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Research Article

Combined Patterns Of Radial Head And Coronoid Process Fractures In The Terrible Triad Of The Elbow: Morphological Analysis And Interobserver Reproducibility.

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Abstract

Objective: To characterize the morphological patterns of radial head and coronoid process fractures in patients with terrible triad injury of the elbow and to assess the interobserver reproducibility of the composite Mason-Regan and Mason-O'Driscoll methods.

Methods: This was a retrospective observational study including 41 patients diagnosed with terrible triad injury of the elbow. Conventional radiographs and computed tomography scans with three-dimensional reconstruction were analyzed. Radial head fractures were classified according to Mason, and coronoid process fractures according to Regan-Morrey and O'Driscoll, resulting in the composite Mason-Regan and Mason-O'Driscoll methods. Interobserver agreement was assessed using Fleiss' kappa, Cohen's kappa, Gwet's AC1, Brennan-Prediger coefficient, and crude percentage agreement.

Results: The mean age was 55.5 ± 17.5 years, with a predominance of male patients (58.5%). Fleiss' kappa was 0.260 for Mason-Regan and 0.166 for Mason-O'Driscoll. The difference between methods was 0.108 (95% CI: -0.015 to 0.241), with no statistical significance. Gwet's AC1 and Brennan-Prediger coefficients were higher than Fleiss' kappa in both systems, suggesting an influence of asymmetric category distribution. The most frequent categories were M3R1, M3R2, and M3O1, indicating a predominance of Mason type III fractures, mainly associated with less extensive coronoid process fractures.

Conclusion: The composite Mason-Regan and Mason-O'Driscoll methods showed limited interobserver agreement. Although the Mason-Regan system demonstrated numerically higher values, there was no statistically significant difference between the methods. These classifications allowed the identification of recurrent morphological patterns; however, given their low reproducibility, they should be interpreted with caution and should not be used in isolation for prognostic or therapeutic decision-making.

Keywords: Elbow; Radius Fractures; Joint Dislocations; Computed Tomography; Reproducibility of Results.

INTRODUCTION

The terrible triad of the elbow corresponds to a complex fracture-dislocation, defined by the association between ulnohumeral dislocation, radial head fracture, and fracture of the coronoid process of the ulna. This injury simultaneously compromises bony, capsular, and ligamentous stabilizers, constituting one of the most severe forms of traumatic elbow instability. Even with the evolution of surgical protocols, it remains associated with residual instability, post-traumatic stiffness, heterotopic ossification, secondary arthrosis, chronic pain, and risk of reintervention, with functional outcomes depending on restoration of joint stability and early mobilization [1-7].

From a biomechanical standpoint, the injury results from the combined failure of radiocapitellar stability, the anterior bony buttress provided by the coronoid process, and the collateral ligament complexes. The radial head acts as a secondary stabilizer against valgus stress and posterolateral translation, whereas the coronoid process contributes to concentric ulnohumeral alignment and functions as a buttress against posterior translation of the ulna [3-5,8].

Computed tomography with three-dimensional reconstructions provides greater accuracy in characterizing radial head and coronoid process fractures, assisting in the assessment of articular congruence and in surgical planning [3-5,10].

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Treatment of the terrible triad aims to restore joint stability and allow early mobilization. Integrated characterization of the fractures may help in understanding the severity of instability and in surgical planning [1,2,6,7,11-13].

To date, few studies have evaluated the combined morphological patterns of radial head and coronoid process fractures in the terrible triad of the elbow, especially with formal analysis of interobserver reproducibility. Considering the high morphological complexity of the terrible triad of the elbow, it was hypothesized that composite classifications would show limited reliability but would be capable of identifying recurrent structural patterns in this injury.

METHOD

An observational, retrospective study was conducted based on the analysis of imaging examinations and clinical data from patients diagnosed with terrible triad injury of the elbow and treated at a specialized shoulder and elbow surgery service. The study was developed in accordance with the recommendations of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE), an international guideline for the design and reporting of observational studies.

