10 Controversies in the Management of Radial Head Fractures in Adults

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10.1 Introduction

10.1.1 Epidemiology

Radial head fractures account for between 1.7 and 5.4% of all fractures and approximately one-third of bone injuries of the elbow. Classically, two clear peaks of incidence have been observed between the ages of 20 and 60 and a distribution by male-female gender of 1:2 to 1:1 [1]. However, more recent studies suggest an epidemiological distribution with slight differences. Kaas estimated an incidence of 2.8 cases per 100,000 inhabitants with a male-female ratio of 2: 3 and a different distribution in terms of age, with female cases being 10–15 years older (48–54 vs. 37–41 years) [2]. These data are corroborated by even more current references in a sample of more than 70,000 patients collected between the years 2007 and 2016 [3]. This last study shows an increase during that period of time in the number of surgical interventions in the management of these injuries, as well as the use of locking plate fixation of comminuted fractures and radial head arthroplasty (RHA); meanwhile radial head resections decrease.

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10.1.2 Anatomy and Biomechanics

The proximal radius consists of the radial head and the neck, and there is a large variation in dimensions, angles, and curvatures. Radial head is not completely circular, nor does it have a uniform elliptical shape. It articulates with the capitellum and the peripheral rim contacts with the lesser sigmoid notch. Articular cartilage covers the concave surface of the radial head in an approximately 280° arc [4]. The term "safe zone" refers to the remaining 80° of the posterolateral margin for screw and plate fixation. Ries et al. states that this area can reach up to 133° expanding the horizon for the reconstruction of more complex fractures [5].

Radial head plays a fundamental role in stabilizing the elbow against valgus, axial, and posterolateral forces. The medial collateral ligament (MCL) resists valgus, and the lateral collateral ligament (LCL) does the same for varus and posterolateral instability [6]. Restoring the length of the radiocapitellar joint is essential to optimize load on the cartilage of the capitellum and to reconstruct both lateral and medial stability. This is a complex goal since the interobserver correlation of radiological studies is low even among experienced surgeons [7]. It may be helpful to aim for a height of the radial head corresponding to the proximal edge of the lesser sigmoid notch with the forearm in neutral rotation.

E. C. Rodríguez-Merchán, A. Moreno-Garcìa (eds.), *Controversies in Orthopedic Surgery of The Upper Limb*, https://doi.org/10.1007/978-3-031-04907-1_10

10.1.3 Classification

Currently, there is still controversy in the classification of radial head fractures. The most widely known is described by Mason [8]. Mason's original classification describes non-displaced fractures (type I), marginal fractures with displacement (≥2 mm) (type II), and comminuted fractures involving the entire radial head (type III). Morrey quantified the extent of articular fragment displacement (>2 mm) and fragment size (≥30% of the articular surface), and Johnston added a fourth type to the Mason classification when the radial head fracture is associated with the dislocation of the elbow [9, 10]. However, these modifications do not present great interobserver correlation. Hotchkiss [11] to better delimit the need for surgical treatment defined a *type 2* fracture as the one with a reconstructible radial head fracture presenting a blocked forearm rotation and a *type 3* fracture as a non-reconstructible radial head fracture.

Given the frequent presence of associated bone and ligament injuries, the Mayo Clinic [12] suggested another modification to the classic Mason classification based on clinical and intraoperative observations adding a suffix that shows the articular injury (c, coronoid; o, olecranon) and ligamentous injury (l, lateral collateral ligament; m, medial collateral ligament; d, distal radio-ulnar joint).

10.2 Diagnosis

10.2.1 Clinical Examination

The main injury mechanism of radial head fractures occurs as a consequence of indirect trauma in falls with the wrist in extension and pronation. This situation produces the contact of the radial head with the capitellum. In the initial inspection, we must evaluate the signs of any fracture such as inflammation, ecchymosis, and functional limitation. Palpation of the radial head, proximal ulna, distal humerus, medial collateral ligament (MCL), lateral collateral ligament (LCL), interosseous ligament, and distal radioulnar joint (DRUJ) should be performed. If the patient allows it, the stability of the elbow as well as flexion/extension and pronation/supination of the wrist must be assessed. Arthrocentesis of the elbow can be useful, in addition to confirming the diagnosis, for removal of the mechanical block when secondary to joint effusion. Finally, the neurovascular examination includes different structures such as the radial, ulnar, median, and posterior interosseous nerves.

10.2.2 Radiological Tests

Anteroposterior, lateral, and Greenspan (forearm in neutral position and the X-ray beam centered on the radiocapitellar joint) views should be obtained in the basic radiological study (Fig. 10.1).

