperative treatment to radial head excision, with or without arthroplasty, depending on fracture type and the amount of displacement [4]. Displacement is classically evaluated on the articular surface of the radio-capitellar joint, but it is also important to consider the position of the radial head fracture relative to the ulna within the proximal radio ulnar joint (PRUJ). The vast majority of partial radial head fractures involve the PRUJ [5]. The portion of the radial head that doesn't conflict with the ulna during pronation is called the safe zone (SZ) [6,7]. Kodde et al. reported a 70% incidence of Mason type 1 fractures, suggesting most patients are treated without surgery. [8] Nevertheless, radial head fractures with associated bony injuries may require treatment and are more common than previously reported. Associated injuries occur in up to 92 % of cases [9] and the most frequently associated fractures involve the proximal ulna (coronoid and olecranon), carpus, and distal radius [8,10,11].

Outcomes are generally inversely proportional to the amount of force involved in the mechanism of injury, with simple fractures doing better than more comminuted ones. [2]. However, the prognosis for these fractures may also be influenced by associated injuries and patient-related factors (age, body index mass, gender, tobacco habit, etc.). Therefore, the purpose of this study is to define whether location and size of the radial head fracture, type of

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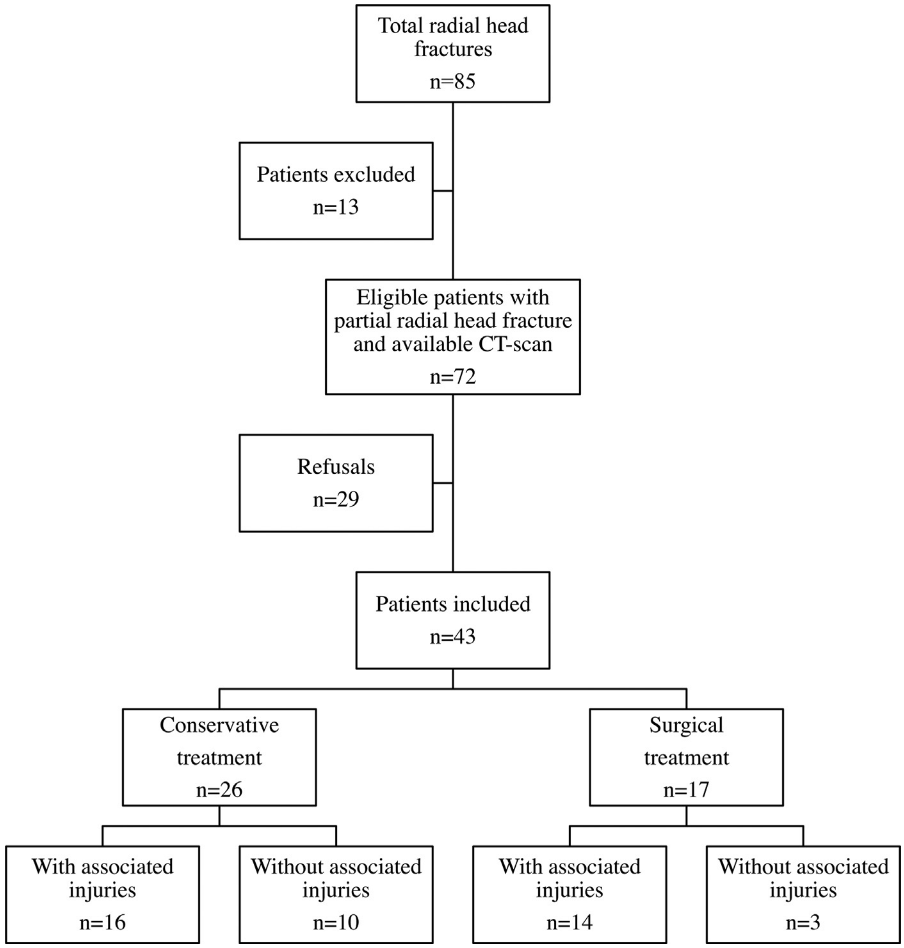

Fig. 1. Retrospective cohort study flowchart.

treatment, associated injuries, and patient related factors influence both ROM and clinical outcomes. Our hypothesis is that nonoperative treatment yields better outcomes in terms of range of motion (ROM), function, and pain.

