AUCTORES
Globalize your Research

International Journal of Clinical Case Reports and Reviews
Federico Ianniccari, MD *
Open Access

Case Series

The role of Technology in the Preoperative Planning and Management of Trans-Ulnar Basal Coronoid Fracture-Dislocations of the Elbow.

Bruno Battiston [1], Maria Cristina Castrogiovanni [2], Federico Ianniccari, [3]*, Monica Cicirello [4], Elisa Dutto [4]

[1] Chief Director of Hand and Upper extremity Unit CTO Orthopaedic Trauma Center, Città della Salute e della Scienza, Torino, Italy.

[2] Orthopaedics and Traumatology Unit Santa Croce and Carle Hospital, Cuneo, Italy.

[3] Residency in Orthopaedics and Traumatology Turin university, Torino, Italy.

[4] Hand and Upper extremity Unit CTO Orthopaedic Trauma Center, Città della Salute e della Scienza, Torino, Italy.

***Corresponding Author:** Federico Ianniccari, MD, Residency in Orthopaedics and Traumatology Turin university, Torino, Italy.

Received Date: May 05, 2026 | **Accepted Date:** July 24, 2026 | **Published Date:** July 31, 2026

Citation: Bruno Battiston, Maria Cristina Castrogiovanni, Federico Ianniccari, Monica Cicirello, Elisa Dutto, (2026), The role of Technology in the Preoperative Planning and Management of Trans-Ulnar Basal Coronoid Fracture-Dislocations of the Elbow, *International Journal of Clinical Case Reports and Reviews*, 36(5); **DOI:10.31579/2690-4861/1110**

Abstract:

Trans-ulnar basal coronoid fracture-dislocations are complex injuries of the proximal ulna recently described in the Mayo classification (2023). The presence of the basal coronoid fracture has a negative prognostic value due to the added following instability and significantly complicates surgical management; therefore, accurate preoperative planning is essential to prevent malreduction and complications. Moreover, the current classification is insufficient to describe the complexity of the associated osteoligamentous injuries. Digital technologies in orthopedics aim to support surgical procedures reducing risks and improving outcomes. Image-Guided Orthopedic Surgery (IGOS) refers to digital systems for preoperative planning and intraoperative navigation that rely on patient imaging and 3D modelling of the surgical site. Contemplating the most relevant applications in trauma surgery, our study focused on the use of digital systems in the preoperative planning phase in these complex injuries.

Four emblematic cases treated between 2021 and 2024 at our Orthopedic Trauma Center were analyzed. Hyper Accuracy 3D® (HA3D®) software was used as a digital support, following a four-step planning protocol: (1) Acquisition of CT scans; (2) Segmentation of anatomical structures; (3) Generation of a 3D model; (4) Virtual reduction of the fracture. We observed slightly better functional results and fewer complications although direct comparison with literature cases remains difficult due to the inherent variability of the fracture patterns.

The purpose of this case series is to demonstrate the potential of technological support in trauma cases where fragment-specific surgery is needed. Specifically, the primary objective is to highlight the substantial variability not only of the trans-ulnar fracture pattern itself but also of the associated osteoligamentous injuries. The HA3D® planning system proved to be reliable for producing accurate 3D models and for supporting virtual reduction with fragment manipulation: our secondary aim is to show how the availability of 3D modeling tools and digital planning systems facilitates understanding and managing these fractures by increasing safety and efficiency during the surgical procedure.

Key words: trans-ulnar basal coronoid fracture-dislocations (TUBC fracture-dislocations); image-guided orthopedic surgery (IGOS); preoperative planning; trauma; elbow fractures

Introduction

The term trans-ulnar basal coronoid fracture-dislocations has been recently introduced to describe a specific injury pattern involving a proximal ulna fracture–dislocation associated with a basal coronoid fracture, as defined in the Mayo classification system [1]. This "coronoid-centric" classification, proposed in 2023 by Barlow et al. of the Mayo

Clinic, categorizes proximal ulna fracture focused on the position of the basal coronoid fragment relative to the olecranon and ulnar metaphysis, distinguishing three main groups: trans-olecranon fractures, Monteggia-like lesions, and trans-ulnar basal coronoid fractures [1]. The first outcome of our work is to analyze a series of emblematic cases of trans-ulnar basal coronoid fracture-dislocations treated at the Hand and Upper Limb Surgery Unit of our Orthopaedic Trauma Center, in order to illustrate the wide-ranging complexity underlying this traumatic injury and its surgical management. Given this complexity, emerging digital technologies may play a significant role in assisting diagnosis, preoperative planning, and intraoperative navigation, particularly in challenging fracture patterns such as these [2, 3]. In this context, the second outcome of our study is to present our experience in applying a digital preoperative planning software to real clinical cases and to provide an overview of the current and future capabilities of technological tools in orthopedic trauma surgery.

Preoperative planning

Preoperative planning represents a critical step in the management of complex fractures, as it improves understanding of the fracture pattern, anticipates implant selection, reduces operative time, and facilitates a more anatomical and stable reconstruction [2]. Standard planning typically relies on CT imaging with 3D reconstruction; however, in several orthopedic subspecialties, Image-Guided Orthopedic Surgery (IGOS) has already been widely implemented [4] and is currently used predominantly in spinal, oncologic, arthroplasty, and pelvic trauma surgery [5]. IGOS supports two main phases of the orthopedic procedure: preoperative planning and intraoperative execution through various enabling technologies (Figure.1)

In the trauma setting, the application of these systems is relatively recent [6]. They allow segmentation of bone fragments, digital labeling, subdivision of fracture components, and detailed planning of the reduction sequence[3]. Several studies have demonstrated promising results.

Du et al. (2015) evaluated closed reduction of long-bone diaphyseal fractures by classifying fracture lines on CT images and then designing a reduction pathway tailored to each fracture pattern. This approach prevented unnecessary manipulations and reduced the risk of iatrogenic injury, achieving displacement errors of less than 2 mm and angular deviations below 1.5° [7].

In 2020, Laguna et al. introduced Augmented Reality (AR) technology specifically for preoperative planning of pediatric elbow fractures. The 3D AR model was positively received by participating orthopedic surgeons, improving their confidence in planning the reduction strategy, selecting implants, and determining their optimal positioning, with an estimated reduction in operative time of approximately 17 minutes [8].

