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ORIGINAL STUDY

Reconstruction of complex radial head fractures using fine-threaded K-wires : clinical outcome and remaining instability

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Radial head replacement or ORIF are established treatment options for Mason type-III and type-IV fractures. The aim of this study was to provide results for reconstruction of these complex fractures using fine-threaded K-wires.

We present results after reconstruction of 15 Mason type-III and 8 Mason type-IV fractures. Parameters used to describe the functional outcome were pain level, range of motion, and clinical scores. To estimate the elbow stability we performed ultrasound examinations under valgus/varus stress.

All radial heads could be reconstructed. The average resting pain level was 0.9 of 10. The average ROM for extension/flexion was 134°, average forearm rotation was 159°. For the whole patient collective the mean MEPS was 86.5 points and the mean QuickDASH was 16.8 points with no significant difference for both groups.

We can recommend ORIF with fine-threaded K-wires for Mason type-III and type-IV fractures of the radial head. Ligamentous injuries can be addressed successfully with external fixation.

Keywords : radial head fractures ; Mason type-III and type-IV, FFS™-osteosynthesis

INTRODUCTION

Fractures of the radial head are frequent injuries and the most common fractures of the elbow joint *(29)*. Radial head fractures are classified traditionally according to the Mason-classification from 1954 with a modification by Johnston for fractures with additional elbow dislocation in 1962 and Broberg and Morrey in 1986 *(3,23,35)*. Surgical methods for Mason type-III and type-IV fractures are still discussed controversially *(51)*. Although good long-term results after simple radial head resection were reported *(1)*, radial head replacement is currently indicated in cases of an impossible reconstruction of the radial head *(25,30,40,43)*. Furthermore there is evidence that radial head reconstruction, if possible is a feasible treatment option besides replacement of the radial head. *(15,19,31,51)*.

Common used fixation devices for these kind of fractures are mini-screws, mini-plates or

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K-wires *(4,50,51)*. Koslowsky et al. described the reconstruction of the radial head in Mason type III-IV fractures with fine-threaded K-wires with a good functional outcome *(28)*

The aim of this study was to provide a healing rate and clinical results of patients with Mason type-III and type-IV fractures of the radial head after surgical treatment with fine-threaded K-wires. A hinged elbow fixation addressed the instability in case of type-IV fractures and the remaining instability was measured at the time of follow up.

PATIENTS AND METHODS

This is a retrospective case series of 23 patients with dislocated fractures of the radial head. 17 patients with Mason type-III and 10 patients with Mason type-IV radial head fractures were surgically treated in one single institution between 02/2006 and 04/2014 by only one surgeon.

23 of 27 patients could be followed in the long-term, 4 patients were lost to follow-up. These 4 patients had no hospital visit more than six months after the operation and were excluded from the study. The remaining 23 patients were periodically examined up to an average of 53 months (range 14-106 months) in a standard outpatient clinical follow-up protocol. Patients' mean age was 56.3 years (range 28-81 years). All final follow-up examinations were performed by the first author and documented in the hospital information system. The follow-up protocol included clinical and sonographic examinations.

Our patient collective included 12 male and 11 female patients. 15 fractures of the radial head were classified as Mason type-III. 8 patients had an additional joint dislocation and were classified as Mason type-IV. Besides history and clinical examination we used X-rays in two planes for primary diagnosis and performed a preoperative CT-scan for surgical planning and detection of additional injuries. Figure 1 shows the preoperative x-rays, Figure 2 a preoperative CT-scan of a Mason type-IV fracture.

The performed operation technique was described by Koslowsky et al for 23 patients in 2007 *(26)*. The fracture reconstruction with the Fragment Fixation

