Options and limits of angle stable plates in the treatment of comminuted radial head fractures

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ABSTRACT

Objective: New angle-stable plates provide more stability and better anatomical fit than previous plates.

Methods: 22 patients treated with an angle-stable plate were included. Postoperative the outcomes were evaluated according to the scoring systems of Morrey, Radin and Riseborough.

Results: 3 patients received a score of excellent, 14 good, and 5 satisfactory. We detected 3 cases of implant failure and 2 cases of postoperative neurological damage. 3 patients received a radial head necrosis.

Conclusions: Our results show that the angle-stable radial head locking plate can only be used in limited cases in the treatment of multi-fragment radial head fractures.

1. Introduction

The radial head is involved in about one-third of all elbow-fractures and up to 3% of all fractures. The mean female patient is 50–60 years old. The average male patient is younger with an average age of 30–40. The sex ratio is about 1:1 (f:m).^{1–4}

The aim of surgical treatment in cases of radial head fractures is the reconstruction of the physiological joint configuration, especially to restore the radial axis of the elbow. Furthermore, a mobilisation-stable osteosynthesis is pursued to enable an early functional mobilisation. The procedure of Open Reduction and Internal Fixation (ORIF) is mostly used for fractures of Mason type II and produces good results.^{4,5} ORIF is also a possibility for Mason type III and IV fractures if a stable status for early functional mobilisation can be achieved. But the success rate seems to be lower in comparison to Mason type II fractures.^{4–7} The possibility of a sufficient osteosynthetic reconstruction is often reduced for Mason type III and IV fractures because of the complexity of the injuries. In particular, high-graded injuries are more likely to show complications such as implant failure, radial head necrosis, pseudarthrosis or restriction of motion.^{8,9}

According to some authors, fractures with more than 3 fragments should not be reconstructed because they have a common chance of a weak outcome and a high complication-rate.^{6,8}

The alternative treatment for these fractures is an endoprosthesis or in rare cases a total resection of the radial head. A partial resection showed unsatisfactory results and is not recommended anymore.^{6,10}

While the total resection is only an option for isolated radial head fractures with an intact ligaments situation and a very restricted indication, radial head prostheses are a relative new option; there are no authoritative long-term results yet and the durability is not yet apparent.^{6,10,11} Therefore, particularly for younger patients, the reconstruction of the radial head is aspired.

The new angle-stable plates offer another option for osteosynthesis. These plates present a better primary stability and a lower profile in comparison to the non-angle-stable plates. These characteristics may allow a wider range of indications as well as a possible mobilisation-stable osteosynthesis for multi-fragmented fractures.^{12–14}

Former studies have demonstrated that ORIF leads to good result in isolated radial head fractures and it has become the established technique for these kind of fractures.¹⁵ The question is if the new angle-stable plates can widen the range of indications and if multi-fragmented fractures can be included.

The aim of this retrospective study is to evaluate the indication, clinical and functional outcome of multi-fragmented radial head fractures treated with angle-stable plate osteosynthesis.

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2. Indications for angle-stable radial head locking plates

- Mason type II fractures involving more than one-third of the articular surface and a displacement of more than 2 mm
- radial head fractures of up to 3 fragments (Mason type III and IV)
- instable fractures of the radial head or neck

3. On basis of this research the following questions should be evaluated

- In which cases were the angle-stable plates used?
- Which outcome can be expected?
- Which indication seems to be a possible option for this kind of plate?
- For which kind of injuries is the angle-stable plate not recommendable?

4. Patients and methods

Between 08/2009–06/2014, 22 radial head fractures in 22 patients were treated with an angle-stable radial head plate, included in this study and re-examined after an average of 28.4 (27.5; 16–56) months.

All patients were examined according to a standardised follow-up protocol, which included the topics of pain, strength, function and everyday complaints.⁶ Furthermore, the subjective satisfaction of the result was evaluated. To assess the outcome of the treatment, the score of Morrey^{16,17} and the score of Radin and Riseborough¹⁸ were used.

To provide internationally valid results, the classification of Mason,¹⁹ modified by Broberg and Morrey,²⁰ was used on the basis of a.p. and lateral x-rays along with a radial head-capitulum view as described by Greenspan.²¹

5. Indication of treatment

In our center, radial head fractures that presented an injury of the articular surface of more than one-third or a dislocation larger than 2 mm were treated surgically.

