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ORIGINAL ARTICLE

Mason type II and III radial head fracture in patients older than 65: is there still a place for radial head resection?

Giuseppe Solarino[1] · Giovanni Vicenti[1] · Antonella Abate[2] · Massimiliano Carrozzo[1] · Girolamo Picca[1] · Biagio Moretti[1]

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Abstract
Purpose To evaluate the clinical outcomes of radial head excision for multifragmentary radial head fracture in patients over 65 years old.
Methods We retrospectively examined 30 patients over 65 years of age treated with radial head excision for comminuted radial head fractures. Patients were evaluated through clinical examinations, administrative questionnaires (DASH—Disabilities of the Arm, Shoulder and Hand; MEPS—Mayo Elbow Performance Score, VAS—Visual Analog Scale) and plain films.
Results The mean follow-up was 40 months (range 24–72 months); 27 out of 30 patients claimed to be satisfied. The mean DASH score was 13 (range 3–45.8) and mean MEPS was 79 (range 65–97). The radiographic evaluation showed 21 cases of elbow arthritis; only two of them complained about pain. Heterotopic ossification was evident in six cases with functional impairment in only one patient. Six patients with increased ulnar variance had clinical distal radio-ulnar joint instability.
Discussion Radial head excision has been considered a safe surgical procedure with satisfactory clinical outcomes. Development in biomechanical studies and prosthetic replacement of the radial head question the validity of radial head excision. In current literature, there are neither long-term follow-up studies on radial head prosthesis outcomes nor studies which consider elderly patient samples.
Conclusion Radial head resection remains a good option when a radial head fracture occurs in elderly patients, taking into account the influence of poor bone quality and comorbidities on the outcome. Radial head excision is not indicated in the presence of associated lesions, because of the risk of residual elbow instability; complications associated with advanced age must be considered and a strict follow-up granted.

Keywords Elbow · Radial head fracture · Mason's classification · Radial head excision · Functional elbow range of motion

Introduction

Radial head fractures are the most frequent traumatic event at the elbow joint, and generally caused by a fall onto an outstretched arm [1–3].

Historically, it has been reported that the majority of fractures of the radial head occur in the age range from 20 to 60, with an average age of 30–40. There is very little patient age and sex epidemiological data about this injury. Recent literature shows that the average age of female patients with fractures of the radial head has increased compared to male patients. This is the result of the increasing average age of the population as well as the increasing functional elbow use over the years. Even though the elbow is not generally considered as a typical fragility fracture site, the recent identification of osteoporotic non-hip/non-spine fractures, the increasing average age of patients involved and the relatively low-energy trauma associated with these fractures, lead us to the

✉ Giovanni Vicenti
dott.gvicenti@gmail.com

1 Orthopaedic Section, Department of Basic Medical Sciences, Neurosciences and Sensory Organs, University of Bari "Aldo Moro", Bari, Italy

2 Orthopaedic and Trauma Department, University of Foggia, Foggia, Italy

conclusion that these are all due to a progressive impairment of bone quality [4–6].

New types of surgical techniques, such as radial head prosthesis, have been introduced over the last 50 years due to the variation of the epidemiological picture of this lesion associated with the need to restore both the anatomy and the biomechanics of the elbow joint [3, 7–13]. Radial head elbow trauma, has been greatly reassessed since O'Driscoll introduced the concept of postero-lateral instability of the elbow. Comminuted fracture patterns, previously considered as simple isolated lesions, are today carefully investigated, especially when caused by high-energy trauma. Undetected and untreated ligamentous lesions are often associated with these fractures, leading to complications such as instability, early arthritic changes both at the elbow and around the joint [8, 9, 13].

The resection of the radial head remains a valid option when comminuted fractures are not associated with other elbow injuries. We conducted a retrospective study evaluating the clinical and radiological outcomes of patients over 65 treated with radial head excision for radial head fractures. We compared our results with those available in literature to understand the current role of this technique. Our hypothesis is radial head excision ensures a good functional Range Of Motion (ROM) in the majority of cases.

Materials and methods

Between March 2006 and January 2012, we identified 52 patients older than 65 from our surgical database who had sustained a radial head fracture treated with primary radial head resection.

Inclusion criteria were the presence of a radial head fracture type II or III according to the Mason Classification and age over 65 years old with no previous dysfunction of the injured elbow. Patients with bilateral fractures, documented elbow dislocation or open fractures were excluded from the study.

