Archives of Orthopaedic and Trauma Surgery (2019) 139:1723–1729
https://doi.org/10.1007/s00402-019-03250-3

TRAUMA SURGERY

Ex situ reconstruction of comminuted radial head fractures: is it truly worth a try?

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Received: 28 January 2019 / Published online: 5 August 2019

Abstract

Introduction Complex radial head fractures are difficult to treat. In cases where stable fixation cannot be achieved, radial head resection or primary arthroplasty are frequently performed. Ex situ reconstruction of comminuted fractures may also be an option. This technique has widely been neglected in the literature, and only two small case series report satisfactory results. The aim of the present case series was to determine the functional and radiological outcomes of ex situ reconstructed Mason III and Mason IV fractures. We expect that the on-table reconstruction of comminuted radial head fractures will lead to bony union with no avascular necrosis in the postoperative course, which will demonstrate that this operative procedure is a reasonable option.

Patients and methods Two Mason type III and seven Mason type IV fractures (including four Monteggia-like lesions) were reconstructed ex situ. The mean age of the patients was 47 years (range 22–64). The clinical examination included RoM tests, elbow stability tests, and a neurological examination. The functional outcome was assessed with the MEPS and DASH score. The radiographic examination included a.p. and lateral views of the elbow to detect non-unions, inadequacy or loss of reduction, radial head necrosis, heterotopic ossifications and signs of posttraumatic arthritis.

Results The mean follow-up time was 39 months (range 11–64). The mean MEPS was 82 points (range 15–100), and the mean DASH score was 20 points (range 0–85). All ex situ-reconstructed radial heads survived, and no signs of avascular necrosis were observed. Bony union was achieved in all but one patient who presented with an asymptomatic non-union. Signs of posttraumatic arthritis were found in all patients. With regard to the radial head, neither secondary resection nor arthroplasty had to be performed. All patients returned to their pre-injury occupations.

Conclusion Ex situ radial head reconstruction can be a reliable option in the surgical treatment of complex radial head fractures associated with severe elbow trauma. Even in the midterm follow-up, no signs of avascular necrosis were observed. Modern implants may even extend the indications for reconstruction in such cases.

Level of evidence Level IV—retrospective cohort study

Keywords Radial head fracture · Mason III and IV · On-table reconstruction · Ex situ reconstruction · Radial head arthroplasty

Introduction

Radial head fractures are common and account for approximately one-third of all fractures around the elbow [1, 2]. According to Mason, fractures are classified as type I through IV, where type IV was added to the original classification 8 years after the initial classification [3, 4]. Type I fractures are simple and not displaced and may be managed conservatively. Type II fractures are simple but displaced and may require operative treatment. Type III fractures are complex, displaced and involve the whole radial head.

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Treatment options consist of open reduction and internal fixation (ORIF), arthroplasty or radial head resection, with different results reported in the literature [5–15]. Type IV fractures are associated with elbow dislocations. Although ORIF is classically performed with all fragments in situ to avoid compromising its blood supply, in situ fixations may not always be achievable because of comminuted fractures and a limited working space. In such cases, the surgeon can decide to either resect the head or perform arthroplasty. However, since the radial column is of great importance for elbow joint stability, resection of the radial head may lead to secondary instability, particularly when a concomitant lesion to the medial collateral ligament is present. Thus, primary arthroplasty is an option in non-reconstructable fractures. However, complications such as stiffness, overstuffing, and loosening of the prosthesis are frequently reported [13, 16, 17].

If anatomic reduction and stable fixation cannot be achieved in situ, the surgeon may even try to reconstruct the radial head on-table prior to fixing it to the radial neck and shaft. Currently, there are only a few reports in the literature about the on-table reconstruction of complex radial head fractures, and these studies all have different techniques, functional results and healing rates [18, 19].

