

Treatment of Modified Mason Type III or IV Radial Head Fracture: Open Reduction and Internal Fixation versus Arthroplasty

Abstract

Background: The treatment of modified Mason Type III or IV fractures is controversial. Many authors report open reduction and internal fixation (ORIF) with reconstruction of the radial head, but others advocate radial head arthroplasty (RHA). This study compares the clinical and radiological outcomes of ORIF and RHA in modified Mason Type III or IV radial head fracture and evaluates correlations between prognostic factors and postoperative clinical outcomes. **Materials and Methods:** 42 patients with modified Mason Type III or IV radial head fractures who were surgically treated between January 2010 and January 2014 were retrospectively analyzed (20 patients with RHA and 22 patients with ORIF group were selected). Clinically, the patient rated elbow evaluation (PREE), the disabilities of the arm, shoulder and hand (DASH), and the range of motion (ROM) were measured. Radiologically, plain radiographs and computed tomography scans were taken. **Results:** The mean PREE scores were 13.9 for the RHA group and 13.0 for the ORIF group, and mean DASH scores were 9.5 and 10.7, respectively. The differences were not statistically significant. When comparing ROM, the patients in the RHA group showed greater movement at all measured angles. In multiple regression analysis, age was the only variable significantly associated with both PREE and DASH. **Conclusion:** Overall, there were no significant differences in clinical outcomes of modified Mason Type III or IV radial head fractures treated with ORIF or RHA. However, a subgroup of younger patients had better clinical outcomes with ORIF treatment. Therefore, ORIF should be the first line of treatment, particularly if the reduction is possible.

Keywords: Radial head fracture, radial head repair, radial head arthroplasty

MeSH terms: Radius, osteosynthesis fractures, arthroplasty, replacement

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Introduction

Fractures of the radial head and neck account for 1.7%–5.4% of all fractures and 33% of all elbow fractures.¹⁻⁴ These fractures are often the result from falling on outstretched arms.^{5,6} The radial head contributes to motion of the elbow such as flexion, extension, pronation, and supination.⁷ It also functions biomechanically as a secondary stabilizer to valgus stress about the elbow and in the longitudinal stability of the forearm.⁸

In general, the treatment of radial head fractures is based on the type of fracture. The most commonly used classification of radial head fracture was proposed by Mason.⁹ Modified Mason Type I and II fractures are treated nonoperatively or by open reduction and internal fixation (ORIF).¹⁰ However, treatment of the modified Mason Type III or IV fractures is still controversial. Many authors reported ORIF with reconstruction of the radial

head,¹¹⁻¹³ but others have advocated radial head arthroplasty (RHA).^{2,14,15}

This study compares the clinical and radiological outcomes of ORIF and RHA in modified Mason Type III or IV radial head fracture. In addition, since no consensus on the treatment for Mason Type III or IV radial head fractures have been reached, the authors evaluated correlations between prognostic factors and postoperative clinical outcomes.

Materials and Methods

Patient selection

The study was registered with Yeungnam University Hospital institutional review board. All patients with the modified Mason Type III or IV radial head fractures who were surgically treated between January 2010 and January 2014 at our university hospital, were reviewed in this study. Inclusion criteria were 18–75 years old patients, who were operated upon by single

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surgeon (Seo JS). Exclusion criteria were patients who were lost to followup, and whose followup period was <1 year. Mean followup was 18.2 months (range 15–31 months), and clinical details of the patients are described in Figure 1.

For initial dislocation of the elbow, the reduction was performed in the emergency department under sedation, followed by radiological evaluation. All patients were treated surgically due to mechanical block of forearm rotation. The RHA was preferred over ORIF when the fracture was too comminuted for reconstruction.

