ACTA ORTHOPAEDICA et TRAUMATOLOGICA TURCICA
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Research Article

Radial head arthroplasty provides successful long-term results in patients treated for comminuted fractures of the radial head, minimum eight-year follow-up

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ARTICLE INFO

Article history:
Submitted January 20, 2025
Received in revised form May 18, 2025
Last revision received form August 18, 2025
Accepted August 18, 2025
Publication Date November 7, 2025

Keywords:
Arthroplasty
Fracture
Mason classification
Outcomes
Radial head
Radial head arthroplasty

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ABSTRACT

Objective: This study aimed to evaluate the long-term results of radial head arthroplasty (RHA) in treating comminuted radial head fractures (RHF).

Methods: Patients who underwent surgery for RHF using the RHA method between 2011 and 2018 were retrospectively analyzed. We included patients who received reconstruction with a radial head prosthesis in the acute or chronic phase due to a comminuted radial head fracture. Patients were excluded if they had a systemic concomitant disease, a previous infection, a fracture or surgery on the same elbow, osteoarthritis, or a follow-up period of less than 5 years. Fractures were classified according to the Mason classification system. For functional assessment, postoperative evaluations included range of motion (ROM), the Mayo Elbow Performance Score (MEPS), and the Quick Disabilities of the Arm, Shoulder, and Hand score (qDASH).

Results: Thirty-five patients (23 male, 12 female) were included in the study. Twenty-five had Mason Type III fractures, and 10 had Mason Type IV RHF. The mean age was 47.8 ± 15.6 years, and the mean follow-up period was 117.3 ± 9.3 months. The mean MEPS was 87.5 ± 10.3, and the mean qDASH score was 16.7 ± 10.8. Patients with Mason Type III RHF demonstrated greater flexion (140° vs. 112.5°) and a larger rotational arc of motion (155.5° vs. 144.9°) compared to those with Mason Type IV fractures. However, extension loss, MEPS, and qDASH scores were comparable between the two groups. Radiological outcomes and complication rates also showed no significant differences between fracture types.

Conclusion: The findings of this study indicate that RHA is an effective treatment option for nonreconstructable RHF, offering reliable pain relief, restoration of elbow mobility, and improved quality of life. These outcomes highlight its value in managing patients with poor prognostic factors, where conventional reconstruction is not feasible, and in preventing long-term functional impairment.

Level of Evidence: Level III, Therapeutic study.

Introduction

Radial head fractures (RHFs) account for about 30% of elbow fractures and about 5% of total fractures.[1] RHF also frequently occur in complex fractures involving the medial column and the coronoid process.[2] The humeroradial joint forms the lateral column of the elbow and acts as an important stabilizer during axial and valgus loads.[2,3] In cases where the radial head is intact, stabilization of the elbow joint can be achieved even in cases of medial collateral ligament (MCL) injuries and small coronoid fractures.[2] Although RHF are generally stable fractures, instability associated with dislocation of the elbow and ligament injuries can be observed in up to 30% of cases.[4]

Operative treatment is indicated for the majority of these unstable radial head injuries and any isolated fractures with significant articular displacement, articular comminution, or mechanical blocks to motion.[4-6] Two methods stand out in these patients, especially in cases with ligament injuries: open reduction with internal fixation (ORIF) and radial head arthroplasty (RHA).[4-7] The RHA has become a favored treatment for nonreconstructable fractures with multiple fragments, patients with poor bone quality, elbow dislocations, Essex-Lopresti injuries, and unstable elbows in Monteggia fractures.[2]

The aim was to investigate, over an average period of 8 years, the clinical and radiological outcomes of the patients who received radial head prostheses due to Types III and IV Mason RHF, that were isolated or associated with fractures of the capitellum and coronoid process.

