# Radial Head Prosthesis after Radial Head and Neck Fractures – Current Literature and Quality of Evidence

## Protéza hlavičky radia po zlomeninách hlavičky a krčku radia – přehled literatury a kvality důkazů

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## SUMMARY

Due to the elbow joint's complex functional anatomy, the multifragmentary nature of many fractures and concomitant destabilizing associated injuries, dislocated fractures of the radial head and neck still present a serious challenge for the orthopedic surgeon. Thorough knowledge of the elbow's anatomy and biomechanics is essential to analyze and understand the injury and plan its treatment. The aim of a differentiated therapy approach is to restore the joint's anatomy and kinetics, stable and painless joint function, and to avoid or at least delay posttraumatic joint changes. The degree of dislocation, stability of fragments, size and number of fractured joint surfaces and associated bony and ligamentous injuries (and the instability they incur) must be addressed in the therapy regimen. There are various treatment options depending on the injury's classification, i.e. a Mason I fracture is treated conservatively, while more severe injuries may require osteosynthesis and endoprosthesis. There is a lack of clear therapy recommendations based on solid evidence regarding Mason classification types III-IV. In particular expert opinions diverge and study results are inconsistent. Especially the value of radial head arthroplasty is still hotly debated.

**Key words:** radial head fracture, radial head prosthesis, radial neck fracture, Mason classification, radial head arthroplasty, elbow injury.

## INTRODUCTION

Radial head fractures constitute 4% of all fractures, are involved in over 30% of all elbow fractures and are diagnosed in 75% of all proximal lower-arm fractures with an incidence of 25 to 30 per 100,000 adults (18, 22). Average age at diagnosis is 40 years and the gender distribution is nearly identical, although males tend to present the most complex fractures (18, 43, 59). Active adults aged 20 to 60 suffer 85% of the radial head fractures (13). Over 90% of these patients present no other dislocations or fractures, or lower-arm instability (22, 31). Radial neck fractures are roughly half as frequent, and although their incidence rises with increasing age (18, 34, 59), they are associated with lower rates of complex injuries. In his analysis of the origin of such injuries in 1924, Dr. Odelberg-Johnson acknowledged the elbow's pathobiomechanics, namely that the radial head fractures as a result of posterior subluxation (45). There is biomechanical evidence for the clinical observation that a forward fall onto an outstretched and prone lower arm causes an indirect transfer of force onto the radial head and compression against the capitellum (1). An indirect transfer of force at a 0 to 80° angle within the elbow joint will usually trigger a radial head or neck fracture. Posterior luxation and radial head fractures have been documented in 75% of experiments. There is ample clinical evidence of the typical longitudinal anterolateral fracture line. In general, 60% of the axial force is transferred via the radial head.

### Anatomy and biomechanics

The elbow, a highly complex three-dimensional joint consisting of bone and ligaments, contains humeroulnar, humeroradial, and proximal radioulnar joints. The medial collateral ligament (MCL) is normally the primary stabilizer to valgus stress, but when the MCL is torn, the radial head absorbs the greatest amount of valgus stress. There is evidence that comminuted radial had fractures are closely associated with a high rate of capsule-ligamentous injuries. The primary stabilizer to varus stress is a lateral ligamentous complex consisting of a radial collateral ligament, the lateral ulnar ligament, ligamentum anulare and accessory collateral ligaments. The lateral ulnar collateral ligament (LCL) originates from an isometric point on the lateral epicondylus and is

attached distal of the back of the ligamentum anulare on the crista supinatoris, thus providing varus and posterolateral stability (64). An intact articulatio humeroradialis is essential to the elbow's and lower arm's valgus and longitudinal stability. In their cadaver study, Morrey et al. demonstrated that the radial head plays the key role as a secondary stabilizer to valgus stress in conjunction with a weakened medial collateral ligament (44).