When no fracture is seen on routine views, some physicians still rely on the fat pad sign, which, despite its high sensitivity for disease in the elbow joint, is not pathognomonic of a fracture due to its decreased specificity in relation to trauma (also seen in hemophilia and rheumatoid arthritis). The sitting axial mediolateral projection is well tolerated due to the arm's placement: elbow joint in an angle greater than 90°, which is more comfortable for patients with tender and swollen joints. This projection is performed with the forearm in supination. The imaging receptor is placed on the dorsal site of the forearm, whereas the central ray is directed at a 45° mediolateral angle over the middle of the elbow joint [13].

CT (computed tomography) scan may be utilized for characterization of the fracture pattern, in case of high suspicion of fracture not confirmed with the initial radiological study and for preoperative planning.

Magnetic resonance imaging (MRI) will rarely be requested, although it may be useful for confirming soft tissue injuries associated with radial head fractures, especially in the most complex cases of joint dislocation [14].

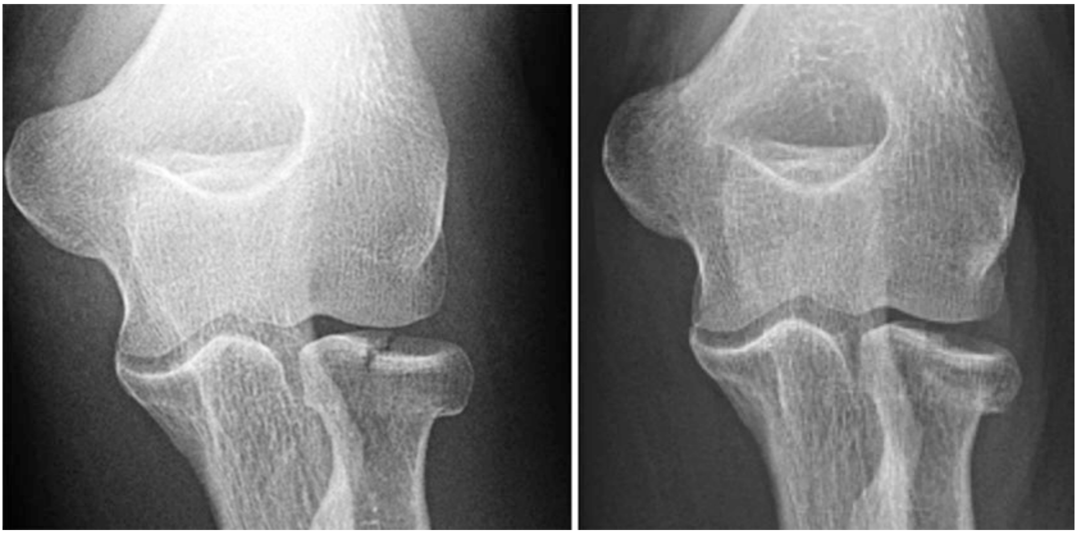

Fig. 10.1 A 22-year-old female patient with type I Mason fracture. Initial X-ray and 6 months after diagnosis. Excellent function without mobility restriction

Table 10.1 Main injuries associated with radial head fracture

Ligamentous injury	Lateral collateral ligament (LCL) 80%, medial collateral ligament (MCL), or both (MCL and LCL)
Essex-Lopresti injury	Interosseous membrane disruption and distal radioulnar joint (DRUJ)
Elbow fractures	Coronoid, olecranon, and capitellum
Elbow dislocation	"Terrible triad"(elbow dislocation, radial head fracture, coronoid fracture)
Carpal fractures (10%)	Hand and scaphoid fractures

10.2.3 Associated Injuries

In general, up to 35% of radial head fractures have associated injuries, depending on the intensity of the triggering trauma and ranging from 20% in undisplaced fractures to 80% in comminuted and displaced fractures [15]. Ring et al. [16] summarized the main injuries associated with radial head fractures in five groups (Table 10.1).

10.3 Management and Treatment

The definitive management of radial head fractures will depend on several factors. Displacement, comminution, stability, articular damage, and the existence of associated injuries in other locations (elbow, forearm, or wrist) will be taken into account. Classification of the type of fracture can be useful for treatment indication [17].

10.3.1 Nonsurgical Treatment

Conservative treatment consists of a short immobilization of 7–10 days with a sling or brachial splint limiting pronation/supination and flexion/extension followed by early mobilization. Patients are evaluated for clinical and radiological control at 2 weeks and to document if motion and pain is improving. By 6 weeks, the patient should have recovered full or nearly full elbow motion. If stiffness persists, a referral to the physiotherapists is indicated.