Although the work by Laguna et al [8]. provides a foundation for the use of AR-based solutions in planning reduction and fixation strategies for upper limb fractures—particularly intra-articular elbow injuries—this anatomical region poses unique challenges. The dynamic nature of reduction maneuvers makes it difficult to apply intraoperative navigation systems based on the acquisition of anatomical landmarks to register morphological characteristics of the fractured segment and define its spatial orientation. By contrast, such navigation technologies have long been successfully employed in elective orthopedic procedures, including pedicle screw placement, pelvic osteotomies, total hip and knee arthroplasty, and ligamentous reconstruction of the knee [9].

Case reports

This study reports data from four emblematic cases of trans-ulnar basal coronoid fracture-dislocations treated in recent years at the Unit of the Hand and Upper Limb Surgery.

These cases were selected to standardize a protocol for technology-assisted preoperative planning. All injuries were classified according to the Mayo Clinic system as trans-ulnar basal coronoid fracture-dislocations [1]. The patients had a mean age of 54.3 years and included three women and one man. Preoperative planning and surgical procedures were performed by three elbow and hand surgeons.

All cases were treated through a posterior longitudinal approach. The ulnar nerve was identified and protected in all procedures. Coronoid fixation was performed as the first step in cases 2 and 4, whereas it was addressed secondarily in cases 1 and 3 due to the presence of radial head fractures; in fact, restoration of radial length is essential for proximal ulnar anatomical reduction.

Preoperative planning Protocol with HA3D® Software

Hyper Accuracy 3D® (HA3D®) is a certified medical device that generates three-dimensional patient-specific anatomical models from conventional imaging (CT, CT angiography, MRI) [10].

The protocol adopted for the use of the software consisted of four phases:

1. **Acquisition and upload of imaging:**

   Import of medical images with a slice thickness <1.25 mm into two platforms—one proprietary (HA3D®) and one commercial (Materialise Mimics Innovation Suite® [11]).

2. **Segmentation:**

   Identification of the relevant anatomical structures (radius, ulna, humerus, and individual fracture fragments).

3. **3D model generation:**

   Reconstruction of the 3D fracture model with color-coded segments and fragments (Figure. 2-3).

4. **Virtual reduction planning:**

   Guided translation and rotation of fragments to recompose the joint surface while preserving native anatomy as closely as possible.

   When available, CT imaging of the contralateral uninjured limb was used to support fragment positioning through mirroring techniques [9].

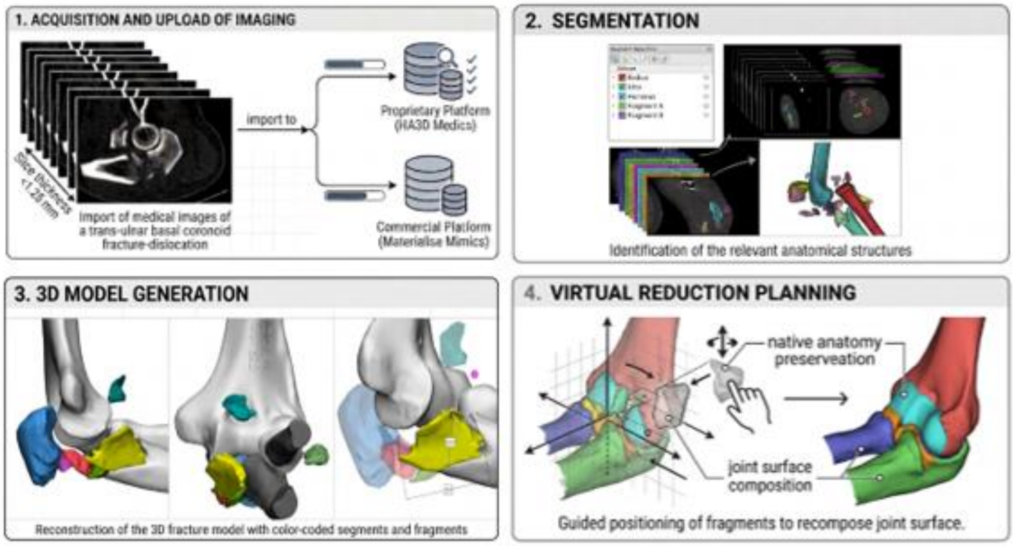

Figure 1: 4-step protocol of preoperative planning adopted by our team

Case 1

A 20-year-old man sustained a left upper limb injury after a bicycle accident, resulting in a trans-ulnar fracture–dislocation with multifragmentary dorsal and proximal cortical ulna fracture, a three-part Mason type III radial head fracture [12], and scaphoid fracture (Figure. 2). After initial reduction and temporary DCO with an external fixator, definitive surgery was performed 10 days post-trauma

Figure 2: Case 1 - 3D reconstruction of trans-ulnar fracture with basal coronoid pattern

During the modeling phase, surgeons explored fragment identification, sizing, and selective hiding. The planning phase allowed comparison of the virtual 3D reduction with the actual intraoperative reduction in the setting of severe coronoid fragmentation, highlighting areas where intraoperative management may be particularly challenging (Figure. 3).

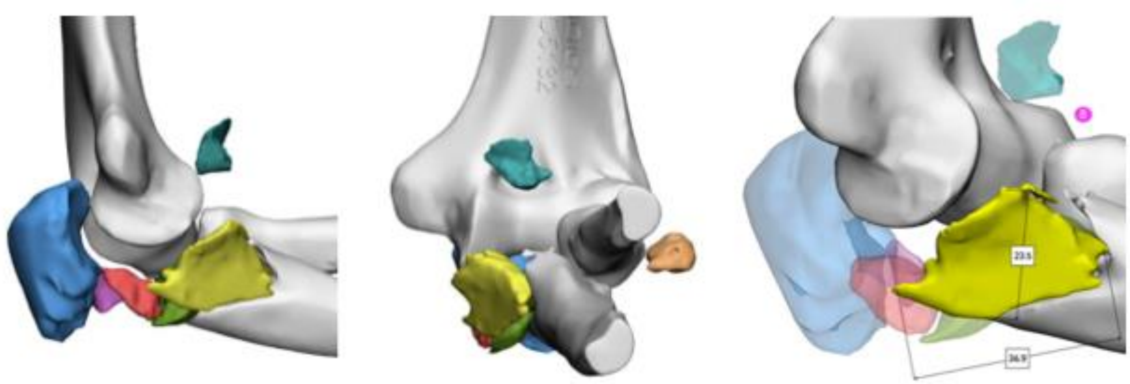

Figure 3: Case 1- 3D modeling and identification by size and colour of the key fragments