Arterial blood is supplied to the radial head via extra- and intraosseous vessels, and branches of the a. radialis and ulnaris form a pericervical ring from which the vessels penetrate the head (35)

### Diagnostics

When taking the patient's history, the physician should note the exact injury mechanism and inspect and palpate the elbow and adjacent joints. Typical of a radial head and neck fracture is the joint's impaired function as revealed in a relief position at 80° flexion, as the joint volume is largest (25–30 ml) at that angle and the patient's pain (caused by intra-arterial hematoma) is thus minimized (43). Standard diagnostics involve taking X-rays of the elbow on 2 planes and additional images of the radial head. Should a complex fracture be suspected, supplemental computed tomography (CT) and magnetic resonance tomography (MRI) also delivers valuable information about instability in conjunction with secondary soft-tissue and ligamentous injuries. Monteggia and Essex-Lopresti injuries should be recognized or detected (21).

### Injury classification

The original classification system according to Mason (37) divides into a non-displaced fracture (Type I), a partially-dislocated radial head fracture (Type II) and a fully-dislocated radial head fracture (Mason Type III). Johnston supplemented Mason's classification with another entity: every radial head fracture coinciding with elbow luxation is characterized as Type IV (33). Broberg and Morrey's expansion of Mason's classification quantifies Type II as a fragment dislocation by > 2–3 mm affecting over 30% of the joint surface and includes radial neck fractures (8). Their system is the most commonly used nowadays. The Mason system's reliability has been questioned because of considerable intra- and interobserver variance (41).

### General postoperative complications

Complications not related to the radial-head fracture therapy include pseudarthrosis, osteonecrosis, malposition, contracture, myositis ossificans and the development of posttraumatic arthrosis. Alone or in combination, these can all lead to serious impairment of of the elbow's mobility (43), (Fig. 2).

## THERAPY OPTIONS

### Conservative, early functional

Conservative therapy is widely considered the treatment of choice for non- or mildly-dislocated fractures (Mason Type I, occasionally Type II fractures). Short-term immobilization (for a few days to 2 weeks of pain relief) can be administered, followed by functional follow-up load-free treatment with a full range of movement. It makes no difference whether the elbow is initially immobilized or not (19). The degree of movement (often limited by intra-articular hematoma and surrounding swelling) usually improves with time. The aim of conservative therapy is to achieve painless, unlimited movement after 6 weeks. In case of pronounced intraarticular hematoma and stubborn pain, the joint can be punctured under sterile conditions after consulting with the patient, who usually experiences immediate pain relief and improved mobility. The puncture site is the „soft spot", the center of the triangle formed by the olecranon, radial head and epicondylus radialis. Follow-up X-rays to exclude a secondary dislocation should be taken between one and two weeks thereafter (52). Osseous consolidation should occur after 6 weeks, at which point the patient should have full range of motion of the elbow. The literature reports of results after conservative therapy from good to excellent across the board; patients observed over the long term describe unlimited rotational mobility and a minimal flexion deficit, as well as no or mild arthrosis (12, 58, 67). A retrospective review describes no significant difference between patients presenting conservatively-treated Mason II fractures involving a dislocation of the joint of 2-mm and those presenting a 3-mm-dislocation after 4 years of follow up (25). According to a relatively recent prospective study by Duckworth et al. (23) describing the outcomes of 103 conservatively-treated patients with Mason-Johnston Type I radial head fractures, 95% had good or excellent results on the Mayo Elbow Performance Score. Their therapy consisted of immobilization via an arm sling for a week followed by physiotherapy. However, the patients were only followed-up for an average of 6 months.

### Removing loose fragments

Every joint blockade during movement should be treated surgically: small fragments of broken bone can be removed provided that reconstruction is not feasible. Cartilage fragments originating from the capitellum or radial head cannot be confirmed in conventional radiography (11). Removal of more than 25% of the joint surface should be avoided (5). Fragments originating from the capitellum are usually a consequence of a posterolateral rotational subluxation of the elbow; according to Caputo, up to 25–33% of the entire joint surface can be removed (11).