Material and methods

Before the start of the study, approval was obtained from the Bilecik Şeyh Edebali University University School of Medicine Ethics Committee (decision number 291278, date: November 06, 2024). Written informed consent was obtained from patients who agreed to participate in the study. Institutional review board approval was obtained before starting the study. This retrospective study examined patients who underwent surgery for radial head replacement between 2011 and 2018. Patients with completed bone development who underwent reconstruction with a radial head prosthesis in the acute or chronic

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Cite this article as: *Gedikbaş M, Aşcı M, Eren MB, Güneş T. Radial head arthroplasty provides successful long-term results in patients treated for comminuted fractures of the radial head, minimum eight-year follow-up. Acta Orthop Traumatol Turc., 2025;59(6):439-445.*

DOI: 10.5152/j.aott.2025.25283

phase due to type III and IV RHF according to the Mason classification were included in the study. Patients were excluded from the study if they had metabolic bone disease, a history of elbow infection, osteoarthritis, a fracture and surgery history on the same elbow, and a follow-up period of less than 5 years. Functional evaluations of the patients with a follow-up period of over 5 years were assessed in the final examination in June 2024. The evaluation was performed by 2 orthopedic and traumatology surgeons who did not participate in the operations and interventions.

A prestudy power analysis based on previous data determined that a sample size of 31 patients would be adequate to reach the desired power of greater than 0.8. Postoperative Mayo Elbow Performance Score (MEPS) was the primary outcome for 2 means *t*-test power analysis.[2,8]

The preoperative data of the patients were retrieved from their medical records (mechanism of injury and time from trauma to surgery). The patients were evaluated by an independent investigator who was not part of the surgical team. Range of motion (ROM), MEPS, and Quick Disabilities Arm Shoulder Hand score (qDASH) were used for the postoperative functional evaluations.[9,10] The RHF were graded according to the Mason fracture classification system,[11] based on the preoperative elbow radiographs and computed tomography (CT) imaging. Follow-up data, including elbow ROM at final follow-up, were recorded. Recorded ROM included elbow flexion, extension, supination, and pronation. Radiographic outcomes included development of heterotopic ossification (HO), posttraumatic arthritis on the capitellum side as well as on the ulnohumeral side, periprosthetic lucency, and radiocapitellar alignment. Any complications or additional operations directly related to the initial elbow injury were recorded, including development of elbow joint contracture, wound infection, and reoperations for hardware removal or revision and contracture release.

Radiological examinations of the patients were performed after 2 weeks, 1 month, 3 months, 6 months, and annually after the first year. In addition, a radiological examination with radiographs of the elbow was performed under the supervision of an independent orthopedic surgeon during the examination in June 2024, during which functional assessments were made.

Surgical technique and rehabilitation

After all patients had been prepared in the supine position, the operation was started with a Kocher incision after the application of a tourniquet. The annular ligament was identified with a marking suture and opened to be sutured at the end of the procedure. Once the broken fragments had been excised, the surface of the capitellum was examined. The MCL, lateral collateral ligament, and interosseous ligament were examined after the radial head was removed. Monopolar designed cementless Acumed Anatomic Radial Head System (Acumed, Hillsboro, OR, USA) was used in all patients who underwent surgery. The size of the component was selected based on the removed radial head. After the intramedullary canal was prepared, trial components with the determined dimensions were tested, and components with the corresponding height and width were used as a press fit. Reinforced, nonabsorbable sutures were used to repair the annular ligament. All patients underwent stability testing after prosthesis implantation and lateral soft tissue and ligament repair. If necessary, an MCL repair was performed, and the operation was completed with the application of a long arm splint.

The patients with terrible triad injuries were initially treated with a radial head prosthesis and fixation of the coronoid process, followed by repair of the concomitant ligamentous and soft tissue injuries. The patient with cartilage damage to the capitellum underwent mosaicplasty with osteochondral grafts of healthy radial head cartilage.

