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ORIGINAL PAPER

Radial head prosthesis in complex elbow dislocations: effect of oversizing and comparison with ORIF

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Abstract
Purpose Elbow dislocations with complex elbow instability (CEI) and unstable radial head fractures require reconstruction by open reduction and internal fixation (ORIF) if possible or alternatively by a radial head prosthesis. The aim of this study was to determine the differential outcome of both strategies and to investigate the contribution of prosthesis-related radiographic factors such as oversizing on clinical outcome.
Methods A total of 53 patients underwent ligament and coronoid refixation, and radial head reconstruction by ORIF (n=18; group 1) or by monopolar modular prosthesis (n=35; group 2). Patients were followed by the Mayo Elbow Performance Score (MEPS) and a radiological score including prosthesis oversizing, joint subluxation, ossifications, capitellar erosions, implant loosening and ulno-humeral osteoarthritis. To investigate the effect of oversizing, group 2 was subdivided by prosthesis overlenghtening≥2 mm.
Results A total of 42 patients (79.2 %) could be followed for 3.0±1.3 years with an average MEPS of 76.8±17.2. Patients with ORIF had slightly better MEPS (82.1±9.9) as compared with group 2 (74.7±19.1) though three ORIF patients required an early conversion to prosthesis. In group 2, oversizing occurred frequently and 50 % showed an overlenghtening≥2 mm. Oversizing significantly decreased MEPS (63.2±21.3 vs 84.7±9.0; p=0.001) and elbow range of motion and increased the occurrence of other radiological abnormalities and the risk for surgical revisions. The radiological score and prosthesis overlenghtening but not prosthesis diameter showed an inverse correlation with MEPS.
Conclusions In CEI a radial head reconstruction with a prosthesis demonstrates similarly good clinical results as compared to ORIF in anatomically sized prosthesis, but prosthesis oversizing could induce other radiographic abnormalities with then deteriorated outcome.

Keywords Complex elbow dislocation · Radial head fracture · Radial head prosthesis · Oversizing

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Introduction

Traumatic elbow dislocations are second only to shoulder dislocations and occur at an approximate rate of 6–13/100,000 [1]. Elbow dislocations are divided into simple dislocations with ligament injuries and complex dislocations with concomitant fractures of the radial head, olecranon, coronoid or the distal humerus. Such complex elbow instabilities (CEI) destabilise the joint because of damage to the articular surface and require surgical repair [2]. CEI is classified by dislocation types and concomitant fractures such as unstable radial head fractures. According to Ring, complex radial head injuries follow patterns with a combination of (1) rupture of interosseous ligaments, (2) medial collateral complex, (3) posterior dislocation, (4) coronoid fracture and posterior dislocation (terrible triad) and (5) transolecranon fractures [3]. An unstable radial head fracture is defined by severely dislocated fractures with fragments at a distance from the fracture site [3]. The stability of the radial head fracture is important for the treatment strategy and complication rates are related to instability as determined by fracture pattern [4].

In CEI the current treatment recommendations for unstable radial head fractures include a reconstruction by open reduction and internal fixation (ORIF) if possible [3] or by replacement with a prosthesis [3], though no treatment option showed any proof of being superior to another [5]. A primary excision of the radial head should be limited to a stable ligamentous situation [6] though should be avoided in CEI as it may lead here to instability and increased tension in the interosseous membrane leading to failure over time [7]. If instability persists despite ligament repair and radial head, an additional hinged fixator can be applied to allow functional rehabilitation postoperatively [8, 9].

The current study focused on the radial head as an important secondary stabiliser of the elbow [10]. The aim was to examine the outcome after surgical repair in patients with CEI and unstable radial head fractures. The study shows results of radial head reconstruction by prostheses compared with ORIF. After reconstruction with a prosthesis the second aim was to determine the effect of prosthesis oversizing (overlengthening≥2 mm), as this has been associated with altered elbow kinematics [11]. Therefore, we undertook a radiological analysis to identify patients with prosthesis oversizing and other important radiographic parameters [12] to investigate the influence of these parameters on functional outcome.