After the chart review, we excluded fifteen patients. Of the remaining thirty-seven patients four refused to return for clinical evaluation or were been lost to follow-up, three died for unrelated causes (Fig. 1).

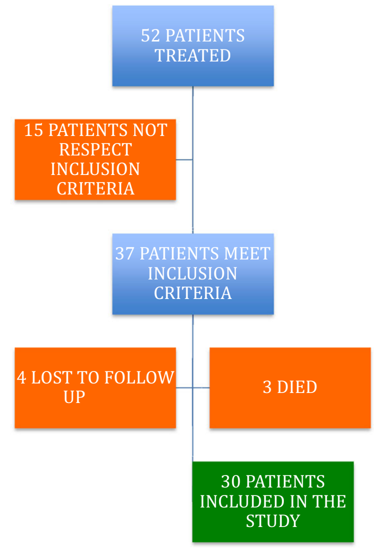

Fig. 1 Flow chart of patients inclusion in the study

The final sample included 30 patients (8 men and 22 women) (with a mean age of 71 years old) at the time of trauma (range 65–80). According to the Mason classification, fractures were classified as type II in 12 cases and type III in 18 cases. Ten patients presented associated bone lesions of the elbow.

In 8 cases, the fracture was the result of high-energy trauma; the remaining 22 cases stemmed from accidental low energy falls from standing height on the street or at home. Fractures affected the right arm in 18 cases; 28 patients were right-handed, 2 left-handed. The fracture involved the dominant side in 20 cases (66.7 %).

Clinical examination at the time of injury showed a swollen elbow in all patients, with ecchymosis in 8 cases; all patients had pain and functional limitations. All patients had preoperative X-rays. Surgery was taken at an average of 4.87 days after the trauma (range 0–11 days).

Twenty-two patients had regional anesthesia, 8 had general anesthesia. Patients were placed in a supine position and a tourniquet ischemia was provided for the upper limb. In isolated fractures of the radial head Kocher's surgical approach was used [14]. In the case of associated lesions, a posterior approach with olecranon osteotomy was performed to carefully view all the structures at the elbow joint; the radial head was then removed and the associated fractures fixed [14]. After careful haemostasis and an accurate layered suture, a compressive bandage was applied. The elbow was immobilized at 90° of flexion and raised position for the first 15 days with a plaster splint which was removed during rehabilitation exercises. A regional anesthetic catheter was placed by the anesthesia team to provide pain relief in the immediate post-operative setting. Immediate post-operative X-rays were always taken. Cryotherapy was applied and analgesic therapy was performed. In seven patients with associated lesions indomethacin (100 mg daily) was administered for 5 weeks to prevent heterotopic ossification (HO) [15]. The rehabilitation program consists of three different phases:

- Post-operative phase (Weeks 0–2) focuses on protection of repaired/injured structures. Active and activeassistive ROM (AROM-AAROM) is initiated as soon as the stability of fracture is achieved under the supervision of the personal therapist. In addition wrist, hand and shoulder rehabilitation is performed to avoid secondary stiffness.

- Post-operative phase II (Weeks 2–8). The protective splint is removed in order to achieve maximum active and passive elbow ROM.
- Post operative phase III (Week 8–month 6) focused on end range parameters and the quality of motion.

Clinical evaluation

All patients were contacted and returned to our hospital for an interview, physical examination and radiographic evaluation. The evaluations were performed and interpreted by two physicians who were not involved in the previous surgical treatment.

We administered the DASH questionnaire (Disabilities of the Arm, Shoulder and Hand) [16]; we also administered the MEPS questionnaire (Mayo Elbow Performance Score) [17] and VAS (Visual Analog Scale) [18]. Patients were also asked to provide categorical verbal comments about their level of satisfaction (very satisfied, satisfied, unsatisfied). The difference in the strength of elbow flexion and extension against resistance between the injured and uninjured sides was estimated on the basis of subjective comparison.

The elbow and wrist ROM were investigated. Elbow flexion and extension were evaluated with the forearm in a neutral position; pronation and supination with the elbow flexed at 90°. The valgus laxity was assessed with the elbow flexed at 20° and the forearm pronated. The posterior lateral rotatory stability was evaluated with the pivot-shift test and the drawer test [19–21].