The patients in the ORIF group were treated using the LCP Radial Head Plate (Synthes, Oberdorf, Switzerland) or LCP Compact Hand System (Synthes, Oberdorf, Switzerland) [Figure 2, case number 25; Figure 3, case number 29]. The patients in the RHA group were treated using EVOLVE Modular Radial Head System (Wright Medical Technology, Arlington, TN, USA) for 14 patients [Figure 4, case number 3], an Anatomic Radial Head System (Acumed, Hillsbro, OR, USA) for three patients and a floating radial head prosthesis (Tornier SA, Saint-Ismier, France) for 3 patients.

Operative procedure

Patients in RHA group received general anesthesia and were placed in a supine position with the affected extremity in abduction. The posterolateral approach was used, and the joint capsule was released after soft tissue dissection. The neck of the proximal radius was osteotomized using a saw blade on the plane 5 mm above the biceps tuberosity. The proximal medullary canal of the radius was then prepared with a reamer to accept the implant. After the demonstration of satisfactory contact between capitulum and trial prosthesis, and a good fit in the radial medullary canal was found, the final real stem was inserted. The definitive prosthesis was then cemented. Finally, a fit bipolar radial articular surface prosthesis was implanted. The annular ligament was repaired with nonabsorbable sutures. If no combined injuries were present, passive rehabilitation was begun 3 days postoperatively.

Patients in the ORIF group were treated with the same incision used in the RHA group. Plates and screws were used, and all patients were immobilized in plaster for 4 weeks. Rehabilitation began when plasters were removed 4 weeks after surgery.

If the patients had a combined olecranon fracture, additional longitudinal skin incisions were applied along the ulna bone. Using an olecranon plate (Zimmer, Warsaw, Indiana, USA), ORIF was done.

Data analysis

Before surgery, data collection included the type of fracture, number of fragments, days from injury to operation, and the distance from tip of radial head to distal tip of distal fragment determined with plain radiograph and computed tomography scan. After surgery, clinical and radiological data were collected during the followup period. Clinically,

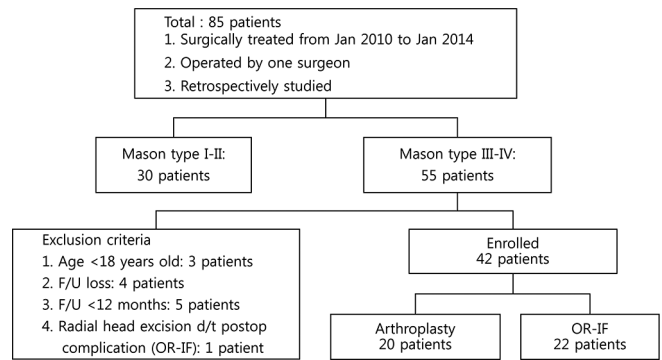


Figure 1: A flow chart showing number of patients in this study. F/U=Followup, d/t=Due to, ORIF=Open reduction and internal fixation



Figure 2: Case number 25: (a and b) Initial anteroposterior and lateral radiograph and computed tomography scan of the left elbow showing radial head fracture (modified Mason Type III). (c) Postoperative anteroposterior and lateral radiograph after open reduction and internal fixation with LCP Radial Head Plate (Synthes, Oberdorf, Switzerland) and LCP Compact Hand (Synthes, Oberdorf, Switzerland). (d) Anteroposterior and lateral radiograph at 1 year followup showing implant *in situ*, congruent radial head