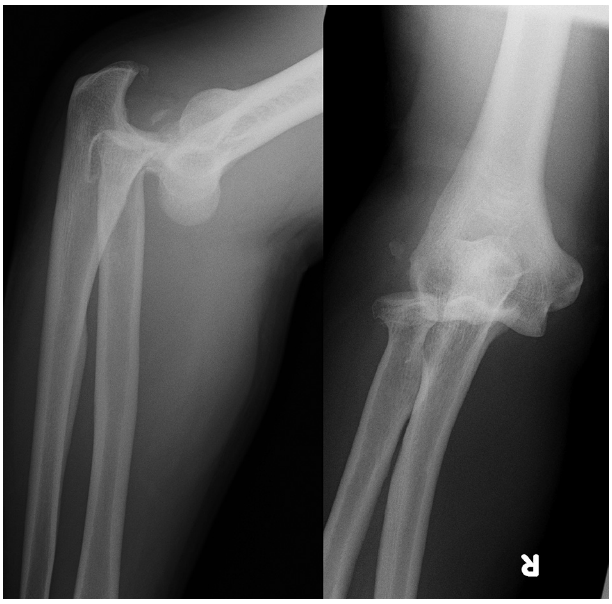

Figure 1. — Preoperative X-rays of a Mason type-IV fracture.

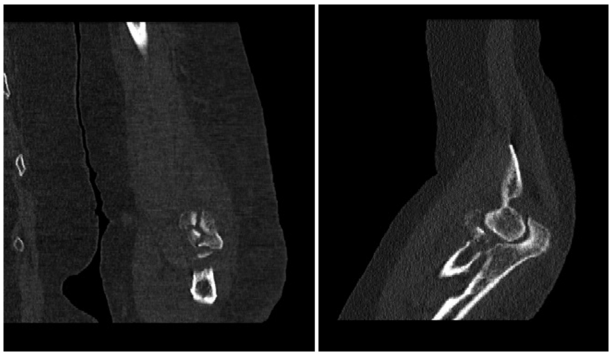

Figure 2. — Preoperative CT-scan of a Mason type-IV fracture.

System (FFS™) was started after open reduction with two or three fine-threaded wires in oblique direction. The remaining fragments were reconstructed with additional wires parallel to the articular surface. The wires were finally shortened to the surface of the bone.

In Figures 3 and 4 the postoperative result after osteosynthesis with fine-threaded K-wires (FFS™) and hinged elbow fixation is shown (X-ray of Mason-IV and Mason-III). Routine implant removal of the FFS™ was not part of the standard treatment protocol.

All of our 23 patients were surgically treated be the same surgeon, which minimizes the performance bias. A lateral Kocher's approach was used in all

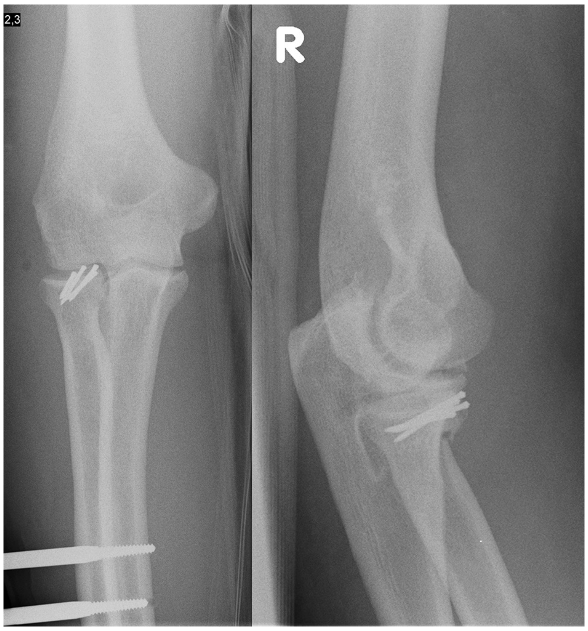

Figure 3. — Postoperative X-rays of a Mason type-IV fracture after osteosynthesis with fine-threaded K-wires (FFS) and hinged elbow fixation.

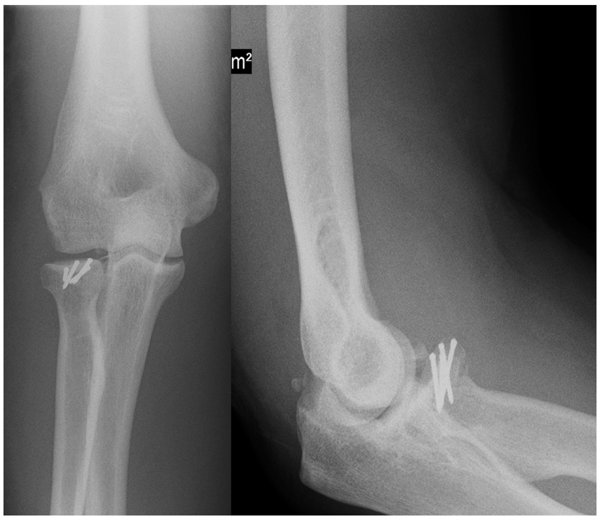

Figure 4. — Postoperative X-rays of a Mason type-III fracture after osteosynthesis with fine-threaded K-wires (FFS).