Mason type II fractures were usually treated with screws, Mason type III and IV fractures mostly with an angle-stable plate. If a reconstruction was not possible, a radial head prosthesis was implanted.

In addition to a.p., lateral and greenspan imaging of the radial head, x-rays of the wrist joint were taken if the injury was a comminuted fracture. If there was a special issue or a better assessment of the fracture was necessary (e.g. in case of an additional fracture of the capitulum humeri), a computer tomography (CT) scan was performed. Depending on the intraoperative appearance, an ORIF was conducted if an anatomically correct and functionally stable reduction was accessible.¹¹

6. Postoperative-treatment

Early functional mobilization was enforced as early as possible. The patients, who had a refixation of the collateral ligament, were instructed to avoid varus and valgus stress for 6 weeks. A dorsal splint was applied to limit the extension of the elbow, if a refixation of the processus coronoideus was indicated. To prevent periarticular ossifications, which is very common in radial head fractures, all patients were medicated with Diclofenac-Colestyramin 145,6 mg for 4 weeks postoperatively.

7. Radiographic examination

In the course of this retrospective study, the x-ray images were interpreted by 2 orthopaedic surgeons. The radiographic evaluation and assessment was held on the basis of the x-ray images of the accident and the follow-up images. Evaluated were the position of the implant, the humeroulnar arthrosis and loss of reduction as well as implant

loosening and implant failure. The grade of periarticular ossification was scaled on the basis of Brooker.²²

8. Ethics committee vote and analysis of the data

This study was approved by the ethics committee of the Medical Faculty of the University of Heidelberg (No. S-531/2011). The study design and patient inclusion follows the declaration of Helsinki in its present form. The analysis of the data was performed using Microsoft Office Excel® 2016 and IBM SPSS® Statistics 24. Data is shown as mean value, median and range.

9. Results

In total, in our collective consisted of 1 (4.5%) Mason type II fracture, 7 (31.8%) Mason type III fractures and 14 (63.6%) Mason type IV fractures. The mean age at the time of the accident was 51.2 (53.0; 21–83) years. The collective showed a sex ratio of 14 (63.6%) women and 8 (36.4%) men. The right extremity was affected in 10/22 (45.5%) cases, the left extremity in 12/22 (54.5%). In half of the cases (11/22 (50.0%)) the dominant side, in the other half (11/22 (50.0%)) the non-dominant side was injured.

In 11/22 (50.0%) cases a direct trauma of the elbow occurred, in 7/22 (31.8%) a forward spill on the outstretched arm and in 4/22 (18.2%) cases a backward spill on the outstretched arm. Mostly the accident happened during sporting activity or leisure (10/22 (45.5%) patients), followed by work accidents (7/22 (31.8%) patients), in a home environment (4/22 (18.2%) patients) and in traffic (1/22 (4.5%) patients). The operation was performed 2.5 (1.0; 0–10) days after the injury on average. 1 (4.5%) patient was first treated externally with a splint and then transferred to our hospital for operation. The mean time between the operation and the pain-adapted, early functional mobilisation was 3.1 (1.0; 1–14) days.

The average follow-up period was 28.4 (27.5; 16–56) months.

A deficit in extension of 13.6° and of 11.6° in flexion compared to the opposite side was evaluated. The flexion and also the deficit of extension were found to be significantly different from the non-injured side (p (flexion): < 0.001; p (deficit of extension): < 0.001) (Table 1). The mean extension/flexion (neutral-zero-method) was 0°/14.5°/122.3° of the affected side compared to the non-affected side with 0°/0.9°/133.9°.

The deficit in pronation was 10.9° (p : 0.003) and 24.5° (p : 0.001) in supination in comparison to the opposite side. The mean pronation/supination was 74.8°/0°/61.4° of the affected side and 85.7°/0°/85.9° of the non-affected side (Table 1).