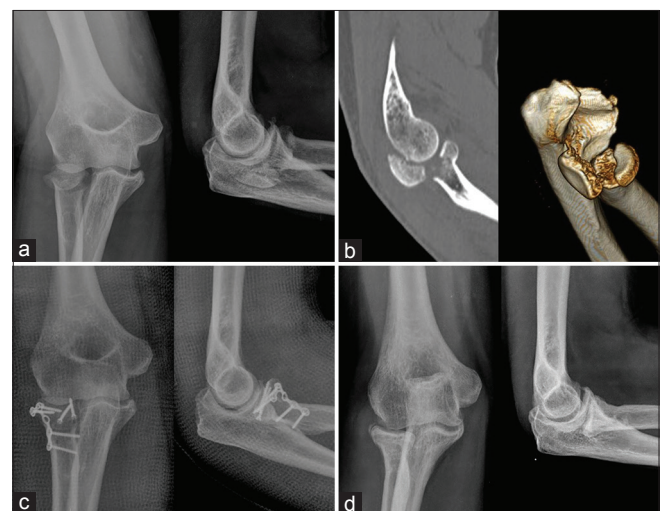


Figure 3: Case number 29: (a and b) Initial anteroposterior and lateral radiograph and computed tomography scan of the left elbow showing radial head fracture (modified Mason Type III). (c) Postoperative anteroposterior and lateral radiograph after open reduction and internal fixation with LCP Compact Hand (Synthes, Oberdorf, Switzerland). (d) Anteroposterior and lateral radiograph after 1 year followup and plate removal well maintained joint space and congruent radial head

the patient rated elbow evaluation (PREE), the disabilities of the arm, shoulder and hand (DASH), and the range of motion (ROM) including flexion, extension, pronation, and supination were measured by standard procedures. In PREE and DASH, higher score indicated increased pain and functional disability (e.g., 0 = no disability; 100 = worst). Radiologically, plain anteroposterior and lateral radiographs were taken [Figures 2-4]. All clinical and radiological evaluations were done by independent observers who were not part of the operative team to avoid potential bias.

Statistics

Sample size and study design were determined based on the results reported by Al-Burdeni *et al.*¹⁶ On the basis of this study, the mean DASH score of the ORIF group and RHA group were 12.0 ± 2.6 (standard deviation [SD]) and 14.1 ± 2.6 (SD), respectively. To achieve statistical power at 0.80, 21 patients for each group were needed. The mean and range for all continuous variables were obtained with Microsoft Excel 2010 (Microsoft Co., Redmond, WS, USA). All statistical analyses were performed using IBM SPSS version 23.0 (IBM Co., Armonk, NY, USA), and $P < 0.05$ was considered to be statistically significant. The Mann–Whitney U-test and Chi-square test were used to test statistical differences between the two groups. To determine possible preoperative factors between clinical outcomes, multiple linear regression analysis was used to identify predictors of the DASH and PREE score.

Results

Patients' characteristics

Of 42 patients, 29 had modified Mason Type III and 13 had Type IV fractures [Table 1]. Twenty patients (47.6%) were

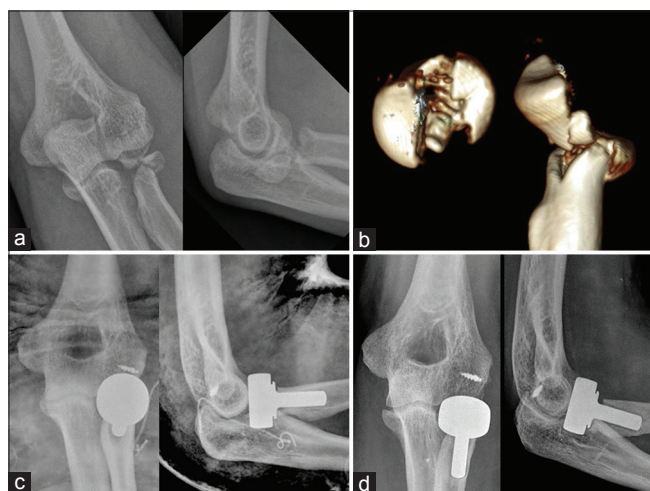


Figure 4: Case number 3: (a and b) Initial anteroposterior and lateral radiograph and three-dimensional computed tomography scan of the left radial head fracture (modified Mason Type III). (c) Postoperative anteroposterior and lateral radiograph after radial head arthroplasty with EVOLVE Modular Radial Head System (Wright Medical Technology, Arlington, TN, USA). (d) Anteroposterior and lateral radiograph for 1 year followup

treated with RHA and 22 patients (52.4%) with ORIF. Most injuries were the result of fall from height (40.4%) and fall with outstretched arm (38.0%). Patients in both groups were comparable, and there were no significant differences in age, number of fragments, days to operation from injury, distance from radial head to distal tip of the distal fragment, operation time, gender, or the type of fracture between the two groups [Table 2].

