Results of Radial Head Prosthetic Replacement in Management of Radial Head Fracture in Terrible Triad Injury of the Elbow

Elsayed Said[a], Hossam A Attyia[a], Mohamed A Soliman[a*], Khaled H Mosallam[a]

[a]Orthopedic Surgery Department, Faculty of Medicine, South Valley University, Qena, Egypt.

Abstract

Background: The "terrible triad injury of the elbow" is complex fracture dislocation injury comprising a notorious combination of elbow dislocation and fractures of the coronoid process and radial head.

Objectives: The work aimed to demonstrate the results of radial head prosthetic replacement in management of fracture head of radius in terrible triad injury of the elbow in terms of clinical and radiological outcomes.

Patients and methods: This is a retrospective study that includes 20 patients that fulfilled inclusion criteria, presented with terrible triad injury of the elbow to Qena University Hospital trauma unit in the period between July 2018 and August 2022, managed with prosthetic replacement of the radial head using non-modular metal spacer and reconstruction of elbow ligaments.

Results: We found that most patients (18 patients, 90%) reported return to previous work and daily activity, at least14 patients (70%) reported good functional ROM in their last follow-up with mean MEPS and QuickDASH scores 76 and 37.09 points, respectively. On the other hand, there was a high rate of complications. Most significantly, two patients (10%) experienced residual valgus instability. Another two (10%) patients demonstrated heterotrophic calcification. Four (20%) patients suffered nerve injury.

Conclusion: Current surgical protocols made it possible to achieve acceptable outcome and regain the joint function using economically affordable, cost-effective, non-modular prosthesis. However, there is still significant risk of long-term disability and high rate of complications.

Keywords: Terrible triad injury; Elbow; Radial head prosthesis.

DOI: 10.21608/svuijm.2022.162836.1407

***Correspondence:** mohamedsolly007@gmail.com

Received: 1 September, 2022.
Revised: 20 September, 2022.
Accepted: 30 September, 2022.
Published: 2 Septembre, 2023

Cite this article as: Elsayed Said, Hossam A Attyia, Mohamed A Soliman, Khaled H Mosallam. (2023). Results of Radial Head Prosthetic Replacement in Management of Radial Head Fracture in Terrible Triad Injury of the Elbow. *SVU-International Journal of Medical Sciences*. Vol.6, Issue 2, pp: 652-664.

Introduction

In the realm of orthopaedics and among the variety of disease designations, the terrible triad injury of the elbow casts a large shadow because the term “terrible” is hardly ever seen in medical terminology no matter how intimidating a disorder is. Therefore, patients and even doctors may harbour doubts about what this so-called terrible triad is, just how terrible it is, and whether it is possible to achieve a satisfactory prognosis **(Xiao et al., 2015)**.

The terrible triad injury of the elbow refers to a constellation of injuries in the elbow that involves a fracture and dislocation of the elbow joint. In particular, the elbow is dislocated in a posterior direction. The coronoid bone is fractured. The third part of the injury is a fracture of the radial head. This term is used because of high rate of complications that often occur **(Pughet al., 2002)**.

Despite the complexities of this injury, deeper understanding of the relevant anatomy, the mechanism of elbow injury, the primary and secondary stabilizers ensuring joint stability, the soft tissue injury patterns, and better methods of surgical repair have led to develop a competent surgical strategy for these injuries. A surgical protocol that includes:(A) fixation or replacement of the radial head, (B) fixation of the coronoid fragment, (C) repair of the lateral collateral ligament complex, and (D) repair of the medial collateral ligament, with application of a hinged external fixator for patients who demonstrate residual instability. This protocol restores congruent elbow stability, allows early motion, enhances functional outcome, and minimizes complications **(Rodriguez-Martinet al., 2011)**.

Since the introduction of the radial head prosthesis in 1941, many alterations in designs and materials have been proposed and tried that have varied in terms of material, fixation technique, modularity. In terms of polarity, it was originally unipolar till Judet introduced bipolar implants, however, its advantage over unipolar implants hasn't been established **(Said et al., 2022)**.