### Open reduction and internal fixation (ORIF)

The aim of head-preserving therapy is stable fixation of the joint surface with the correct inclination on the radius' neck, and the mobilisation-stable reconstruction. For „simple" fractures, standard screws, headless screws, biodegradable polyactite pins and K-wires are most often employed (38, 48, 67). More complex fractures or those affecting the head can be stabilized with an angle-stable T- or L-plate, or anatomically-designed implants.

Depending on its location, the implanted osteosynthetic material can cause limited elbow mobility (10), thus some authors recommend the metal be removed to maximize mobility (56). Essential for successful plate-osteosynthesis is the implant's positioning on the shaft. Attention must be paid to the so-called safe zone, as otherwise lower-arm movement may be mechanically blocked (32). This „safe zone" is identified by its less obvious lateral cartilage; it is located in a neutral position of the arm laterally and extends from the most lateral point 65° in the anterior and 45° posterior directions (56). The literature contains reports of encouraging results after isolated and partially-dislocated radial head fractures (66, 67). On the other hand, some studies report a high rate of implant failure, pseudoarthrosis and poor functional outcomes following osteosynthetic therapy of dislocated radial head fractures (19, 48).

## Resection

Because the articulation of the proximal radius with the capitellum is essential to elbow joint stability, the radial head should not be removed in cases of accompanying elbow or lower-arm instability (4, 8). If absolutely no (sub-) luxation tendency is present once trauma-induced ligamentous instability in the elbow has been resolved, resection of a malformed radial head can improve lower-arm rotation and thus a good long-term outcome (31). Biomechanical studies have demonstrated that the extent of the fracture and radial-head removal are key to elbow-joint stability in both stable and instable elbow joints (5). Radial-head removal is particularly risky in terms of complications when there is an additional instable fracture of the processus coronoideus, while it is considered a contraindication when the membrana interossea antebrachii is damaged (24). Should excision be considered, the „push-pull test" must not reveal more than 2–4 mm of radial mobility (55), and the fully-stretched elbow should be stable after refixation of the lateral collateral ligament. There is some evidence that a lack of articulation in the radius and humerus can result in humero-ulnar arthrosis (7, 28). Should initial head-preserving treatment fail, resection can be considered later as secondary therapy (7), (Fig. 1).

## Radial head arthroplasty

An indication for endoprosthetic replacement is in general an unsatisfactory reconstruction/fixation of the radial head in combination with elbow or lower-arm instability. The proximal radius has complex anatomy, making it very difficult to replace it with a prosthesis (65).

A known complication associated with prosthetic therapy of the radial head is „over-stuffing" of the joint (57). Biomechanical studies have shown that lengthening the radius by 2mm leads to changes in wrist and elbow kinematics (57). Recent studies recommend that the proximal edge of the prosthesis should not be further than 1mm from the incisura radialis ulnae (60, 62). An X-ray of the patient's healthy elbow can serve as a reference in such a case (3) and the coronoid can function


*Fig. 1. A 44-year-old male patient who fell on his elbow. The Mason-Johnston Type IV radial head fracture the luxation of the elbow was treated with the radial head prostheses Tornier CRF II. Three years later the patient had a bicycle accident. Because of loosening of the prosthesis and severe heterotopic ossification the prosthesis was removed and the sustained forearm fracture was fixed by ORIF with plates. In the long term a noticeable limitation of movement was resulting.*

as an intraoperative point of reference (61). This should help prevent radiocapitellum erosion, synovitis, ulnohumeral misalignment, and arthrosis. With „loose-fit" prostheses, that is, those not firmly anchored in the shaft and which can rotate within it, good to very good results have been reported in 67–85% of cases. There have been reports of 0–75% osteolysis for which no clinical correlations were identified (2, 17, 40, 42), (Fig. 2).