Clinical outcomes

At the end of the followup period, all patients had stable elbows without recurrent dislocation. Mean PREE scores were 13.9 (SD 15.0) for the RHA group and 13.0 (SD 13.8) for the ORIF group, but the difference was not statistically significant [Table 3]. Mean DASH score was 9.5 (SD 16.8) for RHA group and 10.7 (SD 17.7) for ORIF group, and the difference was not statistically significant. When comparing ROM, patients in the RHA group showed increased movement in all measured angles, particularly in the flexion/extension arc and supination which were statistically different ($P = 0.042$, $P = 0.022$, respectively) from the ORIF group.

To determine the correlation between preoperative factors and clinical outcomes in the ORIF group, multiple linear regression analysis was used [Table 4]. Age and number of fragments showed statistical significance with the DASH, ($\beta = 1.075$, $P = 0.000$; $\beta = 0.701$, $P = 0.002$ respectively) but age was the only variable significantly associated with PREE ($\beta = 0.943$, $P = 0.003$).

Radiological outcomes and complication

One patient in the RHA group suffered from stiffness, but additional surgery was not indicated. Another patient showed symptoms of tardy ulnar nerve palsy, and therefore, anterior nerve transposition surgery was done 8 months after primary radial head replacement. In the ORIF group, one patient suffered fixation failure because fractured fragments migrated, thus requiring revision to RHA. Two patients showed symptoms of tardy ulnar nerve palsy, and therefore, anterior nerve transposition surgery was done 1 year and 5 years after the primary fixation, respectively. One patient developed elbow stiffness but did not need additional surgery. At final followup, there was no subsidence or implant loosening in the RHA group. All coronoid and radial head fractures showed complete bone union in ORIF group except for the two cases of fixation failure. A year later, plate removal was done for all patients in the ORIF group. This was mainly done out of respect for Eastern culture, which does not accept implants inside the human body,¹⁷ and not because of any complications.

Discussion

The elbow is a highly congruent joint, and the radial head plays an important role as a secondary stabilizer.^{18,19} When this articulation is disrupted, surgical treatment is often