Therefore, we conduct a retrospective study to evaluate the clinical and radiological outcomes of our own patient cohort with ex situ-reconstructed radial head fractures. Our hypothesis is that ex situ reconstruction of Mason III and IV fractures leads to good functional results, bony union and no avascular necrosis in the postoperative course.

Patients and methods

This retrospective study was authorized by the local IRB (2017–726-f-S). According to the ICD-Code (International Statistical Classification of Diseases and Related Health Problems), a total of 415 patients with radial head fractures were treated in our level-I trauma centre between 2010 and 2016. Patients included in the study were above age of 18 years with ex situ-reconstructed Mason III and Mason IV fractures. Further inclusion criteria were the absence of concomitant fractures of the affected extremity (other than Monteggia), the absence of previous injuries of the affected limb and osseous maturity with closed epiphysis. After assessing all patient records, 9 radial head fractures were found to have been reconstructed ex situ (Fig. 1). Among these fractures, there were two Mason type III fractures. Three fractures were associated with elbow dislocations (Mason type IV), and four fractures were assessed as Monteggia-like lesions (3×Bado and Jupiter type 2a, 1×Bado and Jupiter type 2d). The collateral ligaments were ruptured in eight cases, whereas the processus coronoideus was fractured in two cases (2× "terrible triad"). The mean age of the patients was 47 years (range 22–64, SD 14). The dominant arm was involved in seven patients. The mechanism of injury was a fall on the outstretched arm in three cases and a high-velocity accident in six cases. The diagnosis was confirmed by conventional X rays of the elbow in the a.p. and lateral views followed by a CT scan to better analyse the fracture and plan the operative treatment. The demographic data are shown in Table 1.

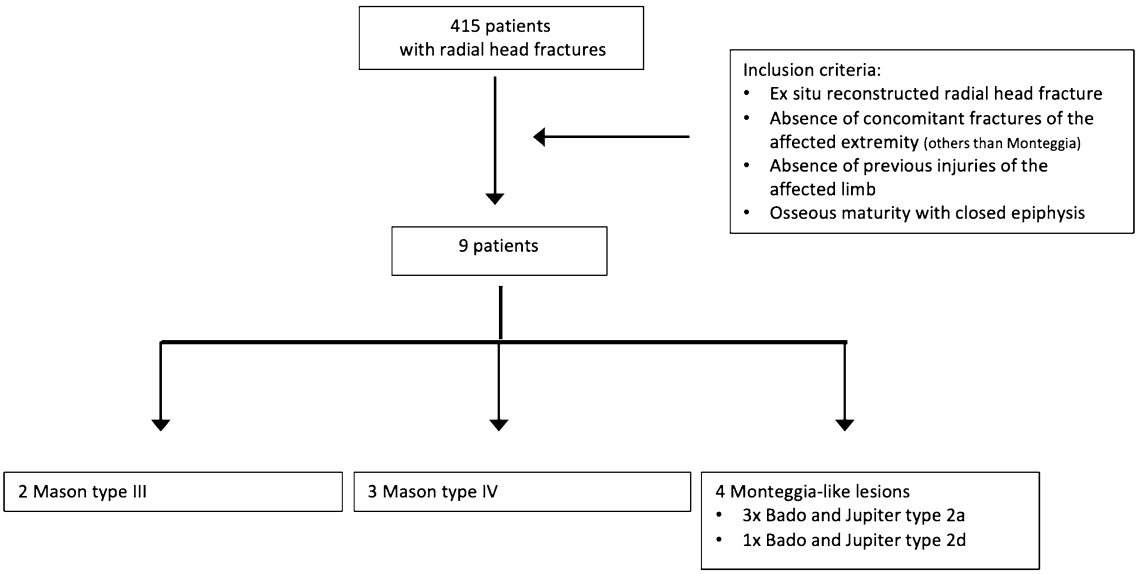

Fig. 1 Flow diagram of patients' inclusion in the study

Table 1 Demographic data of the patient cohort

Sex	
f	4
m	5
Age	
Mean value	48
SD	14
Range	22–64
Side	
Right	7
Left	2
Fracture	
Mason III	2
Mason IV	7
Follow-up (in month)	
Mean value	39
SD	18
Range	11–64