patients. All 15 Mason type-III fractures were treated with open reduction and internal fixation with fine-threaded K-wires (FFS™, Fragment Fixation System™, Orthofix™, Bussolengo, Italy). In addition to open reduction and FFS™-reconstruction, patients with Mason type-IV elbow dislocation pathology and an instability after reconstruction were all treated with a hinged external elbow fixation for six weeks. The surgical technique used for the external fixation was described by Pennig and Gausepohl in the Orthofix reference guide *(41)*. The application was performed on the lateral side with forearm in neutral position after joint reduction and reconstruction of the radial head. Inserting a K-wire in the center of rotation is the crucial step with must be performed precisely. Afterwards the fixator is mounted with cortical screws on humerus and ulna. After checking the regular joint articulation under dynamic examination with an image intensifiers the fixator is finally locked.

10 patients had additional injuries. 8 patients suffered a terrible triad injury of the elbow and 2 patients had fractures distant to the elbow joint (1 distal radial fracture, 1 Mason type-I fracture of the opposite elbow).

To determine the clinical outcome, we focused on pain level, range of motion and stability. In order to objectively measure the pain level, we used a numeric rating scale. The range of motion (ROM) was measured with a standard goniometer. The Mayo Elbow Performance Score (MEPS) and the shortened Disabilities of the Arm, Shoulder, and Hand questionnaire (QuickDASH) were calculated to quantify the subjective functional outcome. If possible, we also evaluated the work and sports/ music module of the QuickDASH. To classify stiffness we used the Jäger-Wirth score *(24)*.

To get objective results concerning joint stability, we examined 21 patients with a 10 MHz ultrasound under valgus and varus-stress in comparison to the healthy joint, according to the technique described for simple elbow dislocations by Hopf et al. *(17)*. Figures 5 and 6 show the medial joint gap of both elbows in a patient with Mason-IV fracture. A neurological status and a subjective measurement of strength were obtained. Intra- and postoperative complications were recorded, especially for wound problems, infections and subsequent operations.

After six days of immobilization a mobilization under guidance of physiotherapists was started. All patients were treated postoperatively with indomethacin 50mg twice a day under gastric protection (omeprazole) for six weeks to minimize heterotopic ossifications *(48)*.

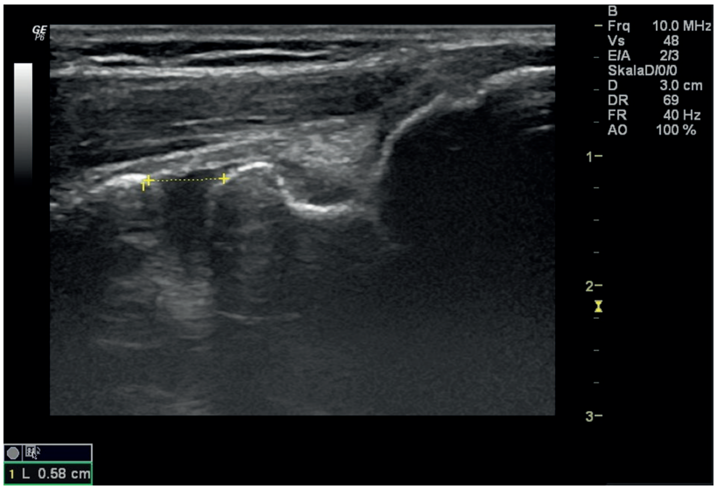

Figure 5. — Medial joint gap of an injured elbow after Mason-IV fracture measured with stress-ultrasound.