Table 1: Patients' demographics

Case number	Sex	Age	Vector	Modified mason type	Associated injury	Number of fragments	Distance (mm) [†]	Time to operation (day)	Operation time (min)	Treat ment	LCL repair	Complication
1	Male	39	F/D	3	LCL rupture	4	9.0	3	270	RHA	Repair	-
2	Female	44	F/D	3	Coronoid process fracture	4	8.5	12	90	RHA	-	-
3	Male	55	F/D	3	LCL rupture	3	20.4	2	105	RHA	Repair	-
4	Female	66	S/D	3	-	3	9.0	12	100	RHA	-	-
5	Female	71	S/D	3	-	2	11.0	4	65	RHA	-	-
6	Female	70	Pedestrian TA	3	Coronoid process fracture	3	10.9	2	150	RHA	-	-
7	Female	46	S/D	3	-	3	9.9	5	115	RHA	-	-
8	Male	51	F/D	3	Coronoid process fracture	2	9.4	5	255	RHA	-	-
9	Male	35	TA	3	-	3	6.5	4	200	RHA	-	-
10	Male	37	F/D	3	-	2	10.3	3	215	RHA	-	-
11	Male	30	S/D	3	-	3	7.2	2	195	RHA	-	-
12	Male	27	TA	3	-	3	6.8	5	205	RHA	-	-
13	Male	36	F/D	3	-	2	8.8	4	180	RHA	-	-
14	Male	55	F/D	4	Terrible triad	3	15.0	1	310	RHA	-	-
15	Male	61	F/D	4	Terrible triad	4	6.0	5	245	RHA	-	TUNP
16	Female	66	S/D	4	Terrible triad	3	8.0	4	310	RHA	-	-
17	Female	68	S/D	4	Terrible triad	5	8.0	1	280	RHA	-	Stiffness
18	Female	73	S/D	4	Terrible triad	4	15.0	5	295	RHA	-	-
19	Female	69	S/D	4	-	4	9.4	5	170	RHA	-	-
20	Female	66	Pedestrian TA	4	Terrible triad	2	13.1	9	140	RHA	-	-
21	Male	18	S/D	3	-	3	9.0	3	160	ORIF	-	-
22	Male	18	F/D	3	-	3	8.0	1	185	ORIF	-	-
23	Male	23	S/D	3	LCL rupture	3	8.0	1	125	ORIF	Repair	-
24	Female	37	S/D	3	-	3	8.0	2	225	ORIF	-	Stiffness
25	Male	46	F/D	3	-	3	8.0	3	175	ORIF	-	-
26	Male	46	F/D	3	Coronoid process fracture	3	12.5	26	400	ORIF	-	Revisional RHA
27	Female	48	TA	3	Coronoid process fracture	2	6.7	4	125	ORIF	Repair	-
28	Male	51	F/D	3	-	2	12.0	1	120	ORIF	-	-
29	Female	53	F/D	3	-	3	17.5	4	160	ORIF	-	-
30	Female	58	TA	3	-	2	11.0	7	165	ORIF	-	-
31	Female	58	S/D	3	-	3	10.2	6	120	ORIF	-	-
32	Male	60	TA	3	-	5	20.0	5	165	ORIF	-	TUNP
33	Female	61	TA	3	-	2	8.0	2	165	ORIF	-	-
34	Female	61	S/D	3	-	4	20.3	2	195	ORIF	-	-
35	Female	73	S/D	3	-	3	15.0	4	220	ORIF	-	-
36	Female	81	F/D	3	-	3	9.0	1	290	ORIF	-	-
37	Male	20	F/D	4	Terrible triad	5	11.1	0	99	ORIF	-	-
38	Male	35	F/D	4	Terrible triad	5	8.5	12	390	ORIF	-	-
39	Male	39	F/D	4	-	3	8.0	3	270	ORIF	-	-
40	Male	45	TA	4	Terrible triad	3	8.4	2	300	ORIF	-	TUNP
41	Female	55	S/D	4	Terrible triad	5	7.0	5	160	ORIF	Repair	-
42	Female	70	S/D	4	Terrible triad	4	10.3	6	250	ORIF	-	-

[†]Distance from radial head to distal tip of distal fragment. LCL=Lateral collateral ligament, RHA=Radial head arthroplasty, F/D=Fall from height, S/D=Slip down, TA=Traffic accident, ORIF=Open reduction and internal fixation, TUNP=Tardy ulna nerve palsy

required. The radial head is a key element in elbow stability during varus, and valgus loading,²⁰ and the radial head is not only important for the humeroradial joint, but also for the stability of the distal radioulnar joint.^{14,21} Therefore, traditional radial head resection is not recommended and is declining in use because of complications such as wrist

Table 2: Characteristics of the study population

Variable	RHA	ORIF	P
Age (year)	53.2±14.9	48.0±17.2	0.351*
Number of fragments	3.1±0.8	3.2±0.9	0.684*
Time to operation (day)	4.6±3.0	4.5±5.3	0.321*
Distance (mm) [†]	10.1±3.3	10.7±3.9	0.791*
Operation time (min)	194.7±75.2	202.9±81.4	0.980*
Sex			
Male	10	11	1.000 [‡]
Female	10	11	