2. Patients and Methods

Patients from a level-1 trauma center were selected from the surgical and radiological databases over a seven-year period. All elbow X-rays were reviewed and all patients 18 years and older with a partial radial head fracture with available CT-scan were eligible. Inclusion criteria were: patients with a partial radial head fracture (OTA/OA type B classification), X-ray, and CT scan with sufficient image quality to visualize the biceps tendon [12]. Exclusion criteria were: fractures involving the entire head or neck of the radius, no available CT-scan, open physes, and pre-existing elbow pathology (osteoarthritis, heterotopic ossification, or prior fracture). Patient flowchart is presented in Fig. 1.

Selected participants were contacted and invited to take part in this study. Demographic data collected included: age, smoking status, hand dominance, height, weight, frequency, and type of physical exercise prior to the fracture. Second, volunteers were invited to complete validated function and Quality of Life (QoL) questionnaires: Quick-DASH (Disability of the Arm, Shoulder and Hand) [13], PREE (Patient-Related Elbow Evaluation) [14], MEPS (Mayo Elbow Performance Score) [15], and Pain scale [16]. Third, participants took new radiographs of both elbows, including standard AP and lateral views, as these provide more reliable data when using the radiological method [17]. The lateral views were taken in

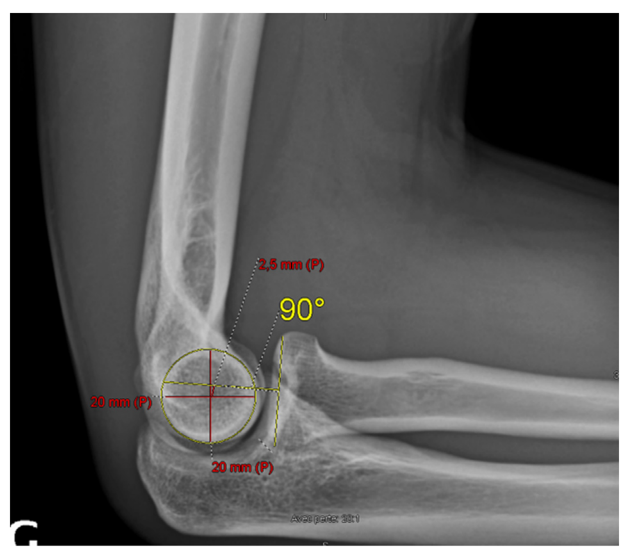

Fig. 2. Radiocapitellar ratio (RCR) = (2.5 mm/20 mm) × 100 = 12.5%.

maximal flexion and maximal extension with the forearm in neutral position to determine ROM. A radiologist reviewed the standard AP and lateral images for diagnostic purposes. (Fig. 2) Radial head fracture fragment displacement was measured on a 90° lateral X-ray (Fig. 3). [18] The maximal flexion and extension lateral X-rays were used to measure range of motion (Figs. 4 and 5) [17]. The

Fig. 3. Axial displacement of the radial head fracture = 4.0 mm.

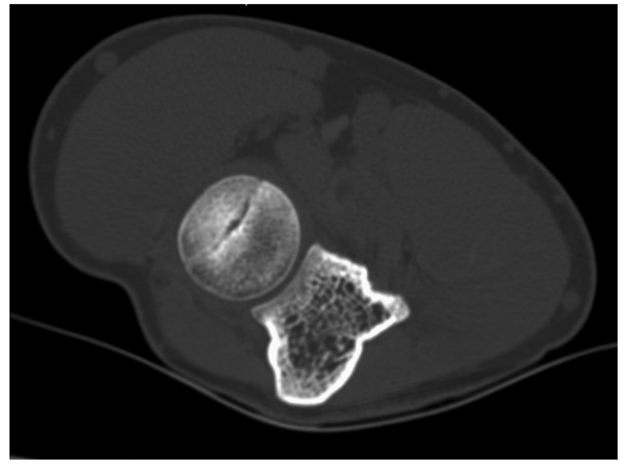

Fig. 6. Fracture located in the SZ and PRUJ.