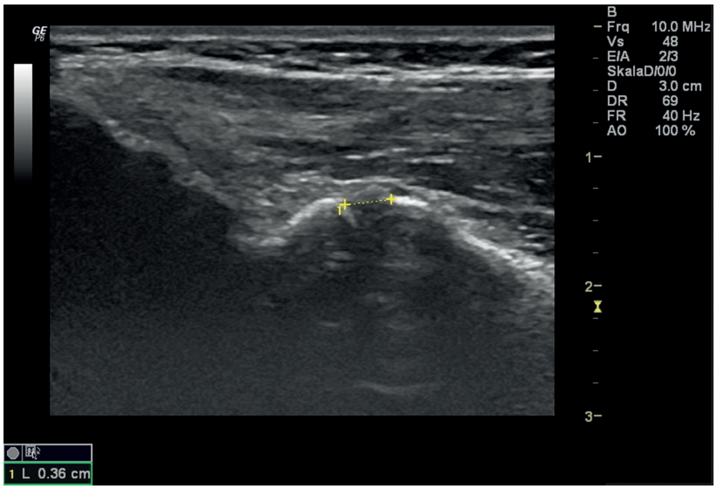

Figure 6. — Medial joint gap of the contralateral elbow measured with stress-ultrasound.

Statistical testing was performed using a t-test for paired variables or a Mann-Whitney rank sum test.

Because this is a retrospective case series without additional examinations to our standard follow-up protocol no institutional review board approval was needed. The informed consent of all patients participating in this study was obtained.

RESULTS

Table I summarizes the patients' data. The average hospital stay was 5.0 days (range 2-12 days). The hospital stay for patients with Mason type-III fracture (average 3.9 days) was significantly shorter than for patients with Mason type-IV fracture (average 7.1 days) (p=0.011).

Clinical results : In the analysis of our whole patient collective we measured an average range of motion for flexion/extension of 134° (± 19° SD) with a range of 90° to 150°. For patients with Mason type-III fractures the average range of motion for flexion/extension was with 141° statistically significant greater than for patients with Mason type-IV fractures (average 120°) (p=0.007). The average extension loss in the Mason-III group was 5°, compared to 18.8° in the Mason-IV group

Table I. — Patient data (n)

No	Age (y)	Sex	Follow-up (mo)	Stay (d)	Diagnosis	Surgical therapy	ROM Ex/ Flex (°)	ROM Pro/ Sup (°)	MEPS	QuickDASH	Resting pain (NRS)	Stability	U/S Δ lat (mm)	U/S Δ med (mm)	Re-operation
1	64	f	106	5	Mason 3	FFS + spongiosa	150	180	95	0	0	stable	0	3	0
2	64	f	85	11	Mason 3	FFS + screws	110	135	65	70.5	4	unstable	37	2	3
3	51	m	84	2	Mason 3	FFS	140	135	80	20.5	1	slightly unstable	4	0	0
4	43	f	82	2	Mason 3	FFS	145	180	95	4.5	0	stable	5	4	0
5	59	m	78	5	Mason 3	FFS	150	180	100	0	0	stable	-	-	0
6	54	m	76	5	Mason 4	FFS + fixator	150	160	100	0	0	stable	4	10	0
7	44	m	72	9	Mason 4	FFS + fixator	120	150	75	18.2	0	slightly unstable	12	23	0
8	39	f	68	2	Mason 4	FFS + fixator	115	135	80	15.9	2	slightly unstable	12	10	0
9	68	f	68	5	Mason 3	FFS	140	160	85	13.6	0	slightly unstable	10	-4	0
10	32	m	68	2	Mason 3	FFS	150	170	100	9.1	0	stable	3	2	0
11	60	m	66	3	Mason 3	FFS	150	165	100	6.8	0	slightly unstable	15	5	0
12	53	f	53	2	Mason 3	FFS	150	180	80	13.6	0	stable	0	8	0
13	46	m	50	2	Mason 3	FFS	130	135	70	50	7	stable	3	-1	0
14	64	m	48	12	Mason 4	FFS + fixator	115	120	95	6.8	0	slightly unstable	23	10	1
15	64	m	46	5	Mason 3	FFS	140	160	85	18.2	0	slightly unstable	2	9	0
16	70	f	28	4	Mason 3	FFS	120	180	95	6.8	0	slightly unstable	8	-3	0
17	30	m	20	6	Mason 4	FFS + fixator	145	180	95	11.4	0	slightly unstable	24	14	0
18	52	f	14	2	Mason 3	FFS	150	180	85	13.6	0	stable	2	2	1
19	78	f	15	9	Mason 4	FFS + fixator	90	110	75	47.7	2	slightly unstable	25	2	0
20	28	m	14	2	Mason 3	FFS	140	160	85	25	0	stable	0	2	0
21	76	f	27	8	Mason 4	FFS + fixator	130	170	85	4.5	1	stable	4	2	0
22	81	m	26	6	Mason 3	FFS	150	180	100	0	0	stable	-	-	0
23	75	f	14	6	Mason 4	FFS + fixator	95	160	65	29.5	3	unstable	24	5	0