The work aimed to demonstrate the results of radial head prosthetic replacement in management of fracture head of radius in terrible triad injury of the elbow in terms of clinical and radiological outcomes.

Patients and methods

This was a retrospective study that included 20 patients, presented with terrible triad injury of the elbow to Qena university hospital trauma unit in the period between July 2018 and August 2022, managed with prosthetic replacement of the radial head using non-modular metal spacer and reconstruction of elbow ligaments.

Each case was managed on its own merits and necessary repairs and reconstructions were done. Standard reconstruction techniques for each injury component were implemented.

This work was approved by the Research Ethics Committee of our institution(Approval code: 255), informed and written consent was obtained from all participants.

Patient Selection

Inclusion criteria: skeletally mature individuals, all patients suffered terrible triad injury of the elbow with radial head component not amenable for internal fixation.

Exclusion criteria: Isolated radial head fractures, open fractures, pathological fractures and associated upper limb fractures.

Pre-operative assessment: All of the patients were subjected to the following:

- Initial management and resuscitation: trauma survey and resuscitation measures to stabilize general condition.
- History taking including: Age, sex, , hand dominance, job, pre-fracture working ability and skills, medical co-morbidities and mechanism of injury, duration from injury till operation were recorded preoperatively
- Clinical Examination: Attention was given to neurovascular status and any skin or soft tissue compromise.
- Investigations: Routine Laboratory work up and preoperative fitness. Plain X-ray: Plain radiographs including a preliminary AP and lateral radiographs of the affected elbow was performed for diagnosis. Computed tomography (CT scan) with 3D reconstruction**:** mandatory for assessment of the fracture pattern and stability.

Surgical Technique

Under tourniquet, Lateral skin incision was done directly over the middle of the lateral condyle and extended distally as required.

After dissection of subcutaneous tissue and fascia, there usually was a bare area over the lateral epicondyle denoting avulsion of the lateral collateral ligament; lateral capsulotomy was done to expose radial head. After irrigation and removal of hematoma and bony debris, evaluation of bony and soft elements was done and giving attention to radial head as the pillar of our surgery. Fragments of the radial head were collected and reassembled, an oscillating saw was used to make a smooth surface for seating of the base of the implant.

Dissection must not continue below the annular ligament or retract vigorously, because the Posterior Interosseous Nerve (PIN) lies within the substance of the supinator muscle and is vulnerable to injury.

Reaming of intramedullary canal of the radius to prepare it to accept the stem of the implant using a curette or small rasp followed by irrigation to remove bony debris. It was noted that 6.5 tab from DHS set was found useful and very handy in this step.

At this point, there were three items that need to be addressed respectively:

1.Anterior capsular repair

2. Radial head replacement

3. Repair of lateral collateral ligament

Starting with anterior capsular repair , using locking non absorbable sutures for repair passing within the anterior capsule then encircling the coronoid fragment,dorsal incision on the proximal ulna was done, two drill holes within the fracture bed creating tunnels were done from the dorsal border of ulna **(Fig.1)**.

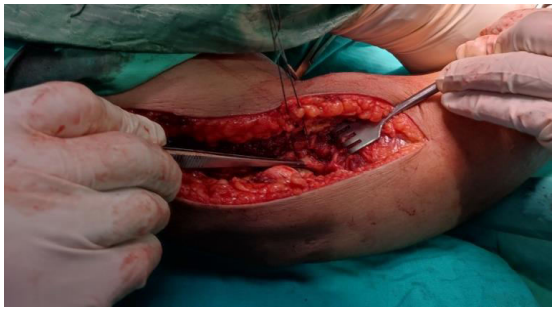

Fig. 1. Sutures encircling coronoid fragment

Sutures were retrieved through the tunnels in fracture bed by a passer or straight needle or surgical loop made of prolene suture, tying the sutures was left to the very last (**Fig.2**).