Nondisplaced or minimally displaced fractures (<2 mm), with minor articular involvement (<30%), without associated injuries or mobility blocks could be treated in this way. Herbertsson et al. [18] showed good or excellent results even in more complex cases. From our point of view, simple fractures with displacement between 2 and 5 mm may be treated nonsurgically or with internal fixation. Guzzini [19] reported 50/52 good or excellent results in his study in Mason type II fractures with a MEPS score of 94.5 (65–100) and DASH score of 12.4 (0–46). Controversy continues to exist regarding the management of this type of fracture, and there are no Level I/ II studies available to guide treatment in this uncommon scenario.

10.3.2 Surgical Treatment

Surgical treatment options include excision, internal fixation, and radial head arthroplasty. Goals of operative treatment include restoration of elbow stability and forearm rotation. The use of arthroscopy can be useful as an added value in cases where we decide to perform osteosynthesis. Figure 10.2 shows a good treatment algorithm for radial head fractures.

10.3.2.1 Surgical Approach and Arthroscopic Techniques

The preferred approaches for the vast majority of radial head fractures are those described by Kocher and Kaplan. In cases with greater comminution, a more posterior approach may be necessary.

Isolated fractures, especially those affecting the anterior half with intact collateral ligaments and without residual instability, can be treated by the Kaplan exposure performed between the extensor carpi radialis and the extensor digitorum muscle. The main risk of this approach is injury to the posterior interosseous nerve in the most distal area of the incision. It is advisable to perform the intervention with the forearm in pronation, and there is a "safe area" dissecting up to 29 mm from the radiocapitellar joint and up to 42 mm from the lateral epicondyle [20].

The Kocher approach exposes the joint in the interval between the anconeus and the extensor carpi ulnaris (ECU). It allows the reduction of fractures associated with instability, lesions of the LCL, and comminution. The radial nerve is protected by the muscular flap of the ECU; we can even perform the synthesis of coronoid fractures detaching the extensors from the humerus and elevating the anterior capsule [21].

In recent years, the use of arthroscopic techniques has gained popularity. Rolla et al. first described a standard approach for arthroscopic fixation of radial head fractures with cannulated screws in a case-series of six patients [22]. A study with a series of 20 patients with arthroscopically assisted radial head fractures revealed discrepancies in fracture classification regarding conventional imaging studies. Classification inconsistencies were found in 70% of the X-Ray cases and in 9% of the CT or MRI ones. Besides that, in 60% percent of the cases, arthroscopy revealed a larger number of loose bodies than described in CT/MRI, and osteochondral lesion of the capitellum was found in 80% of cases. It

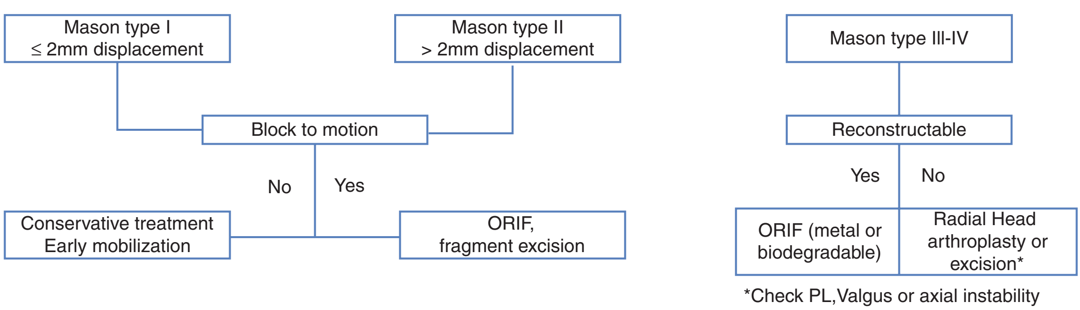

Fig. 10.2 Treatment algorithm for radial head fractures

can also be very useful in cases of LCL involvement and posterolateral rotational instability (PRLI). The authors conclude that arthroscopically assisted fracture reduction and internal fixation reduces invasiveness and reliably allows for excellent clinical outcomes [23]. New accessory portals have been described to facilitate reduction and screw placement in the radial head, and good reproducibility of Kirschner wire placement from distal AM and AL portals was observed among different surgeons [24].