Cemented bipolar and monopolar prostheses have yielded similarly good results: 93% of patients achieved very good and good results. As with data describing loosening in conjunction with loose-fit protheses, those on cemented prostheses and loosening have been highly inconsistent. Burkhart et al found no radiological evidence of lysis in any patient after 8.8 years, whereas Lim et al. reported lysis in 66% of patients after 30 months, Popovic et al. in 53% of patients after 8.4 years (9, 36, 46), (Fig. 3).

The Judet, a cemented bipolar long-shaft prosthesis, has presented loosening very seldom. The concept of bipolarity, which reduces shearing force on the shaft, together with stable fixation with cement and a long shaft has seldom displayed loosening over the long term (9).

In the beginning of endoprosthetic replacement the silicone prostheses (Silastic®) were implanted, which were associated with destructive synovitis and arthritis triggered by material debris (63). Material breakage has also been observed (6). Silicone prostheses are seldom employed nowadays due to their inferior biomechanical properties compared to metal prostheses (22).

Prosthetic models for replacement of the radial head can be in general classified as unipolar or bipolar, monoblock or modular, anatomical or non-anatomical, and cemented or press-fit. Unipolar monoblock-prostheses (i.e., Liverpool radial head replacement – Biomet, Swanson Titanium Radial Head-Wright Medical Technology) are obsolete because they failed to restore the radial head's anatomy and kinetics. Modular unipolar implants (i.e., MoPyc-Laboratory Bioprofide – Tornier, Avanta-Small Bone Innovations, Evolve-Wright Medical Technology) have revealed better clinical results (16, 29). These can, however, cause mild joint incongruity which in turn over the long term can cause degenerative changes in the capitellum's joint surface and localized pain. Even with implants of the last generation, it is difficult to reproduce the diameters, height, medial offset and cervico-cephalic angle of the native radial head despite the wide modularity available. Moreover various strategies have been applied to restore asymmetric anatomy. For example, there is the concept of the loose-fit prothesis which is intentionally not firmly anchored in the neck, and bipolar protheses with a mobile joint surface (20, 29). The pros and cons of mono- and bipolar prosthesis-integration are controversial. On the one hand, biomechanical studies have shown that monopolar prostheses tend to be more stable, while bipolar prostheses are better centered on the capitellum across the entire range of movement and thus cause milder surges of force on the articular cartilage (14). Another theoretical advantage of bipolar prostheses is that they reduce