Values are presented as mean±SD. *Mann-Whitney test, [†]Distance from radial head to distal tip of distal fragment, [‡]Chi-square test. RHA=Radial head arthroplasty, ORIF=Open reduction and internal fixation, SD=Standard deviation

Table 3: Clinical outcomes of the radial head arthroplasty and open reduction and internal fixation groups

Variable	RHA	ORIF	P
PREE	13.9±15.0	13.0±13.8	0.280*
DASH	9.5±16.8	10.7±17.7	0.237*
Flexion (°)	127.6±11.3	125.4±9.3	0.256*
Extension (°)	16.4±8.9	20.1±8.5	0.077*
Flexion/extension arc (°)	111.1±15.4	105.2±10.9	0.042*
Pronation (°)	64.5±13.8	61.5±10.9	0.405*
Supination (°)	70.9±8.3	66.0±8.4	0.022*
Pronation/supination (°)	135.4±19.8	127.6±14.2	0.199*

Values are presented as mean±SD. *Mann-Whitney test. RHA=Radial head arthroplasty, ORIF=Open reduction and internal fixation, PREE=Patient-rated elbow evaluation, DASH=Disabilities of the arm, shoulder, and hand, SD=Standard deviation

Table 4: Results of multiple linear regression analysis between preoperative factors and clinical outcomes in open reduction and internal fixation group

Variable	PREE		DASH	
	β	P	β	P
Age (year)	0.943	0.003	1.075	0.000
Number of fragments	0.497	0.081	0.701	0.002
Time to operation (day)	-0.272	0.158	-0.278	0.052
Distance (mm)*	-0.341	0.188	-0.365	0.058

*Distance from radial head to distal tip of distal fragment. ORIF=Open reduction and internal fixation, PREE=Patient-rated elbow evaluation, DASH=Disabilities of the arm, shoulder, and hand

degeneration, persistent instability, and loss of muscle strength.²²

RHA is indicated for irreparable radial head fractures associated with elbow instability. The clinical outcomes which have been reported are mostly from short term followup, but the results are generally favorable.²³⁻²⁶ Harrington *et al.*²⁷ reported 20 cases of RHA with 16 cases having excellent or good results at an average of 12 years' followup. They concluded that metal prosthesis could restore stability of the elbow joint and

prevent displacement of the radial head, thus reducing complications of the ulnoradial joint. However, Sun *et al.* reported in metaanalysis that the revision rate of RHA in modified Mason Type III and IV was 16.7%, and the main reasons were an overstuffed prosthesis (44%) and subluxation (22%).²⁸ They highlighted the need for proper diameter and length of the prosthesis and also asserted that the excised radial head could be used for accurate diameter determination. Repeated length determination should be made using prosthesis models to reduce revision rate.

On the other hand, many authors have reported that ORIF could achieve satisfactory results in comminuted radial head fractures.²⁹⁻³¹ King *et al.* reported 14 cases of ORIF in modified Mason Type II and III injuries with 100% of the results categorized as good and excellent.¹² Chen *et al.* reported 23 cases of ORIF in unstable, multi-fragmented radial head fractures with 65.2% satisfaction.³² However, Sun *et al.*²⁸ indicated in metaanalysis that the revision rate of ORIF in modified Mason Type III and IV was 20.1%, and that it was higher in RHA, but not statistically significant.

There are several reports that compare ORIF and RHA in modified Mason Type III or IV radial head fractures, but results were contradictory. Chen *et al.*³² reported that Broberg and Morrey elbow scores at 2 years' followup were 72.4 and 92.1, respectively and that the differences were statistically significant. However, Al-Burdeni *et al.*¹⁶ reported 15-month followup DASH scores of 14.1 and 12.0 for ORIF and RHA, respectively, but these differences were not statistically significant. Our study also showed similar clinical outcomes for both the ORIF and RHA groups, but ROM was better in the RHA group.