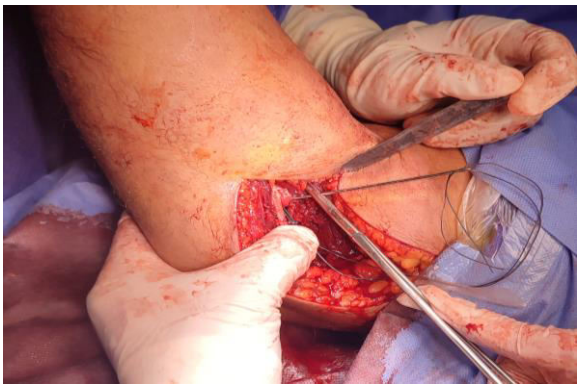

Fig.2. passing coronoid sutures using straight needle through fracture bed

Regarding radial head, ideal size and cementing vs. press-fitting was decided by trial implant, implant diameter should fit the inner diameter of the assembled radial head fragments, the height of the implant should correspond to the height of the fragments to avoid overstuffing (The implant used for replacement was a non-modular metal spacer that was cheap and economically affordable), if cementing was required the canal was gently filled with PMMA bone cement. The implant was then inserted into the canal, gentle impaction with impactor or a blunt instrument. Fluoroscopic imaging was obtained to ensure appropriate sizing.

As for the LCL reconstruction, running locking absorbable sutures (Vicryl) was passed through the LCL complex and the posterolateral capsule, the isometric point on the lateral epicondyle was identified at the centre of the arc of the capitellum by Kirschner wire under image as demonstrated in (**Fig.3**), drill tunnels were done by k-wires, sutures were retrieved through the bone tunnels by straight needle.

Fig. 3. Tunnel drilled by k-wires for lateral collateral ligament reconstruction

Finally, all sutures were tensioned in specific order starting with the coronoid sutures in the dorsal aspect of proximal ulna, sutures were tensioned with the elbow concentrically reduced and in 90° flexion and the forearm in full supination then the sutures of LCL were tensioned, After that, the annular ligament and the common extensor layer were repaired in a side-to-side fashion using absorbable sutures. After repair, the elbow was fluoroscopically examined for stability as shown in (**Fig.4**),

and the safe arc of motion was documented. Skin and subcutaneous closure was done using absorbable sutures.

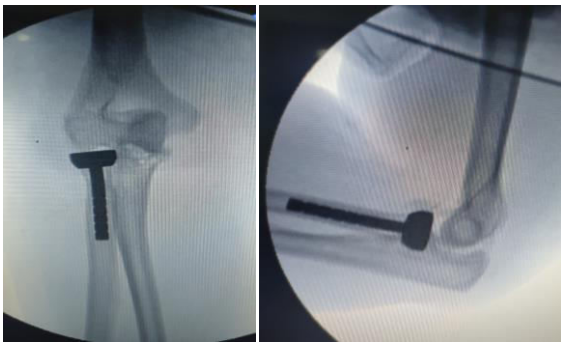

Fig. 4. C-arm images after repair

Postoperative care

A) Medications prescribed: Pain control using analgesics postoperatively to ensure early mobilization. Anti-edematous measures: elevation and medication. Postoperative antibiotics were used for 1 week

B) Immediate Postoperative Plain radiograph: Anteroposterior (AP) and lateral radiographs were obtained in the first postoperative day.

C) ROM exercise started as early as possible

Outcome assessment

- Follow up appointments were scheduled at 1.5 months, 3 months and 6 months.
- Clinical assessment of elbow performance: Functional evaluation consisted of ROM, Mayo elbow performance score (MEPS) and QuickDASH score (Arabic version).
- Radiological assessment: Plain radiograph was requested and evaluated in each visit including lateral and postero-anterior views of elbow joint, all radiological findings were recorded.
- Complications: Relevant complications were reported and tracked during the course of follow-up.

Statistical analysis

Data was analyzed using statistical package for social sciences (SPSS) version 24. Categorical data was described using frequencies and percentages. Numerical data was described in terms of mean and standard deviations if normally distributed. Kolmogrov-Semornov test was used to test the normality of distribution of numerical variables. McNemar test was used to test the association between paired categorical variables. Repeated measures ANOVA was used to test the difference between more than 2 paired numerical variables at different follow up intervals. *P* value less than 0.05 was considered statistically significant.