Surgical procedure

Based on the review of the operative records, the operations were performed by seven different surgeons with the patient placed in the supine position under general anaesthesia with an additional brachial plexus block in all cases. The decision to perform an ex situ reconstruction instead of arthroplasty or resection was based on the operating surgeon. Using the Kocher approach, the radial head fracture was exposed. In three cases, the additional ulna fracture was addressed via a dorsal approach. In one case, the radial head fracture was fixed via a dorsal approach prior to fixation of the concomitant ulnar fracture. The radial head fragments were retrieved from the joint and fixed on-table using reduction clamps and k-wires followed by interfragmentary screw fixation. The radial head was repositioned and fixed to the radial shaft with a T-plate (DepuySynthes, Umkirch, Germany) or a preshaped radial head plate (Medartis, Basel, Switzerland) (Figs. 2 and 3). A review of the operative records revealed additional collateral ligament fixation using anchor systems in eight patients and additional ORIF of the proximal ulnar fracture in four patients with Monteggia-like lesions. According to the patient records, the affected arm was immobilized in a static brace for 1 week and followed by active-assisted exercise. If collateral ligament surgery was performed, a functional brace was applied for 6 weeks to allow the reconstructed ligaments to heal. In one case, a hinged external fixator was used because the elbow joint remained unstable after the bony and soft-tissue reconstruction.