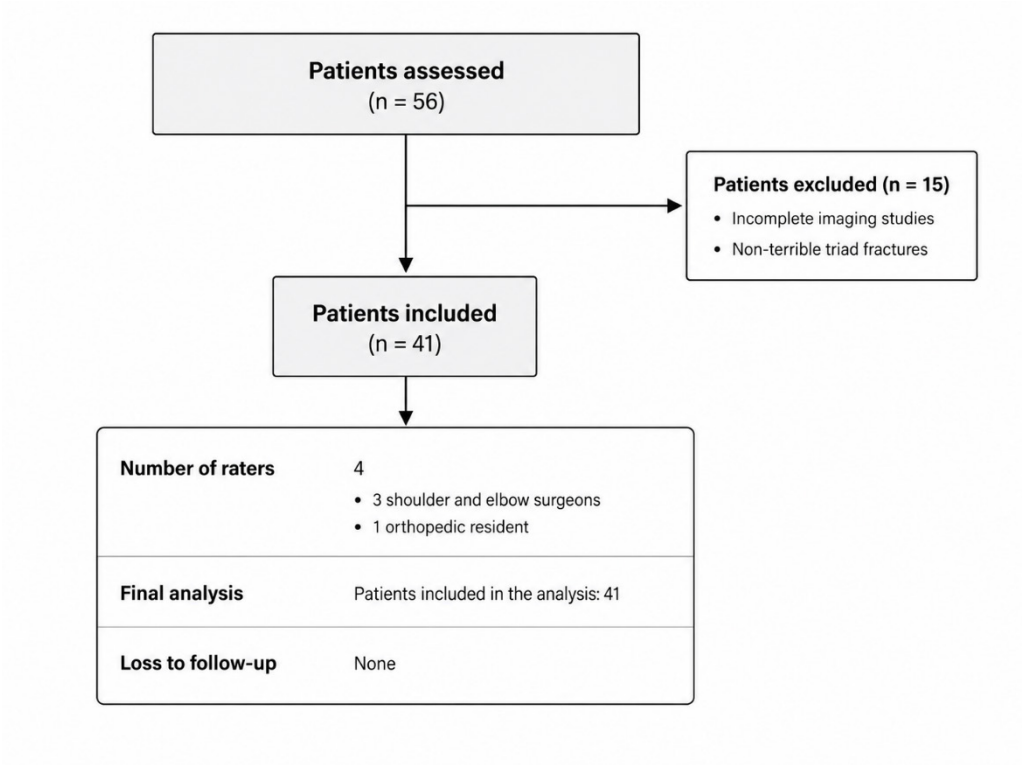
Inclusion and exclusion criteria

Skeletally mature patients of both sexes with clinical and radiographic diagnosis of terrible triad injury of the elbow were included. The injury was characterized by the association between ulnohumeral dislocation, radial head fracture, and coronoid process fracture.

Patients were excluded if they had incomplete examinations, low-quality images, absence of three-dimensional reconstruction, fractures not compatible with the definition of terrible triad, chronic or neglected injuries, previous surgery on the affected elbow, or unavailable essential clinical data for analysis. The sample selection flowchart was prepared according to STROBE recommendations,

sequentially demonstrating the number of patients assessed, excluded, and included in the final analysis, as shown in **Figure 1**.

Figure 1. Flowchart of patient selection included in the study according to STROBE recommendations.



Legend: *STROBE-based patient flow diagram. Of the 56 patients assessed for eligibility, 15 were excluded due to incomplete imaging studies or fractures not classified as terrible triad injuries. A total of 41 patients were included in the final analysis.*

Sample

The final sample consisted of 41 patients diagnosed with terrible triad injury of the elbow and with complete data available for analysis. The mean age of the participants was 55.5 ± 17.5 years. Regarding biological sex, there was a predominance of male patients, with 24 cases (58.5%), compared with female patients, with 17 cases (41.5%). The demographic characteristics of the

sample are presented in **Table 1**.

Table 1. Demographic characteristics of the patients included in the study.