Radiographic evaluation

AP (anterior–posterior) X-rays were all taken with the forearm in a supine position to calculate the carry angle and the ulnar variance with the perpendicular method [22, 23]. Elbow and wrist osteoarthritis were classified according to the Broberg and Morrey classification [9]: grade 0 normal joint, grade 1 mild reduction with initial osteophytes, grade 2 discrete reduction of the rhyme with the presence of osteophytes, grade 3 severe degeneration with joint destruction. Elbow ectopic bone formations were classified according to the Hastings and Graham system: Class I includes patients with positive radiographs for heterotopic ossification, but no functional limitations. Class II radiographs demonstrate heterotopic ossification, and there is a functional limitation—either in the flexion/extension axis (Class IIA), the pronation/supination axis (Class IIB), or both (Class IIC). Class III patients have ectopic bone with ankylosis either in flexion/extension (Class IIIA), pronation/supination (Class IIIB), or both (Class IIIC) [24, 25].

Results

No complications were reported at the time of surgery. No patient was subjected to further surgical treatment at the elbow or wrist. The mean follow-up was 40 months (range 24–72 months).

Fourteen patients were completely free of pain at the elbow; eight complained of mild pain and 8 of moderate pain when lifting weights over 5 kg. Two patients with moderate pain had associated injuries. Two patients had mild varus laxity and three patients had mild valgus laxity at the stress test. All but one of them had sustained associate injuries at the elbow joint. The Pivot shift test and the drawer test were negative in all patients. Three patients with elbow instability showed signs of mild osteoarthritis and three of them had coronoid anterior ossification.

Five patients complained of mild pain and three of moderate pain at the wrist; three patients with wrist pain had sustained associated injuries at the elbow. Radiographic signs of moderate wrist arthritis were observed in two patients with mild pain. Three patients had a radiographic image of ulna plus (average 3 mm). Two of them had increased instability of the distal radial–ulnar joint (DRUJ) and both had sustained a complex fracture pattern. Three patients complained of symptoms of ulnar nerve irritation, but did not received additional surgical treatment.

In patients with isolated fractures the average flexion was 127°; average extension −9°; average pronation 81°; average supination 82°. Patients with associated injuries had lower values of ROM when compared with patients affected by isolated radial head fracture: mean flexion 124°, mean extension 11°, mean pronation 78° and mean supination 80°.

The mean DASH score was 13 (range 3–45.8); mean MEPS was 79 (range 65–97). The group of patients with associated lesions had a mean DASH score of 24 while patients with isolated radial head fractures had a mean of 12.3 score. When a categorical opinion was asked, 18 patients were highly satisfied and nine were moderately satisfied (Table 1).

Table 1 Clinical results at 24 months after surgery

	No pain	Mild pain	Moderate pain
Patient	14	8	8
	Average	Min	Max
Meps	79	65	97
Dash	13	3	45, 8
Ph highly satisfied	9	Pt moderately satisfied	18

Radiographic analysis

The carry angle has a mainly cosmetic, rather than functional role in adults compared to children, where its reduction can lead to a progressive increase of elbow valgus deformity [26].

The average value of carry angle was 24° (range 14–32). Four cases showed mild arthritic changes while 3 showed moderate arthritic change, including 1 symptomatic case; no significant reduction of the humeral–ulnar joint line was found. The presence of heterotopic ossification was evaluated according to the Hastings and Graham criteria [24, 25]. Four elbows had type I ossification, 1 had type IIA ossification (Figs. 2, 3). Patients with grade IIA ossification had associated injuries to the elbow at the time of injury (Table 2).

Normally, the length between the radius and ulna is almost equal (neutral ulnar variance). When a shorter ulna is observed it is defined as a negative ulnar variance or an "ulna minus". An ulna minus was measured in five patients with a mean value of 3.5 (range 1.3–4 mm). Two patients with increased ulnar variance had clinical DRUJ instability; both cases resulted from complex elbow injuries.

Fig. 2 XRay control 4 years follow up: F 69 yo with fracture type III isolated of the radial head; arthrosis grade II, HO grade IIa Carrying angle 24°. DASH 14,3. MEPS 81,4

Fig. 3 XRay control 4 years follow up: F 69 yo with fracture type III isolated of the radial head; arthrosis grade II, HO grade IIa Carrying angle 24°. DASH 14,3. MEPS 81,4

Table 2 Radiographic results

	Patients		
Carrying angle	Average	Min	Max
	24°	14°	32°
Arthrosis (Broberg–Morrey)	Grade I	Grade II	Grade III
	4	3	0
Ho (hasting graham)	Class I	Class II	Class III
	4	A B C	0
		1 0 0	
Variance ulnar	Ulna plus	Ulna minus	Neutral
	3	5	22

Discussion

Data collected from our study are in line with the outcomes reported by literature [8–11]. The limit of this study is its retrospective nature and the lack of a large sample size.