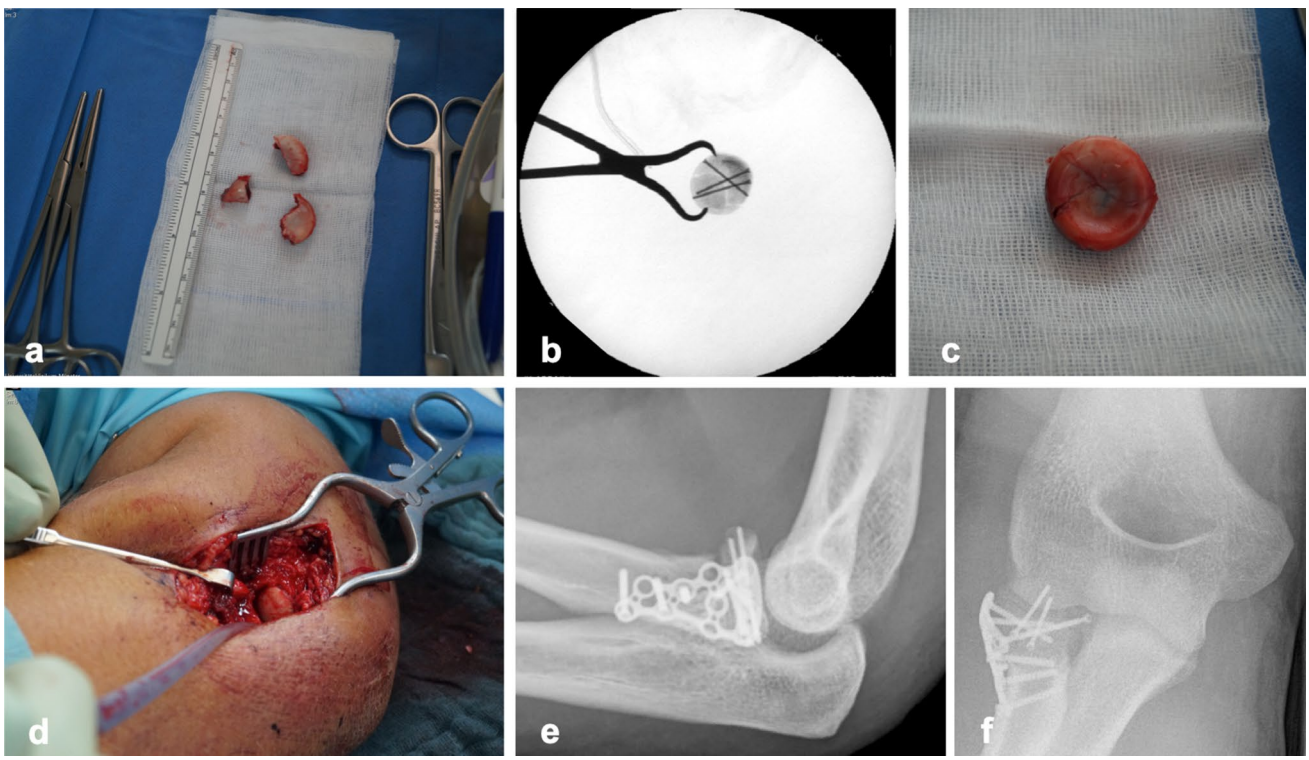

Fig. 2 Intraoperative situation: **a** fragments were retrieved and cleaned; **b**, **c** reconstruction of the radial head with interfragmentary screws; **d** repositioning of the head to the shaft; **e**, **f** 6-weeks follow-up