In 9 (40.9%) cases a posttraumatic high restriction in movement were measured. We defined a deficit in extension of more than 30°, a maximal flexion under 100° and a pronation respectively supination under 50° as high. A high deficit in flexion was found in 3/22 (13.6%) patients with a mean flexion of 93.3° (95.0; 90–95°) (opposite side: 111.7° (120.0; 95–120°); p > 0.05/). Likewise, 3/22 (13.6%) showed a

Table 1
Results of the clinical examination mean (median; minimum-maximum).

	affected extremity	non-affected extremity	p
flexion	122.3° (127.5; 90–145°)	133.9° (140.0; 95–150°)	< 0.001
deficit of extension	14.5° (15.0; 0–40°)	0.9° (0.0; -5–10°)	< 0.001
Supination	61.4° (70.0; 5–90°)	85.9° (90.0; 70–90°)	0.001
Pronation	74.8° (80.0; 10–90°)	85.7° (90.0; 70–95°)	0.003
cubitus valgus	9.8° (10.0; 0–25°)	7.7° (10.0; 0–15°)	0.160
strenght (kg)	22.7 kg (22.0; 1–47 kg)	26.1 kg (25.5; 10–51 kg)	0.010
wrist flexion	56.1° (60.0; 20–80°)	59.8° (60.0; 40–80°)	0.112
wrist extension	59.8° (60.0; 30–80°)	61.4° (60.0; 30–80°)	0.216
radial abduction	25.0° (25.0; 10–35°)	27.0° (30.0; 20–35°)	0.066
ulnar abduction	35.2° (40.0; 10–40°)	37.5° (40.0; 30–40°)	0.102

high deficit in extension of 33.3° (30.0; 30–40°) (opposite side: 3.3° (0.0; 0–10°), $p > 0.05$). As well as 3/22 (13.6%) patients presented a high deficit in pronation with a mean motion of 33.3° (40.0; 10–50°) (opposite side: 70.0° (70.0; 70–70°), $p > 0.05$) and 7/22 (31.8%) patients showed a restricted supination of 25.7° (30.0; 5–45°) (opposite side: 85.7° (90.0; 80–90°), $p < 0.05$).

3/9 (33.3%) patients who presented a high restriction in motion, were restricted in 1 direction of motion, 5/9 (55.6%) patients were restricted in 2 directions and 1/9 (11.1%) patient was restricted in 3 directions. The mean time between the operation and the beginning of the early mobilisation was 2.6 (1.0; 1–14) days for these 9 patients.

A mean cubitus valgus of 9.8° (10.0; 0–25°) was measured on the injured arm in comparison to 7.7° (10.0; 0–15°) on the other side.

Strength measurement, by using the Jamar® - hand - dynamometer, showed a mean strength of 22.7 (22.0; 1–47) kg on the injured arm in comparison to 26.1 (25.5; 10–51) kg on the non-injured side ($p < 0.05/p: 0.010$). In comparison to the opposite side, the relative strength of the injured arm was 90% on average. A lack of strength of more than 5 kg was found in 6/22 (27.3%) cases. 15/22 (68.2%) patients reported on a subjectively felt reduction of strength.

10. Analysis of the scores

According to the score by Morrey(16, 17), 3/22 (13.6%) patients presented excellent, 14/22 (63.6%) patients good and 5/22 (22.7%) patients satisfactory results after 28.4 (27.5; 16–56) months. No result was rated poor (0.0%). Mean score by Morrey was 84.9 (89.0; 54–100) points.^{16,17} According to the criteria by Radin and Riseborough¹⁸ we evaluated 7 (31.8%) good, 9 (40.9%) fair and 6 (27.3%) poor results.

In comparison with the classification by Mason, modified by Broberg and Morrey,²⁰ our study showed 1 (100.0%) good result for Mason type II fractures, 1 (14.3%) excellent, 4 (57.1%) good and 2 (28.6%) satisfactory results for Mason type III fractures and 2 (14.3%) excellent, 9 (64.3%) good and 3 (21.4%) satisfactory results for Mason type IV fractures.

According to the score by Radin and Riseborough¹⁸ our collective presented 1 (100.0%) fair outcome for Mason type II fractures, 3 (42.9%) good, 2 (28.6%) fair and 2 (28.6%) poor outcomes for Mason type III fractures and 4 (28.6%) good, 6 (42.9%) fair and 4 (28.6%) poor outcomes for Mason type IV fractures.

In 1 (4.5%) case an isolated fracture and in 21 (95.5%) cases comminuted fractures were diagnosed. The 1 (100.0%) case showed a good result according to the score by Morrey.^{16,17} The comminuted fractures presented in 3/21 (14.3%) cases an excellent, in 13/21 (61.9%) cases a good and in 5/21 (23.8%) cases a satisfactory result according to the score by Morrey.^{16,17}

11. Associated injuries

20/22 (95.2%) patients of our collective suffered from at least 1 associated injury. Mostly diagnosed was a fracture of the processus coronoideus (16/22 (72.7%)), follow by a disruption of the ventral capsule (15/22 (68.2%)) as well as a disruption of the radial (15/22 (68.2%)) and the ulnar ligament complex (12/22 (54.5%)). In 2/22 (9.1%) cases a postoperative injury of a nerve was detected which caused a neurological deficit respectively a neurological pain. 3/22 (13.6%) patients presented a monteggia-like lesion and 1/22 (4.5%) patient an Essex-Lopresti lesion (Table 2).