10.3.2.2 Open Reduction and Internal Fixation (ORIF)

Mason type II fractures with>2 mm displacement and block to motion and Mason type III reconstructable fractures are the main indications for open reduction and osteosynthesis (Fig. 10.3).

From the current literature [12], clear indications for surgery are mechanical block after aspiration of the hematoma, two-part fractures with displacement >5 mm (head fragment) or >4 mm (neck), and fractures with comminution (>2 parts). The main objective is anatomical reconstruction and maintaining joint stability. In addition to the conventional radiological study, a CT scan may be useful in preoperative planning. At the time of surgery, examination of the lateral ulnar collateral ligament (LUCL), for injury and instability, is mandatory. The temporary use of Kirschner wires can be useful to promote reduction. As we said in the previous section, new arthroscopic techniques can provide information on the existence of associated injuries and assist in fracture reduction. Headless screws (1.5–2.4 mm) are typically used to fix head fragments with or without involvement of the radial neck. In fractures with extension toward the neck, low profile plates of 1.5 or 2.0 mm should be preferred for osteosynthesis. They must be positioned in the "safe zone" area described in the introduction as approximately 100° centered on the equator of the radial neck in neutral position. These plates may need to be removed in more than half of the cases once the fracture has healed according to Neumann et al. [25]. A recent study of 28 patients with Mason type II-III fractures shows excellent results in 85% of cases, returning to full activity after osteosynthesis. They indicate as good prognostic factors for open reduction and

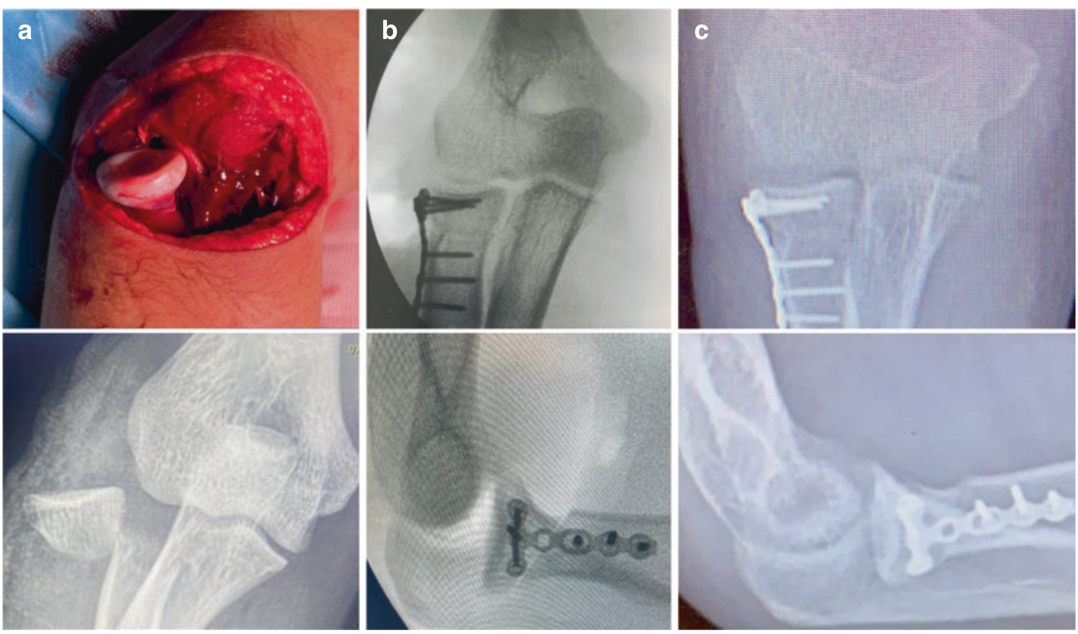

Fig. 10.3 (**a**) Traumatic open radial head fracture treated with open reduction and internal fixation (ORIF); (**b**) anteroposterior (AP) and lateral intraoperative fluoroscopic control; (**c**) AP and lateral radiographs at 6 months

synthesis cases in which the size of the fragment is large enough and there is little bone loss and metaphyseal resorption [26].