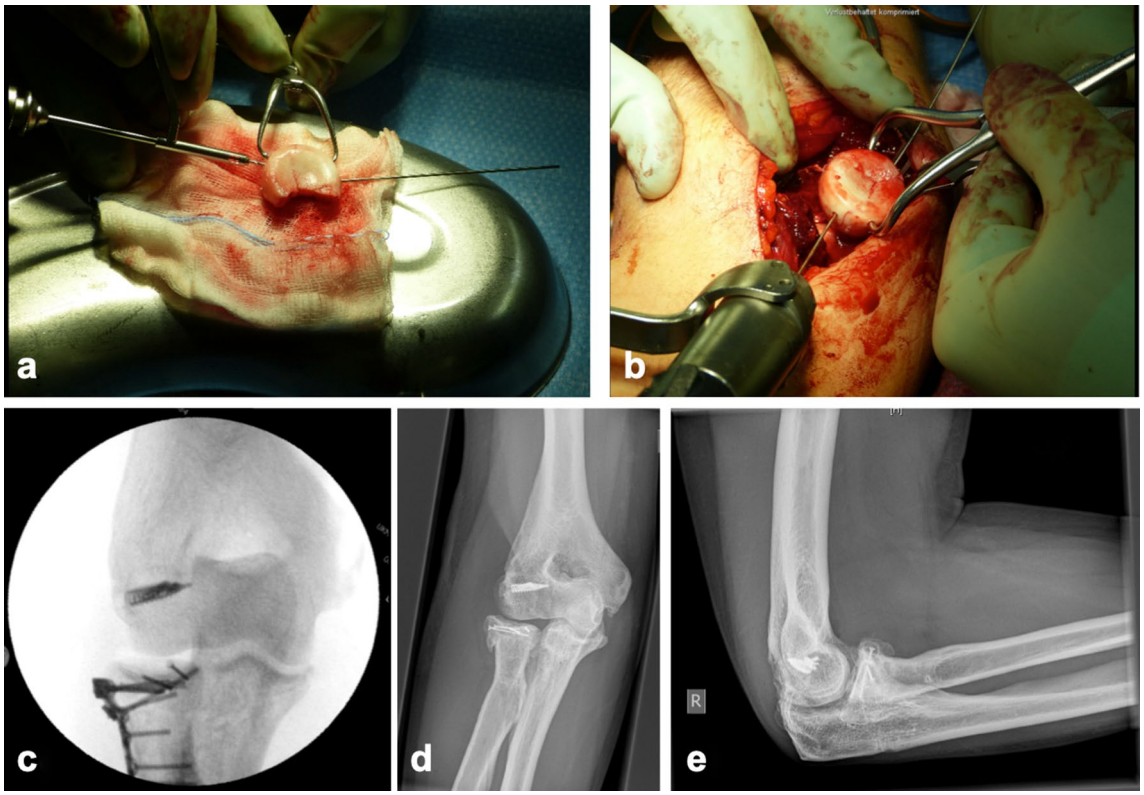

Fig. 3 Intraoperative situation **a** on-table reconstruction of the radial head; **b** fixation of the head to the shaft; **c** intraoperative X ray showing additional anchor fixation of the ligaments; **d**, **e** 3-year follow-up (after partial removal of the implants)

Follow-up examination

All nine patients with ex situ-reconstructed radius heads were contacted for clinical and radiological follow-up examinations. The clinical examinations were performed and interpreted by two senior physicians, who are specialised in injuries of the upper extremity and were not involved in the previous surgical treatment. The clinical examination contained the assessment of the elbow range of motion using a goniometer, elbow stability tests and a neurological examination (Fig. 4). Two validated scoring systems were used to determine the functional outcome: the Disability of the Arm, Shoulder and Hand questionnaire (DASH) and the Mayo elbow performance score (MEPS) [12, 16, 19]. The radiographic examination included a.p. and lateral views of the elbow to detect non-unions, inadequacy or loss of reduction, radial head necrosis, heterotopic ossifications (according to the Hastings and Graham system [20]) and signs of post-traumatic arthritis (according to the Broberg and Morrey classification [6]). The evaluation of the radiographs was performed by the above-mentioned two senior physicians. Any discrepancies concerning the radiological assessment were resolved by a third independent senior radiologist. Furthermore, complications such as nerve injury, infections and hardware-related complications were noted.

Results

All patients were available for the follow-up examination. The mean follow-up time was 39 months (range 11–64, SD 18). Based on the review of the operation records, the average number of articular radial head fragments fixed intraoperatively was 3 per patient (range 3–6).

Clinical outcome

The clinical examination revealed a mean MEPS of 82 points (range 15–100, SD 28), and the mean DASH score was 20 points (range 0–85, 36). Flexion of the elbow averaged 120° (range 100–140°, SD 10°). The extension deficit averaged 20° (range 0°–60°, SD 20°). Furthermore, the average arc of forearm rotation was 120° (range 50°–180°, SD 50°), with an average supination of 50° (range 0–90, SD 40°) and an average pronation of 70° (range 50°–90°, SD 20°). One of the patients showed mild laxity under varus stress but the lateral Pivot-shift test was negative, i.e. there was no sign of posterolateral instability of the elbow. None of the patients showed neurological deficits. Table 2 illustrates the functional results of all patients.