Most patients with concomitant injuries showed a combination of more than 1 concomitant injury (19/20 (95.0%)).

The part of the collective with concomitant injuries showed in 3/20 (15.0%) cases an excellent result, in 12/20 (60.0%) cases a good result and in 5/20 cases (25.0%) a satisfactory result. The mean score by Morrey(16) was 84.3 (86.5; 54–100) points. The other 2 patients without concomitant injuries presented 2 (100.0%) good results (score by Morrey(16): 92.0 (92.0; 90–94) points (Table 2).

Table 2

Concomitant injuries.

	number of cases (n = 22)	percent
with concomitant injuries	20	90.9%
isolated injury	2	9.1%
Information on concomitant injuries		
fracture of the processus coronoideus	16	72.7%
elbow luxation with fracture of the processus coronoideus	13	59.1%
elbow luxation without fracture of the processus coronoideus	3	13.6%
injury of the radial ligamentous apparatus	15	68.2%
injury of the ulnar ligamentous apparatus	12	54.5%
injury of the ventral capsule	15	68.2%
fracture of the olecranon	1	4.5%
monteggia-like lesion	3	13.6%
Essex-Lopresti lesion	1	4.5%

12. Radiographic results

At the time of the follow-up examination, an implant failure was detected in 3/22 (13.6%) cases. In 1 (4.5%) case a plate was broken, in the other 2 (9.1%) cases a screw was loosening. In 3/22 (13.6%) cases we observed a necrosis of the radial head. In 2 (9.1%) of these cases a radial head prosthesis was implanted, in the other case a total elbow prosthesis.

The remaining 19/22 (86.4%) presented an adequate radiological healing. The periarticular ossification was classified according to Brooker.²² No patient presented periarticular ossification. Also, no distinctive humeroulnar arthrosis was diagnosed.

13. Subjective rating of the patients

Pain was rated low to moderate by 10/22 (45.5%) patients and high by 3/22 (13.6%) patients. The remaining 9/22 (40.9%) patients did not report any pain. The subjective pain measured by the visual analogue scale (VAS) showed a mean score of 2.0 (1.0; 0–10) points. 9/22 (40.9%) patients rarely had pain, 7/22 (31.8%) occasionally, 6/22 (27.3%) regularly and 0/22 (0.0%) constantly.

A subjectively recognised reduction of strength was reported by 15/22 (68.2%) patients.

6/22 (27.3%) patients were very satisfied with their result, 11/22 (50.0%) rated the result as good and 5/22 (22.7%) as satisfying. None of the patients were dissatisfied with their outcome.

14. Functional outcome

In everyday life and in daily use 19/22 (86.4%) patients reported no restriction and 2/22 (9.1%) described low restriction. 1/22 (4.5%) patients had to change the place of employment because of the outcome.

4/22 (18.2%) patients were, at the time of the accident, already retired. Of the remaining 18 patients, 16 (88.9%) were able to restart work within 6 months, 1 (5.6%) within 12 months and 1 (5.6%) patient needed more than 12 months. Most patients (20/22 (90.9%)) did not report any restrictions in the wrist, while 2/22 (9.1%) patients complained about a subjectively recognised loss of function in their wrist. 19/22 (86.4%) patients did not report any pain in the wrist, while 1/22 (4.5%) patients reported about pain when in intense use and 2/22 (9.1%) when in gentle use. None of the patients had pain in the wrist at rest.

15. Complications

In this collective we detected in 3 (13.6%) cases a failure of implant. In 1 (4.5%) of these cases a broken plate and in the other 2 (9.1%) cases

Table 3
Complication rate and re-operation reference to the classification of Mason(20).

fracture-type	number of fractures	type of complication	number of complications	re-operation
Mason type II	1	–	0	1 x arthrolysis
Mason type III	7	1 x nerve damage 1 x implant failure	5	–
Mason type IV	14	3 x radial head necrosis 1 x nerve damage 2 x implant failure	12	3 x radial head prosthesis 3 x arthrolysis
total	22	3 x radial head necrosis 2 x nerve damage 3 x implant failure	17	3 x radial head prosthesis 4 x arthrolysis

a loosening of a screw were found.