Materials and methods

Study population This retrospective level III study was done in agreement with the local Ethics Committee (No. 8937.084.14) and included 53 CEI patients with radial head fractures. The mean patient age was 48.3±16.3 years.Thirty-four patients were male and 19 female. From 2009 to 2013 patients were treated at a Level 1 trauma centre. Patients with previous elbow injuries and comorbidities such as autoimmune diseases, malignancies or heart insufficiencies were excluded.

All patients underwent elbow X-rays and a computed tomography (CT) scan after joint reduction. Coronoid fractures were classified according to Regan and Morrey [13] and radial head fractures according to Mason as modified by Johnston [14] and by Ring [3].

Treatment algorithm At first, patients underwent a pre-operative reduction of the dislocated elbow joint. The operation was planned according to X-rays and CTs. During surgery the radial site was addressed for reconstruction of the radial head by ORIF (group 1) or, in case of unstable fracture pattern, by reconstruction with a monopolar modular metallic prosthesis (group 2, Evolve prosthesis, DePuy Synthes, Kirkel, Germany). In detail, patients with one to four fragments underwent ORIF if an anatomical reconstruction was achieved. In all cases of widely dislocated fragments that allowed no anatomical reconstruction patients underwent prosthesis insertion. In order to determine the prosthesis head diameter the excised radial head parts were used as described by Alolabi et al. [15]. The length of the prosthesis stem was determined under fluoroscopy. Greatest care was taken to avoid incorrect length of the stem by reference to the proximal prosthesis end and the humeroulnar joint line [16].

The concomitant injury patterns of patients from groups 1 and 2 are illustrated in Table 1. All concomitant olecranon and capitellum fractures were fixed by ORIF. Unstable coronoid fractures were fixed with anchors (type I), screws or plates (type II/III). Additionally, a radial and ulnar collateral ligament repair was done by anchors. In case of persisting instability with a tendency to re-dislocation after bone and ligament repair, an additional hinged external fixator was used [8] to obtain appropriate stability during functional rehabilitation. Before wound closure the extensor and flexor muscles were reattached by sutures and bone anchors, respectively. All patients obtained a postoperative splint and received postoperative functional rehabilitation within seven days after surgery. Depending on the soft tissue swelling, the splint was used for two to six weeks with continuous functional treatment.

Clinical and radiographic outcome parameters and follow-up A total of 42 patients (79.1 %) could be followed for midterm clinical examinations after 3.0±1.3 (1.1–5.1) years. Patients lost to follow-up could not be reached due to a change of residency. The clinical outcome was determined by the Mayo Elbow Performance Score (MEPS) [17] and a visual analogue pain scale (VAS), range of motion (ROM) and complications were determined.

Average radiographic follow-up was done after 13.2±13.5 months. In group 2, the radiographic analysis included seven items according to recent studies [12, 18]: prosthesis oversizing [≥2 mm overlengthening in anteroposterior (AP) view] ([16]; Fig. 1), heterotopic ossifications, radiolucent lines

Table 1 Injury and radial fracture patterns

	Group 1 (*n*=18)	Group 2 (*n*=35)
Radial head fracture	18	35
Type I	1	2
Type II	3	2
Type III	0	2
Type IV	12	24
Type V	2	5
Coronoid fractures	14	30
Type I	10	24
Type II	3	2
Type III	1	4
Lateral collateral ligament	8	22
Ulnar collateral ligament	5	9
Olecranon fractures	2	5
Capitellar fractures	2	3
Injury requiring fixator	0	6