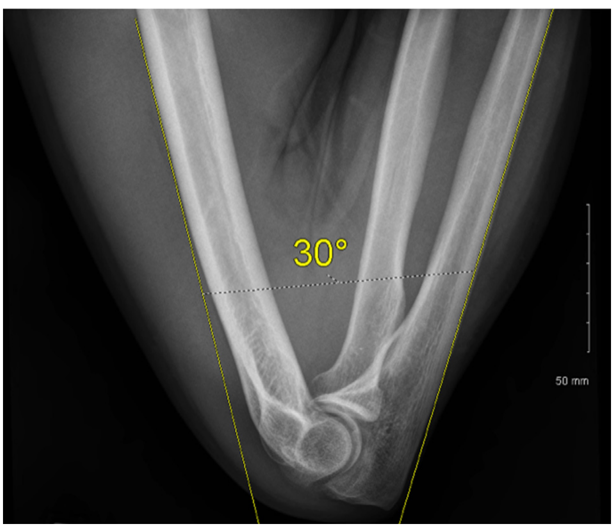

Fig. 4. Maximal flexion = 180°–30° = 150°.

Fig. 5. Maximal extension = 166°–180°=–14°.

same radiological series were taken on the contralateral side. Horizon medical imaging 12.0 (McKesson, Richmond, Canada) software was used for all radiographic measurements. The uninjured elbow was selected to represent the pre-operative reference, since it has been shown that ROM is similar on both sides [17,19]. The fracture angle is defined as the angle between the two fracture lines of the proximal aspect of the radial head in axial view. This angle was determined using CT-scan (Fig. 6).

The CT-scan was used to determine the radial head fracture angle in the axial view and the position of the fracture according to the PRUJ. A stencil previously designed and validated was used to classify the fracture as PRUJ positive or negative [20]. The stencil was applied on the axial view of the scan, aligned with the insertion of the biceps tendon on the radial tuberosity. Subsequently, while keeping the stencil affixed to the screen, images were scrolled until the proximal aspect of the radial head was shown. Then, using a stencil indicating where the SZ and PRUJ were situated, the fracture was analyzed. The angle attesting that the radial head fracture was in the SZ only, starting from the radial tuberosity, was between 108° and 212°, clockwise for a right elbow and counter-clockwise for a left elbow [20]. Then, it was easy to determine whether the fracture involved the SZ and/or the PRUJ. After determining the position of the fracture with the stencil, the fracture angle was measured with the radiology software.

Participants were separated into two groups, based on treatment type (surgical and nonoperative management). As this was a retrospective study, treatment was decided by the treating surgeon at time of presentation. Patients who underwent surgical treatment for associated injuries were still considered nonoperative if the radial head fracture was not treated surgically. Statistics were performed with StatPlus software (version 6, AnalystSoft, CA). The demographic characteristics of both groups were first compared using unpaired Student *t*-test and Fisher's exact test. The Student *t*-test was used to compare both groups according to ROM outcomes and QoL scores.

Participant characteristics and associated injuries were tested for correlation with four QoL questionnaires. All patients were included into a Pearson correlation analysis. Student's *t*-test analysis compared the impact of associated injuries on outcome parameters. A power study, based on a difference of 10° of total ROM loss between the 2 treatment groups, a standard deviation of 8° [21], an alpha of 0.05 and a power of 80%, found that 12 patients per group were needed [22]. The local ethics committee approved this retrospective cohort study design.