Cepni et al. [27] also advocate reconstructive treatment for Mason type II–III fractures whenever possible. In their recent study with 28 patients, they collected good results with a Mayo Elbow Performance score of 92 (range 60–100) and a disability of arm, shoulder, and hand (DASH) score of 15.5 (range 2.5–55.2). However, complications appear up to 25.9%, and 22.2% of the patients underwent a revision surgery. For comminuted fractures in which adequate reduction is difficult to obtain, the "on-table" reconstruction technique may be used. This technique consists in carrying out the reduction and osteosynthesis of the fracture with the main fragments on the surgical table to later proceed to anatomical reconstruction in the patient. Bosinger [28] used this technique in six patients for Mason type III and IV fractures with excellent clinical results, although one of the patients had symptoms of degenerative changes. Controversy regarding the advantage of surgical treatment of these fractures still exists. Hermena et al. [29] in a systematic review of the current literature comparing open reduction and osteosynthesis vs. radial head arthroplasty for Mason type III fractures conclude that radial head arthroplasty may be a better option when treating these complex fractures, but the current evidence is weak. Isolated fractures or that involving only part of the radial head should be treated with ORIF. Nevertheless, this option is prone to failure due to nonunion, loosening of the fixation device, restricted forearm rotation, and elbow stiffness, especially in comminuted fractures. Another valid option could be to fix the radial head in isolation without synthesizing the shaft in order to preserve vascularization and avoid hardware problems. In this way, nonunion rates of 70% have been registered for Mason type III fractures with a mean follow-up of 76 months (range, 12–152 months), but the patients remain asymptomatic [30]. Gokaraju et al. collected data from 46 patients comparing ORIF, radial head arthroplasty or excision with similar functional results, and range of motion in the three groups. The complication rate is around 39% in the group treated with osteosynthesis with indications for revision in his series including nonunion and prominent hardware causing impingement. Current designs including radial head specificity and low-profile implants with locking option may be helpful in reducing the risk of reoperations [31]. Perhaps the greatest controversy exists for type II Mason fractures. Lindenhovius classic study [32] included 16 patients with a 22-year follow-up and demonstrated no appreciable advantage over the long-term results of nonoperative treatment of Mason type II fractures. Along the same lines and for this specific type of fractures, a recent systematic review did not find statistically significant differences in favor of ORIF vs. nonsurgical treatment; however, in this second group the development of osteoarthritis in the radiocapitellar joint appears to be more likely [33]. In order to improve the results of surgical treatment, new implants are being developed, such as polylactide pins, proving the feasibility of ORIF of unsalvageable radial head fractures. Smaller diameter pins (1.5 mm) allow the fixation of each fragment from different directions handling in a simpler way than screws and plates. Tarallo et al. [34] demonstrated good clinical and functional results in their series of 82 patients treated with resorbable pins, although there was up to 8.5% redisplacement of the fracture fragments vs. 1.6% in the mini-screws group. Similarly, another retrospective study shows excellent results with this technique in a series of 17 patients for fractures considered unsalvageable [35]. Other more current alternatives carried out in biomechanical studies in cadavers find superior mechanical properties with the use of magnesium pins [36].

10.3.2.3 Excision of Radial Head

This technique would be indicated in cases of isolated and displaced and with great comminution radial head fractures. Given the frequent associated ligamentous injury with secondary instability, a thorough evaluation is required before selecting this option. It can be a valuable alternative in patients with low functional demand, intercurrent infection, or failure of previous reconstructions. The radius pull test described by Smith et al. [37] makes it possible to assess longitudinal instability by applying traction (shoulder at 90° abduction and internal rotation-90° elbow flexion and neutral rotation) or by using a bone reduction clamp. With the aid of the fluoroscope, radial migration greater than or equal to 3 mm of increase in ulnar variance is verified, confirming the lesion of the interosseous membrane. Antuña et al. reviewed a long-term (15 years) series of 26 patients younger than 40 years with excellent clinical and functional results in 24 of them, and none required a new reoperation [38]. A recent study with only 11 patients with Mason type III–IV fractures and a follow-up of 47.6 months shows good results (Mayo Elbow Performance score: 83.2 points) in 81% of the cases; however, seven patients had a valgus deformity, and two of 11 cases had elbow instability in valgus stress [39]. Another retrospective series comparing arthroplasty vs. radial head resection in cases of instability and dislocation shows similar results in both groups, although a greater number of reoperations (25%) were observed in the second group, mainly associated with heterotopic ossification as a secondary complication [40]. Mahzar et al. concluded that the results were similar between these last two alternatives, even for injuries as complex as the terrible triad, with no statistically significant differences in visual analogue scale (VAS) for pain, Mayo Elbow Performance score (MEPS), and disabilities of arm, shoulder, and hand (DASH) score [41]. Finally, a recent systematic review analyzing the three possible types of surgical intervention (osteosynthesis, excision, and radial head arthroplasty) suggests that prosthetic replacement constitutes the best treatment of choice for efficacy and safety, although resection behaves as a safest choice to minimize postoperative complications and enable patients to perform all daily life activities [42].