Variable	Result
Age	55.5 (± 17.5)
Biological sex: Male Female	 24 (58.5%) 17 (41.5%)

Legend: *Categorical data (biological sex) are presented as absolute number (n) and percentage (%). Age is presented as mean (± standard deviation).*

Ethical aspects and LGPD

The study was approved by the Research Ethics Committee of the responsible institution under consolidated opinion No. 5,583,561, CAAE No. 59213422.6.0000.5058. The research followed Resolution No. 466 of 2012 of the Brazilian National Health Council and the Brazilian General Data Protection Law, Law No. 13,709 of 2018. Data were anonymized and analyzed in aggregate form.

Imaging protocol

Images were evaluated using RadiAnt DICOM Viewer software, Poznań, Poland. The images were anonymized, randomized, and made available to the raters in DICOM format, including radiographs, multiplanar computed tomography sections, and three-dimensional reconstructions. All raters had access to the same set of images.

Fracture classification

Radial head fractures were classified according to Mason. Coronoid process fractures were classified according to Regan-Morrey and O'Driscoll. The Mason-Regan and Mason-O'Driscoll combinations were used as exploratory composite methods for descriptive and reproducibility assessment purposes; they did not constitute previously validated classification systems for therapeutic decision-making.

Observer evaluation

The images were evaluated independently by four observers: three orthopedists with experience in shoulder and elbow surgery and one orthopedic resident. Each rater individually classified the radial head fractures according to Mason and the coronoid process fractures according to the Regan-Morrey and O'Driscoll systems while blinded to the evaluations of the other participants.

Interobserver agreement was determined from the individual classifications assigned by each rater, without adopting consensus as the primary variable. This strategy was used to preserve the analysis of reproducibility of the classification systems used.

Before the definitive evaluation, a conceptual alignment session was held among the observers to standardize the criteria of the adopted classifications. Cases belonging to the final study sample were not used during this stage.

Combined analysis

The combined analysis was performed to evaluate the association between the morphological patterns of radial head and coronoid process fractures in the terrible triad of the elbow. For this purpose, combinations were used between the Mason classification, applied to radial head fractures, and the Regan-Morrey and O'Driscoll classifications, applied to coronoid process fractures.

The combination of Mason and Regan-Morrey was named Mason-Regan and represented in the MxRy format, in which Mx corresponds to the radial head fracture type according to Mason and Ry corresponds to the coronoid process fracture type according to Regan-Morrey. Similarly, the combination of Mason and O'Driscoll was named Mason-O'Driscoll and represented in the MxOy format, in which Oy corresponds to the coronoid process fracture type according to O'Driscoll.

The use of composite classifications was intended to broaden the integrated interpretation of the injury.

Statistical analysis

Statistical analyses were performed using R software, version 4.4.1 (R Core Team, R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were described using mean, standard deviation, median, and interquartile range, whereas categorical variables were presented as absolute and relative frequencies. Interobserver agreement was assessed using Fleiss' kappa, Cohen's kappa, crude percentage agreement, Gwet's AC1, and the Brennan-Prediger coefficient. The 95% confidence intervals (95% CI) were obtained using the percentile bootstrap method with 5,000 resampling's, adopting a significance level of 5%. No prior sample size calculation was performed because this was a retrospective exploratory study involving a consecutive series of relatively uncommon injuries.