Results

Demographic data

Twenty four patients presented with terrible triad injury of the elbow, 4 cases dropped follow up, 20 patients were included to participate in the study. Their age ranged between 21 and 66 years old with a mean of 39.4 ± 14.14 years old, 14 patients (70%) were males.

Clinical assessment of elbow performance as summarised in **(Table .1)**.

Table. 1. Clinical follow up assessment

Variables	1st visit*	2nd visit*	3rd visit*	*P* value**
Flexion	102 ± 8.94	111 ± 16.19	122 ± 24.62	.003
Extension	32.5 ± 9.25	28 ± 10.81	22 ± 13.99	.001
Pronation	58.5 ± 18.93	63.5 ± 20.53	72.5 ± 20.16	<.001
Supination	59 ± 19.71	61 ± 19.17	69.5 ± 18.98	<.001
MEPS	65 ± 11.92	76 ± 9.95	84.5 ± 13.27	<.001
Quick DASH	43.2 ± 4.92	37.09 ± 6.11	30.01 ± 9.52	<.001

* Follow up appointments at 1.5 months, 3 months and 6 months

**Repeated measures ANOVA

Flexion: Degree of maximum flexion significantly increased over follow up from 102 ± 8.94 degrees to 111 ± 16.19 degrees. This significantly increased to reach 122 ± 24.62 degrees in the 3rd follow up visit. This was statistically significant (*p*=.003).

Extension: Degree of maximum extension significantly decreased over follow up from 32.5 ± 9.25 degrees to 28 ± 10.81 degrees. This significantly decreased to reach 22 ± 13.99 degrees in the 3rd follow up visit. This was statistically significant (*p*=.001).

Pronation: Degree of maximum pronation significantly increased over follow up from 58.5 ± 18.93 degrees to 63.5 ± 20.53 degrees. This significantly increased to reach 72.5 ± 20.16 degrees in the 3rd follow up visit. This was statistically significant (*p*<.001).

Supination: Degree of maximum supination slightly increased over follow up from 59 ± 19.71 degrees to 61 ± 19.17 degrees. However, this was statistically insignificant (*p*=.126). however, This significantly increased to reach 69.5 ± 18.98 degrees in the 3rd follow up visit. This was statistically significant (*p*<.001).

Mayo elbow performance score: The MEPS significantly increased over follow up from 65 ± 11.92 points to 76 ± 9.95 points. In addition, this fatherly increased to reach 84.5 ± 13.27 points in the 3rd follow up visit. This was statistically significant (*p*<.001) as shown in (**Fig.5**).

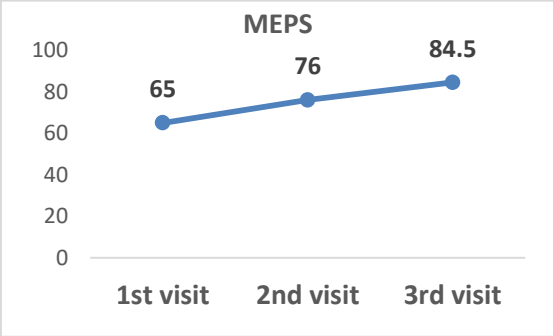

Fig.5.Follow up of MEPS among included patients

QuickDASH score: The QuickDASH score significantly decreased over follow up from 43.2 ± 24.92 points to 37.09 ± 26.11 points. In addition, This furtherly decreased to reach 30.01 ± 29.52 points in the 3rd follow up visit. This was statistically significant (*p*<.001) as shown in **(Fig.6)**.

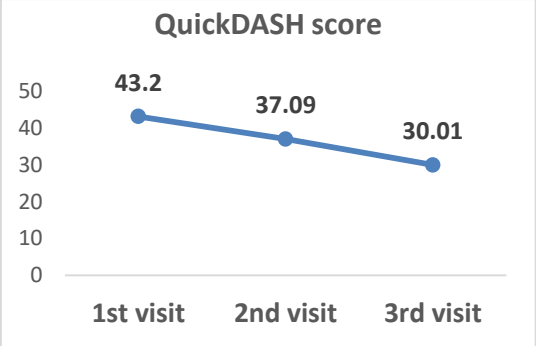

Fig. 6.Follow up of QuickDASH among included patients

Radiographic findings as summarised in **(Table 2)**.