Radial head fragments were first fixed with two headless cannulated screws. Indirect reduction of the coronoid tip was then achieved using independent posteroanterior screws through the ulnar metaphysis. Due to substantial coronoid bone loss, the basal fragment was hinged open, and reconstruction of the greater sigmoid notch was obtained using remaining bone fragments. Definitive fixation was completed using two olecranon plates (a precontoured medial plate and a manually contoured lateral straight plate) (Figure. 4).

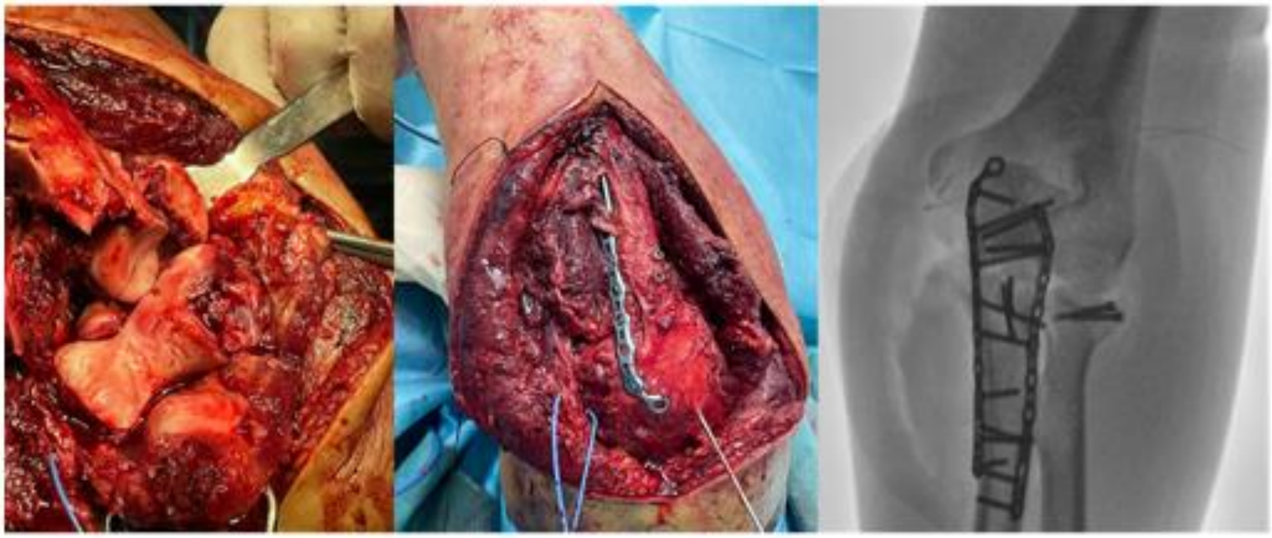

Figure 4: Case 1 - intraoperative main passages and post-operative check

Postoperatively, the limb was immobilized in an above-elbow fiberglass splint at 40° of flexion for 3 weeks, followed by an articulated brace with free ROM for a total of 6 weeks. At 45 days, ROM included 100°–50° of flexion–extension and 60°–40° of pronation–supination. Intensive physiotherapy was initiated.

At 2 years, radiographs showed solid union. Due to discomfort from prominent ulnar screws, hardware removal was planned. Final ROM was 140°–10° of flexion–extension and 90°–70° of pronation–supination. Residual disability scores were: DASH [13] 14.2 and MEPS [14] 100 (Figure. 5).

Figure 5: Case 1 - clinical result at 2 years of follow up: almost complete flexion-extension and pronation-supination

Case 2

A 58-year-old woman sustained polytrauma following a rear-end motor vehicle collision, presenting with:

– comminuted supracondylar femoral fracture,

– posterior tibial plateau fracture,

– complex left elbow dislocation,

– articular C3 fracture with pedicle extension.

Post-DCO, CT with external fixation identified a trans-ulnar fracture–dislocation with multifragmentary proximal ulnar metaphyseal involvement (Figure. 6).

Figure 6: Case 2 - 3D reconstruction from CT

In this case as well, a HA3D® 3D model and reduction plan were created using the Medics platform (Figure. 7). A critical aspect was selecting the most appropriate fixation strategy to restore the correct angulation of the greater sigmoid notch and achieve joint congruency, leading to a hybrid fixation approach.

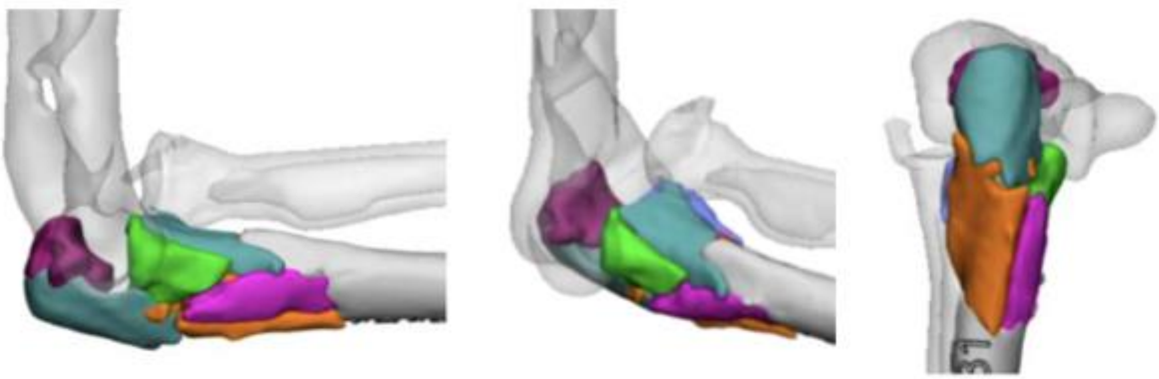

Figure 7: Case 2 - 3D modeling and guided positioning of the fragments with mirroring technique of the contralateral limb

Definitive surgery was performed 2 weeks post-trauma. Reduction began with the coronoid process, which was fixed using compression screws. Dorsal cortical fragments were then reduced and bridge-plated between the ulnar diaphysis and olecranon using medial and lateral anatomic olecranon plates. Stability was augmented using metal tension band wiring and high-strength cerclage wire. An external fixator at 45° was maintained until suture removal two weeks after the operation, followed by a hinged elbow brace with progressive ROM release. (Figure. 8).