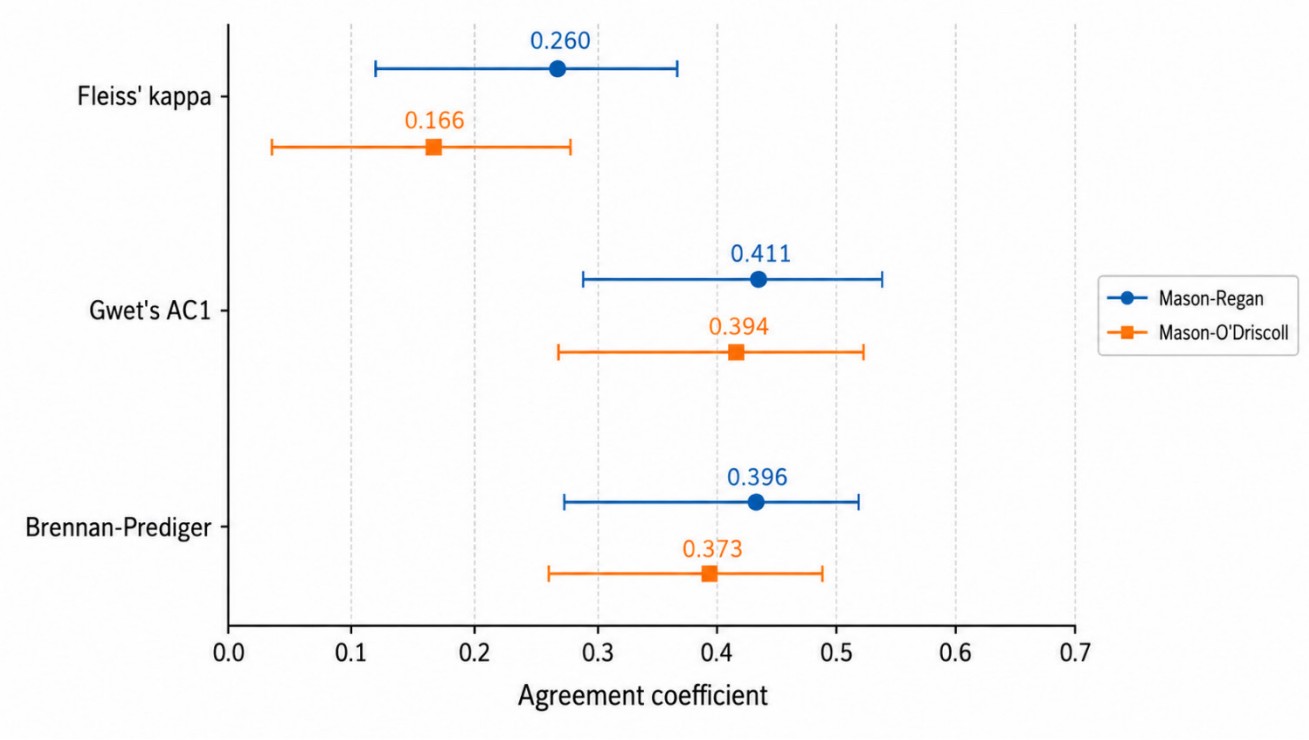
RESULTS

The study included 41 patients diagnosed with terrible triad injury of the elbow and complete data available for analysis. The mean age of the sample was 55.5 ± 17.5 years. Male patients predominated, with 24 patients (58.5%), compared with female patients, with 17 patients (41.5%), as shown in Table 1.

In the analysis of interobserver agreement, the combined Mason-Regan system showed a Fleiss' kappa coefficient of 0.260, whereas the Mason-O'Driscoll system showed a lower value, with Fleiss' kappa of 0.166. Similarly, the alternative

coefficients were also higher for the Mason-Regan system, with Gwet's AC1 of 0.411 and Brennan-Prediger coefficient of 0.396, compared with the Mason-O'Driscoll system, which showed Gwet's AC1 of 0.394 and Brennan-Prediger coefficient of 0.373.
In both classification systems, Gwet's AC1 and Brennan-Prediger coefficients were higher than Fleiss' kappa, suggesting a possible influence of asymmetric category distribution on the traditional agreement estimate. Overall, the findings indicate slight to moderate interobserver agreement, with slightly superior performance of the Mason-Regan system compared with Mason-O'Driscoll, as shown in **Figure 2**.