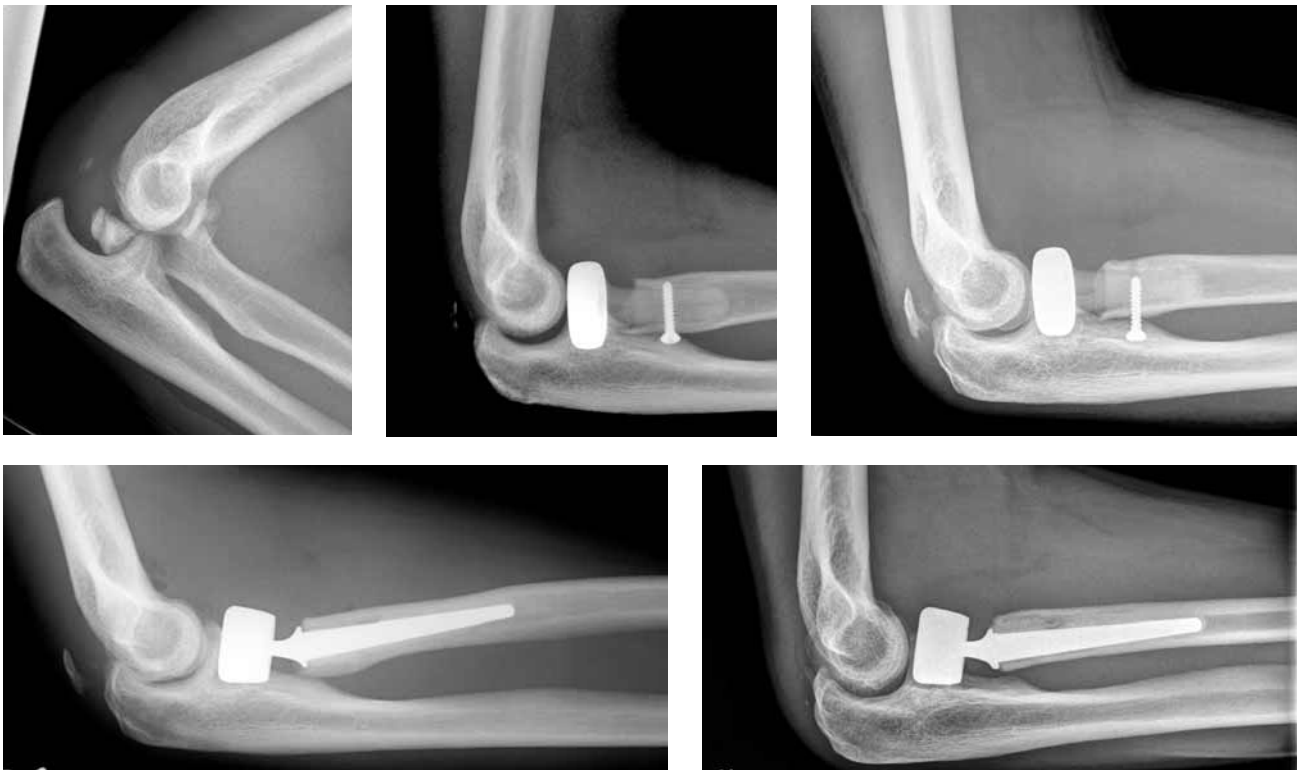

*Fig. 2. A 22-year-old professional wrestler who sustained Mason-Johnston Type IV radial head fracture coinciding with an elbow luxation during a competition. Initial treatment with radial head prostheses from Mathys. Five months later the prosthesis was changed into the Tornier CRF II prosthesis because of a loosening of the screw with resulting pain. Afterwards the clinical results after 11 years were good.*

a|b|c
d|e

„stress at the interface stem-bone and head-cartilage“ which would enable less aseptic loosening and decrease wear of the ulnar and humeral articular cartilage (27), (Fig. 4).

It is debatable whether a prosthesis implantation after primary osteosynthesis leads to a worse outcome. Morrey compared 124 (group 1) primarily- to 24 (group 2) secondarily-implanted prostheses and observed 92%