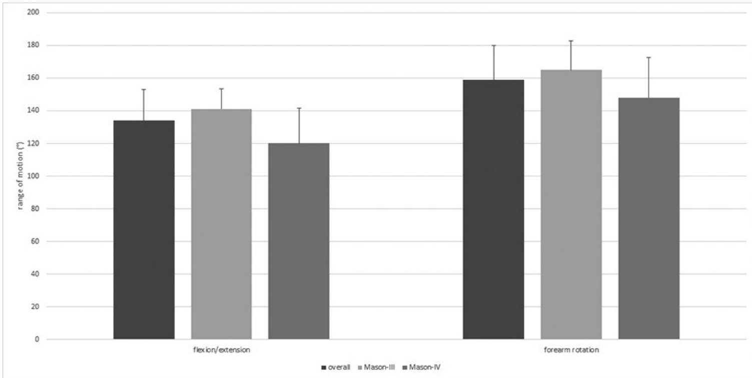

Figure 7. — Mean range of motion of our patient collective.

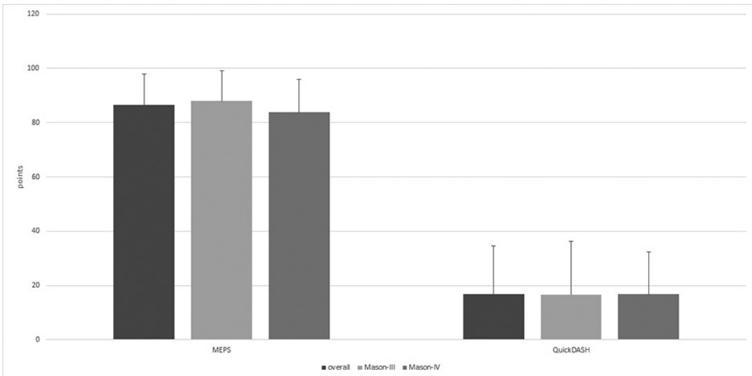

Figure 8. — Mean functional outcome scores of our patient collective.

(average flexion loss Mason-III : 4°, Mason-IV 15°). Both results showed a statistically significant difference between both groups.

Concerning forearm rotation (pronation/supination) we saw an average range of motion of 159° (± 21° SD). The Mason-III group showed an average range of forearm rotation of 165°, compared to 148° of the Mason-IV group. There was no statistical significant difference between both groups for the range of forearm rotation. Figure 7 shows the range of motion of both groups.

22 patients were classified as minor stiffness (grade I) on the Jäger-Wirth score, 1 patient had moderate stiffness (grade II).

The mean MEPS was 86.5 points (± 11.4 SD) with a range of 65 to 100 points. Both groups had a comparable MEPS score with an average MEPS of 88.0 points for the Mason-III group and 83.8 points for the Mason-IV group. In the whole patient collective we measured a mean QuickDASH of 16.8 points (± 17.9 SD) with a range of 0 to 70.5 points. Similar to the MEPS there was no significant difference for both groups for the QuickDASH (Mason-III : 16.8 points, Mason-IV : 16.7 points in average). The work and sports/music module of the QuickDASH could be ascertained for 16 patients. The average score for the work module was 8.2 points (± 16.9 SD). The sports/music module showed an average value of 17.2 points (± 21.8 SD). In our patient collective the fracture classification had no influence on functional outcome. Figure 8 shows the functional outcome of both groups.

According to the MEPS we graded 11 patients (48%) as stable. 10 patients were classified as slightly unstable (≤ 10° varus/valgus) and 2 patients had more than 10° instability during varus stress. No redislocation happened in the follow-up period.