Al-Burdeni *et al.*¹⁶ also performed a regression analysis of preoperative factors and clinical outcomes and concluded that patient age and poor outcome was highly correlated. Considering the fact that the durability of radial head prosthesis is not long, those authors suggested that young patients with modified Mason III or IV radial head fractures are optimal candidates for ORIF rather than RHA procedures.

There are several limitations in this study. As a retrospective review and not randomized control study, the data collected are only as good as the accuracy of the medical record. Therefore, this study has the disadvantage of selection bias as RHA was done in comminuted fractures, and thus, the two groups were not comparable. The followup period was short, and authors were not able to comment on the rate of degenerative arthritis. Due to a small number of cases, we have not been able to control for combined injuries. Therefore, a large, double-blind, and randomized prospective study is needed to verify the comparison of RHA and ORIF. In addition, in patients with combined injuries, the authors could not rule out the effect of the combined procedures on clinical outcomes.

Conclusion

Clinical outcomes of modified Mason Type III or IV radial head fractures treated with ORIF or RHA were not significantly different. Furthermore, in the ORIF group, the younger the patient, the better the clinical outcome. Considering the short durability of radial head prostheses, the authors suggest that for modified Mason Type III or IV radial head fractures in young patients, ORIF should be performed first, if the reduction is possible.

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Conflicts of interest

There are no conflicts of interest.