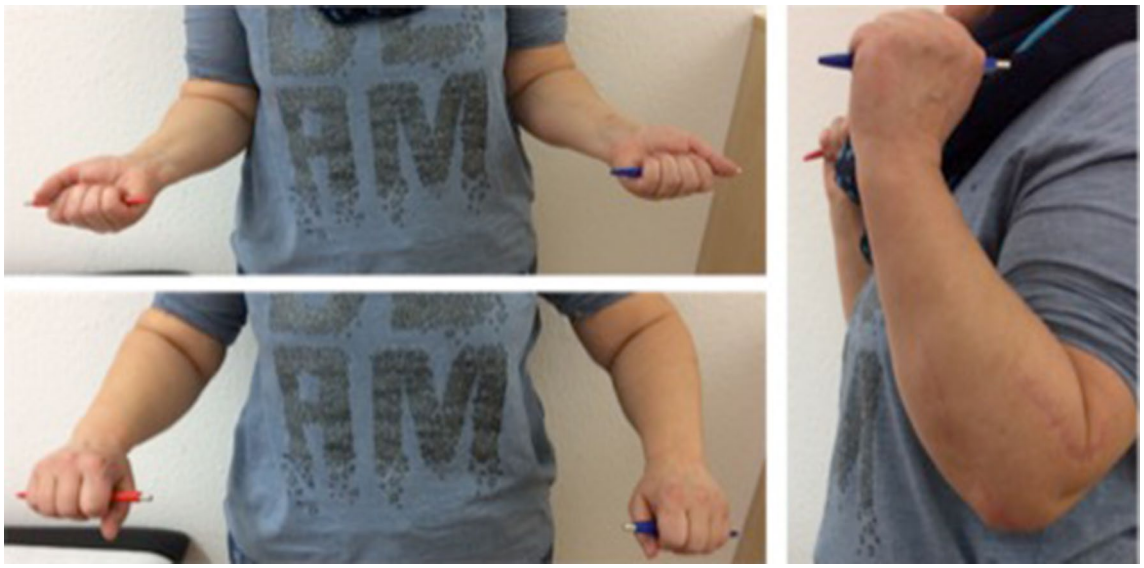

Fig. 4 Functional results 12 months after the operation

Table 2 Range of motion, functional and radiographical results

	Mean value	SD	Range
Functional score			
MEPS	82	28	15–100
Pain	35	15	0–45
Motion	19	2	15–20
Stability	9	3	0–10
Function	19	11	0–25
DASH	20	36	0–85
Range of motion			
Flexion	120°	10°	100–140°
Extension	− 20°	− 20°	− 60° to 0°
Supination	50°	40°	0–90°
Pronation	70°	20°	50–90°
Radiological score			
Arthrosis (Broberg and Morrey Score)			
Grad 0	0		
Grad 1	5		
Grad 2	4		
Grad 3	0		
Grad 4	0		
Ossification (Hastings and Graham Score)			
Grad I	5		
Grad lia	3		
Grad IIb	1		
Grad lic	0		
Grad III	0		

SD Standard deviation; *MEPS* Mayo Elbow Performance Score; *DASH* Disability of the Arm, Shoulder and Hand; Broberg and Morrey Classification [6]; Hastings and Graham Classification [20]

Radiological outcome

All ex situ-reconstructed radial heads survived, and no signs of avascular necrosis were observed at the final follow-up. Bony union was achieved in all but one patient who presented with an asymptomatic non-union. Signs of posttraumatic arthritis were found in all patients (grades 1 and 2 according to Broberg and Morrey [6]). Furthermore, mild ossifications were observed in all patients (grades I, IIa and IIb according to Hastings and Graham [20]) (Table 2).

Complications

Seven patients required a surgical revision. In two cases, the radial head plates had to be removed due to ulnar-radial impingement with limited pronation-supination. In another two cases, arthroscopic arthrolysis was performed due to posttraumatic elbow stiffness. The other three patients had ulnar plates removed on request due to soft tissue irritation after the fracture has healed uneventfully. The average time to revision operation was 7 months (range 1–19, SD 7).

With regard to the radial head, neither secondary resection nor arthroplasty had to be performed.

All patients returned to their pre-injury occupation.

Discussion

The most important finding of the present study is that all ex situ-reconstructed radial heads survived and showed bony union, except for one case. No signs of avascular necrosis were observed within the follow-up period. Corresponding

to successful fracture healing, the clinical results were satisfying. The MEPS was excellent in five of the nine patients and good in two of the nine patients. The following two patients showed poor results: one patient with a Monteggia-like lesion (Bado and Jupiter type 2a) that was operated on 12 days after the initial injury (all other patients were treated operatively within 24 h after injury); and one patient with a Mason type IV fracture that needed additional stabilization with a hinged external fixator.

Currently, there are only two reports in the literature that exclusively focus on ex situ or on-table reconstruction of complex radial head fractures. Businger et al. [18] found excellent results in two patients with on-table reconstruction who demonstrated an average range of motion of 0°–6°–141° for extension-flexion and an average MEPS of 99.2 points.