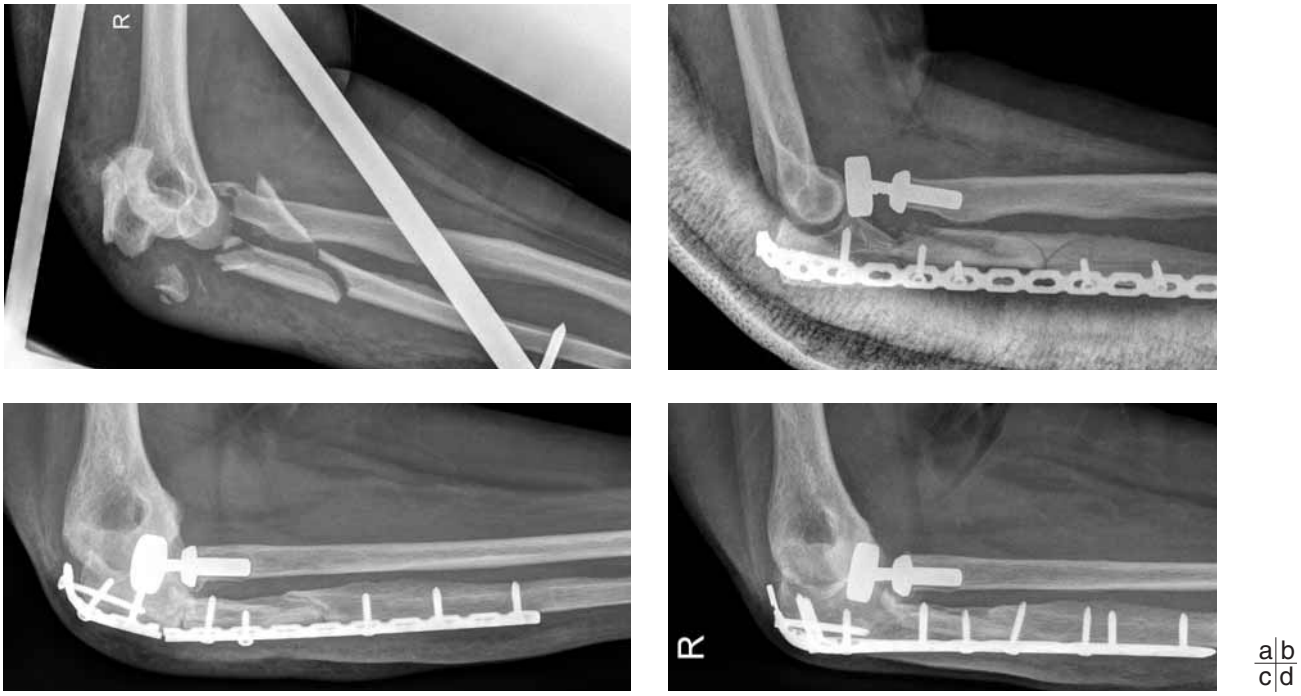


*Fig. 3. A 73-year-old women fell down the stairs and sustained an open complex forearm fracture in combination with a Mason-Johnston Type IV radial head fracture with luxation of the elbow. After initial treatment with an external fixator an ORIF with a plate in combination with an implantation of the radial head prosthesis (Katalyst; uncemented bipolar prosthesis form Argo medical) was performed. One year later a reosteosynthesis was perfomed because of a hypertrophic pseudarthrosis of the olecranon. Severe osteolysis around the prosthesis were found.*


*Fig. 4. A 39-year-old male patient fell from the ladder and had a Mason Johnston Type IV radial head fracture with luxation of the elbow. A bipolar cemented prosthesis from Tornier CRF II was implanted and a refixation of the had a Mason-Johnston Type IV radial head fracture with luxation of the elbow lateral collateral ligament was performed. Eleven years later the X-ray shows heterotopic ossification and loosening around the stem, nevertheless the patients has almost a full range of motion, has no pain and works full time as a craftsman.*

satisfied patients in the first group, whereas just 48% in the second group were satisfied (43). In their investigation of patients after secondary implantation after malunion and nonunion, after primary resection, and after the failure of previous prostheses, Shore et al. reported good and very good results in 65% of patients after an average 2.4 years' follow-up (54). Chapman et al. detected no significant differences between primary and secondary prosthesis-implantation in the functional scores and mobility parameters they examined (15), (Fig. 5).

## Radial head arthroplasty for Mason Type III fractures

Diverse head-preserving types of osteosynthesis have been described for Type III fractures, as have radial head arthroplasty and radial-head removal (67). Some authors recommend resection or endoprosthetic treatment for complex injuries, especially those caused by high-speed trauma (43). Partial resection is not recommended (53). Some authors consider (according to their experience) the presence of more than 3 joint fragments to constitute a negative prognosis factor (48). ORIF presents the surgeon with a genuine challenge, as it is very time-consuming when there are multiple fragments. It is these fracture manifestations that are very difficult to reconstruct, especially when the bone quality is poor or when it seems impossible to fixate tiny fragments. In such situations, secondary complications (i.e., secondarily-dislocated fragments and pseudarthrosis) are a genuine risk. This is why the intraoperative decision to undertake head-preserving osteosynthesis should only be made when anatomic reposition and stable internal fixation can be assured (38, 48). The alternative to resection is not technically difficult for the surgeon, but it is associated with certain complications (49). Several prospective, randomized investigations have demonstrated the superiority of prosthetic therapy over head-preserving osteosynthesis (16, 50).