10.3.2.4 Radial Head Arthroplasty (RHA)

In cases of comminuted fractures, with a large number of fragments or complicated reconstruction and with poor bone quality, radial head arthroplasty may be the treatment of choice (Fig. 10.4).

The concomitant existence of posterolateral instability (external collateral ligament complex injury), valgus instability (MCL injury), or axial instability (interosseous membrane injury) should be taken into account. However, the therapeutic approach should be individualized focusing not only on the above aspects but also on other characteristics such as age, dominant hand, and baseline activity of the patient. One of the most critical aspects is determining the correct size and height of the implant. Overestimating or underestimating height can lead to loosening and

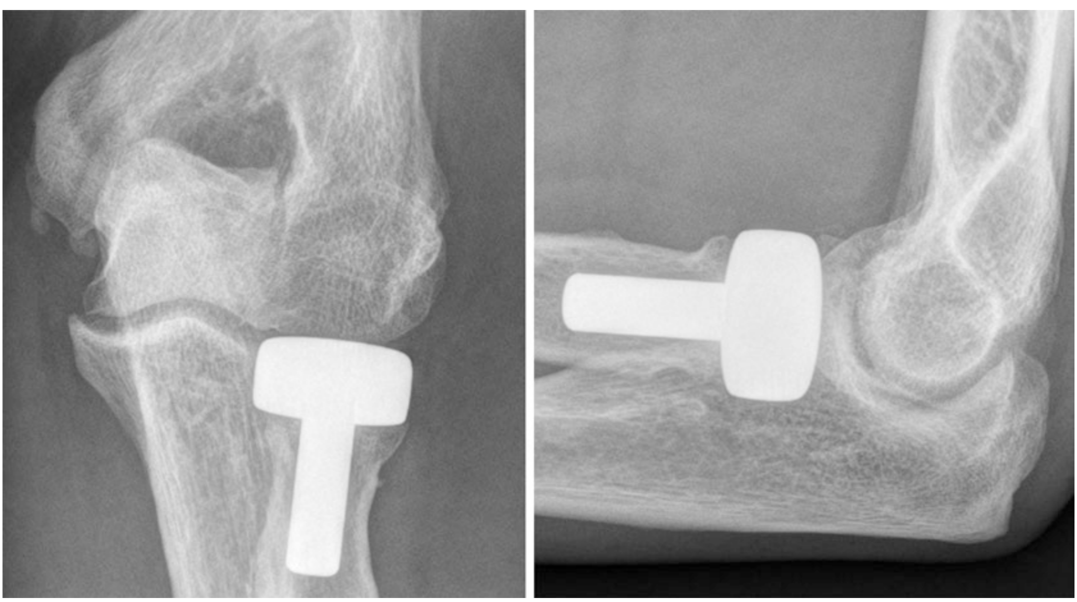

Fig. 10.4 X-ray control anteroposterior and lateral (EVOLVE prosthesis) at 12 years

early degenerative changes or instability, respectively. Morphologic parameters of the radiocapitellar joint (humeral condyle diameter, radial head diameter, and radial head height) measured with radiographic analysis could be useful to predict RHA size preoperatively [43]. The lesser sigmoid notch and the lateral coronoid edge [44] can be used as anatomical landmarks. The intraoperative radiographic study is very useful to avoid radial head overlengthening. Elbow and forearm motion and stability are tested using fluoroscopy after insertion of the trial implant. The medial ulnohumeral joint space should be parallel, and radiographic widening of this joint space is a sign of significant radial implant overlengthening, not the lateral ulnohumeral space widening since cartilage thickness is variable. Radial head overstuffing or overlengthening may produce pain and decreased range of motion making a second intervention necessary to remove the prosthesis. Maltracking may be due to an imperfect radial neck cut or a canal broached in a wrong direction.

Regarding the *type of implants*, we can differentiate unipolar (the most commonly used) or bipolar, anatomical or nonanatomical, and cemented stems, loose-stemmed, or press-fit ingrowth protheses. Despite the fact that anatomical implants reproduce biomechanical behavior in a similar way to the native radial head, they have not shown greater clinical relevance to date [45]. Bipolar prostheses are cemented into the radial neck and theoretically can provide improved congruency during elbow motion.