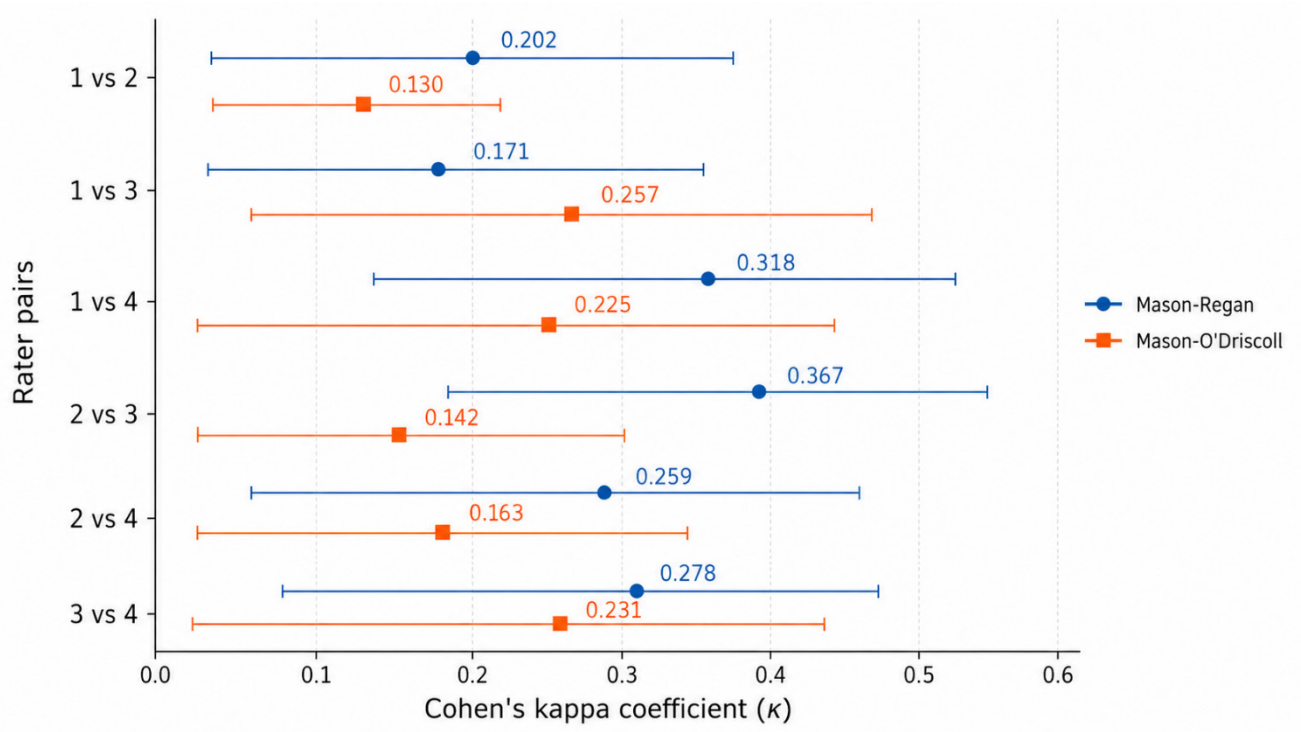
Figure 2. Global interobserver agreement according to classification method.



Legend: *Agreement coefficients comparing the Mason–Regan and Mason–O'Driscoll classification systems, expressed as Fleiss' kappa, Gwet's AC1, and Brennan–Prediger indices. Points indicate coefficient estimates and horizontal bars represent confidence intervals.*

The paired analysis showed variability in the levels of agreement between raters, as presented in **Figure 3**. In the Mason-Regan system, Cohen's kappa coefficients ranged from 0.171 to 0.367, with the highest value observed between raters 2 and 3 (κ = 0.367), followed by pairs 1 and 4 (κ = 0.318) and 3 and 4 (κ = 0.278).
In the Mason-O'Driscoll system, coefficients ranged from 0.130 to 0.257, with the highest agreement between raters 1 and 3 (κ = 0.257), followed by pairs 3 and 4 (κ = 0.231) and 1 and 4 (κ = 0.225). Overall, the coefficients remained low in magnitude in both classification systems, indicating limited interobserver agreement in paired comparisons. However, a trend toward higher values for the Mason-Regan system was observed in most evaluated pairs, except in the comparison between raters 1 and 3, in which the Mason-O'Driscoll system showed a higher agreement coefficient.

Figure 3. Pairwise agreement between raters according to classification method.



Legend: *Pairwise inter-rater agreement for the Mason–Regan and Mason–O'Driscoll classification systems, expressed as Cohen's kappa coefficients (κ). Points represent estimated coefficients, and horizontal bars indicate confidence intervals for each rater pair.*

The overall distribution of composite categories demonstrated a concentration of classifications in a few patterns, as shown in Table 2. In the Mason-Regan system, the predominant categories were M3R1 (n = 65; 39.6%) and M3R2 (n = 54; 32.9%), followed by M2R1 (n = 26; 15.9%). In the Mason-O'Driscoll system, the most frequent category was M3O1 (n = 86; 52.4%), followed by M2O1 and M3O2, both with 29 classifications (17.7%).