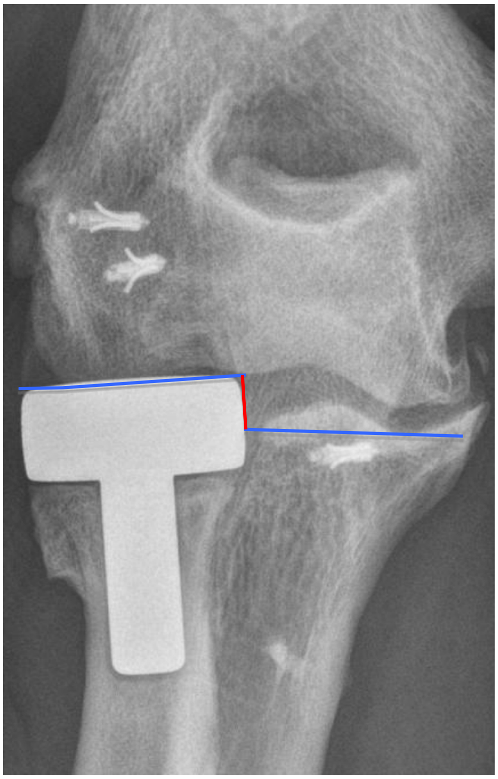

Fig. 1 Measurement of prosthesis overlengthening (mm) (*red line*) as the distance between the two *blue lines* (parallel to the prosthesis surface and parallel to the humeroulnar joint line)

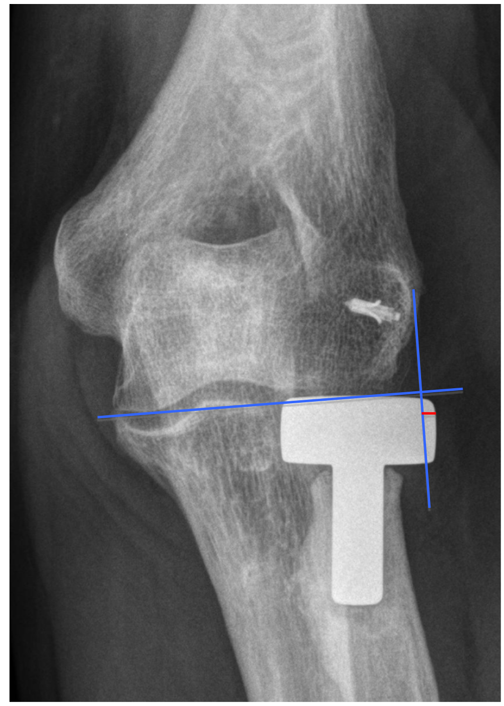

Fig. 2 Measurement of the lateral prosthesis protrusion (mm) (*red line*) as the distance from the lateral prosthesis edge to the *vertical blue line*. *Blue lines* are perpendicular and tangential to the lateral epicondyle and the humeroulnar joint line, respectively

around the prosthesis, joint incongruence, humeroulnar osteoarthritis and capitellar erosions. Each item was rated by 0 points (not fulfilled) or 1 (fulfilled), and a score with a range from 0 to 7 was thereby determined. Additionally, a lateral protrusion of the prosthesis head and the prosthesis diameter were determined in AP view (Fig. 2)

Statistics Mean and standard deviation (SD) were calculated for continuous variables and mean and median for ordinal variables. The primary outcome parameter was the MEPS. Significance between the MEPS and a variable (group) was determined by Student's *t* test. A correlation between two variables (radiographic score and MEPS) was calculated by Pearson's coefficient *R*.

Results

Study population and surgical treatment The study population (n=53) was divided in group 1 (18 patients) and group 2 (35 patients) depending on the reconstruction type of the radial head. Both groups had a similar distribution of patient gender and comorbidities. The injury patterns were matchable between groups. In detail, patients with unhappy triads were distributed similarly to both groups (77.8 % in group 1 and 85.7 % in group 2) as well as concomitant olecranon and capitellar fractures (Table 1). However, patients from group 1 were younger than those in group 2 (42.1±16.7 vs 50.7±15.8). All patients had type IV radial head fractures according to Mason/Johnston [14]. According to Ring [3] group 2 consisted of unstable radial head fractures solely. In contrast, group 1 included only five patients with unstable fracture types. Surgery was done after 5.4±5.2 days, and three patients (8.5 %, group 2) underwent initial joint reduction with a rigid fixator and secondary definitive surgery.

In group 2, 35 patients received the prosthesis during initial surgery, while 3 patients underwent a secondary conversion to prosthesis due to failure of ORIF after 59.3±6.7 days. In contrast, a stable radial head ORIF was achieved in the remaining 15 patients in group 1. Concomitant olecranon fractures were fixed by plates (n=4) or by tension band (n=3). The distribution of injury types and associated repair is illustrated in Table 1.