Postoperatively, prophylactic antibiotic therapy and indomethacin 75 mg twice daily for 3 weeks were administered to prevent the development of heterotrophic ossification.[12] After 24 hours, the drain was removed and it was ensured that there were no wound problems in the elbow and forearm, and the patient was discharged on the second postoperative day. With the exception of 8 patients who underwent surgery for a terrible triad, all patients were immobilized in a long arm splint for the first week after surgery, regardless of the type of fracture. During this time, shoulder, wrist, and finger movements were trained. After the edema and pain had subsided in the first week, the splint was removed and the flexion, extension, pronation, and supination of the elbow joint were trained under the supervision of a physiotherapist. In the fourth week after the operation, the patients were trained for 1 month with strengthening and movement against resistance. In patients operated on for a terrible triad, fixed immobilization in 90° flexion in a functional splint was performed during the first week. In the second week, controlled movement was then trained in a splint between 30° and 110° and in the third week between 115° and 130°. From the fourth week onwards, these patients also began strengthening and movement exercises against resistance like other patients.

Statistical analysis

The data were analyzed using SPSS Statistics version 23.0 (IBM SPSS Corp.; Armonk, NY, USA). The distribution of the data was evaluated using the Kolmogorov–Smirnov test. The categorical data were assessed using the Pearson chi-square, Fisher exact, and Fisher–Freeman–Halton tests. The parametric and nonparametric data were evaluated using a Student's *t*-test and a Mann–Whitney *U*-test, respectively. For nonnormally distributed data, the dependent groups were evaluated using the Shapiro–Wilk and Wilcoxon signed-rank tests. A value of $P < .05$ was considered significant for all analyses. Survival time without removal or revision was estimated using the Kaplan–Meier method.

Results

During the study period, 122 patients were found to have undergone surgery for fractures of the radial head. Of these, 39 patients were reconstructed with a radial head prosthesis. Because 2 patients did not have available information and 2 others did not want to be included, 35 patients were included in the study. The last patient who met the inclusion and exclusion criteria underwent surgery in 2016. (Figure 1: Flowchart) The mean age of the patients was 47.8 ± 15.6 years (with a range of 29-78 years) and the mean follow-up period was 117.3 ± 9.3 months (with a range of 96-134 months). Of the patients included in the study, 23 were male, and 12 were female. Twenty patients

HIGHLIGHTS

- A radial head prosthesis can be used safely after fragmented and non-reconstructable radial head fractures.
- In the vast majority of patients with a radial head prosthesis, a functional range of motion of the elbow joint can be achieved.
- A radial head prosthesis that is performed with due care and in accordance with its technique retains its effectiveness in the long term, and its functional results are excellent and good.

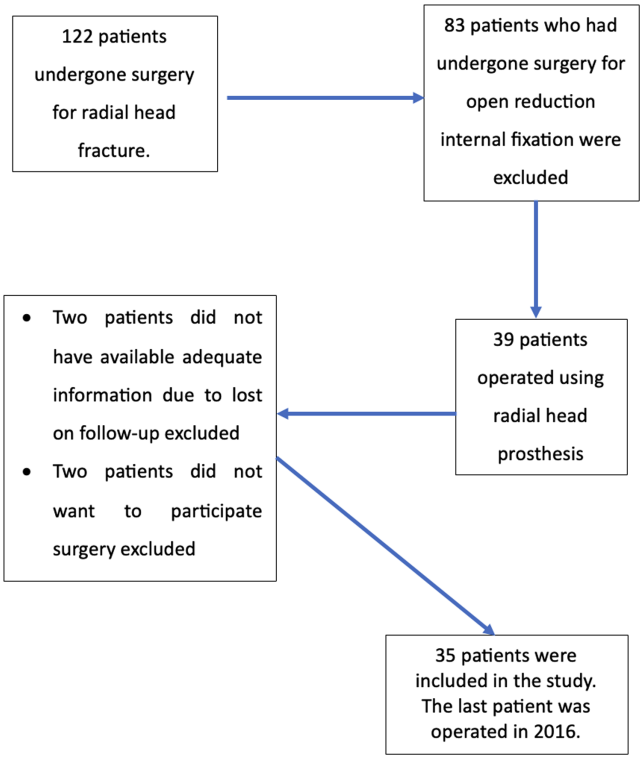

Figure 1. Presentation of the patients participating in the study in the form of a flow chart according to the inclusion and exclusion criteria.

underwent right elbow surgery, and 15 patients underwent left elbow surgery. Ten patients had a type IV fracture while 25 patients had a type III fracture according to the Mason classification (Table 1). Eight patients had concomitant terrible triad injuries and 1 patient had concomitant chondral damage to the capitellum.