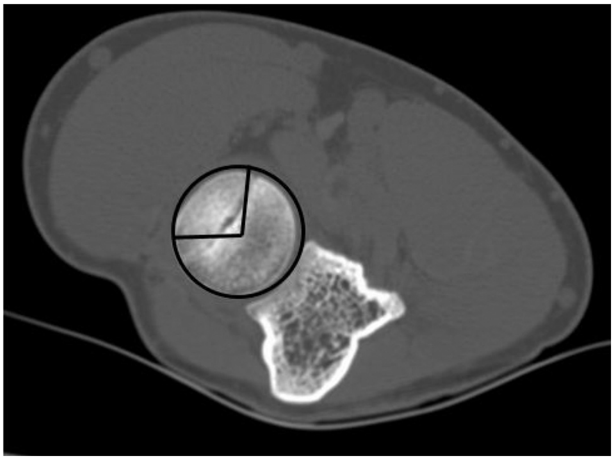

Fig. 7. Fracture located in the SZ only.

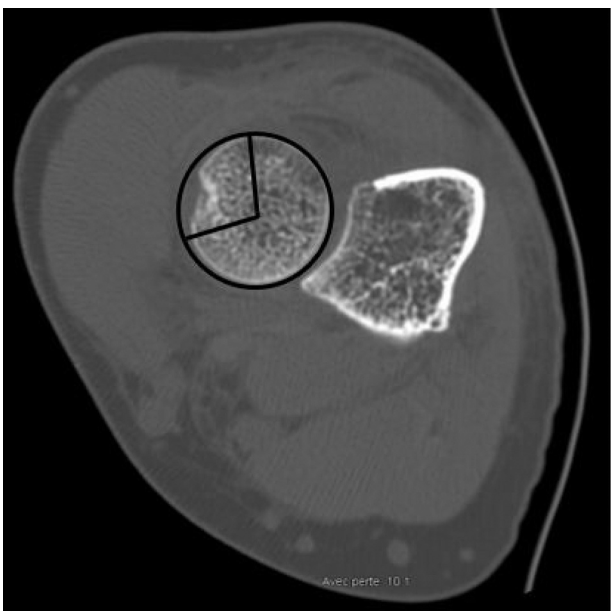

Fig. 8. Radial head fracture angle = 115° (SZ and PRUJ).

3. Results

Forty-three patients were included in the study cohort. There were 27 males and 16 females with a total mean age of 49.6 years old. The mean delay between injury and functional evaluation was 3.5 years (1–7 years). The dominant side was injured in 42% of cases. The vast majority of radial head fractures (88%, $n = 38$) involved both the SZ and the PRUJ (Figs. 7 and 8). Seventy percent ($n = 30$) of participants had at least one associated injury. Twenty-six participants underwent conservative treatment and 17 had surgery. Neurological lesions included traumatic brain injury, median, ulnar or radial nerve injury, and were present in four participants. Heterotopic ossification (HO) was found in 16% of elbows ($n = 7$) (Table 1).

The comparison between the normal and injured side revealed that maximal extension (mean +11.5° vs. +20.1°, $p < 0.001$) and total ROM (mean 133.4° vs. 122.1°, $p < 0.001$) were significantly decreased. The average strength for the JAMAR test was 35 kg for the healthy side and 32 kg for the injured side. There was no significant difference between the healthy and fractured side for the available supination and pronation data (Table 2). The average Quick DASH, MEPS, PREE and Pains Scale scores were 18.5, 87.6, 26.8 and 3.4 respectively.

3.1. Factors affecting ROM

Comparison of demographic characteristics (Table 1) showed that patients treated surgically demonstrated a statistically higher number of associated ulna fractures (9 vs. 12, $p = 0.031$). The surgical group presented with larger fracture fragments, as demonstrated by a greater fracture angle ($p = 0.010$) (Fig. 9; Table 3.). The Quick DASH, PREE, MEPS and Pain scale were comparable between both groups. The presence of associated injury was correlated with decreased extension ($p = 0.004$) and decreased total ROM ($p = 0.002$) (Table 4). The loss of flexion ($p = 0.01$) and total ROM ($p = 0.016$) was significantly higher in patients with heterotopic ossification (Tables 5–6).