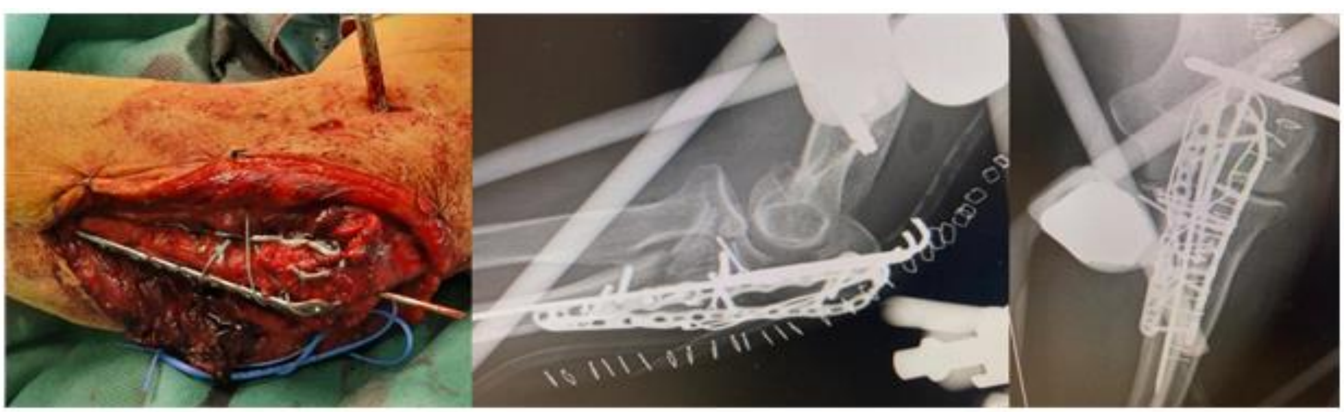

Figure 8: Case 2 - Intraoperative reduction-fixation and post-operative lateral and anteroposterior radiographs

At 2 months, ROM was 100°–15° with mild intolerance to the olecranon K-wires and nearly complete pronation–supination. Subsequent evaluations revealed ROM limitation, increased hardware prominence, and new-onset ulnar nerve paresthesias with positive Tinel’s sign. At 5 months, K-wire removal, ulnar nerve neurolysis, and submuscular transposition were performed, with progressive symptom improvement (Figure. 9).

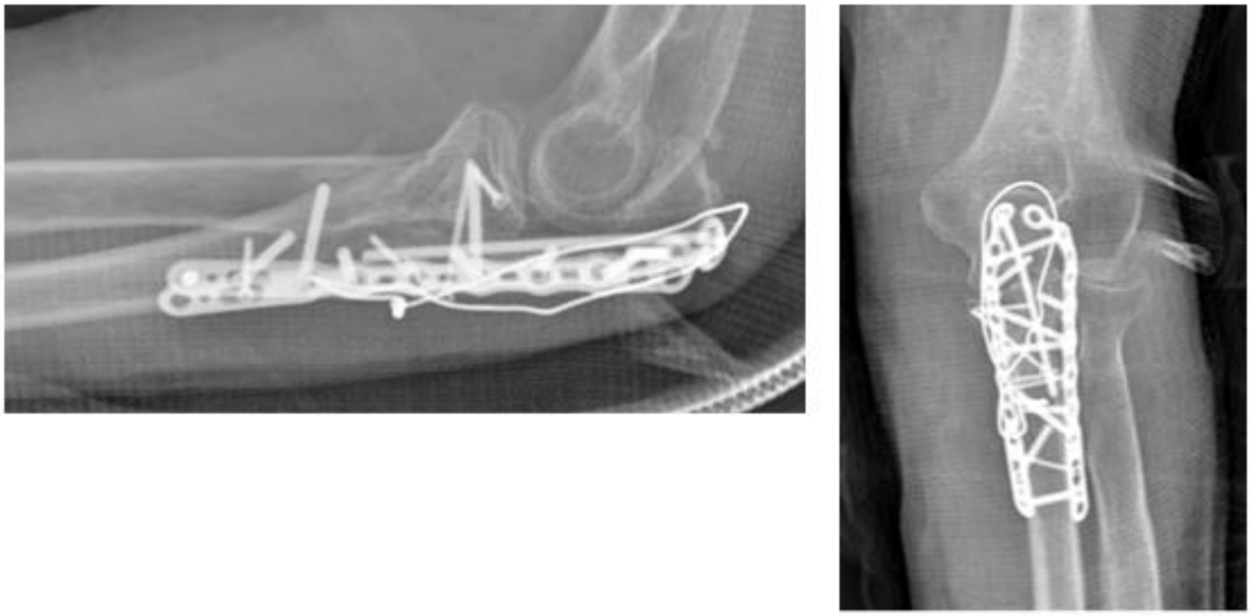

Figure 9: Case 2 - Post-operative lateral and anteroposterior X-Rays after 2nd surgery: ulnar nerve neurolysis with submuscular anterior transposition and K-wirehardware removal (cerclage wire did cause neither prominence nor intolerance, therefore it was not removed)

Two months after the second surgery, residual extension lag was approximately 35°, flexion around 100°, DASH [13] 63.3, and MEPS [14] 60. ROM at 6 months after second surgery was F/E 130°-0° and P/S 70°-0°-80°.

Case 3

A 72-year-old woman sustained a right elbow injury after falling down the stairs, presenting with a nondisplaced proximal humerus fracture, a trans-ulnar fracture–dislocation, and a Mason type II radial head fracture. Preoperative planning was performed with CT-based 3D reconstruction using the HA3D® software (Figure. 10). Comparison with the contralateral healthy ulna allowed the surgical team to anticipate the reduction strategy, while touch-based interaction tools facilitated visualization of optimal fragment positioning.