Table 2. Overall distribution of composite categories assigned by the four raters.

Method	Category	n	%
Mason-Regan	M1R1	3	1.8
	M1R2	3	1.8
	M2R1	26	15.9
	M2R2	9	5.5
	M3R1	65	39.6
	M3R2	54	32.9
	M3R3	4	2.4
Mason-O'Driscoll	M1O1	5	3.0
	M1O2	1	0.6
	M2O1	29	17.7
	M2O2	5	3.0
	M3O1	86	52.4
	M3O2	29	17.7
	M3O3	9	5.5

Legend: *Frequencies represent the sum of classifications assigned by the four raters to the 41 patients included in the study. Thus, for each classification system - Mason-Regan and Mason-O'Driscoll - 164 classifications were obtained in total. Therefore, the total number of observations presented in the table exceeds the number of patients evaluated.*

In the comparison between methods, the difference between Fleiss' kappa coefficients, calculated by subtracting the values obtained for Mason-Regan and Mason-O'Driscoll, was 0.108 (95% CI: -0.015 to 0.241). Because the confidence interval includes

zero, no statistically significant difference was observed between the methods regarding overall interobserver agreement.

DISCUSSION

The present study demonstrated limited interobserver agreement for the composite Mason-Regan and Mason-O'Driscoll methods in the evaluation of fractures associated with the terrible triad of the elbow. Although the Mason-Regan method showed numerically higher values, the difference between Fleiss' kappa coefficients was 0.108 (95% CI: -0.015 to 0.241), indicating no statistically significant difference between the classification systems.

The low agreement observed may be explained by the anatomical and biomechanical complexity of the terrible triad of the elbow, an injury characterized by the association between elbow dislocation, radial head fracture, coronoid process fracture, and associated ligament injury [1-5]. The literature emphasizes that final elbow stability depends on adequate restoration of the bony and ligamentous stabilizers, especially the radial head, the coronoid process, and the lateral ligament complex [1-5].

In the global analysis, the Mason-Regan method showed Fleiss' kappa of 0.260, whereas the Mason-O'Driscoll method showed Fleiss' kappa of 0.166, both compatible with low-magnitude agreement. Gwet's AC1 and Brennan-Prediger coefficients were higher than Fleiss' kappa in both methods, with values of 0.411 and 0.396 for Mason-Regan, respectively, and 0.394 and 0.373 for Mason-O'Driscoll. This finding suggests an influence of asymmetric category distribution on the conventional kappa estimate, a phenomenon previously described in interobserver reliability studies [20,21].

The distribution of classifications demonstrated a predominance of patterns involving Mason type III fractures associated with less extensive coronoid process fractures. In the Mason-Regan method, the most frequent categories were M3R1 and M3R2; in the Mason-O'Driscoll method, M3O1 predominated, followed by M2O1 and M3O2. These findings are consistent with Li et al., who observed a predominance of less extensive coronoid process fractures in patients with terrible triad injury [19]. In contrast, Klug et al. highlighted the importance of complex radial head fractures, especially Mason type III, for the outcomes of these injuries [22].

Interobserver variability may also be related to inherent limitations of the classifications used, especially regarding interpretation of comminution, degree of displacement, articular extension, and fracture reconstructibility. Previous studies have already demonstrated reproducibility limitations in classifications applied to radial head fractures, including the modified Mason classification [24]. In the case of the coronoid process, difficulty may be even greater because its assessment requires detailed analysis of fragment morphology and the relationship with elbow instability [4,5].

The lower agreement observed in the Mason-O'Driscoll method may be associated with the greater anatomical complexity of this classification, which requires more detailed tomographic assessment, preferably with multiplanar and three-dimensional reconstructions [4,5]. The presence of apical, anteromedial, or basal fragments may modify the interpretation of the injury pattern and influence therapeutic decision-making [4-6,10].