3.2. Factors affecting function

Worker's compensation was a risk factor associated with decreased Quick DASH score ($r = -0.3$, $p = 0.037$). Loss of maximal extension was also correlated with the Quick DASH ($r = -0.4$, $p = 0.011$) and Pain scale scores ($r = -0.3$, $p = 0.030$). Loss of total range of motion was also correlated with Quick DASH ($r = -0.5$, $p = 0.003$), PREE ($r = -0.4$, $p = 0.012$) and Pain scale ($r = -0.4$, $p = 0.020$) results. Regarding associated injuries, elbow dislocation negatively influenced the Quick DASH ($r = -0.3$, $p = 0.040$) score, while ulna fractures correlated with worse MEPS ($r = -0.3$, $p = 0.035$). The presence of an associated injury was correlated with a loss of extension ($p = 0.004$) and of total ROM ($p = 0.002$) (Table 4).

4. Discussion

Treatment for partial radial head fractures is guided in part by the Mason classification, although associated injuries and motion block are important factors. Nonoperative treatment has traditionally been used for simple and nondisplaced radial head fractures, while surgical treatment was reserved for complex and displaced fractures [3,8,23,24]. The purpose of this study was to evaluate the impact of treatment choice on elbow ROM and function, at a minimum of one year following radial head fracture. Our hypothesis was that nonoperative treatment would yield better outcomes. However, we found no statistical difference in outcomes based solely on treatment type, which confirms findings from previous studies. Nonetheless, the p-value remained low ($p = 0.071$) when we compared the fragment's axial displacement between the nonoperative and surgical groups. The average initial articular step-off was also different between the two groups with 1.82 mm and 3.44 mm, respectively. It should also be noted that both groups in our study were not comparable, as shown by the greater displacement in the operated group. Indeed, a systematic review by Strujis et al. of 24 studies, between 1966 and 2004, on 825 radial head fracture patients, concluded that the evidence was insufficient to determine optimal treatment for type II-IV radial head fractures [25]. Furthermore, Yoon et al., found no benefit to ORIF in partial radial head fractures [26]. The retrospective nature of the present study made it impossible to establish what guided the treatment choice (conservative or surgical) which could also be a relevant factor. A prospective study, using only Mason's classification and displacement of the fragment to determine treatment, is currently being conducted by Bruinsman et al. (2014) who published their study protocol, but the results have yet to be reported.

Table 1
Demographics.

	Total cohort ($n = 43$)	Nonoperative treatment group ($n = 26$)	Surgical treatment group ($n = 17$)	p value
Age (range)	49.6 (20–87)	48.7 (20–87)	50.9 (25–73)	0.672[a]
BMI (range)	27.8 (18–38)	27.0 (18–35)	29.0 (22–38)	0.218[a]
Gender				
Male (%)	27 (63)	18 (69)	9 (53)	0.343[b]
Female (%)	16 (37)	8 (31)	8 (47)	
Smoking (%)	7 (16)	5 (19)	2 (12)	0.685[b]
Physical activity				
Yes (%)	32 (74)	20 (77)	12 (71)	0.728[b]
1–2 times/week	14			
3–4 times/week	13			
5–7 times/week	5			
Work accident (%)	8 (19)	6 (23)	2 (12)	0.446[b]
Traffic accident (%)	4 (9)	3 (12)	1 (6)	1.000[b]
Monotrauma (%)	26 (60)	17 (65)	9 (53)	0.528[b]
Dominance				
Right handed (%)	41 (95)	26 (100)	15 (88)	0.151[b]
Fracture of the dominant elbow (%)	18 (42)	10 (38)	8 (47)	0.753[b]
Localization of the fracture				
SZ only	2 (5)	2 (8)	0	0.510[b]
PRUJ only	3 (7)	3 (12)	0	0.266[b]
SZ and PRUJ	38 (88)	21 (80)	17 (100)	0.067[b]
Patients with associated injuries (%)	30 (70)	16 (62)	14 (82)	0.187[b]
Number of associated injuries	45	22	23	
Dislocation (%)	10 (23)	4 (15)	6 (35)	0.158[b]
Humerus fracture (%)	14 (33)	9 (35)	5 (29)	0.753[b]
Distal humerus	8 (19)	6 (23)	2 (12)	–
Medial epicondyle	1 (2)	1 (4)	0	–
Lateral epicondyle	5 (12)	2 (8)	3 (18)	–
Ulna fracture (%)	21 (49)	9 (35)	12 (71)	**0.031**[b]
Coronoid	15 (35)	7 (27)	8 (47)	–
Olecranon	8 (19)	3 (12)	5 (29)	–
Proximal ulna	7 (16)	3 (12)	4 (24)	–
ORIF of the humerus (%)	4 (9)	3 (12)	1 (6)	1.000[b]
ORIF of the ulna (%)	12 (28)	4 (12)	8 (47)	**0.037**[b]
Type of treatment				
Resection of the fragment (%)	1 (2)	–	1 (6)	–
Screw(s) (%)	6 (14)	–	6 (35)	–
Plate and screws (%)	1 (2)	–	1 (6)	–
Prosthesis (%)	9 (21)	–	9 (53)	–
Extraction of material (%)	2 (5)	–	2 (12)	0.151[b]
Heterotopic ossification (%)	7 (16)	2 (8)	5 (29)	1.000[b]
Neurological lesions (%)	4 (9)	2 (8)	2 (12)	0.528[b]