At the last follow-up examination, the patients' function was assessed using the MEPS and the qDASH scale. The mean MEPS was 87.5 ± 10.3 while the mean qDASH score was 16.7 ± 10.8 (Table 2).

Table 1. Characteristics of Patients

	All Patients	Mason Type III	Mason Type IV
Total	35	25 (71.4%)	10 (28.6%)
Mean age (SD)	47.8 (15.6)	41.8 (13.0)	56.2 (18.9)
Follow-up (SD)	117.3 (9.3)	117.1 (9.2)	118 (11.0)
Sex			
Male	23 (64.3%)	15 (60%)	7 (70%)
Female	12 (36.7%)	10 (40%)	3 (30%)
Side			
Right	20 (50%)	15 (66%)	5 (50%)
Left	15 (50%)	10 (34%)	5 (50%)
Trauma			
Low energy	25 (64.3%)	20 (80%)	2 (25%)
High energy	10 (35.7%)	5 (20%)	8 (75%)
Radiolucency around radial neck			
No	28 (80%)	21 (84%)	7 (70%)
Yes	7 (20%)	4 (16%)	3 (30%)
Heterothropic ossification			
No	32 (91.5%)	24 (96%)	8 (80%)
Yes	3 (8.5%)	1 (4%)	2 (20%)
Capitellar erosion			
No	31 (89.6%)	24 (96%)	7 (70%)
Yes	4 (11.4%)	1 (4%)	3 (30%)

Table 2. Investigating the Impact of Fracture Types on Outcomes

	All Patients	Mason Tip III	Mason Tip IV	*P*
Loosening	2	1	1	.505
Heterotopic ossification	3	1	2	.176
Capitellar erosion	4	1	3	.041[b]
Flexion	132.1 ± 16.1	140.0 ± 11.5	112.5 ± 2.8	.004**
Extension deficit	5.1 ± 12	4.0 ± 5.6	7.0 ± 9.4	.254**
Supination	77.1 ± 4.6	78.5 ± 4.1	73.7 ± 4.7	.093**
Pronation	75.3 ± 4.9	77.0 ± 4.8	71.2 ± 2.5	.046**
qDASH	16.7 ± 10.8	17.1 ± 10.1	15.7 ± 13.9	.720**
MEPS	87.5 ± 10.3	89.5 ± 9.2	82.5 ± 12.5	.268*

[b]Fisher exact test.
*Student *t*-test.
**Mann–Whitney *U* test.

The examination of the average ROM of the patients revealed a flexion of the elbow of 132.1° while a loss of 5.1° was observed during extension. Supination of the forearm was found to be 77.1° while pronation was measured at 75.3° (Table 2). When the joint ROM of the patients was examined, it was observed that flexion was less than 120° in 5 patients and extension limitation was 45° in one of these patients. Of these patients who could not reach functional ROM, 1 underwent surgery due to isolated Mason type III RHF, 1 due to isolated type IV RHF, and 3 due to type IV RHF accompanied by terrible triad injury (Table 3).

A comparison by fracture type showed that patients with type IV Mason fractures had more capitellar erosion (P=.041) and less pronation motion (P=.046) while patients operated on for type 3 Mason fractures had better elbow flexion and thus better joint ROM (P=.004). It was also observed that patients with type 3 Mason fractures had better functional scores although this result was not statistically significant (Table 2). One patient, who had a cartilage injury in the capitellum and underwent mosaicplasty, (Figure 2) had full ROM and did not experience any pain or difficulty during daily living activities.