Radial head fractures are frequently part of complex elbow lesions consisting of dislocations, lesions of the medial and lateral ligament complex, forearm instability secondary to interosseous membrane injuries and fractures of the distal humerus and coronoid [27]. Recently, there has been a change in the epidemiological distribution of this type of fracture, typically involving young male patients. The increase in the frequency of this pattern of injury in the female population is due to the increment of low-energy trauma (accidental falls with outstretched arm) in elderly women; this results in enhanced complexity and an increased recurrence of type III Mason fracture [6]. Although the elbow is not typically considered as a fragility fracture site, the definition of "non-hip/non-spine fractures" secondary to osteoporosis, along with the epidemiology and pathogenesis of radial head fractures has prompted new interest in these lesions [28]. Coexisting injuries at the elbow joint further complicate surgical treatment; poor bone stock threatens hardware fixation and prosthetic osteointegration with difficulties arising both during surgery and post-operative clinical and radiological evaluation. A patient's comorbidities could cause delay in the healing process, promote infective issues and compromise the patient's compliance to early rehabilitation programs [27]. Radiolucent lines at X-ray follow-up surrounding radial head prosthesis are a common finding often associated with ambiguous interpretation. Clinical examination should always be performed in these cases to investigate anterolateral forearm pain which leads to a diagnosis of mobilization or poor osteointegration of the prosthesis [29].

Arthritic changes are common at weight bearing joints (hip and knee); the high congruence of the articular surfaces and the presence of strong ligamentous structures at the elbow joint contribute to its stability and delay degenerative changes; however, in the elderly, traumatic events result in early symptomatic arthritic changes [30, 31].

Clinical trials and applied biomechanical studies indicate the radial head as an important stabilizer of the elbow and forearm [32]. It is considered as a secondary stabilizer of the elbow joint, which plays a vicariant role when a medial collateral ligament injury occurs especially in the pathogenesis of posterior-lateral rotatory elbow instability [27, 33, 34]. When this traumatic pattern occurs, the first aim of the treatment is to restore elbow stability; this is even more important in the elderly, considering the additional difficulties associated with this age group. Careful clinical examination at the time of trauma and appropriate imaging techniques promote the comprehension of the pattern and almost definitively exclude the presence of associated injuries. This approach is even more important for type III fractures of the radial head, which are more likely to be connected to complex injuries at the elbow [35, 36].

Some authors raised the question of the validity of the common procedure of the resection of the radial head when multifragmentary fractures occur [37]. Late complications of this procedure are well documented in literature such as pain, instability, proximal migration of the radius, strength decrease, osteoarthritis and valgus deformity [7]. A recent study by Antuna et al. evaluated functional outcomes in patients younger than 40 who were treated with radial head excision for isolated radial head fractures with a 25-year follow-up. The authors assumed the resection of the radial head, following type II–III fractures without associated lesions, as a safe procedure with good functional results (90 % of cases). Radiographic degenerative changes at the elbow joint were not strictly associated with clinical symptoms [10].

In current medical literature, there is no consensus about the best approach to treat these fractures in elderly patients.

In our series, 16 out of 18 patients who underwent radial head resection for isolated radial head fractures had satisfactory results; the mean DASH value was 12.3. Patients with associated complex lesions of the elbow joint presented functional limitation of the ROM at the elbow with an average DASH questionnaire value of 24; however, all were subjectively satisfied. This confirms the importance of restoring the anatomy of the elbow joint when complex lesions occur. Good clinical practice recommends careful pre-operative imaging studies, intra-operative fluoroscopy evaluation of the elbow and DRUJ stability; this is highly recommended when a prosthetic replacement or an external fixation is planned to avoid postoperative instability.

With regard to the secondary outcomes in the prosthetic replacement of the radial head, several papers reported encouraging short-term outcomes, while little is known about the long-term follow-up. Implantation of radial head prosthesis in young patients has different implications to those relating to patients of advanced age. The mean follow-up for radial head replacement reported in literature is of almost 5 years; studies are mainly retrospective, lacking in large series numbers [37].