The paired analyses reinforced the variability between raters. In the Mason-Regan method, Cohen's kappa coefficients ranged from 0.171 to 0.367, whereas in the Mason-O'Driscoll method they ranged from 0.130 to 0.257. These results indicate that disagreement was not restricted to a single pair of raters but reflected an overall limitation in the reproducibility of the composite classifications, a finding consistent with the literature on complex elbow fractures [3-5,24].

Although the present study did not evaluate clinical, functional, or radiographic outcomes, integrated morphological characterization may contribute to surgical planning. Contemporary treatment protocols for the terrible triad emphasize sequential reconstruction of elbow stabilizers, including treatment of the radial head, selective management of the coronoid process, and lateral ligament repair [2,3,7,11]. Different therapeutic strategies, such as osteosynthesis or radial head arthroplasty and specific coronoid fixation techniques, may influence stability, mobility, and postoperative complications [6-18,22].

This study has limitations related to its retrospective design, reduced sample size, and dependence on the quality of previously available imaging examinations. The low incidence of terrible triad injury of the elbow may limit statistical power to detect subtle differences between classification methods [1-3]. In addition, the heterogeneous experience of the raters may have influenced the observed variability, especially given classification systems applied to complex anatomical patterns [4,5,24].

Another limitation was the absence of intraobserver evaluation, which prevents analysis of the stability of classifications over time. Reliability studies should ideally include both interobserver and intraobserver agreement, especially when subjective interpretation of imaging findings is possible [20,21,24].

Despite these limitations, the use of complementary coefficients, such as Gwet's AC1 and Brennan-Prediger, strengthens the statistical analysis by reducing exclusive dependence on kappa in a scenario of asymmetric category distribution [20,21]. However, the composite classifications evaluated should still be considered exploratory, without definitive prognostic or therapeutic validation.

CONCLUSION

The composite Mason-Regan and Mason-O'Driscoll methods showed limited interobserver agreement in the evaluation of fractures associated with the terrible triad of the elbow. Although the Mason-Regan system demonstrated numerically higher agreement, there was no statistically significant difference between the methods. The distribution of classifications showed a predominance of patterns involving Mason type III fractures, mainly associated with less extensive coronoid process fractures, suggesting potential descriptive usefulness of these classifications for morphological characterization and communication between raters. However, given the low reproducibility observed, these methods should be interpreted with caution and should not be used in isolation for prognostic or therapeutic decision-making.

REFERENCES

1. Chen HW, Liu GD, Wu LJ. Complications of treating terrible triad injury of the elbow: a systematic review. PLoS One. 2014;9(5):e97476.

2. Rodriguez-Martin J, Pretell-Mazzini J, Andres-Esteban EM, Larrainzar-Garijo R. Outcomes after terrible triads of the elbow treated with the current surgical protocols: a review. International Orthopaedics. 2011;35(6):851-860.

3. Jones ADR, Jordan RW. Complex elbow dislocations and the "terrible triad" injury. The Open Orthopaedics Journal. 2017;11:1394-1404.

4. de Klerk HH, Ring D, Boerboom L, van den Bekerom MPJ, Doornberg JN. Coronoid fractures and traumatic elbow instability. JSES International. 2023;7(6):2587-2593.

5. Masouros P, Christakakis PC, Georgiadou P, Kourtzis D, Moustakalis I, Papazotos N, Garnavos C. Coronoid fractures and complex elbow instability: current concepts. Orthopedic Reviews. 2024;16:118439.

6. Liu G, Pan S, Zhang K, et al. Surgical treatment for terrible triad injury of the elbow with anteromedial coronoid fracture through a combined surgical approach. Medicine. 2018;97(31):e11627.

7. Wang Y, Li X, et al. Surgical treatment of "terrible triad of the elbow". Orthopaedic Surgery. 2010;2(2):141-148.

8. Afifi A, Galal S, et al. Radial head fixation vs replacement in terrible triad: preliminary results of a prospective cohort study with patient reported outcome. Indian Journal of Orthopaedics. 2020;54(Suppl 2):254-259.

9. Ahn YS, Woo SH, Kim S, Lim JH, An TH, Kim MS. Does the coronoid fracture in terrible triad injury always need to be fixed? BMC Surgery. 2024;24:125.