Clinical follow-up (42 patients) The average MEPS of all patients was 76.8±17.2. ORIF patients (n=12) showed slightly better MEPS (82.1±9.9) than patients with a primary (n=27) or secondary (n=3) reconstruction by prosthesis (74.7±19.1; p=0.11). Patients with terrible triads (n=36) had a MEPS of 75.1±17.5, and patients with dynamic fixator due to persisting instability despite prosthetic reconstruction (n=6) achieved a MEPS of 68.3±19.7.

The elbow ROM measurements showed good results in both groups with an ROM of 114.2±20.3°, without noticeable differences between groups. In group 1, flexion was 129.6±10.5° (110–140°) and extension deficit was 11.7±7.5° (0–25°). In group 2, flexion was 130.2±12.9° (100–140°) and extension deficit was 17.5±12.8° (0–40°).

Interestingly, the radiographic analysis after prosthetic reconstruction (see below) found that oversizing with prosthesis overlengthening≥2 mm significantly reduced ROM (123.4±15.7 vs 100.4±23.2; p=0.003). The analysis of residual pain showed an average VAS of 2.9±2.2 without differences between group 1 (2.8±1.5) and group 2 (2.9±2.4). Patients with oversizing showed a trend for increased pain (2.4±2.0 vs 3.4±2.8; p=0.27). In group 1, all patients returned to previous work, compared to 91.3 % in group 2.

Radiographic score and prosthesis oversizing (group 2) Of the prosthesis patients, 90 % developed at least one radiographic abnormality, with an average amount of 3±2.3. Frequent radiographic abnormalities included radiolucent lines in 63 %, heterotopic ossifications in 53 %, oversizing in 50 %, capitellar erosions in 20 % and subluxation with prosthesis incongruence in 20 % of patients. The radiographic score considerably affected the clinical outcome: a radiographic score of ≥2 led to significantly lower MEPS (63.7±20.1 vs 85.7±9.4; p=0.0006). The influence of each radiographic parameter on MEPS is shown in Table 2. Of the patients, 50 % showed a prosthesis overlengthening ≥2 mm, and average overlengthening was 2.3±2.2 mm. For further investigation of the oversizing effect a subdivision of group 2 was done into patients *without* oversizing (group 2A; n=15) or *with* oversizing (2B; n=15). In group 2B, prosthesis overlengthening was 3.9±1.7, compared with 0.6±0.9 in group 2A (p<0.0001). Oversizing affected clinical outcome and led to significantly lower MEPS in group 2B (63.2 vs 84.7; p=0.001). Consequently, 60 % of group 2B patients had a poor or fair clinical outcome. No significant changes in patient age or fracture classification patterns were found between groups 2A and 2B. Patients with oversizing further had a significantly higher radiological score (4.6±1.9 vs 1.4±1.3; p<0.0001). However, oversizing did not lead to higher rates of heterotopic ossifications (2A 46.7 vs 2B 60 %; p=0.48), while all other radiographic abnormalities were significantly increased by oversizing (p<0.05). A considerable correlation was found between oversizing and MEPS, and the radiographic score, respectively (Fig. 3a; R=−0.72).

Table 2 Radiographic abnormalities and MEPS in group 2 (+: fulfilled; −not-fulfilled)

	+ (MEPS)	− (MEPS)	p
Heterotopic ossifications	16 (68.1)	14 (82.1)	0.04
Subluxation prosthesis	6 (55)	24 (79.6)	0.003
Radiolucent lines	19 (68.2)	11 (85.9)	0.01
Capitellum erosions	6 (52.5)	24 (80.2)	0.0006
Secondary osteoarthritis	13 (63.5)	17 (83.2)	0.003
Incongruence	15 (61.6)	15 (83.7)	0.007
Oversizing	15 (64.7)	15 (84.7)	0.002

In contrast to oversizing, the prosthesis head diameter and lateral protrusions did not affect MEPS (Fig. 3b; correlation R=−0.1). Seventeen patients with lateral protrusions of the prosthesis were identified and these patients had a lower average MEPS of 72.9±18.5, compared to patients without lateral protrusions (76.9±20.2; p=0.58). The average lateral protrusion of the prosthesis was −0.6±2.8 mm, without differences between groups 2A (−0.4±3.0 mm) and 2B (−0.7±2.7 mm).