The choice of the type of prosthesis (anatomical or straight; modular or monoblock; bipolar or unipolar) is still debated. Modular prostheses better preserve patient's anatomy, having both different stem and head dimensions available. The use of bipolar prosthesis has increased over the last few years; some authors complain of residual instability when these devices are implanted especially with concomitant ligamentous injuries [35, 36]. Evenience of prosthetic replacement complications (chondromalacia, osteolysis, heterotopic ossification, elbow osteoarthritis, deep infection, loosening and breakage of the implant) should be taken into account. In the elderly, comorbidities such as diabetes and chronic diseases, the increase risk of soft tissue and implant damage complicate the situation.

The fixation of prosthetic components can be significantly affected by poor bone stock as well as muscle fibroadipose degeneration, affecting good functional recovery. In regard to the health organization policy and the prosthesis cost issues and follow-up, radial head replacement needs to be carefully evaluated [8, 12, 29, 38].

Conclusion

For comminuted isolated fractures of the radial head, radial head excision remains a viable surgical option even in elderly patients; it is a quick and easy technique to perform, with low complications and a high rate of good/excellent results. It is a less invasive procedure when compared with spacers and prosthesis of the radial head, which have a steep learning curve, high social costs and considerable risks.

Radial head fractures associated with other elbow lesions require primarily the restoration of the joint stability; in elderly patients both local and general issues should be considered. In these cases isolated radial head resection is to be avoided, proceeding with a therapeutic algorithm consisting of the prosthetic replacement of the radial head and the restoration of humero-ulnar anatomy and ligamentous complexes. The clinical examination at the time of injury, the radiographic evaluation supported by CT scan, intraoperative maneuvers to test elbow stability and a correct surgical approach are mandatory to achieve satisfactory results.

Compliance with the ethical standards

Conflict of interest No financial or other relationships that might lead to a conflict of interest are present in this article. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article. Authors, their immediate family and any research foundation with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article. No funds were received in support of this study.

Human and Animal Rights The work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki 1964).

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

References

1. Bohrer JV (1933) Fractures of the Head and Neck of the Radius. Ann Surg 97:204–208
2. Coleman DA, Blair WF, Shurr D (1987) Resection of the radial head for fracture of the radial head. Long-term follow-up of seventeen cases. J Bone Joint Surg Am 69:385–392
3. Herbertsson P, Josefsson PO, Hasserius R, Besjakov J, Nyqvist F et al (2004) Fractures of the radial head and neck treated with radial head excision. J Bone Joint Surg Am 86:1925–1930
4. Court-Brown CM, Caesar B (2006) Epidemiology of adult fractures: a review. Injury 37:691–697
5. Duckworth AD, McQueen MM, Ring D (2013) Fractures of the radial head. Bone Joint J 95:151–159
6. Kaas L, van Riet RP, Vroemen JPAM et al (2010) The epidemiology of radial head fractures. J Shoulder Elbow Surg 19:520–523
7. Ikeda M, Oka Y (2000) Function after early radial head resection for fracture: a retrospective evaluation of 15 patients followed for 3-18 years. Acta Orthop Scand 71:191–194
8. Goldberg I, Peylan J, Yosipovitch Z (1986) Late results of excision of the radial head for an isolated closed fracture. J Bone Joint Surg Am 68:675–679
9. Broberg MA, Morrey BF (1986) Results of delayed excision of the radial head after fracture. J Bone Joint Surg Am 68:669–674
10. Antuña SA, Sánchez-Márquez JM, Barco R (2010) Long-term results of radial head resection following isolated radial head fractures in patients younger than forty years old. J Bone Joint Surg Am 92:558–566
11. Janssen RP, Vegter J (1998) Resection of the radial head after Mason type-III fractures of the elbow: follow-up at 16 to 30 years. J Bone Joint Surg Br 80:231–233
12. Postacchini F, Morace GB (1992) Radial head fracture treated by resection. Long-term results. Ital J Orthop Traumatol 18:323–330
13. Radin EL, Riseborough EJ (1966) Fractures of the radial head. A review of eighty-eight cases and analysis of the indications for excision of the radial head and non-operative treatment. J Bone Joint Surg Am 48:1055–1064
14. Patterson SD, Bain GI, Mehta JA (2000) Surgical approaches to the elbow. Clin Orthop Relat Res 370:19–33
15. Burd TA, Hughes MS, Anglen JO (2003) Heterotopic ossification prophylaxis with indomethacin increases the risk of long-bone nonunion. J Bone Jt Surgery Br 85:700–705
16. Hudak PL, Amadio PC, Bombardier C (1996) Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). Am J Ind Med 29:602–608
17. Cusick MC, Bonnaig NS, Azar FM et al (2014) Accuracy and reliability of the Mayo Elbow Performance Score. J Hand Surg Am 39:1146–1150
18. Hawker GA, Mian S, Kendzerska T, French M (2011) Measures of adult pain: visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF. Arthritis Care Res (Hoboken) 63(Suppl 1):S240–S252
19. Charalambous CP, Stanley JK (2008) Posterolateral rotatory instability of the elbow. J Bone Joint Surg Br 90:272–279
20. O'Driscoll SW (2000) Classification and evaluation of recurrent instability of the elbow. Clin Orthop Relat Res (370):34–43
21. Savoie FH, Field LD, Ramsey JR (2006) Posterolateral Rotatory Instability of the Elbow: diagnosis and Management. Oper Tech Sports Med 14:81–85
22. Kumar B, Pai S, Ray B et al (2010) Radiographic study of carrying angle and morphometry of skeletal elements of human elbow. Rom J Morphol Embryol 51:521–526
23. Parker AS, Nguyen M, Minard CG et al (2014) Measurement of Ulnar Variance From the Lateral Radiograph: a Comparison of Techniques. J Hand Surg Am 39:1114–1121
24. Viola RW, Hastings H (2000) Treatment of ectopic ossification about the elbow. Clin Orthop Relat Res (370):65–86
25. Hastings H, Graham TJ (1994) The classification and treatment of heterotopic ossification about the elbow and forearm. Hand Clin 10:417–437
26. Meluccio A, Cardis C, Geminiani A et al (2009) Il trattamento delle fratture intra-articolari dell'omero distale: esperienza clinica e chirurgica dell'Ospedale Regionale di Aosta | The treatment of intra-articular distal humeral fractures: clinic and surgical experience at Aosta Regional Hospital. G Ital di Ortop e Traumatol 35:190–197
27. Giannicola G, Polimanti D, Bullitta G et al (2014) Critical time period for recovery of functional range of motion after surgical treatment of complex elbow instability: prospective study on 76 patients. Injury 45:540–545
28. Ioannidis G, Flahive J, Pickard L et al (2013) Non-hip, non-spine fractures drive healthcare utilization following a fracture: the Global Longitudinal Study of Osteoporosis in Women (GLOW). Osteoporos Int 24:59–67