The ultrasound stress test : The average lateral joint gap of the treated elbow was 6.5mm (± 1.0mm SD), with a reference of 5.5mm (± 0.7mm SD) for

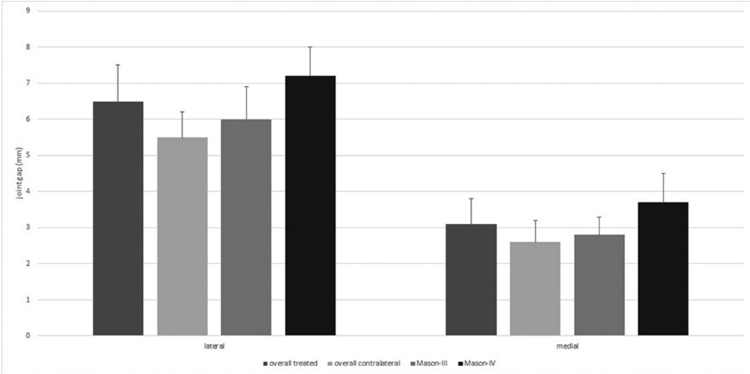

Figure 9. — Mean medial and lateral joint gap (in mm) of our patient collective.

the contralateral elbow. According to these results, the average medial gap of the treated elbow was 3.1mm (± 0.7mm SD), compared to 2.6mm (± 0.6mm SD) for the unaffected joint. The differences for both joint gaps under valgus/varus tress of treated and healthy joint were statistical significant (lateral : p=0.001, medial : p=0.012).

For the Mason-III group we found an average lateral and medial joint gap under the mentioned examination conditions of 6.0mm (± 0.9mm SD) and 2.8mm (± 0.5mm SD) respectively. The measured values for the Mason-IV group were 7.2mm (± 0.8mm SD) laterally and 3.7mm (± 0.8mm SD) medially. The statistical analysis showed a significant difference between both groups for the lateral as well as the medial joint gap (lateral : p=0.006, medial : p=0.002).

In the isolated statistical analysis of the Mason-IV group we got a significant wider joint gap of the treated elbow medially and laterally in comparison to the unaffected joint (lateral : p=0.002, medial : p=0.005). In the Mason-III group we discovered a statistical significant wider joint gap only on the lateral side (p=0.025). The ultrasound measurements of the patient collective are presented in Figure 9.

During the follow-up examinations we registered no neurological complication or nerve damage. 11 patients complained a subjective loss of strength in daily routine at the affected extremity.

No wound infections were seen postoperatively. 3 patients had subsequent operations over the years. 2 patients had a removal of the implants, because of persistent pain and limited range of motion. The third patient had three operations during the follow up period in an external institution. This patient had the worst functional outcome of our patient collective with a QuickDASH of 70.5 points and a MEPS of 65 points.

DISCUSSION

Although simple radial head resection without replacement becomes less popular, good long-term results were published for this simple and inexpensive treatment *(1,15,30,40)*. In the situation of an unreconstructable radial head a prosthetic replacement with different types and shapes is well known and many good results are available *(5,7,13,32,33)*. In fact a radial head replacement to restore the radial column seems to be effective, especially in cases of additional ligamentous injuries *(25,49)*. But even with good outcomes, studies after radial head replacement report concerns about prosthetic shape, frequent loosening of the prosthesis, difficult estimation of the correct prosthetic height and instability of the elbow joint *(1,10,18,37)*. These at least theoretical concerns lead to the consensus that radial head reconstruction, if possible seems to be the most favorable treatment option *(19,31,51)*.

The dogma published by Ring in 2002 *(43)* stated that fracture fixation of more than three fragments of the radial head results in a high non-union and failure rate, so reconstruction was not recommended in cases with a comminution of more than three radial head fragments. The lack of vascularization of the radial head fragment and the lack of new implants such as locked angle mini- and anatomical shaped plates could be a reason for this pessimistic paradigm. It was shown, that the vascular structures of the radial head were more compromised by plate fixation than by special designed screw implants*(27)*.

Zwingmann et al. *(51)* compared different fixation techniques with best results for screws ahead of biodegradable pins and plates. Good results after osteosynthesis with mini-plates were published from Burkhart et al. *(4)* and Zhao et al. *(50)*. Koslowsky et al. *(26)* compared four different fixation devices in an experimental study in a sawbone model. There was superior quality of reduction and stability for FFS™-implants. This one-step fixation technique convinces with easy handling and a short operation time *(26)*.