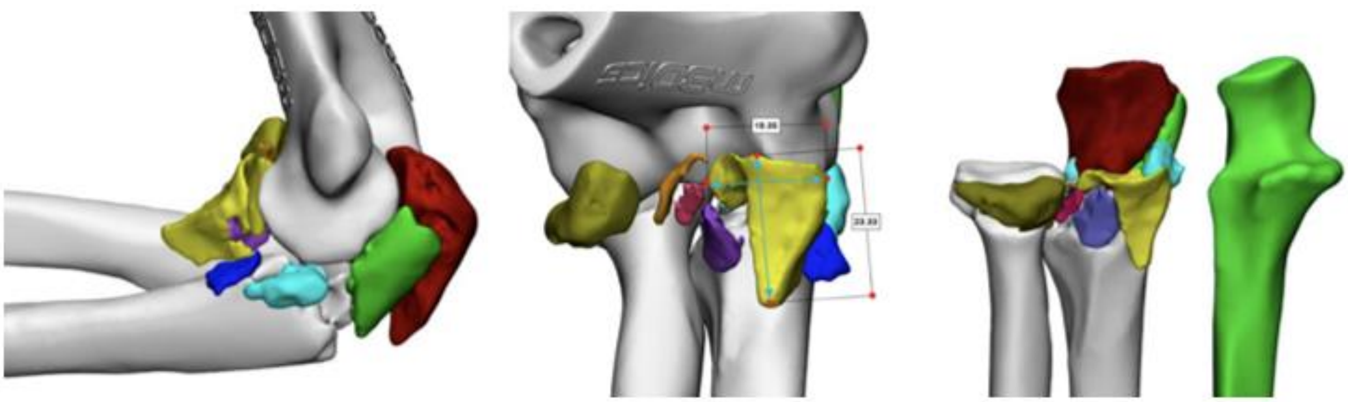

Figure 10: Case 3 - Three-dimensional modeling and reduction planning with colour-labeling of the fragments

Based on the preoperative simulation, prosthetic replacement of the radial head was selected, along with reconstruction of the main ulnar fragments (coronoid and olecranon) using two headless compression screws (HCS) and two precontoured ulnar plates. Definitive surgery was performed 20 days after the injury, fully respecting the preoperative plan without intraoperative deviations (Figure.11).

At the 6-month follow-up, the patient demonstrated a flexion–extension ROM of 100°–50° and full pronation–supination. She reported improving paresthesias in the ulnar nerve distribution. Functional scores were: DASH [13] 45.2 and MEPS [14] 70.

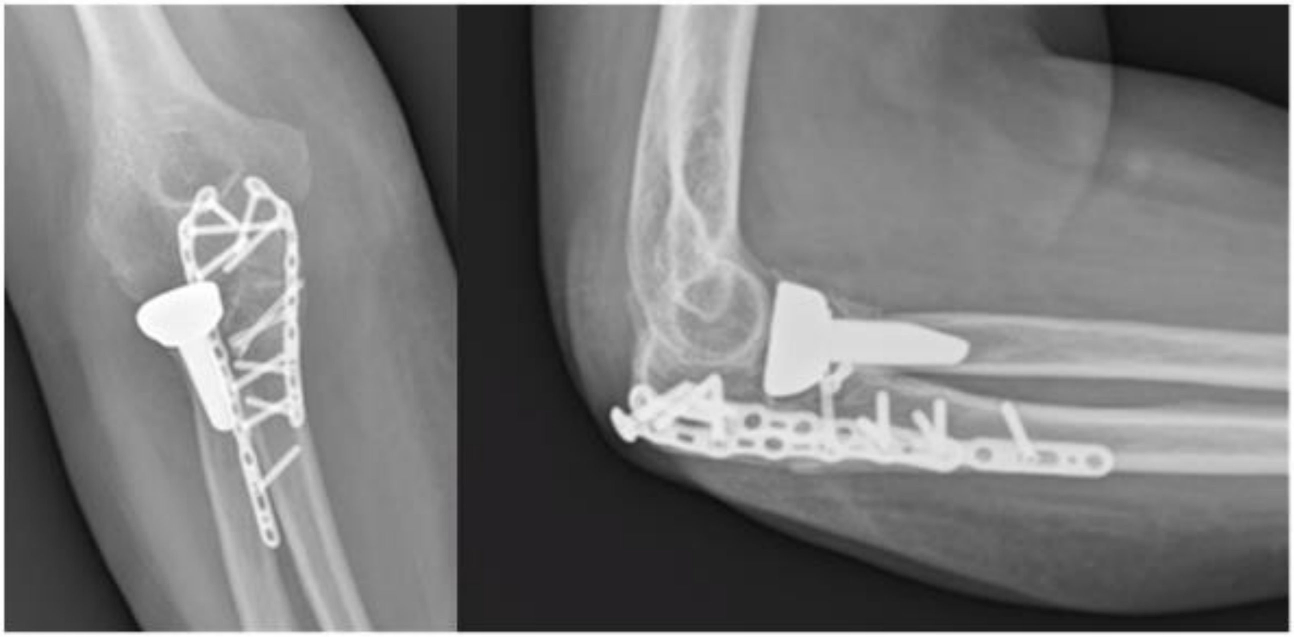

Figure 11: Case 3 – Anteroposterior and lateral radiographic check-up at 6 months

Case 4

A 52-year-old woman sustained a motorcycle accident resulting in a Gustilo type I open trans-ulnar fracture–dislocation with radial head dislocation, right radial shaft fracture, and fractures of the proximal phalanges of the 3rd and 4th fingers, as well as the base of the 5th metacarpal of the left hand (Figure. 12).

Figure 12: Case 4 - Tridimensional reconstruction of pre-operative CT

Following DCO with an external fixator and CT evaluation, HA3D® software was used to map the fragments and quantify bone loss (Figure. 13).