Complications and revision surgery Complication rates were generally high with an average of 42.2 % in all patients, with 33.3 % in group 1 and 46.7 % in group 2 (Table 3). This included minor complications such as nerve irritations as well as complications leading to revision surgery. The overall surgical revision rate was 26.2 %, and the main reason for revision surgery was early failure of ORIF in group 1 with conversion to a prosthesis (n=3). Another patient required an ulnar nerve decompression. Thus, four patients (26.7 %) underwent revision surgery in group 1, compared to seven patients (23.3 %) with ten revision surgeries in group 2. Group 2B showed a higher revision rate than group 2A (53.3 vs 13.3 %), and prosthesis oversizing led to a 2.2× higher risk of revision surgery. In group 2B, five patients underwent revision surgery due to oversizing in combination with arthrofibrosis, and patients received arthrolysis with conversion to a smaller prosthesis (n=2) or complete removal without replacement as the joint was considered stable intraoperatively (n=3).

Irrespective of groups, complications significantly deteriorated the functional outcome and ROM (MEPS 82.4±10.4 vs 64.2±22.5; p=0.009; VAS 2.5±2.1 vs 3.7±2.2; p=0.10; restriction of ROM 20.5±17.7 vs 37.7±21.3; p=0.01). Similarly, patients that underwent revision surgery showed deteriorated MEPS (63.1±24.9). A representative case with unstable radial head fracture and anatomical reconstruction with a prosthesis and ligament repair is shown in Fig. 4.

Discussion

CEI with unstable radial head fractures are difficult to treat and prone to complications [4]. Here we report midterm results after surgical repair of CEI and show differential outcome with variation of radial head fracture subtypes [3] and reconstruction strategy by ORIF or prosthesis. The results