Loosening: Only at the third visit, 20% of patients (4 patients) developed loosening. This was statistically significant (p<.001)

In all, no cases with cemented prosthesis demonstrated loosening while 33.3% of cases with cementless prosthesis (4 patients) demonstrated loosening as a radiographic finding. However, it didn't reach statistical significance (P=.117) as shown in **(Fig.7)**. By running a Spearman correlation analysis, a negative correlation was found between cementing and loosening where cemented prostheses were associated with lower incidence of loosening. However, the correlation did not reach a statistical significance (r = -0.408, P = .074).

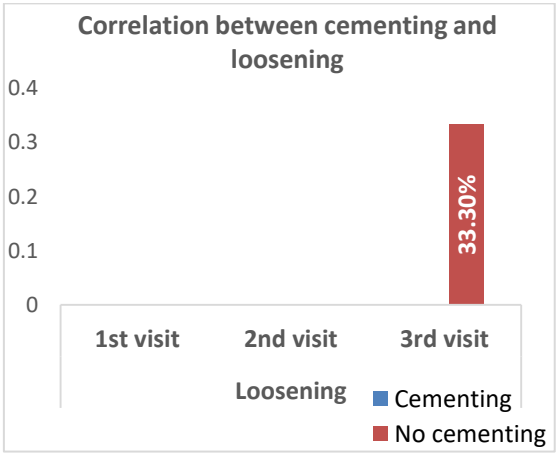

Fig.7.Correlation between cementing and loosening among included patients

Osteoarthritis: Unfortunately six patients (30%) developed radiological signs of osteoarthritis of the elbow joint (p<.001).

Reported complications as summarised in **(Table 2)**.

Heterotrophic ossification: No patients developed heterotrophic ossification on the 1st follow up visit. However, on the 2nd and 3rd visits, we found that 10% of patients (2 patients) developed ossification on the medial and lateral aspects of the elbow joint with no apparent involvement of the biceps and triceps tendons (anterior and posterior aspects of the elbow joint). This was statistically significant (p<.001).

Residual instability and joint stiffness: We found that 10% of patients (2 patients) demonstrated mild residual valgus instability in all visits, also showed subluxation in radiographic follow-up, These were statistically insignificant (p=1.00) respectively. On the other hand, we found a decrease in the prevalence of partial stiffness from 90% of participating patients in the first visit to 40% of patients

in the third visit. This was statistically insignificant (p=.002).

General (non-prosthetic related) complications: No patients developed postoperative infection. However, four (20%) patients developed iatrogenic nerve injury. Two patients had PIN injury presenting with finger drop and wrist drop. No improvement was observed at last follow-up and scheduled for a second operation. Another two patients had ulnar nerve injury presenting with paraesthesia. Complete improvement was observed at last follow-up with no residual neurological deficit.

Table 2. Radiographic results and reported complications

Variables	1st visit*	2nd visit*	3rd visit*	*P* value**
Loosening	0	0	4 (20%)	<.001
Subluxation	2 (10%)	2 (10%)	2 (10%)	1.000
Osteoarthritis	0	6 (30%)	6 (30%)	<.001
Heterotrophic ossification	0	2 (10%)	2 (10%)	<.001
Infection	0	0	0	1.000
Residual instability	2 (10%)	2 (10%)	2 (10%)	1.000
Partial stiffness	18 (90%)	16(80%)	8 (40%)	.002

* Follow up appointments at 1.5 months, 3 months and 6 months

**Repeated measures ANOVA

Discussion

The focus of surgical research regarding prosthetic replacement of the radial head and reconstruction of the elbow ligaments is to obtain a stable joint that allows early motion in order to retain its function and prevent joint stiffness.