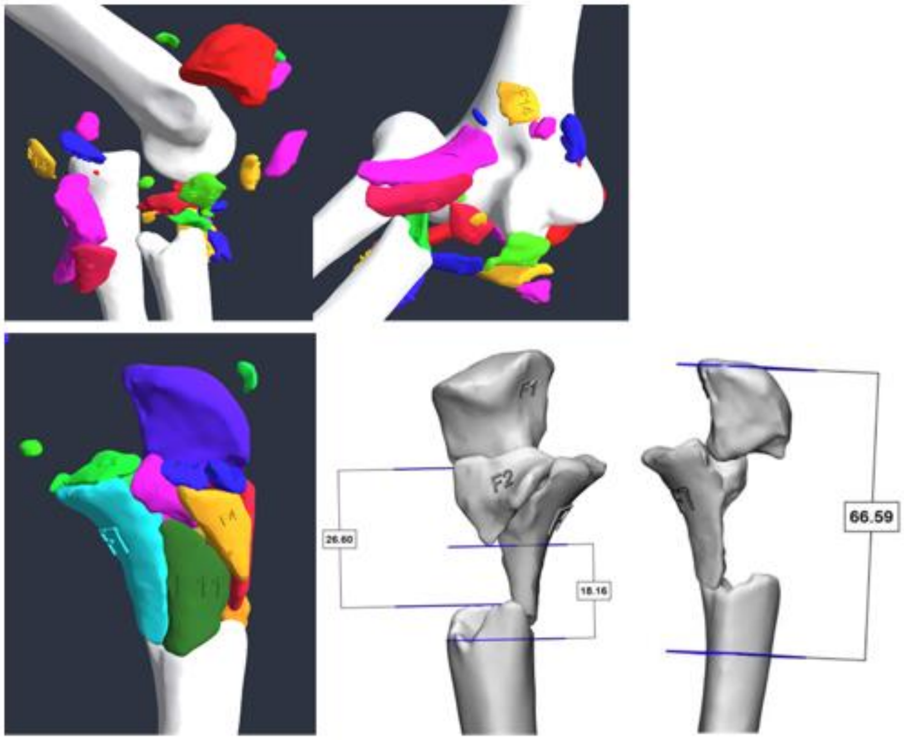

Figure.13: Case 4 - Preoperative planning with HA3D® 3D model: Colour-labeling of fragments (above); virtual positioning using mirror-technique with contralateral limb: it is essential to reconstruct the anterior mass of the olecranon to prevent postero-anterior instability (bottom left). Identification of key fragments (bottom right): we chose key fragments by their importance in articulation restoration and by their size. Thanks to fragments' dimensions we can calculate where positioning screws and plate for the synthesis.

At 2 weeks, definitive surgery was performed consisting of fracture reduction, a 4-cm iliac crest autograft to fill the ulnar bone defect, fixation with a dorsal plate plus two anatomic olecranon plates, a 3.5-mm 7-hole LCP plate for the radial shaft, and medial collateral ligament (MCL) reinsertion (Figure. 14). The external fixator was reapplied for 3 weeks and then replaced with a hinged elbow brace permitting progressive ROM over 6 weeks.

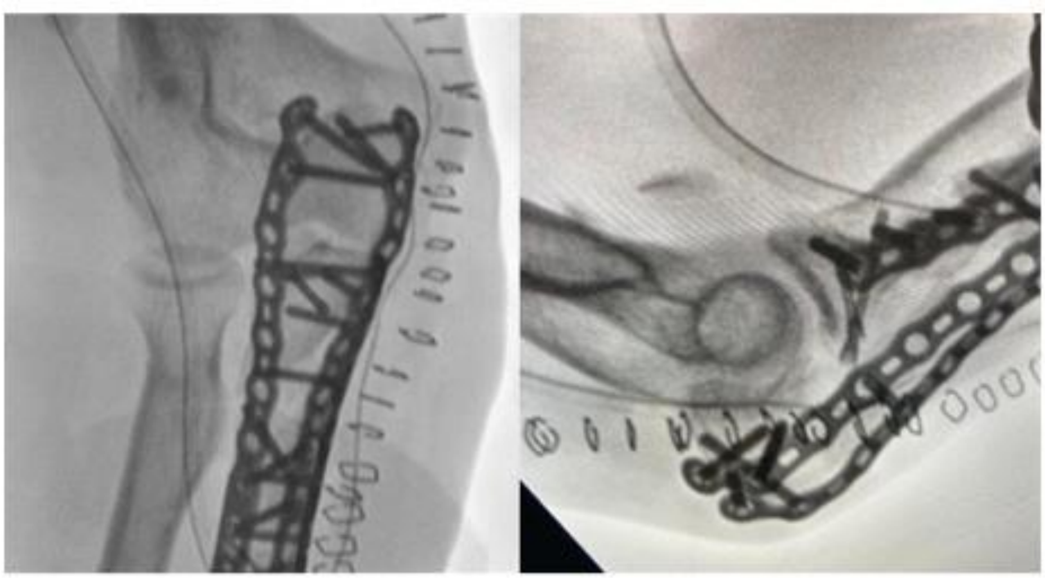

Figure 14: Case 4 – Anteroposterior and lateral radiographs for intraoperative check

A superficial septic complication was identified at approximately 7 postoperative days, and targeted antibiotic therapy resulted in gradual clinical improvement.

At 4 months, patient satisfaction was assessed through MEPS [12] (score 90) and DASH [11] (32.4). Flexion–extension was 90°–60°, with nearly full supination and 10° of pronation (Figure. 15 - 16). At 18 months, DASH [13] was 12.3 and MEPS [14] remained 90, with ROM of 100°–50°, supination 60°, and complete loss of pronation (0°).

Figure 15: Case 4 – Anteroposterior and lateral radiographs, 2 months follow-up after surgery

Figure 16: Case 4 - Clinical results at 18 months follow-up in flexion-extension and pronation-supination with contralateral comparison

Results

Virtual preoperative planning increased surgeons' confidence in anticipating the position of critical fragments, selecting the appropriate fixation method or prosthetic components (Case 3), addressing bone loss in comminuted patterns (Case 4), and better understanding fragment morphology and dimensions. Although direct comparison between cases was not possible due to heterogeneous fracture patterns, operators consistently perceived greater surgical confidence and a subjective reduction in operative time.