The radiological examination carried out at the last check-up revealed periprosthetic radiolucency in 2 patients (Figure 3), loosening in 2 patients, erosions in the capitellum in 4 patients, and HO in 3 patients. Two patients were diagnosed with prosthesis loosening. One of these patients had been operated for a Mason type 3 fracture, the other for a Mason type 4 fracture. In the patient who had been operated for a Mason type 3 fracture, the loosening was observed in the seventh postoperative year and revision surgery was performed in the postoperative 99th month. In the other patient, the loosening was observed in the fifth postoperative year and the revision surgery was performed in the postoperative 102nd month. Both patients were followed closely after loosening was observed at zone 1-5 levels according to the classification described by Chen et al.[13] As they were asymptomatic, revision surgery was awaited. When all patients had radiological loosening extending to zone 3 and became symptomatic, revision surgeries were performed. In both patients, revision surgery was performed with a longer, monopolar designed, cemented stem. (Figure 4) Survivorship rates of the prosthesis were 100% (95% CI=100%-100%) at 2 years, 97% (95% CI=86%-100%) at 8 years, and 94% (95% CI=68%-100%) at 10 years.

Other common complications such as instability, periprosthetic infection, damage to the ulnar nerve, and complex regional pain syndrome were not observed.

Table 3. Characteristics of the Patients who Were Unable to Achieve Functional Range of Motion

Number	Gender	Age	Follow-up Time (Year)	Mason Classification	Flexion	Extension	Supination	Pronation	qDASH	MEPS
1	M	52	8	Type IV+TT	110	−45	40	40	4.5	70
2	F	65	8	Type III	115	0	40	35	9	80
3	M	32	9	Type IV+TT	110	−10	35	35	4.5	70
4	F	76	10	Type IV+TT	115	−5	35	40	9	80
5	M	32	9	Type IV	110	−10	35	35	4.5	70

F, female; M, male; MEPS, Mayo Elbow Performance Score; qDASH, Quick Disabilities Arm Shoulder Hand Score; TT, terrible triad.

Discussion

The study results indicate that in patients who underwent reconstruction with radial head prosthesis due to RHFs that were isolated or accompanied by additional injuries, joint ROM and functional outcomes were successfully regained and maintained at the end of long-term follow-up.

The literature has shown that ORIF, radial head excision, and RHA application are among the surgical options for the treatment of radial head comminuted fractures.[2,14] However, in injuries associated with Essex-Lopresti lesions, the terrible triad, Monteggia fractures, and MCL injuries, radiocapitellar joint contact must be maintained to preserve the normal kinematics of the elbow joint.[2,5,15,16]

The blood supply to the radial head is intraosseous in adults, and Yamaguchi et al[17] showed that the supplying artery enters from the anterolateral part of the radial neck.[18] Due to these anatomical conditions, osteonecrosis can develop even if a successful osteosynthesis is performed in fractures with multiple fragments. This can lead to pseudarthrosis, failure of the implant, and a painfully stiff elbow.[19,20] The radial head prosthesis is therefore an alternative for patients with multifragmented acute radius fractures and failure of the ORIF.[6] Ring et al[20] examined the outcomes of patients with types II and III Mason fractures treated with ORIF and found that fixation failure, nonunion, and stiff elbows were more common in patients with type III fractures. In addition, a study comparing ORIF and arthroplasty for Mason type III fractures found that patients who underwent arthroplasty had fewer complications and better outcomes.[7] Thus, the use of RHA was considered appropriate for types III and IV fractures.

The most important indicator for the evaluation of surgical results is the achievement of a functional ROM of the elbow joint that enables the patient to perform everyday activities. The first study on this topic was conducted by Morrey et al,[21] and they reported that a flexion-extension arc of 100° and a pronation-supination arc of 100° should be present so that the patient can meet basic needs such as personal hygiene and eating meals without difficulty. In large studies examining the outcomes of patients undergoing RHA, it was found that the flexion arc varied between 113° and 127° while the

Figure 2. Intraoperative view of the patient with osteochondral defect in the capitellum. A: osteochondral defect area in the capitellum, B: osteochondral autograft harvested from the excised radial head, C: mosaicplasty applied to the defect area.