In our retrospective study, 20 patients with terrible triad injury of the elbow were treated with repair of coronoid and anterior capsule by trans-osseous sutures, prosthetic replacement of radial head, and reconstruction of the lateral collateral ligamentous complex. Analyzing the mechanism of injury in the current study revealed that injury was due to falling from height in all cases (100%). Sample of this study presented more prevalence of males (70%, 14 patients) to females (30%, 6 patients). Both the dominant side (Right) and the non-dominant side (Left) were equally affected. Most cases were in the 4th decade (6 cases) and 5th decade (6 cases) with a mean age of 39.4 years (± 14.14 SD).

Chen et al retrospectively evaluated 12 cases with terrible triad injury, Sample of this study also presented more prevalence of males (66.67%, 8 cases) to females (33.33%, 4 cases), with an average age of 44.5 years (range, 26-62 years), only 7 of them (58.33%) were due to falling from height, The time from injury to operation was 5-14 days, with an average of 6 days **(Chen et al., 2021)**.

Regarding clinical and functional outcome in our study, most cases reported good functional range of motion in their last follow-up, 18 cases (90%) reported return to previous work and daily activity, 14 cases (70%) achieved functional flexion-extension arc >100° and 6 cases (30%) with flexion-extension arc <100°, 16 cases (80%) achieved functional pronation-supination arc >100° and 4 cases with

pronation-supination arc <100°. Evaluation of elbow performance and function through Mayo elbow performance score, 8 cases (40%) reported excellent score, also 8 cases (40%) reported good, only 4 cases (20%) reported fair and there wasn't any case with poor with mean score 76 points (± 9.95 SD) in last follow-up. As for the QuickDASH score, 14 cases reported excellent to satisfactory only 6 cases reported poor with mean score 37.09 points (± 26.11 SD) in last follow-up.

According to Giannicola et al., 26 elbows, with a mean age of 52 years, were operated and underwent the same surgical and rehabilitation treatment. Final functional outcome was assessed by MEPS and QuickDASH scores. The mean follow-up was 31 months. At final evaluation, mean flexion, extension, supination and pronation were 137°, 10°, 77° and 79°, respectively; mean MEPS and QuickDASH scores were respectively 96 and 8 points.

In Zhang et al., There were 21 elbows included, and the mean follow-up duration was 32 months (range, 24 : 48 months). At the last follow-up the mean flexion-extension arc of the elbow was 126° and the mean forearm rotation was 139°. The mean MEPS was 95 points (range, 85-100 points), with 19 excellent results and two good results.

In another series, There were 23 patients (24 elbows) available for evaluation with this injury, The mean range of flexion was 135° (range, 110° : 145°), extension was 8° (range, 0° : 40°), supination was 75° (range, 15° : 85°), and pronation was 80° (range, 20° : 90°) **(Leighet al., 2012)**.

Table 3. Comparison of results between our study and other studies

Authors	Year	No of patients	Age, years (range)	Follow-up, months (range)	MEPS	Q-DASH
Pugh et al.	2004	36	41.4 (13–76)	(20–65)	88 (45–100)	
Egol et al.	2007	29	53 (28–79)	(12–105)	81 (45–100)	
Forthman et al.	2007	22	48.1 (24–75)	(12–46)		
Lindenhovius et al.	2008	18	47 (22–76)	(10–53)	88 (65–100)	
Zeiders et al.	2008	32		(12–60)		
Wang et al.	2010	8		11	78	28
Chemama et al.	2010	23	46	n/a	87	
Giannicola et al.	2015	26	52	31	96	8
Ikemoto et al.	2017	20			84	14.27
Our study	**2022**	**20**	**39.4 (21-66)**	**6**	**84.5 (70-100)**	**30 (0-75)**