A systematic review with a meta-analysis revealed the highest rate of success (92%) treating Type III Mason fractures after ORIF, followed by endoprosthetic therapy (a success rate of 79%) and for resection, only 56% (67). Several authors identified ORIF as being the better therapy quite early on in comparison to resection, due to the former's superior force to ensure initial elbow and lower-arm stability coupled with the low risk of developing arthrosis (31, 47, 51). Miller et al. conclude that satisfactory results are obtainable via all three therapies (resection, osteosynthesis, prosthesis), (39).

In short, osteosynthetic therapy is preferable as it has yielded the greatest success in comparison with resection with or without prosthesis implantation. This only applies as long as osteosynthetic therapy is technically feasible and there is a good chance of success. Metal prostheses implantation can be considered as the primary therapy option in cases of difficult or osteosynthetically non-reconstructable fractures (66). However, Mason's classification reveals its limitations when such decisions must be made.

## Radial head arthroplasty for Mason Type IV fractures

Mason-Johnston Type IV fractures are by definition all manifestations of radial head fractures accompanied by posterior elbow luxation (33), a fact that makes evaluating published studies difficult as the injuries such patient cohorts present are necessarily highly diverse. Elbow luxation is often associated with an injury to the medial collateral ligament, which are the elbow's primary stabilizers for valgus stress. In conjunction with this particular combination of injuries, radial head preservation is enormously important (53). Should radial head-preservation treatment be impossible, a good alternative is endoprosthetic therapy accompanied by stabilization of the ligaments.

A systematic review with a meta-analysis revealed pooled success rates for "osteosynthesis" at 86%, for "resection" 84%, and for the therapy group "prosthesis" 77%; differences that were not statistically significant. The "prosthesis" therapy group containing primary or

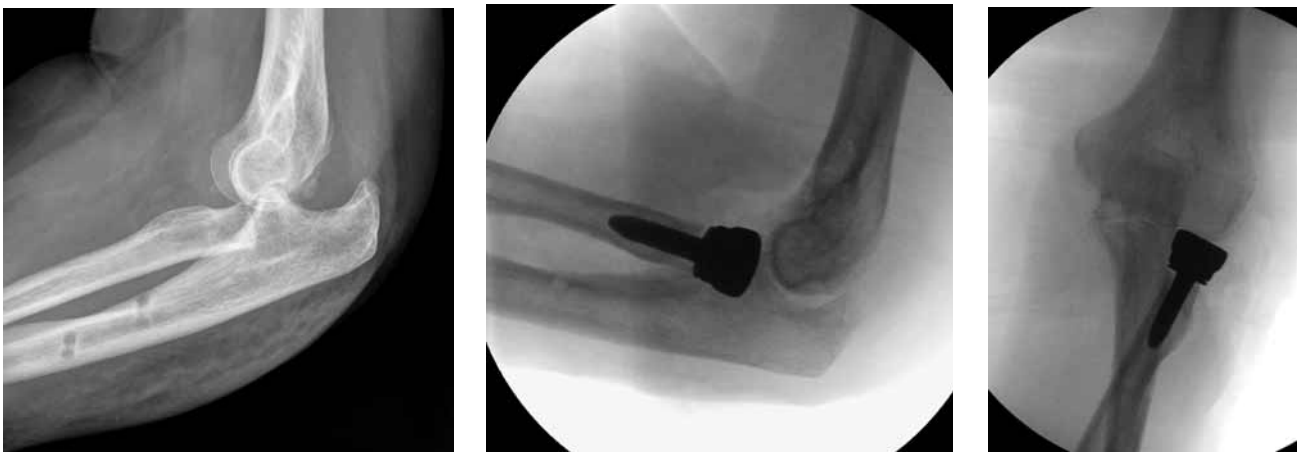

*Fig. 5. A 65-year-old female patient who fell on ice sustained a Mason-Johnston Type IV radial head fracture with luxation of the elbow. The initial treatment was a resection of the radial head, a reconstruction of both collateral ligaments and osteosynthesis with a fixator with motion capacity. After removal of the fixator the elbow luxated again. Afterwards an uncemented bipolar radial head prosthesis (Synthes) was implanted.* a | b | c