More recently, Kiran Kumar et al. [19] reported six patients with on-table reconstruction of Mason type III radial head fractures. After a mean follow-up of 25 months, bony union was achieved in only 3 of the 6 patients, and in one case, avascular necrosis occurred. In all non-united fractures, a metaphyseal comminution was present. Regardless of the non-union, the functional results were satisfying with a mean flexion of 135°, an extension contracture of 5° and a Broberg and Morrey score of 90 points.

In addition, Chen et al. reported 23 radial head fractures, of which 10 were reconstructed externally using lag screws and fixation of the head against the radial neck with only k-wires [8]. There was one case of a non-union and three fixation failures that required radial head replacement. The overall complication rate was 47.9%. However, fixation failure may be related to the method of fixation (k-wires) since lower implant failure rates were reported for plate fixation, even in comminuted radial head fractures [7, 9]. Crönlein et al. [9] recently presented the results of 20 patients treated with anatomically preshaped low-profile locking plates for type III and IV fractures. After a mean follow-up of 30 months (range 18–53), excellent functional results with only minor ROM deficits, particularly for pronation–supination, were observed. Implant failure and non-unions were not observed in that series. The authors concluded that even complex radial head fractures could be managed successfully with modern implants, and therefore, ORIF should be the first option to treat these complex fractures.

Most fractures in the present case series were associated with concomitant lesions of the elbow. Four fractures were found in Monteggia-like lesions, and three fractures occurred with elbow dislocations. With a mean MEPS of 82 points, the functional results in our cohort of patients are comparable to those reported in the literature for Monteggia-like lesions and elbow dislocations. Wu et al. found a MEPS of 89 points in patients treated with ORIF for Mason type III and IV fractures [21]. However, the functional results were significantly better after fixation of less-complex Mason type II fractures (mean MEPS 97 points) than for more complex fractures. Burkhart et al. reported on functional results after fixation of Mason type III and IV fractures with newly developed preshaped angular stable plates [7]. Overall, a mean MEPS of 87 points (range 60–100) was achieved. The mean extension deficit was 12°. They did not observe any implant-related complications. Similar to Crönlein et al., they concluded that even complex fractures could successfully be reconstructed with these modern implants [7, 9].

In complex radial head fractures, two other treatment options exist, i.e. radial head resection or arthroplasty. Radial head arthroplasty has been shown to be a reliable alternative if stable fixation cannot be achieved in complex radial head fractures [22]. Similar results can be expected when compared to ORIF. In a recent meta-analysis, Sun et al. [23] found better outcomes for patients treated with arthroplasty compared to those treated with ORIF for Mason type III and IV fractures. However, the methodological quality of the included studies was moderate to low. Excision of the radial head seems to be a poor alternative because this method results in inferior outcomes, subsequent valgus deformation and proximal radial migration.

Since the number of patients with on-table radial head reconstruction is rather low in the presented case series and seven different surgeons performed the operations, it is not possible to derive a clear treatment algorithm for such complex fractures. However, the distinct aim of the study was to evaluate the healing rate and the risk of avascular necrosis after ex situ reconstruction. In all but one case, the fracture has healed, and we did not observe signs of avascular necrosis. It must be the aim of future prospective studies to proof these results in comparison to other treatment options, i.e. radial head replacement.

Conclusion

Despite the high rate of secondary interventions, ex situ radial head reconstruction can be a reliable option for the surgical treatment of complex radial head fractures associated with severe elbow trauma. Even in the mid-term follow-up, no signs of avascular necrosis were observed. We conclude that the risk of avascular necrosis after complex, multifragmentary radial head fracture and ex situ reconstruction can be neglected. The high revision rate was not specifically associated to the radial head reconstruction but the complexity of the injury itself.

Funding There is no funding source.

Compliance with ethical standards

Conflict of interest The authors declare they have no conflicts of interest.

Ethical approval All procedures performed in this study were in accordance with the local IRB and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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