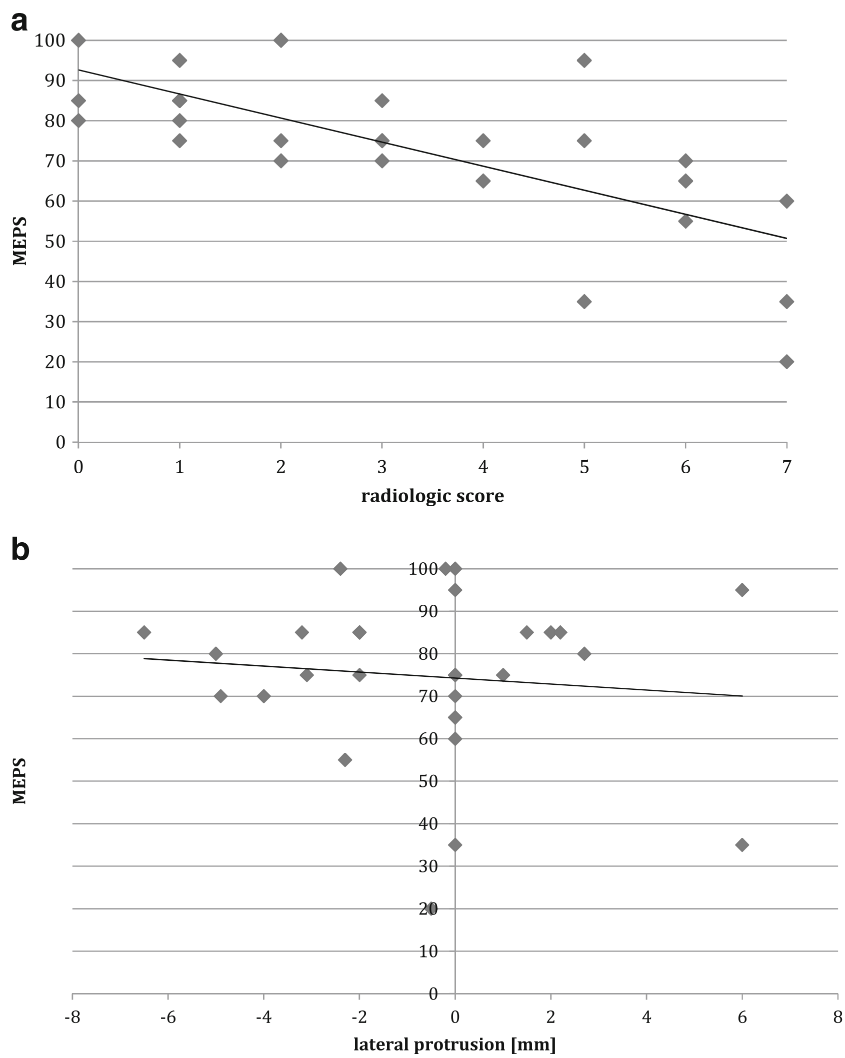

Fig. 3 **a** Correlation between MEPS and radiological score (R=−0.72). **b** Correlation between MEPS and prosthesis lateral protrusion (R=−0.1)

Table 3 Complications and revision surgeries

	Group 1 (n=12+3[a])	Group 2A (n=15) oversizing<2 mm	Group 2B (n=15) oversizing>2 mm
Complications			
Infection	0	1	1
Nerve palsy	1	2	4
Pseudarthrosis	1	0	0
Secondary dislocation/subluxation	3[a]	1	5
Total	2+3[a]	4	10
Revisions			
Nerve decompression	1	0	1
Metal removal and conversion to prosthesis	3[a]		
Prosthesis replacement		1 (infection)	2 (oversizing)
Removal of prosthesis		1 (ossification)	3 (oversizing)
			1 (infection)
Open arthrolysis	0	0	1
Total	1+3[a]	2	8