29. Flinkkilä T, Kaisto T, Sirniö K et al (2012) Short- to mid-term results of metallic press-fit radial head arthroplasty in unstable injuries of the elbow. J Bone Joint Surg Br 94:805–810
30. An KN, Morrey BF, Chao EY (1986) The effect of partial removal of proximal ulna on elbow constraint. Clin Orthop Relat Res (209):270–279
31. Rettig LA, Hastings H, Feinberg JR (2008) Primary osteoarthritis of the elbow: lack of radiographic evidence for morphologic predisposition, results of operative debridement at intermediate follow-up, and basis for a new radiographic classification system. J Shoulder Elbow Surg 17:97–105
32. Morrey BF, An K-NN (1985) Functional Anatomy of the Ligaments of the Elbow. Clin Orthop Relat Res 201:84–90
33. Beingessner DM, Dunning CE, Gordon KD et al (2004) The effect of radial head excision and arthroplasty on elbow kinematics and stability. J Bone Joint Surg Am 86:1730–1739
34. Tarassoli P, McCann P, Amirfeyz R (2013) Complex instability of the elbow. Injury. doi:10.1016/j.injury.2013.09.032
35. Pugh DMW, Wild LM, Schemitsch EH et al (2004) Standard surgical protocol to treat elbow dislocations with radial head and coronoid fractures. J Bone Joint Surg Am 86:1122–1130
36. Ring D, Jupiter JB, Zilberfarb J (2002) Posterior dislocation of the elbow with fractures of the radial head and coronoid. J Bone Joint Surg Am 84:547–551
37. Yu S, Yan H, Ruan H et al (2015) Comparative study of radial head resection and prosthetic replacement in surgical release of stiff elbows. Int Orthop 39:73–79
38. Capomassi MA, Clembosky GA (2010) Use of a polymethacrylate radial head spacer in temporary reconstruction of complex radial head fracture with associated elbow instability. Tech Hand Up Extrem Surg 14:252–258