Loose stemmed implants have shown encouraging results in the reconstruction of complex radial head fractures [46]. An impeccable review by van Riet [47] includes recent studies with good or excellent results in 70–87% of radial head arthroplasties for all types of prosthetic designs. Laumonerie et al. [48] collect the experience of more than 146 patients treated with the EVOLVE Proline implant (modular, unipolar, loose-fitting radial head implant system), a mean follow-up of 4.8 years (range 1–14), concluding that outcomes are satisfactory, and associated complication rates are low (reoperation in 12 patients, with implant revision in 2 patients). A recent systematic review and meta-analysis for fixed-stem implants [49] shows that not all devices behave in the same way, with differences in revision rates, certain complications, and functional scores with worse outcomes in Essex-Lopresti or terrible triad injuries. This would imply an exquisite selection of the type of implant and individualization of each case. Other long-term studies conclude that press-fit radial head arthroplasty seems to become an alternative with satisfactory results in most patients with complex fractures despite finding an implant survival at 24 months of only 69.5% and a reoperation rate of 26.7% [50]. The greatest controversy continues to focus on Mason type III fractures. Chen et al. [4] showed better results for RHA (91%) compared to ORIF (65.2%) in their study with 45 patients and a follow-up of 2 years. With similar results, a systematic review [51] concluded that radial head replacement appeared to reach better outcomes in patients with Mason type III radial head fractures followed 5 years or less, finding a lower rate of complications (13.9%) in relation to osteosynthesis (58.2%). Following this line, another meta-analysis [52] indicated that RHA results in better function and reduced postoperative complications than ORIF-M (metal implants) and ORIF-B (biodegradable implants) over 2 years in the treatment of displaced radial head fractures. However, Kyriacou et al. [53] in a systematic review that includes 210 cases of “terrible triad” found no differences in results, risk of reoperation, and rate of complications between reconstruction and arthroplasty, suggesting that open reduction and internal fixation should be performed when a satisfactory reconstruction can be achieved as the longevity of RHA in young patients with terrible triad injury is currently questionable. Comparing radial head replacement versus excision in cases of previous instability, there are also studies that logically opted in favor of prosthetic reconstruction [54].

The main *complications* are stiffness, residual pain, and instability. However, it is quite common to find patients with neurological alterations secondary to the surgical intervention, an underestimated problem in the literature. The risk factors that have been most related to this complication are inappropriate retraction in the anterior aspect of the radial neck, a prolonged ischemia time, and concomitant coronoid, or olecranon fracture fixation [55].

Recent short- and medium-term studies such as that of Cho et al. [56] show good clinical results despite the appearance of radiological complications. Specifically, in their series of 24 patients with a mean follow-up of 58.9 months (range, 27–163 months), they found 16.7% heterotopic ossification, capital wear in 20.8%, and arthritic changes in 29.2% of the cases. For press-fit stems in the medium term, we can find up to 60–70% of proximal stress shielding regardless of the design, although no clinical correlation has been seen regarding stem loosening [57]. It is advisable to follow the patient with serial radiographs. A recent study including 24 patients operated on in the context of elbow fracture dislocation and a 10-year follow-up revealed the presence of osteolysis in all cases with moderate to high correlation to clinical outcomes, suggesting the need for close control of these cases [58] (Fig. 10.5).