Regarding the first study outcome, albeit in a small cohort, the four cases demonstrated that the diagnosis of trans-ulnar elbow fracture can encompass a wide spectrum of proximal ulnar fracture complexity. The coronoid process—although the defining element of the Mayo classification and a major prognostic factor [1, 3, 15]—may itself be further fragmented, complicating reduction. Moreover, careful evaluation of dorsal ulnar cortical fragmentation is crucial, as this structure provides anchorage for basal coronoid fragments and represents a key prognostic determinant. Additionally, trans-ulnar fractures do not preclude associated fractures and/or ligamentous injuries, each requiring dedicated treatment strategies [16].

Reduction and fixation strategies were individualized based on fracture characteristics. Coronoid fixation was achieved through plate screws (Cases 2 and 4), headless cannulated screws (Case 3), or independent compression screws (Case 1). Case 2 required supplemental stability through metal tension band wiring and high-strength cerclage wire. Case 4 required an autologous bone graft to compensate for segmental bone loss.

Complications were in line with those reported in literature [16, 17] and were mainly attributable to fracture severity and trauma mechanism (Table 1):

	Case 1	Case 2	Case 3	Case 4
Hardware intolerance	✓	✓	-	-
Ulnar nerve neuropathy	-	✓	✓	-
Functional stiffness	-	✓ heterotopic ossifications	✓	✓
Surgical site infection	-	-	-	✓

Table 1: Postoperative complications

Functional outcomes and range of motion were difficult to compare due to follow up timing and different patterns of fracture (Table 2-3).

	Case 1	Case 2	Case 3	Case 4
Follow-up time	2 yrs	8 mths	6 mths	4 mths (18 mths)
DASH	14,2	63.3	45	32,4 (12,3)
MEPS	100	65	70	90 (90)

Table 2: Functional results

	Case 1	Case 2	Case 3	Case 4
Follow-up time	2 yrs	8 mths	6 mths (13 mths)	4 mths (18 mths)
Flex-Ext	140°-10°	100°-35°	100°-50° (130°-0°)	90°-60° (100°-50°)
Prono-supination	90°-70	90°-80	90°-85° (70°-80°)	10°-80° (0°-70°)

Table 3: Range of motion (ROM)

Use of the HA3D® system was rated positively by surgeons, and in Case 4 it was considered essential for preoperative planning.

Discussion

Trans-ulnar basal coronoid fracture–dislocations are complex injuries in which the fundamental coronoid fracture pattern guides surgical management and influences the likelihood of postoperative complications [15, 18]. Adverse outcomes involving both the joint (stiffness, heterotopic ossification, instability, post-traumatic osteoarthritis) and the soft tissues (ulnar nerve neuropathy, skin compromise, infection) are widely documented in the literature [17, 19-24].

The classification introduced by the Mayo Clinic group in 2023 further strengthened the prognostic role of the coronoid process in fracture–dislocations involving the proximal ulna [1,18]. However, as acknowledged by the authors themselves, several limitations remain. Specifically, the system does not account for the degree of comminution of the proximal ulna or the coronoid process, nor does it consider associated radial head injuries. Furthermore, it does not provide treatment recommendations.

To date, a standardized surgical technique for these injuries has not been established. Recent articles, such as those by Blonna et al. [25] and by Atwan et al. [3], attempt to outline a step-by-step surgical technique (the former) or to provide tips and tricks based on an accurate CT imaging review (the latter). Nevertheless, the absence of a classification capable of accurately describing the substantial variability of proximal ulna fracture patterns—as well as their associated injuries—makes surgical decision-making particularly challenging and surgeon-dependent.

Current surgical strategies may follow three general principles:

(1) restoring ulnar length by reducing and stabilizing the dorsal ulnar cortex as an initial step, followed by secondary deep approaches to address associated osseous or ligamentous injuries [25];

(2) addressing the coronoid fracture after a temporary reduction and/or initial fixation of the ulna fracture, using a posterior skin approach with dedicated window for the antero-medial facet [16];

(3) fixating the coronoid fracture and any anterior osseous or ligamentous lesions through a posterior trans-fracture approach, with subsequent stabilization of the dorsal cortex [26].

The choice among these approaches ultimately depends on the surgeon's preference but can be substantially supported by preoperative planning.

In parallel, recent technological advancements have transformed not only preoperative planning but also intraoperative execution. Digital three-dimensional modeling systems have long been used in elective orthopedic, oncologic, and spinal procedures [6], yet their application in trauma surgery remains limited. Our study therefore focused on evaluating the use of such systems during the preoperative planning phase for trans-ulnar elbow fractures. According to the participating surgeons, the HA3D® system proved valuable in all cases.

The availability of a 3D model of the anatomical region of interest allowed for precise surgical planning, optimal implant selection, anticipation of intraoperative challenges, and overall improved surgeon comfort [3, 8]. Shorter operative times may, in turn, reduce the risks of infection, intraoperative blood loss, and postoperative complications, while enhancing patient recovery.

A limitation of the present work is the small sample size, dictated by the rarity and heterogeneity of such complex lesions. The resulting data are therefore descriptive and not comparable, reflecting the current absence of a classification system capable of standardizing the wide variability of proximal ulna fracture morphology.

Conclusion

Trans-ulnar fracture–dislocations are recently characterized injuries that remain difficult to treat and are frequently associated with suboptimal outcomes: this kind of traumatic lesions often present with significant comminution and loss of bone tissue, complicating reduction, stabilization and implant selection. According to the first objective of our study, the four clinical cases analyzed proved to be emblematic in showing how a diagnosis of trans-ulnar fracture can correspond to extremely heterogeneous fracture patterns of the basal coronoid and other associated bone structures, which the current Mayo Clinic classification fails to describe exhaustively.

With regard to the second aim of the study, high-resolution CT imaging, three-dimensional reconstruction, and digital planning systems enable the identification of strategic fragments, precise anticipation of reduction maneuvers, and optimization of implant positioning. When needed, they also allow preoperative identification of accessory surgical steps, ultimately reducing operative time and improving surgeon's confidence and efficiency during procedures.

In the management of the trauma patient, a multidisciplinary approach involving not only collaboration among healthcare professionals but also continuous interaction with computer scientists and digital engineers is desirable. Such collaboration should become a routine component of clinical practice, especially considering ongoing technological advancements.