[a] Three failed ORIF were allocated to group 1 in this table

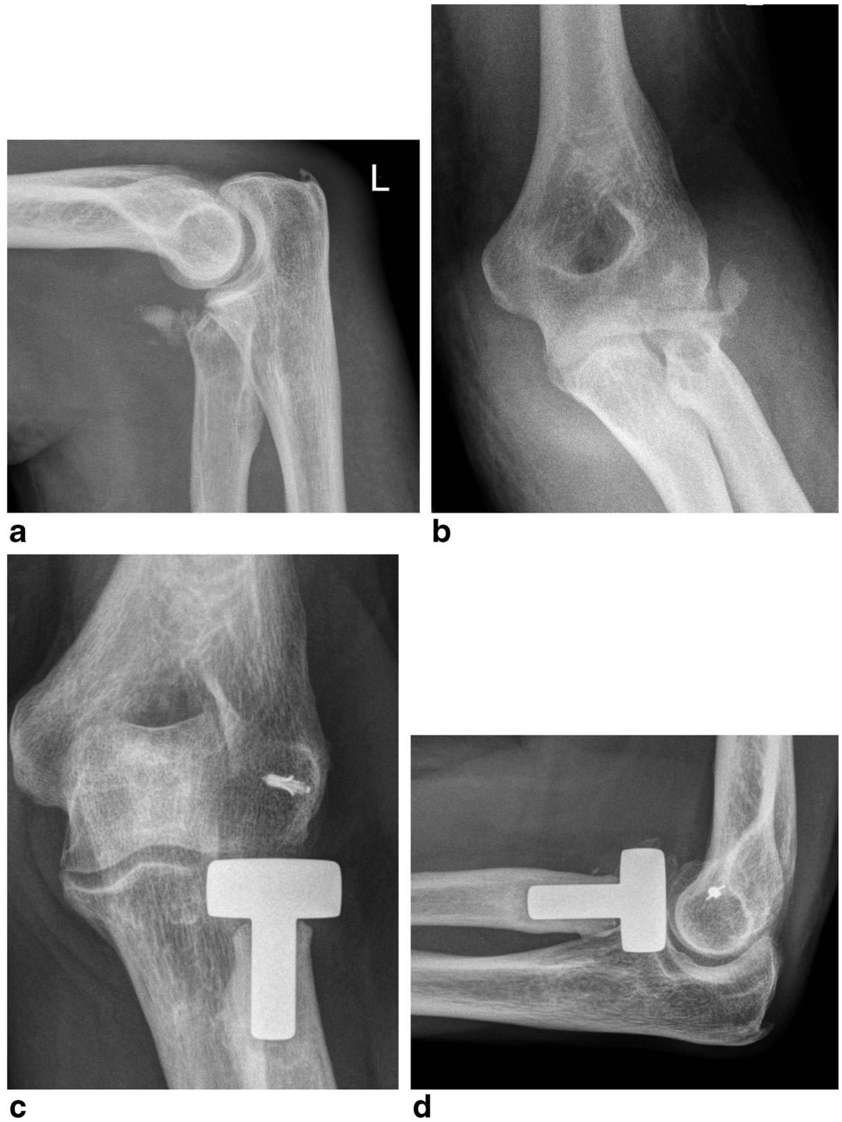

Fig. 4 Terrible triad with an unstable radial head fracture after closed reduction (**a**, **b**) and reconstruction with a prosthesis (**c**, **d**)

demonstrated an overall slightly better functional outcome after ORIF. However, analysis of the subgroups after prosthetic reconstruction showed a clear effect of radiological abnormalities [12, 18] and oversizing [16] on functional outcome. Patients without overlengthening ≥2 mm (group 2A) had significantly better outcome than patients with oversizing (group 2B) and even slightly better MEPS compared with ORIF patients (group 1).

Currently there are no randomised studies to compare different radial head reconstruction strategies. Surgical management should provide the best prospects for the restoration of normal anatomy and joint stability, as the radial head is an important secondary stabiliser to valgus stress with constraints to posterolateral forces [10]. In stable fractures, the results after ORIF or even resection of the radial head are rather good [19, 6], and good long-term outcome results in patients with ORIF of Mason type IV fractures were reported [20]. However, failure of fixation with non-unions occurs frequently in unstable fractures [21]. If the radial head cannot be restored reliably, reconstruction with a radial head prosthesis is appropriate. Attempts to reconstruct the radial head by ORIF at all costs might be inadequate in CEI, leading to ORIF failure as seen in three patients of this study (Table 3). Particularly in terrible triad injuries, a prosthesis might be the better option [3, 22]. Good clinical midterm results have been demonstrated after using a metallic monopolar modular prosthesis [23], and Leigh and Ball showed comparable results between ORIF and prosthetic reconstruction [5], in agreement with our results.

Our study showed a complication rate of 45.2 %, which was comparable to other studies [4]. Three of our ORIF patients had the typical complication with failure and dislocation of the osteosynthesis [3] and received a secondary radial head prosthesis which might lead to worse results than a primary prosthesis [24]. Similarly, radiographic abnormalities were shown after prosthetic reconstruction, as reported by other authors [12]. These radiographic changes clearly affected the clinical outcome, and patients with two or more radiological abnormalities had significantly lower MEPS with a high inverse correlation between the radiographic score and the functional outcome (Fig. 3a). Oversizing was defined by prosthesis overlengthening ≥2 mm [16] and occurred frequently despite great intra-operative care to avoid this phenomenon. It was shown that overlengthening seems to be the most relevant contributor to clinical outcome, in contrast to prosthesis diameter and lateral protrusion. This highlights the need for proper restoration of the prosthesis length, which appears to be difficult according to our study results and noted by others [16, 12, 18]. While the excised radial head can be used for diameter determination [15], length determination appears much more difficult. An overly long prosthesis may lead to capitellar erosions [25], as biomechanically an overlengthening >2.5 mm will alter elbow kinematics [11].

The limitations of this study included the retrospective character of the study leading to heterogeneous group compositions. In conclusion, CEI with complex radial fractures require a stable joint reconstruction, and the decision for ORIF or reconstruction with a prosthesis should be based on fracture stability. If a radial head prosthesis is used, prosthesis oversizing should be avoided as it may contribute to worse outcome with other radiographic abnormalities.

Conflict of interest The authors declare that they have no conflict of interest.

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