3/22 (13.6%) patients had a necrosis of the radial head which led to the implantation of a radial head prosthesis in 2 (9.1%) cases and to a total elbow prosthesis in 1 (4.5%) case.

Postoperative neurological damage was presented by 2 (9.1%) patients and expressed as a hypesthesia or pain. In both cases the finding was still present at the time of the re-examination. A paresis was not diagnosed (Table 3).

16. Discussion

A combination of dislocated fractures and instable joint is a challenge not only due to the difficult operative treatment, but also due to the early functional mobilisation. Generally, there is a consensus to treat non-dislocated fractures conservatively and fractures of Mason type II with a dislocation of more than 2 mm and higher classified fractures operatively.^{23,24}

For Mason type III and IV fractures there are different options available: reconstruction, radial head resection without replacement or radial head prosthesis. The prosthesis is often the method of choice for comminuted fractures with concomitant injuries, while the resection is seen more critical in the last years and only an option if the fracture is isolated and without any damage to the collateral ligaments.¹⁰

There are only few data about the outcome of angle-stable plate osteosynthesis in cases of comminuted radial head fractures available. The aim of this study was to evaluate the clinical outcome of the patients who suffered a comminuted radial head fracture and were treated with an angle-stable plate.

The question is if the indication of osteosynthetic treatment can be expanded to include comminuted fractures using the new angle-stable plates. Is there a new operative option that allows to preserve the radial head and therefore the function of the elbow?

We evaluated 22 patients who suffered a radial head fracture and were treated with an angle-stable plate. 17 (77.3%) of these patients were rated excellent or good and 5 (22.7%) satisfactory according to the score by Morrey.¹⁶ No patient presented a poor outcome. The mean score by Morrey¹⁶ was 84.9 points. Of the 5 patients with satisfactory results, 2 had a Mason type III fracture and 3 had a Mason type IV fracture. In these 5 cases we diagnosed a fracture of the processus coronoideus in 4 cases and a monteggia-like lesion in 2 cases.

Our patients showed a mean flexion of 122.3°, a deficit in extension of 13.6° compared to the non-injured arm, plus a pronation of 74.8° and a supination of 61.4°. In 9 (40.9%) cases we measured a postoperative high restriction of motion in at least 1 direction of motion. Especially, the supination was often affected (7/22 (31.8%)).

8/22 (36.4%) patients presented postoperative complications. An implant failure was diagnosed in 3 (13.6%) patients that showed as a broken plate or a loosening screw. 2 (9.1%) of these 3 patients suffered a combination of radial head fracture and elbow luxation.

In other 3 (13.6%) cases we identified a radial head necrosis that led to an implantation of a radial head prosthesis in 2 (9.1%) cases and to an implantation of a total elbow prosthesis in the remaining case

(4.5%). Postoperative neurological damage was presented by 2 (9.1%) patients and expressed as a hypesthesia or pain.

At the moment, there are only a few sources reporting about angle-stable plates in treatment of radial head fractures.

In a biomechanical study Burkhart et al. describe that in a comparison of 3 non-angle-stable plates to 3 new anatomic-preformed angle-stable plates the angle-stable plates show an enhanced primary stability.¹³ The assumption is that this characteristic and a lower profile of the implants enable surgeons to reconstruct multi-fragment fractures while reducing damage on soft tissue and produce superior results to the current methods.

Burkhart et al. present in a clinical study that angle-stable plates can produce good result for comminuted fractures of the radial head. In their collective 18/21 (85.7%) patients show an excellent or good result and the remaining 3 (14.3%) patients a fair result measured by the Mayo Elbow Performance Score. They have found 1 partial radial head necrosis, no implant failure and no pseudarthrosis.¹⁴ We also have not found any pseudarthroses - a known complication of earlier osteosynthesis procedures - but in our collective we observed the other mentioned complications.