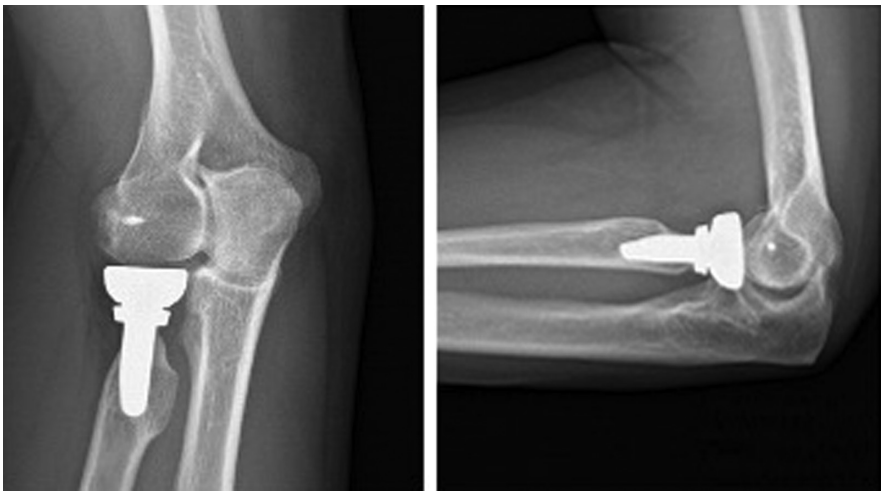

Figure 3. X-ray images of the elbow of the patient, who is in the 10th year after the operation. Osteolysis in the neck area without instability is observed.

Figure 4. X-ray images of the patient who underwent surgery for revision arthroplasty. A: Loosening findings in the 7th year after surgery for a Mason type 3 radial head fracture, B: Early postoperative radiographs after revision surgery.

rotation arc varied between 121° and 159°.[2,4,22,23] When examining the results of the patients, it was found that the flexion-extension arc was approximately 125° and the rotation arc was approximately 150°. These results show that the outcomes achieved in the patients were consistent with both the aforementioned functional ROM reported by Morrey et al and the outcomes reported in the additional studies.

The MEPS and DASH scores are frequently used in the evaluation of clinical outcomes of radial head prostheses. In a review study conducted by Kaur et al[24] to evaluate the functional outcomes of radial head prostheses, they analyzed studies with an average follow-up of 23-106 months. The average MEPS of these studies was 85.8 ± 4.1.[24] In the same study, the average qDASH score was reported as 18.1 ± 5.9. The average qDASH score was 16.7 ± 10.8, and the average MEPS was 87.5 ± 10.3 in the study. These results also accord with those in the literature.

There are 2 different types of RHA, which differ in their polarity: monopolar and bipolar. There are many publications in the literature comparing the results of these 2 prosthesis designs, but contradictory results are reported.[25-29] However, the general opinion is that there are more complications in patients undergoing surgery with bipolar implants.[29] Previous systematic reviews on this topic concluded that HO, osteoarthritis, loosening, and radiolucency were more common in patients with bipolar prostheses.[28-31] In addition, biomechanical cadaver studies have shown that monopolar prostheses maintain stability better in cases involving soft tissue injuries.[32-35] In studies examining functional results, it was seen that excellent/good results were achieved in the evaluation made with MEPS in both prosthesis designs, and the average DASH score was 19.0 in the monopolar design and 16.3 in the bipolar design.[27,29,30] In light of all this information, when comparing the results with the literature, it is believed that the functional and radiological results of the patients who have undergone surgery using a monopolar design prosthesis are consistent with the literature and that good results can be achieved with surgery using a monopolar design prosthesis performed carefully and in accordance with the technique.