Declarations

Conflict of interest and funding

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. No funding is declared for this article

Consent to participate Not applicable.

Ethical approval Not applicable.

References

1. Barlow JD, Nieboer MJ, Cancio-Bello AM, et al. (2023). A coronoid-centric classification system of proximal trans-ulnar fracture-dislocations has almost perfect intraobserver and interobserver agreement. *J Shoulder Elbow Surg*.; 32(12):2561-2566.
2. Hernandez D, Garimella R, Eltorai AEM, Daniels AH. (2017) Computer-assisted Orthopaedic Surgery. *Orthop Surg*.; 9(2):152-158.
3. Atwan, Yousif, Alexandra M. Arguello, and Jonathan D. Barlow. (2024). "Transulnar Basal Coronoid Fractures – Surgical Tips and Tricks." *JSES Reviews, Reports, and Techniques* 4 (3): 632–638.
4. Fan X, Zhu Q, Tu P, Joskowicz L, Chen X. (2023) A review of advances in image-guided orthopedic surgery. *Phys Med Biol*.; 68(2):02TR01.
5. Wang H, Wang F, Newman S, et al. (2016) Application of an innovative computerized virtual planning system in acetabular fracture surgery: A feasibility study. Injury.; 47(8):1698-1701.
6. Hamadeh A, Lavallee S, Cinquin P. (1998). Automated 3-dimensional computed tomographic and fluoroscopic image registration.*Comput Aided Surg Off J Int Soc Comput Aided Surg*.; 3(1):11-19.
7. Du H, Hu L, Li C, He C, Zhang L. et al. (2015) Preoperative trajectory planning for closed reduction of long-bone diaphyseal fracture using a computer-assisted reduction system: Preoperative trajectory planning for CAOS. *Int J Med Robot*.; 11(1):58-66.
8. Laguna B, Livingston K, Brar R, et al. (2020) Assessing the Value of a Novel Augmented Reality Application for Presurgical Planning in Adolescent Elbow Fractures. *Front Virtual Real*.; 1:528810.
9. Mavrogenis AF, Savvidou OD, Mimidis G, Papanastasiou J, Koulalis D. et al. (2013) Computer-assisted navigation in orthopedic surgery. *Orthopedics.* Aug;36(8):631-642.
10. (2024). Hyper Accuracy 3D product of Biomedica Italia s.r.l. in collaboration with Medics tools for medicine.
11. (1992). Materialise Mimics Sfodtware, Materialise NV.
12. Morgan SJ, Groshen SL, Itamura JM, Shankwiler J, Brien WW. et al. (1997). Reliability evaluation of classifying radial head fractures by the system of Mason. *Bull Hosp Jt Dis* N Y N.; 56(2):95-98
13. Hudak PL, Amadio PC, Bombardier C, et al. (1996) Development of an upper extremity outcome measure: The DASH (disabilities of the arm, shoulder, and head). *Am J Ind Med*.; 29(6):602-608.
14. Baessler A, Eason RR, Joyce MR, et al. (2022) Reliability Testing of the Mayo Elbow Performance Score in Post-operative Patients. *J Surg Orthop Adv*.; 31(4):229-232
15. Bellato E, O'Driscoll SW. (2019) Management of the Posttraumatic Coronoid-Deficient Elbow. *J Hand Surg*.; 44(5):400-410.
16. Jung, H.-S., Nam, H.-C., Chu, M. S., & Lee, J.-S. (2025). The Challenge of Trans-Ulnar Basal Coronoid Fracture-Dislocations: A Surgical Strategy Based on the Pattern of Coronoid fracture. *Clinics in Orthopedic Surgery,* 17(2), 300–307.
17. Henssler L., Kerschbaum M., Zanklmaier M., Wieczorek LA., Alt V. et al. (2026) The Coronoid as the Key Fragment of Trans-Ulnar Fracture-Dislocations of the Elbow: Insights from a Retrospective Cohort Comparison Using the Coronoid-Centric Mayo Classification System. *Journal of Orthopaedics and Traumatology* 27 (1)
18. Nieboer MJ, Cancio-Bello A, Mallett KE, et al. (2024) Trans-ulnar fracture dislocations of the elbow: a systematic review and clarification of classification systems. *J Shoulder Elbow Surg*.; 33(4):975-983.
19. Haller JM, Hulet DA, Hannay W, Cardon J, Tashjian R. et al. (2021) Patient Outcomes After Transolecranon Fracture-Dislocation. *J Am Acad Orthop Surg.;* 29(3):109-115.
20. Chammas M. (2014). Post-traumatic osteoarthritis of the elbow. *Orthop Traumatol Surg Res*.; 100(1): S15-S24.
21. Cho CH, Kim DH, Na SS, Choi BC, Kim BS. (2020) Trans-Olecranon Fracture-Dislocations of the Elbow: A Systematic Review. *Diagnostics.;* 10(12):1058.
22. Lindenhovius ALC, Brouwer KM, Doornberg JN, Ring DC, Kloen P. (2008) Long-Term Outcome of Operatively Treated Fracture-Dislocations of the Olecranon. *J Orthop Trauma*.; 22(5):325-331.
23. Sanchez-Sotelo J, Morrey M. (2016) Complex elbow instability: surgical management of elbow fracture dislocations. *EFORT Open Rev*.; 1(5):183-190.
24. Steinmann SP. (2008) Coronoid process fracture. *J Am Acad Orthop Surg*.; 16(9):519-529
25. Blonna D., Garruto S., Caranzano FF., Pascucci F., Hoxha N. et al. (2025) Treatment of proximal trans-ulnar fracture

dislocations based on a step-by-step coronoid-center surgical technique: Proposal of a surgical algorithm based on coronoid management and windows approach. *JB JS Open Access*; 10(4):e25.00190

26. Cha, S. M., & Shin, H. D. (2019). Fixation of the Various Coronal Plane Fracture Fragments, Including the Entire Coronoid Process, in Patients with Mayo Type IIB Olecranon Fractures - Four Methods for Fixation. *Indian Journal of Orthopaedics*, 53(2), 224–231.

DOI:10.31579/2690-4861/1110