BMI: body mass index; ORIF: open reduction and internal fixation; PRUJ: proximal radio ulnar joint; SZ: safe zone. The bold indicated significant p values.

[a] Student t-test.

[b] Fisher's exact test.

Table 2
JAMAR, pronation and supination data.

Measurements	Healthy side	Fractured side
Pronation ($n = 38$)	Mean: 86° ± 9° Range: 50° to 95°	Mean: 89° ± 3° Range: 80° to 95°
Supination ($n = 38$)	Mean: 81° ± 14° Range: 30° to 95°	Mean: 86° ± 8° Range: 65° to 98°
JAMAR ($n = 43$)	Mean: 35 kg ± 14 kg Range: 14 kg to 70 kg	Mean: 32 kg ± 14 kg Range: 4 kg to 70

4.1. Clinical outcomes

Among the variables used to evaluate outcome, ROM was the most important determinant.

Although there is no other data on the effect of associated injuries on radial head fractures for ROM and function using QoL questionnaires, our results indicate that the presence of associated injuries significantly influences extension and total range of motion of the elbow. Indeed, stiffness is the most common adverse outcome of a radial head fracture, secondary to capsular contracture [3]. Studies by Kodde et al. and Lapner et al. reported concomitant injuries in 11% and between 10 and 30% of radial head fracture patients respectively [4,23], while Itamura et al. reported associated injuries in 92% of cases following an MRI evaluation [9]. Coronoid fractures are reported to be the most commonly associated injury according to Capo et al. (17/25 = 68%) [5], while Van Riet et al. found that 20 out of 46 patients with a Mason II radial head fracture also had a coronoid fracture, olecranon fracture, medial and/or lateral collateral ligament tears [10]. Similarly, our results showed that 70% of patients had associated injuries; coronoid fractures being the most frequent, followed by olecranon fractures. This data highlights the importance of detection for associated lesions and raises the question of whether a systematic CT-scan might be a necessary adjunct when treating these types of injuries.

For QoL scores, the overall mean outcomes for the entire cohort (43 patients) were worse when compared to established historical data for the DASH score, PREE score, and pain scale but better for the MEPS score. The Quick DASH scores following radial head fracture reported in previous studies ranged from 6.0 to 14.1 [27]. Fowler et al. reported a systematic review of 11 articles on patients over 50 years of age that had undergone a radial head arthroplasty with a mean MEPS score of 88.6/100 and an extension deficit of 15.9° [28]. They also reported an overall median pain score of 0 (range 0 to 8) [29]. This differs from our own results (3.4/10) and could be attributed to the more complex nature of the associated injuries