The most common complications after radial head prostheses are HO, loosening, posttraumatic arthritis, and nerve damage.[36] Although the incidence of HO varied between 36% and 46.9% in previous studies, Ha et al[1] reported that additional surgery was required for HO in

about one quarter of patients.[23,37] Floating elbow injuries, severe injuries such as the terrible triad, prolonged immobilization, and delayed surgery have been reported as risk factors for the development of HO.[8,38,39] In this study, the HO rate was 8.5% and 2 of these 3 patients have Mason type IV fractures. The lower HO rate in the study vs. that in the literature was likely due to the low number of Mason type IV fractures, lower trauma to surgery time, and effective indomethacin prophylaxis in the population. Moreover, revision rates after RHA typically vary between 0% and 29%.[2,5] The most common reason was joint stiffness followed by painful loosening.[5] In a recent systemic review, Davey at al[40] analyzed the minimum results after 8 years; the rate of revision arthroplasty was 3%.[40] Kachooei et al[41] reported in their systematic review that the most common reasons for revision or removal were HO, instability, and joint stiffness, with 3.8% of patients requiring revision and 10% requiring revision/removal. In this series, 2 patients (5.7%) had to be revised due to painful loosening. The revision arthroplasty and implant removal rates are low and consistent with the literature. This can be attributed to the low incidence of HO, the preservation of joint ROM in patients, and the absence of early subluxation and dislocation. These outcomes are likely due to careful dissection and appropriate adjustment of prosthesis height and size.

One of the most important problems in patients with RHA is the development of capitellar erosion, which causes chronic pain and limitations in the long term due to the increased load.[42,43] In a cadaver study conducted by Aşık et al,[42] the load transfer to the capitellum of the native radial head, the monopolar radial head prosthesis, and the bipolar radial head prosthesis was biomechanically analyzed and they found that there was no significant difference between the 2 different designs, except in the full extension supination position. In another biomechanical study conducted by Chytas et al,[44] it was reported that capitellar erosion can occur even when overstuffing is avoided. This was attributed to variations in the native anatomy of the radial head that could not be fully accommodated and to the fact that the implant is harder than the native radial head. Another recent cadaver study by Heifner et al,[45] found that capitellar erosion was related to malalignment rather than prosthesis design and height. When the literature is examined, it is seen that the rate of capitellar erosion development after RHA is between 25% and 40%.[46-48] The results show that 11.5% of the patients developed capitellar erosion. The lower result compared to the literature is likely due to the implantation of the RHA with an anatomical design, paying careful attention to anatomical alignment and overstuffing .

After implantation, bone resorption can be observed at the neck of the radius in the seventh month after the operation due to the stress shielding effect. This typically affects 6%-22% of patients and does not lead to instability or revision of the prosthesis.[2,8,33,47,49] When the patients were examined, it was found that 2 patients (5.7%) developed a resorption phenomenon, a result comparable to that in the aforementioned studies.

The limitations of the study are as follows: 1) it is a retrospective study, 2) the operations were performed by 2 different surgeons, 3) the number of patients was relatively small compared to previous studies, 4) there was no control group with ORIF and bipolar radial head prosthesis. A further limitation of the study is that the changes in wrist variance were not examined radiologically. However, the study benefited from the use of the same implant in all patients, which eliminated the risk of bias that can occur due to implants with different characteristics; the long follow-up period; and the assessment of functional outcomes by 2 independent reviewers who used more than 1 scoring system.

After multifragmented and irreparable RHF, successful results can be achieved with a radial head prosthesis, even if there are additional injuries causing instability. This method ensures a functional ROM of the elbow joint, preserves the radial length, and prevents secondary wrist problems.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of University of Bilecik Şeyh Edebali University (Approval no: 291278; Date: November, 06, 2024).

Informed Consent: Written informed consent was obtained from the participants who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – M.A.; Design – M.A.; Supervision – M.B.E., T.G.; Resources – M.G.; Materials – M.A.; Data Collection and/or Processing – M.G.; Analysis and/or Interpretation – M.G.; Literature Search – M.G., M.B.E.; Writing – M.G.; Critical Review – T.G.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: The authors declared that this study has received no financial support.

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