10. Wang C, Zhang C, Zhou D, Lu D, Li Z, Duan N, Zhang K. A novel and superior Lasso-plate technique in treatment for coronoid process fracture in the terrible triad of elbow. Scientific Reports. 2023;13:11656.

11. Chen HW, Bi Q. Surgical outcomes and complications in treatment of terrible triad of the elbow: comparisons of 3 surgical approaches. Medical Science Monitor. 2016;22:4354-4362.

12. Barros Prieto E, Noboa E, Ballesteros C, Peñaherrera C, Endara F, Barros Castro A. Elbow terrible triad: advancing current concepts in the treatment of 13 cases. Trauma Case Reports. 2025;57:101146.

13. Sangani K, et al. A case series of terrible triad elbow injuries treated with lasso suture fixation for coronoid, tripod fixation for radial head, and LCL repair. Journal of Orthopaedic Case Reports. 2025;15(4):210-214.

14. Gonçalves LBJ, Silva Neto JA, Correa Filho MRC, Andrade RP, Andrade MAP, Gomes AH, Vilela JCS. Terrible triad of the elbow: influence of radial head treatment. Revista Brasileira de Ortopedia. 2014;49(4):328-333.

15. Miyazaki AN, Checchia CS, Fagotti L, Fregoneze M, Santos PD, Silva LA, Sella GV, Checchia SL. Evaluation of the results from surgical treatment of the terrible triad of the elbow. Revista Brasileira de Ortopedia. 2014;49(3):271-278.

16. Santos AA, Tonelli TA, Matsunaga FT, Matsumoto MH, Netto NA, Tamaoki MJS. Result from surgical treatment on the terrible triad of the elbow. Revista Brasileira de Ortopedia. 2015;50(4):403-408.

17. Ikemoto RY, Murachovsky J, Nascimento LGP, Pereira EB, Strose E, Almeida LHO. Terrible triad of the elbow: functional results of surgical treatment. Acta Ortopédica Brasileira. 2017;25(6):283-286.

18. Galbiatti JA, Cardoso FL, Ferro JAS, Godoy RCG, Belluci SOB, Palacio EP. Terrible triad of the elbow: evaluation of surgical treatment. Revista Brasileira de Ortopedia. 2018;53(4):460-466.

19. Li S, Li X, Lu Y. Analysis of radial head and coronoid process fractures in terrible triad of elbow. European Journal of Orthopaedic Surgery & Traumatology. 2019;29(4):775-784.

20. Zec S, Soriani N, Comoretto R, Baldi I. High agreement and high prevalence: the paradox of Cohen's Kappa. The Open Nursing Journal. 2017;11:211-218.

21. Wongpakaran N, Wongpakaran T, Wedding D, Gwet KL. A comparison of Cohen's Kappa and Gwet's AC1 when calculating inter-rater reliability coefficients: a study conducted with personality disorder samples. BMC Medical Research Methodology. 2013;13:61.

22. Klug A, Nagy A, Gramlich Y, Hoffmann R. Surgical treatment of the radial head is crucial for the outcome in terrible triad injuries of the elbow. Bone Joint J. 2020;102-B(12):1620-1628.

23. Lopiz Y, Ciller G, Ponz-Lueza V, Echevarria M, Donadeu S, Bartrina A, et al. Fracture patterns, outcomes, and complications of terrible triad injury in elderly patients. J Shoulder Elbow Surg. 2025;34(4):1098-1104.

24. Sheps DM, Bouliane M, et al. The interobserver reliability of classification systems for radial head fractures: the Hotchkiss modification of the Mason classification and the AO classification systems. Canadian Journal of Surgery. 2009;52(4):277-282.

25. Guitton TG, Ring D; Science of Variation Group. Diagnostic accuracy of two-dimensional and three-dimensional imaging and modeling of radial head fractures. Journal of Hand and Microsurgery. 2013;5(1):13-17.

26. Ghori H, Bagga R, Tathgar A, Stone A, Murphy RJ, Phadnis J. Reliability of the CURL classification for proximal ulna fracture-dislocations of the elbow. JSES International. 2024;8(2):371-377.