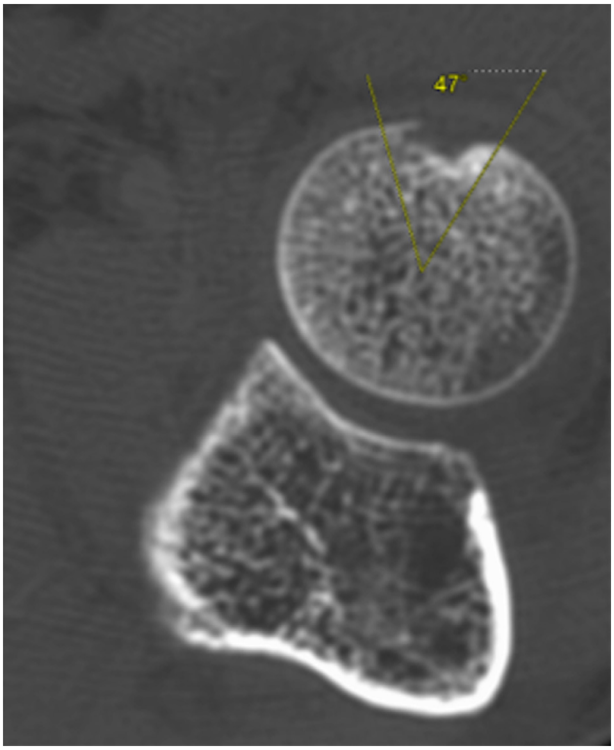

Fig. 9. Radial head fracture angle = 47° (SZ only).

in the current series and explain the discrepancy with the literature. Furthermore, replacement may lead to less pain than fracture fixation or conservative treatment [30,31].

The link between worker's compensation status and worse outcome in fractures is well documented. In this cohort it was associated with worse Quick DASH scores. The correlation was low but significant.

According to Hong et al. the presence of heterotopic ossification is also associated with decreased ROM [30]. Foruria et al. reported 48 cases of HO among 142 fractured proximal radius or ulna treated surgically and 20% of these had a decreased ROM [32]. In our study, sixteen percent ($n = 7$) of patients had HO. Two of the 17 surgically treated patients developed HO, which is less than the literature. The appearance of HO is gradual and increases with time, severity of trauma, and residual joint instability [33].

4.2. Radiological data

There is no significant difference in the axial displacement of the fragment between the nonoperative and surgical groups, but the *p*-value remains low ($p = 0.071$). The average initial articular step-off for the conservative and surgical groups were 1.82 mm and 3.44 mm respectively, which correlated with our protocol of a 2 mm cut-off for surgical treatment [34].

This study has some limitations associated with its design. Indeed, this is a retrospective, voluntary-based study with its inherent selection bias. Comparing patients with and without surgery in a retrospective manner probably also means comparing two different groups of patients. Moreover, patients with a CT-scan do not represent the majority of patients with a radial head fracture. It is likely that only the more complex fractures had a CT scan, excluding the simple, non-displaced fractures from the cohort. Therefore, the severity of elbow trauma in these patients is probably greater than in those with simple radiographic images. Furthermore, the two groups were not perfectly comparable when it came to associated fractures and fragment type. The group with surgery presented greater displacement acutely which could also explain why the Quick DASH, PREE and pain scale results were worse than those reported by the literature. Finally, the supination and pronation data were not available for the entire cohort. These considerations

Table 3
Impact of conservative versus surgical treatment.

	Conservative treatment group ($n = 26$)	Surgical treatment group ($n = 17$)	*p* value (Student *t*-test)
Fracture angle (°)	119.04	163.29	**0.010**
Fracture step-off (mm)	1.82	3.44	0.071
Loss of flexion (°)	1.69	4.06	0.229
Loss of extension (°)	7.42	10.59	0.301
Loss of total ROM (°)	9.12	14.65	0.136
Variation of RCR (%)	6.03	8.93	0.101
Quick DASH	18.8	18.1	0.809
PREE	25.3	29.2	0.705
MEPS	88.5	86.2	0.642
Pain scale	3.3	3.6	0.723

The flexion, extension, total ROM, and RCR report the difference between the uninjured and injured side. Quick DASH: Quick Disability of the arm, shoulder and hand; PREE: patient-rated elbow evaluation; MEPS: mayo elbow performance score. The bold indicated significant *p* values.