In our study and in terms of radiological evaluation and complications, Four (20%) elbows have shown loosening as a radiographic finding with no significant impact on clinical outcome as all

of them demonstrated full range of motion with good to excellent MEPS, a negative correlation was established between cementing and loosening where cemented prostheses were associated with lower incidence of loosening. However, it was statistically insignificant (r = -0.408, *P* = .074). Six (30%) elbows demonstrated radiographic osteoarthritis, 2 (10%) elbows demonstrated subluxation as a radiographic finding in last follow-up. Although these 2 cases demonstrated mild clinical valgus residual instability, it didn't have an impact on their clinical and functional outcome as their MEPS and QuickDASH scores were 80 and 27.5 respectively. In all, two (10%) cases demonstrated radiographic heterotrophic calcification which had the worst impact on clinical outcome regarding range of motion as they had the narrowest flexion-extension (60°) and pronation-supination arcs (15°) which necessitates surgery (arthrolysis), also the worst scores ; MEPS and Quick DASH scores were 70 and 72.7 respectively. However, surgery wasn't performed at their own request.

In all, no postoperative infection was detected. On the other hand, 4 (20%) cases suffered iatrogenic nerve injury. Two patients had posterior interosseous nerve injury presenting with finger drop and wrist drop. No improvement was detected at last follow-up. Another two patients had ulnar nerve injury presenting with paraesthesia. Complete improvement was observed at last follow-up with no residual neurological deficit. Partial stiffness was observed in most cases(18 patients, 90%) in first follow-up with marked improvement in last follow-up (8 patients, 40%).

According to Domos et al., twenty two patients who underwent fixation of terrible triad injuries were identified with a mean follow-up of 32 months, The overall complication rate was 41% in nine patients. Four (23%) cases demonstrated post-traumatic arthritis (one mild, three moderate). Also four (23%) cases required subsequent metal removal surgery to improve range of movement, especially in the pronation-supination arc. One other patient required emergency fasciotomy for compartment syndrome. All fractures have united and the final radiographs revealed heterotrophic calcification in five and arthritic changes in four cases, without causing significant functional deficit in most cases. In all, 50% of the radial head implants had asymptomatic resorption of the proximal radial neck. There was no evidence for infection or loosening of any radial head prosthesis.

A systematic review included 16 studies, involving 312 patients. The proportion of patients who required reoperation ranged from 0: 54.5%, with most studies reporting that around one third of patients experienced the need for reoperation. Overall, 70 of 312 (22.4%) patients experienced complications requiring reoperation. The most common complications that did not require reoperation were heterotrophic ossification (reported by 39 of 312 [12.5%] patients in 10 of 16 studies) and arthrosis (reported by 35 of 312 [11.2%] patients in 4 of 16 studies). Pugh et al. reported that 4 of 36 (11.1%) patients experienced limited range of motion and that 2 of 36 (5.6%) patients experienced radioulnar synostosis. Ring et al. reported that 5 of 11 (45.4%) patients suffered residual instability in the form of redislocation. Garrigues et al. reported that 3 of 40 (7.5%) patients experienced limited flexion, residual instability, or had an oversized radial prosthesis **(Chen et al., 2014)**. Both (**Table 3 & 4)** summarise a

comparison of results between our study and the aforementioned studies.

Table 4. Comparison of results between our study and other studies

Authors	Averaged flexion	Averaged extension	Forearm pronation	Forearm supination
Pugh et al.	131±11	19°±9		
Forthman et al.	134° (100–150)	17° (0–45)	75° (0–90)	62° (0–85)
Lindenhovius et al.	135° (120–145)	17° (0–45)	78° (45–90)	63° (20–90)
Zeiders et al.	130°	12° (0–20)		
Wang et al.	126	21	71	75
Chemama et at.	127	18	70	64
Giannicola G	137	10	79	77
Our study	**122 (70-150)**	**22 ± 13.99**	**72.5 (30-90)**	**69.5 (30-90)**

The present study had some limitations; first of all, due to the relatively low incidence of the terrible triad injury, as a single-centre study, we had a small number of patients, decreasing statistical power. Second, as with any retrospective study, this investigation design has several limitations that warrant consideration. Second, as with any retrospective study, this investigation design has several limitations that warrant consideration. Third, the follow-up period was relatively short where potential long-term problems associated with implant may yet occur.