References

1. Beingessner DM, Dunning CE, Gordon KD, Johnson JA, King GJ. The effect of radial head excision and arthroplasty on elbow kinematics and stability. *J Bone Joint Surg Am* 2004;86-A:1730-9.
2. Holmenschlager F, Halm JP, Winckler S. Fresh fractures of the radial head: Results with the Judet prosthesis. *Rev Chir Orthop Reparatrice Appar Mot* 2002;88:387-97.
3. Morrey BF. *The Elbow and its Disorders*. Philadelphia, PA: Saunders; 1985.
4. Morrey BF, Sanchez-Sotelo J. *The Elbow and its Disorders*. 4th ed. Philadelphia, PA: Saunders/Elsevier; 2009.
5. Pike JM, Athwal GS, Faber KJ, King GJ. Radial head fractures-an update. *J Hand Surg Am* 2009;34:557-65.
6. Rosenblatt Y, Athwal GS, Faber KJ. Current recommendations for the treatment of radial head fractures. *Orthop Clin North Am* 2008;39:173-85, vi.
7. Popovic N, Gillet P, Rodriguez A, Lemaire R. Fracture of the radial head with associated elbow dislocation: Results of treatment using a floating radial head prosthesis. *J Orthop Trauma* 2000;14:171-7.
8. Morrey BF, Tanaka S, An KN. Valgus stability of the elbow. A definition of primary and secondary constraints. *Clin Orthop Relat Res* 1991;265:187-95.
9. Mason ML. Some observations on fractures of the head of the radius with a review of one hundred cases. *Br J Surg* 1954;42:123-32.
10. Rizzo M, Nunley JA. Fractures of the elbow's lateral column radial head and capitellum. *Hand Clin* 2002;18:21-42.
11. 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 Br* 2003;85:1040-4.
12. King GJ, Evans DC, Kellam JF. Open reduction and internal fixation of radial head fractures. *J Orthop Trauma* 1991;5:21-8.
13. Ring D, Quintero J, Jupiter JB. Open reduction and internal fixation of fractures of the radial head. *J Bone Joint Surg Am* 2002;84-A:1811-5.
14. Bain GI, Ashwood N, Baird R, Unni R. Management of mason Type-III radial head fractures with a titanium prosthesis, ligament repair, and early mobilization. Surgical technique. *J Bone Joint Surg Am* 2005;87 Suppl 1:136-47.
15. Johnson JA, Beingessner DM, Gordon KD, Dunning CE, Stacpoole RA, King GJ. Kinematics and stability of the fractured and implant-reconstructed radial head. *J Shoulder Elbow Surg* 2005;14 1 Suppl S:195S-201.
16. Al-Burdeni S, Abuodeh Y, Ibrahim T, Ahmed G. Open reduction and internal fixation versus radial head arthroplasty in the treatment of adult closed comminuted radial head fractures (modified Mason type III and IV). *Int Orthop* 2015;39:1659-64.
17. Tieyi Y, Shuyi L, Yan Z, Guohua H, Jin S, Rui J. Minimally invasive plating for fresh displaced midshaft fractures of the clavicle. *Orthopedics* 2014;37:679-83.
18. Morrey BF, Chao EY, Hui FC. Biomechanical study of the elbow following excision of the radial head. *J Bone Joint Surg Am* 1979;61:63-8.
19. Rymaszewski LA, Mackay I, Amis AA, Miller JH. Long term effects of excision of the radial head in rheumatoid arthritis. *J Bone Joint Surg Br* 1984;66:109-13.
20. Jensen SL, Olsen BS, Tyrdal S, Søjbjerg JO, Sneppen O. Elbow joint laxity after experimental radial head excision and lateral collateral ligament rupture: Efficacy of prosthetic replacement and ligament repair. *J Shoulder Elbow Surg* 2005;14:78-84.
21. Rozental TD, Beredjikian PK, Bozentka DJ. Longitudinal radioulnar dissociation. *J Am Acad Orthop Surg* 2003;11:68-73.
22. 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;32:630-6.
23. Brinkman JM, Rahusen FT, de Vos MJ, Eygendaal D. Treatment of sequelae of radial head fractures with a bipolar radial head prosthesis: Good outcome after 1-4 years followup in 11 patients. *Acta Orthop* 2005;76:867-72.
24. Chapman CB, Su BW, Sinicropi SM, Bruno R, Strauch RJ, Rosenwasser MP. Vitallium radial head prosthesis for acute and chronic elbow fractures and fracture-dislocations involving the radial head. *J Shoulder Elbow Surg* 2006;15:463-73.
25. Grewal R, MacDermid JC, Faber KJ, Drosdowech DS, King GJ. Comminuted radial head fractures treated with a modular metallic radial head arthroplasty. Study of outcomes. *J Bone Joint Surg Am* 2006;88:2192-200.
26. Loreto CA, Rollo G, Comitini V, Rotini R. The metal prosthesis in radial head fracture: Indications and preliminary results. *Chir Organi Mov* 2005;90:253-70.
27. Harrington IJ, Sekyi-Otu A, Barrington TW, Evans DC, Tuli V. The functional outcome with metallic radial head implants in the treatment of unstable elbow fractures: A long term review. *J Trauma* 2001;50:46-52.
28. Sun H, Duan J, Li F. Comparison between radial head arthroplasty and open reduction and internal fixation in patients with radial head fractures (modified mason Type III and IV): A meta-analysis. *Eur J Orthop Surg Traumatol* 2016;26:283-91.
29. Geel CW, Palmer AK, Ruedi T, Leutenegger AF. Internal fixation of proximal radial head fractures. *J Orthop Trauma* 1990;4:270-4.
30. Kelberine F, Bassères B, Curvale G, Groulier P. Fractures of the radial head. Analysis of a series of 62 surgically treated cases. *Rev Chir Orthop Reparatrice Appar Mot* 1991;77:322-8.
31. Pearce MS, Gallannaugh SC. Mason Type II radial head fractures fixed with herbert bone screws. *J R Soc Med* 1996;89:340P-4.
32. Chen X, Wang SC, Cao LH, Yang GQ, Li M, Su JC. Comparison between radial head replacement and open reduction and internal fixation in clinical treatment of unstable, multi-fragmented radial head fractures. *Int Orthop* 2011;35:1071-6.