In cases of a radial head fracture with additional elbow dislocation (Mason-IV) the soft tissue injury seems to be a further challenge : An episode of plaster immobilization without further surgical treatment was published but early functional treatment seems mandatory to prevent elbow stiffness *(16)*. Alternative therapies like direct ligament repair *(22,44)* and hinged external fixation *(14,28)* are discussed controversially. A recent prospective multicenter study showed good functional results after hinged external fixation with the possibility of early mobilization in case of complex elbow dislocations *(20)*. We performed this therapy for addressing the soft tissue injuries in Mason type-IV fractures. For treatment of elbow instability in complex elbow dislocations in combination with Mason type-IV fractures, hinged external fixation is well known *(14,34,45,47)*. Major complications of external fixation on the elbow a rare *(6)*, but radial nerve problems have been reported *(42)*.

In a study of Janssen and Vegter *(21)* no patient with a Mason type-III fracture and subsequent radial head resection had symptoms of instability. Faldini et al. *(9)* reported 8 of 32 patients with mild instability after radial head resection. Our results show, that the increased instability of patients with additional elbow dislocation is verifiable in clinical and stress-ultrasound examination. These results are in accordance with the results of Hopf et al. *(17)*, where 26 patients with simple elbow dislocations were treated with hinged external fixation for six weeks. A significant objective stability difference between former dislocated elbow and the unaffected side was detected. Hopf et al. *(17)* explained this phenomenon by a non-anatomical position of the ligaments insertion and the fact that the elbow is forced into an isolated hinged joint, although there is evidence for side movement of the proximal humero-ulnar joint in addition to isolated flexion and extension *(2)*. Although a significant minor instability was seen in all patients, this fact clearly contrasts their clinical results and relevance even in comparison to ligament reconstruction *(36)*.

In contrast to the complex ligamentous injuries our Mason-III group only had a significant wider joint gap isolated on the lateral side compared to the unaffected joint : A reason for this could be an underestimated postero-lateral joint stability for Mason type III fractures or an iatrogenic Kocher's approach associated soft tissue damage in the situation of the reconstruction procedure.

In a study of Herbertsson et al. *(16)* 21 patients with Mason type-IV fractures were followed in the long-term with a loss of flexion of 3° and a loss of extension of 9°, which is similar to our results (loss of flexion 8°, loss of extension 10°). This applies also for the study of Ikeda et al. *(19)* who described results comparable to ours for range of motion in a comparative study of ORIF and radial head resection for 28 patients. Compared to a study of Burkhart et al. *(4)*, who treated radial head fractures (15 Mason type-III, 6 Mason type-IV) with a locking plate osteosynthesis we measured a slightly better range of motion in our patient collective. Several results for studies with radial head replacement showed a slightly more impaired range of motion compared to ORIF *(38,46)*.

The significant difference between Mason-III and -IV patients in ROM of flexion/extension is a result of the greater soft-tissue injuries in case of additional joint dislocation. The ligamentous and capsular injuries to the elbow joint are important influencing factors for the outcome of these fractures and the development of an persistent elbow instability *(8,11,12,39)*.

Radial head excision showed a good functional outcome similar to the functional scores of open reduction and internal fixation *(1,18)*. Studies with patients after implantation of a radial head prosthesis showed a slightly worse functional outcome scores compared to ORIF *(38,46)*.

Limitations of this study are its retrospective design and the absence of control groups with performed radial head resection and prosthetic replacement for the radial head pathology or direct ligament repair or reconstruction to address the instability. Also only 23 of 27 patients and their treatment procedure could be analyzed. The time of the follow-up examination is with 14 to 106 months very different, which makes it difficult to compare the results among themselves. Besides this we had no comparable radiographic data, so no meaningful statement regarding rate of early osteoarthritis or heterotopic calcifications could be given.

CONCLUSION

Reconstruction of Mason type-III and type-IV fractures of the radial head using fine-threaded K-wires shows good functional results in our patient collective with rare postoperative complications. This fixation technique can be performed for most comminuted fractures of the radial head and can avoid primary resection of this important bony stabilizer of the elbow joint. In case of additional dislocation a temporary hinged external fixation can successfully protect the radial head during the healing period and address elbow instability. Although a minor persistent joint instability could be detected, it seems to have no effect on the clinical outcome.

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