Also, the clinical parameters in our study were inferior to the results of Burkhart et al. (mean flexion: 135.2°; extension deficit: 12.1°; pronation: 70.9°; supination 63.6°).¹⁴

A similar collective of high-graded radial head fractures with concomitant injuries from Moghaddam et al. that was treated with a radial head prosthesis achieved 79 (83; 47–98) points according to the score by Morrey.¹⁶ The range of motion in this collective was 128° in flexion, the deficit in extension was 20° while the supination was 71° and the pronation 75°. Noticeably, the deficit of supination was higher in our study, while the deficit of extension was lower. Also, the complication rate was lower in the collective of Moghaddam et al. (14.3% (2 high periarticular ossifications, 1 subluxation of a prosthesis, 1 superficial infect, n = 28)).⁶

For a comparison to previous non-angle-stable plates and conventional reconstruction the meta study of Zwingmann et al. is probably the most suitable and meaningful. They analysed 841 separate studies and finally interpreted 58 of them to find the best treatment for Mason type II to IV fractures. Zwingmann et al. show that ORIF is the best method for Mason type II to IV fractures. For Mason type III fractures ORIF is described as the superior method with a success rate (=excellent and good results) of 92% (including plate osteosynthesis: 83%). In comparison radial head prostheses achieved a rate of 79%. For Mason type IV fractures the results are similar for the different methods with a tendency to better results for ORIF (ORIF: 87% (including plate osteosynthesis: 83%); prosthesis: 77%).⁴

To conclude, the explanatory power of this study is limited because of the relatively low number of cases and the missing comparison group. A primary prospective study is difficult to realise, because radial head fractures with an additional luxation of the elbow joint are treated in the context of primary emergency care. Also, non-dislocated fractures are often treated conservatively, isolated fractures are mostly treated osteosynthetically and comminuted fractures with a radial head

resection or radial head prosthesis. Potential comparison groups to our collective can only be found if the indication is not ambiguous and are therefore difficult to realise in a randomised, prospective study. A positive aspect of this study is the elaborate clinical examination and documentation.

Discussion in literature about the promising treatment of comminuted radial head fractures is still ongoing as of today.^{1,8,25} As per recommendation of Ring et al., fractures of more than 3 fragments should not be reconstructed because a poor outcome and many complications like implant failure, necrosis, pseudarthrosis and restriction of motion can be expected.⁸

Nevertheless, interest in the reconstruction and preservation of the radial head is rising because in a prosthetic treatment there is always the risk of loosening and the prostheses cannot simulate the anatomic high variability of the radial head precisely. It is uncertain if this deviation will cause problems in long-term because there are only a few data about long-term results available yet.^{26–30} Also, the resection of the radial head is seen more critically recently because the indication requires a stable joint that is unusual in comminuted radial head fractures and radiographic long-term results showed degenerative changes in the elbow joint.³¹

The primary diagnostic and the correct choice of therapy are essential for the healing process and outcome. Often the intraoperative situation is more complex than assumed by the preoperative diagnostic findings.³² Our results demonstrate that high-graded fractures frequently come along with further injuries. This hypothesis was also confirmed by other authors.^{6,32,33} Concomitant injuries seem to have an influence on the later outcome. Therefore, an early diagnosis of ligamentous and osseous injuries as well as the choice of osteosynthesis material are essential criteria for the success and the achievement of a good result. It is necessary to reconstruct the radial head and the ligamentous structures as well as to achieve a functional stability. A problematic osteosynthesis can lead to relevant periarticular ossifications up to a synostosis.^{1,34–37} A residual step joint in the articular surface can cause painful degenerative changes. In such cases the implantation of a radial head prosthesis or - if the injury is isolated - a radial head resection seems preferable.¹¹

Our results show that angle-stable plate osteosynthesis can result in similar outcome as non-angle-stable plates or radial head prosthesis according to the score by Morrey¹⁶ but is not superior as assumed because of the biomechanical study by Burkhart et al.¹³ Also, in this collective we observed a relatively high number of complications and restricted restriction of motion. Especially the treatment of combined and dislocated fractures show a high rate of poor functional outcome and implant failure.

The use of angle-stable radial head locking plate must be seen critical and is only possible in limited cases in the treatment of multi-fragment radial head fractures.

Essential for the clinical outcome is especially the correct indication and choice of the right implants. Important seems to be that the primary stability is adequate, so a passive mobilization could be started in the early postoperative phase. Otherwise the arm has to be immobilized via cast. Our assumption is that an immobilization that lasts too long causes a restriction of motion, but starting mobilization too early could cause a loss of reposition.

We observed a visibly higher restriction of supination than of pronation in our collective. Thus, it is important to pay heed to the consequent exercise of supination during the postoperative phase. If a temporary immobilization is indicated, it should be in maximal supination because this seems to be the direction of motion which became restricted the most while immobilized and is the most difficult to recover afterwards.