Table 4
Impact of associated injuries.

	No associated injuries ($n = 13$)	With associated injuries ($n = 30$)	*p* value (Student *t*-test)
Angle of fracture (°)	137.69	136.03	0.465
Fracture step-off (mm)	2.63	2.39	0.381
Loss of flexion (°)	2.31	2.77	0.414
Loss of extension (°)	2.92	11.17	**0.004**
Loss of total ROM (°)	5.23	13.93	**0.002**
Variation of RCR (%)	6.44	7.49	0.220
Quick DASH	21.0	17.4	0.105
PREE	34.0	23.7	0.171
MEPS	83.1	89.5	0.108
Pain scale	4.2	3.0	0.104

The flexion, extension, total ROM and RCR report the difference between the uninjured and injured side Quick DASH: Quick Disability of the arm, shoulder and hand. PREE: PAtient-rated elbow evaluation. MEPS: mayo elbow performance score. The bold indicated significant *p* values.

Table 5
Impact of fracture localization.

	SZ only ($n=2$)	PRUJ only ($n=3$)	p value (Student t-test)
Angle of fracture (°)	67.50	95.33	0.162
Fracture step-off (mm)	2.40	0.67	0.086
Loss of flexion (°)	3.00	3.67	0.442
Loss of extension (°)	0	9.33	0.186
Loss of total ROM (°)	3.00	13.00	0.208
Variation of RCR (%)	7.32	5.44	0.299
Quick DASH	11.00	16.33	0.207
PREE	1.00	30.33	0.234
MEPS	100	85	0.136
Pain scale	0	3	0.212

The flexion, extension, total ROM and RCR factors report the difference between the uninjured and injured side Quick DASH: Quick Disability of the arm, shoulder and hand. PREE: patient-rated elbow evaluation; PRUJ: proximal radio ulnar joint; SZ: safe zone.

Table 6
Impact of heterotopic ossification.

	With HO ($n=7$)	Without HO ($n=36$)	p value (Student t-test)
Angle of fracture (°)	130.14	137.78	0.374
Fracture step-off (mm)	1.07	2.73	0.076
Loss of flexion (°)	9.00	1.39	**0.001**
Loss of extension (°)	11.00	8.22	0.247
Loss of total ROM (°)	20.00	9.61	**0.016**
Variation of RCR (%)	7.97	7.09	0.363
Quick DASH	17.43	18.72	0.358
PREE	35.57	25.14	0.220
MEPS	90.00	87.08	0.327
Pain scale	3.00	3.47	0.346

The flexion, extension, total ROM, and RCR report the difference between the uninjured and injured side. Quick DASH: Quick Disability of the arm, shoulder and hand. PREE: patient-rated elbow evaluation; PRUJ: proximal radio ulnar joint; HO: heterotopic ossification. The bold indicated significant p values.

make it more difficult to conclude on the value of partial radial fracture treatment.

5. Conclusion

The findings in this study should encourage surgeons to be mindful of the presence of associated injuries when deciding on treatment for partial radial head fractures. Following the application of our treatment algorithm, there was no significant difference between treatment modalities. However, patients with associated injuries had a significant loss of extension and total elbow ROM, which were both correlated with worse functional outcome scores. Therefore, definitive treatment choice should consider all related injuries and specifically address them to favor early mobilization and potentially prevent worse outcomes.

Ethical Review Committee Statement

Research Ethics committee approval granted by the HSCM #2015-1168.

Disclosure of interest

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The other authors declare that they have no competing interest.

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Author contributions

Anne Couture: study design, analysis of data, drafting of article and final approval. Jonah Hébert-Davies, Julien Chapleau, G. Yves Laflamme, Emilie Sandman: acquisition of data, critical revision and final approval. Dominique M. Rouleau: study design and conception, acquisition and interpretation of data, drafting of article and final approval.

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