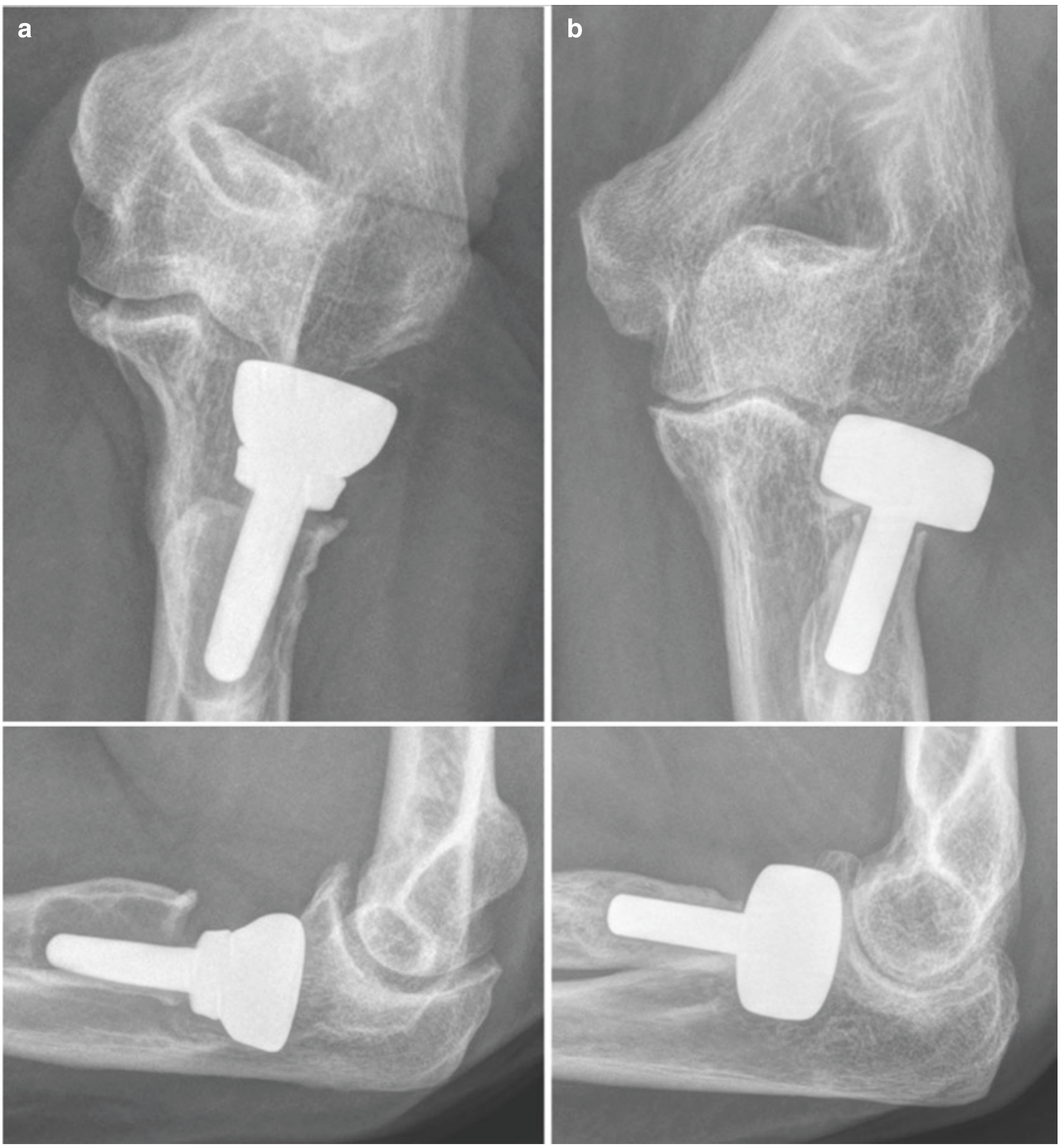

Fig. 10.5 (**a**) Radiographic control of the Acumed prosthesis at 13 years of follow-up (severe osteolysis in asymptomatic patient), (**b**) X-ray control of the EVOLVE prosthesis at 15 years of follow-up

Removal or revision of the implant would be indicated if the loosening becomes symptomatic with pain, instability, or striking radiological failure. The main causes of RHA revision were symptomatic loosening (30%), stiffness (20%), pain (17%), overstuffing (9%), dissociation of the prosthesis (5%), and symptomatic osteoarthritis (OA, 4%) [59]. Loss of range of motion both in flexion/extension and pronation/supination accompanied by pain should alert the surgeon. One of the factors that have been associated with a greater risk of failure and revision of the RHA is the delay of the initial surgical intervention. In one series, 55% of failed radial head implants were implanted more than 6 weeks after the initial injury [60]. Given that the number of radial head arthroplasties has increased in recent years, the percentage of complications associated with it is up to 23% [61]. It is therefore necessary to know the diagnosis and the possible causes of failure of RHA as well as the treatment alternatives. An excellent review raises an interesting algorithm with the existing technical solutions on this matter at the present time [62].

10.4 Conclusions

Radial head fractures account for up to one-third of elbow joint bone injuries. Mason's classification with the modifications of Hotchkiss and Morrey is still valid and is the most used today. Diagnosis through clinical examination and complementary imaging tests allows the bone and ligament structures involved to be identified. Following the criteria of displacement, joint block, possibility of reconstruction, and stability of the fracture, a treatment algorithm can be established. Within conservative management, early mobilization is essential. Regarding surgical treatment, the use of low-profile implants and the development of biodegradable alternatives can be useful for osteosynthesis. Arthroscopy is an additional and less invasive tool than traditional alternatives. Radial head excision should only be the technique of choice for non-reconstructable cases without associated instability, chronic infections, and patients with low functional demand. Radial head arthroplasty, through the wide range of solutions offered by the industry, has gained ground in recent years to support the management of the most complex cases, although a close monitoring of the possible medium and long-term complications and survival of the different implants is necessary.

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