17. Conclusion for clinical practice

Comminuted radial head fractures with ligamentous involvement

remain difficult to treat adequately. It is essential to reconstruct the radial head and to achieve a functional stability.

The angle-stable osteosynthesis is a potential therapy even for comminuted fractures. In these cases, the outcome seems to depend particularly on the concomitant injuries and on an early and adequate functional mobilization. It allows an attempt of anatomic repositioning and the reconstruction of the articular surface as well as the restoration of the radial axis. In this study we observed a relatively high number of restricted functional results and implant failures. Therefore, the indication for angle-stable radial head locking plates is to see critically and the individual circumstances of each patient must be considered. If intraoperative an adequate stability to perform an early functional mobilisation cannot be achieved a plate osteosynthesis should be relinquished. In doubt a radial prosthesis is preferable.

Conflicts of interest

There is no conflict of interest. The corresponding author confirms that there is no connection to a company whose products are mentioned in this article or to a company whose is marketing a competing product. The presentation of the topic is independent and the description of the subject is product-neutral.

References

- Ambacher T, Maurer F, Weise K. Treatment results after primary and secondary resection of the radial head. *Unfallchirurg*. 2000;103(6):437–43.
- Zimmermann G, Wagner C, Moghaddam A, Studier-Fischer S, Wentzensen A. Radiusköpfchenfraktur und Ellenbogenluxation. *Trauma Berufskrankh*. 2004;6(4):297–303.
- Duckworth AD, Clement ND, Jenkins PJ, Aitken SA, Court-Brown CM, McQueen MM. The epidemiology of radial head and neck fractures. *J Hand Surg*. 2012;37(1):112–9.
- Zwingmann J, Welzel M, Dovi-Akue D, Schmal H, Sudkamp NP, Strohm PC. Clinical results after different operative treatment methods of radial head and neck fractures: a systematic review and meta-analysis of clinical outcome. *Injury*. 2013;44(11):1540–50.
- Boulas HJ, Morrey BF. Biomechanical evaluation of the elbow following radial head fracture. Comparison of open reduction and internal fixation vs. excision, silastic replacement, and non-operative management. *Chir Main*. 1998;17(4):314–20.
- Moghaddam A, Lennert A, Studier-Fischer S, Wentzensen A, Zimmermann G. Prosthesis after comminuted radial head fractures: midterm results. *Unfallchirurg*. 2008;111(12):997–1004.
- Ruchelsman DE, Christoforou D, Jupiter JB. Fractures of the radial head and neck. *J Bone Joint Surg Am Vol*. 2013;95(5):469–478.
- Ring D, Quintero J, Jupiter JB. Open reduction and internal fixation of fractures of the radial head. *J Bone Joint Surg Am Vol*. 2002;84-a(10):1811–1815.
- Cobb TK, Beckenbaugh RD. Nonunion of the radial neck following fracture of the radial head and neck: case reports and a review of the literature. *Orthopedics*. 1998;21(3):364–368.
- Rief H, Raven TF, Lennert A, et al. Ist die posttraumatische Radiuskopfresektion noch zeitgemäß? Is radial head resection after trauma still considered up to date? *Obere Extremität*. 2014;9(2):121–127.
- Ring D. Radial head fracture: open reduction-internal fixation or prosthetic replacement. *J Shoulder Elbow Surg*. 2011;20(2 Suppl):S107–S112.
- Burkhart KJ, Nowak TE, Kim YJ, Rommens PM, Muller LP. Anatomic fit of six different radial head plates: comparison of precontoured low-profile radial head plates. *J Hand Surg*. 2011;36(4):617–624.
- Burkhart KJ, Mueller LP, Krezdorn D, et al. Stability of radial head and neck fractures: a biomechanical study of six fixation constructs with consideration of three locking plates. *J Hand Surg*. 2007;32(10):1569–1575.
- Burkhart KJ, Gruszka D, Frohn S, et al. Locking plate osteosynthesis of the radial head fractures: clinical and radiological results. *Unfallchirurg*. 2015 Nov;118(11):949–956. <https://doi.org/10.1007/s00113-014-2562-y>.
- Röhm C, Lill H, Korner J, Josten C. Radiusköpfchenfrakturen Radial head fractures. Reconstruction, resection, replacement? *Trauma Berufskrankh*. 2002;4(S1):S91–S95.
- Morrey BF. *The Elbow and its Disorders*. 2 ed Philadelphia: Saunders; 1993:383–404.
- Morrey BF, Sanchez-Sotelo J. *The Elbow and its Disorders*. 4 ed Philadelphia: Saunders/Elsevier; 2009:80–91.
- Radin EL, Riseborough EJ. 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 Vol*. 1966;48(6):1055–1064.
- Mason M. Some observations on fractures of the head of the radius with a review of 100 cases. *Br J Surg*. 1954;42:123–132.
- Broberg MA, Morrey BF. Results of delayed excision of the radial head after fracture. *J Bone Joint Surg Am Vol*. 1986;68(5):669–674.
- Greenspan A. *Skelettradiologie Orthopädie, Traumatologie, Rheumatologie, Onkologie 3. Neubearb. Aufl.* New York: Urban u. Fischer; 2003.
- Brooker AFB, Robinson RA. Ectopic ossification following total hip replacement.