Conclusion

This study indicates that current surgical protocols made terrible triad injury less terrible as it used to be in the past and it is possible to obtain quite good results using readily available cost-effective and affordable non-modular prostheses , all due to deeper understanding of the elbow anatomy and biomechanics and the growing experience in reconstruction techniques. However, challenges still persist and remain a troublesome injury to treat due to a variety of factors.

Recommendations

- The goal of the surgery is to obtain a stable joint that allows early motion, which must be started as early as possible, avoiding varus stress.
- All potential material needed for reconstruction must be prepared (screws, suture anchors, plates, prosthesis, etc.) before the operation, as intraoperative predicaments may surface up with a variety of possible scenarios.
- A major pitfall in the use of a metal radial head prosthesis is overstuffing or insertion of a prosthesis that is too large in diameter or thickness. it is always recommended to err on the smaller size to avoid wearing of the capitellum and radial notch.
- Although there is a negative correlation between loosening and cementing, we couldn't establish advantage of cemented prostheses over non-cemented prosthesis based on the data of our study in terms of clinical and functional outcome.

- A functional elbow with good performance can be expected following standard protocol. Nonetheless, adequate rehabilitation and intensive physiotherapy program is fundamental to achieve the best possible outcome.

Conflicts of Interest: The authors declare no conflicts of interest regarding the publication of this paper.

References

- **Chen HW, Liu GD, Wu LJ (2014).**Complications of treating terrible triad injury of the elbow: a systematic review. PloS one, 9(5):e97476.
- **Chen T, Ma X, Ma J, Yu R, Yu D (2021).**[Short-term effectiveness of free radial head reconstruction of coronoid process combined with artificial radial head replacement in treatment of complex terrible triad of elbow]. Chinese journal of reparative and reconstructive surgery, 35(2):139-43.
- **Domos P, Griffiths E, White A (2018).**Outcomes following surgical management of complex terrible triad injuries of the elbow: a single surgeon case series. Shoulder & elbow, 10(3): 216-22.
- **Elsayed S, Mohamed A, Ali AS, Khaled HM, Ahmed MA, Hamdy T (2022)**. Efficacy and safety of monopolar versus bipolar radial head arthroplasty: a systematic review and meta-analysis. Journal of Shoulder and Elbow Surgery. 31(3):646-55
- **Giannicola G, Calella P, Piccioli A, Scacchi M, Gumina S (2015).**Terrible triad of the elbow: is it still a troublesome injury? Injury, 46 Suppl 8:S68-76.
- **Hoppenfeld S, De Boer PG, Buckley R (2009).** Surgical exposures in orthopaedics : the anatomic approach. 4th ed. Philadelphia, Pa. ; London: Lippincott Williams & Wilkins; 2009.
- **Leigh WB, Ball CM (2012).**Radial head reconstruction versus replacement in the treatment of terrible triad injuries of the elbow. Journal of shoulder and elbow surgery / American Shoulder and Elbow Surgeons, 21(10):1336-41.
- **Pugh DM, McKee MD (2002).** The “terrible triad” of the elbow. Tech Hand Up Extrem Surg, 6: 21–29
- **Pugh DM, Wild LM, Schemitsch EH, King GJ, McKee MD (2004).**Standard surgical protocol to treat elbow dislocations with radial head and coronoid fractures. The Journal of bone and joint surgery American volume, 86(6):1122-30.
- **Rodriguez-Martin J, Pretell-Mazzini J, Andres-Esteban EM, Larrainzar-Garijo R (2011).**Outcomes after terrible triads of the elbow treated with the current surgical protocols. A review. International orthopedics, 35(6):851-60.
- **Xiao K, Zhang J, Li T, Dong YL, Weng XS (2015).**Anatomy,

definition, and treatment of the "terrible triad of the elbow" and contemplation of the rationality of this designation. Orthopedic surgery, 7(1):13-8.

- **Zhang C, Zhong B, Luo CF (2014).**Treatment strategy of terrible triad of the elbow: experience in Shanghai 6th People's Hospital. Injury, 45(6):942-8.