secondary treatment settings and material (Silastic vs. metal) were allocated as follows: the pooled success rates for "primary prosthesis (metal)" amounted to 82%, "primary prosthesis (Silastic)" to 28%, and "secondary prosthesis (metal)" to 76%. Due to small case numbers, the difference in these success rates did not achieve significance. Here, too, we observe a mild trend toward primary prosthesis implantation, as with Mason-Johnston Type III fractures.

## COCHRANE COLLABORATION REVIEW

In January 2013, a Chinese working group participating in the Cochrane Collaboration published a systematic review of the surgical therapy of radial head fractures (26). They assessed only randomized, prospective studies for their review and metaanalyses. Given the poor quality of the evidence, this raises the concern that many of the trials included failed to fulfill their inclusion criteria. In their literature search, the Cochrane group of Gao et al. identified 294 studies potentially qualified for inclusion. After combing through the abstracts, they reduced the number of studies to 284. Another seven were excluded after reading the papers. Ultimately only three prospective-randomized investigations could be included: these are listed in Table 1.

Study results from Ruan et al. and Chen et al. were pooled in terms of their success rates (excellent and good results according to the Broberg and Morrey classification) and frequency of complications. Their metaanalyses revealed statistically significant differences between osteosynthesis and prostheses already in the original papers. Here, prosthetic therapy appears more beneficial. Nevertheless, Gao et al. conclude cautiously (despite low case numbers) that there is at least a little solid evidence to favor prosthetic replacement for Type III Mason fractures. This is, however a recommendation based on short-term follow-up, as none of the studies' follow-up periods exceeded two years, a conclusion that contradicts the present authors' data from their systematic review and metaanalysis (67), which assessed and analyzed many more published findings reporting on follow-up periods of ≥12 months, demonstrating that osteosynthesis yields the best results for both Type III and IV Mason fractures. Results from the Helling et al. (30) working group were described rather than analyzed because of the lack of comparable studies from the Cochrane Collaboration. As illustrated above, Helling et al. detected no significant difference between biodegradable and metallic implants for treating dislocated radial head fractures.

## CONCLUSIONS

All in all, the amount of solid evidence backing up any one therapy for radial head fractures remains unsatisfactory, especially for severe fractures classifiable as Mason-Johnston Type III and IV. Many of the studies are limited by their low case numbers and clearly limited follow-up periods, which make it impossible to obtain up-to-date and valid data on the durability of the prostheses.

*Table 1. Studies included by Gao et al. (26)*

| Helling et al. (2006), (30) | Ruan et al. (2009), (50) | Chen et al. (2011), (16) |
|---|---|---|
| biodegradable implants vs. metal implants for dislocated radial head | osteosynthesis vs. prosthesis for Typ III Mason-Johnston fractures | prosthesis vs. osteosynthesis for instable unstable, multi-fragmented radial head fractures |

The articulation between the radius and capitellum is a key anchor of stability in cases of instable radial head fractures accompanied by elbow and lower-arm instability. Having examined the current literature and according to our own clinical experience, we recommend the osteosynthetic therapy of Mason II to IV fractures whenever possible once the patient's trauma morphology has undergone careful assessment, but not at any price or in every case. For example, complete resection of the radial head in conjunction with reconstruction „ex situ" on the operating table should be avoided, as osteonecrosis may be the consequence over the short term following denudation of the bone. Moreover, no intra-articular stages or defects can be tolerated, as the risk of symptomatic arthrosis is relatively high in such a situation. In such cases we recommend prosthesis implantation, which can yield a relatively good outcome, whereas secondary prosthesis implantation is associated with worse clinical outcomes over the long term. Resection also has its advantages as a therapy option, especially in elderly patients.

*Conflict of interest: None of the authors has a conflict of interest to declare.*

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