- Incidence and a method of classification. *J Bone Joint Surg Am*. 1973;55:1629–1632.
23. Akesson T, Herbertsson P, Josefsson PO, Hasserijs R, Besjakov J, Karlsson MK. Primary nonoperative treatment of moderately displaced two-part fractures of the radial head. *J Bone Joint Surg Am Vol*. 2006;88(9):1909–1914.
 24. Tejwani NC, Mehta H. Fractures of the radial head and neck: current concepts in management. *J Am Acad Orthop Surg*. 2007;15(7):380–387.
 25. Lindenhovius AL, Felsch Q, Doornberg JN, Ring D, Kloen P. Open reduction and internal fixation compared with excision for unstable displaced fractures of the radial head. *J Hand Surg [Am]*. 2007;32(5):630–636.
 26. Beredjickian PK, Nalbantoglu U, Potter HG, Hotchkiss RN. Prosthetic radial head components and proximal radial morphology: a mismatch. *J Shoulder Elbow Surg/American Shoulder and Elbow Surgeons [et al]*. 1999;8(5):471–475.
 27. Popovic N, Djekic J, Lemaire R, Gillet P. A comparative study between proximal radial morphology and the floating radial head prosthesis. *J Shoulder Elbow Surg/American Shoulder and Elbow Surgeons [et al]*. 2005;14(4):433–440.
 28. Arbter D, Piatek S, Probst A, Holmenschlager F, Winckler S. Results after Judet radial head prosthesis for non-reconstructable radial head fractures. *Unfallchirurg*. 2012;115(11):1000–1008.
 29. Delclaux S, Lebon J, Faraud A, et al. Complications of radial head prostheses. *Int Orthop*. 2015;39(5):907–913.
 30. Kuhn S, Burkhart KJ, Schneider J, et al. The anatomy of the proximal radius: implications on fracture implant design. *J Shoulder Elbow Surg/American Shoulder and Elbow Surgeons [et al]*. 2012;21(9):1247–1254.
 31. Pike JM, Athwal GS, Faber KJ, King GJ. Radial head fractures—an update. *J Hand Surg*. 2009;34(3):557–565.
 32. Itamura J, Roidis N, Mirzayan R, Vaishnav S, Learch T, Shean C. Radial head fractures: MRI evaluation of associated injuries. *J Shoulder Elbow Surg/American Shoulder and Elbow Surgeons [et al]*. 2005;14(4):421–424.
 33. Ring D. Displaced, unstable fractures of the radial head: fixation vs. re- placement—what is the evidence? *Injury*. 2008;39(12):1329–1337.
 34. Ikeda M, Sugiyama K, Kang C, Takagaki T, Oka Y. Comminuted fractures of the radial head. Comparison of resection and internal fixation. *J Bone Joint Surg Am Vol*. 2005;87(1):76–84.
 35. Ikeda M, Yamashina Y, Kamimoto M, Oka Y. Open reduction and internal fixation of comminuted fractures of the radial head using low-profile mini-plates. *J Bone Joint Surg*. 2003;85(7):1040–1044.
 36. Lill H, Voigt C. [Injuries of the elbow joint]. *Der Chirurg. Zeitschrift für alle Gebiete der operativen Medizin*. 2004;75(10):1037–1050 quiz 51.
 37. Mutschler W, Burri C, Rübenacker S. Rekonstruktive chirurgie fehlverheilte ellbogengelenkbrüche. *Orthopä*. 1990;19:324–331.