CASE REPORT

A Peculiar Case of Open Complex Elbow Injury with Critical Bone Loss, Triceps Reinsertion, and Scar Tissue might Provide for Elbow Stability?

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Abstract

Background: Complex elbow injuries (CEIs) are severe and rare lesions, difficult to treat correctly due to the different patterns of clinical presentations. Standard methods cannot often be applied. The main goals of the treatment are performing a stable osteosynthesis of all fractures, obtaining a concentric and stable reduction of the elbow by repairing the soft tissue constraint lesions, and allowing early motion. Since the introduction of virtual reality (VR) approaches in clinical practice, three-dimensional (3D) computed tomography (CT) and 3D printing have revolutionised orthopaedic surgeries, thus helping to understand the anatomy and the pathology of complex cases.

Case description: We discussed a case of CEI, characterised by an extended soft tissue (IIIB Gustilo classification) and neurovascular lesions associated with bone loss in a young female patient. Olecranon fracture was type IIIB according to Mayo classification. We outlined the steps of a pluri-tissue reconstructive approach and stressed the importance of 3D printing in the preoperative planning for such cases. Finally, peculiar final functional patient outcomes were reported.

Conclusion: In this case, we found out that triceps reinsertion and scar process may provide for the joint stability in a low-demanding patient. 3D printing and VR approaches in clinical practice can be useful in the management of CEIs associated with an important bone and soft tissue loss.

Keywords: Complex elbow injury, Elbow instability, 3D printing, Olecranon bone loss.

Strategies in Trauma and Limb Reconstruction (2021): 10.5005/jp-journals-10080-1504

Background

Complex elbow injuries (CEIs) are severe lesions with at least two structural elements of the joint involved.[1] The incidences of elbow fractures and elbow fracture-dislocation are, respectively, 7-8:10,000[2] and about 1,75:100,000.[3]

CEI results from high-energy traumas, such as car crashes.[2] These lesions are rare, and their treatment is difficult due to the different patterns of clinical presentations. Standard methods cannot often be applied.

A huge problem in CEI is an associated ligament lesion, which usually implicates high instability with subluxation or dislocation of the elbow joint.[4]

It is important to decide which injured structures between the capsule and the ligament need to be repaired to reach good outcomes.[5]

Moreover, CEI can be associated with open and contaminated fractures with bone loss. In these settings, the soft tissue envelope is usually damaged, and immediate skin coverage cannot be provided without increasing infection risks. Neurovascular lesions can further complicate such intricate situations.

The main treatment purposes are performing a stable osteosynthesis of fractures, obtaining a concentric and stable elbow reduction by repairing the soft tissue constraint lesions, and allowing early motion.[6]

Indeed, the incorrect treatment of CEI can lead to joint instability, early osteoarthritis[5], and reduction in range of motion (ROM)[7] with loss of function during daily activities.[8]

Because of that, CEI management required a multidisciplinary approach to accomplish the best reconstructive strategy and to provide the most excellent clinical and functional patient outcomes.

Correct reconstructive strategy steps are to collect patient's medical history, to perform exhaustive physical examinations, and to assess the associated lesions, accurately evaluating the diagnostic imaging (X-rays, computed tomography (CT), and magnetic resonance (MR)).[2,9]

Along with the introduction of virtual reality (VR) in clinical practice,[10] 3D CT and 3D printing revolutionised orthopaedic

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How to cite this article: Facco G, Politano R, Marchesini A, *et al.* A Peculiar Case of Open Complex Elbow Injury with Critical Bone Loss, Triceps Reinsertion, and Scar Tissue might Provide for Elbow Stability? Strategies Trauma Limb Reconstr 2021;16(1):53–59.

Source of support: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors

Conflict of interest: None

surgeries and helped to understand the anatomy and the **pathology** of complex cases.[11–14]

Nowadays, 3D printing permits a patient-specific printed model production[10,15,16] from CT images.[12,17,18] 3D printed models could be useful in surgical planning and clinical decision-making.[12,19]

We discussed a case of CEI characterised by an extended soft tissue neurovascular and bone loss in a young patient. We outlined the steps of a pluri-tissue reconstructive approach and emphasised the importance of 3D printing in the preoperative planning for such cases. Therefore, we reported the patient's final functional outcomes.

Case Description

Case Presentation

In October 2017, a 39-year-old woman was involved in a car accident reporting an open contaminated elbow fracture-dislocation characterised by severe olecranon and posterior distal humeral condyle bone loss (Fig. 1). The soft tissue envelope was damaged with muscle and skin loss (IIIB Gustilo classification[20]). Olecranon fracture was type IIIB, according to Mayo classification.[21] She also reported ulnar nerve lesions with a complete ulnar deficit and elbow instability with an annular ligament lesion.

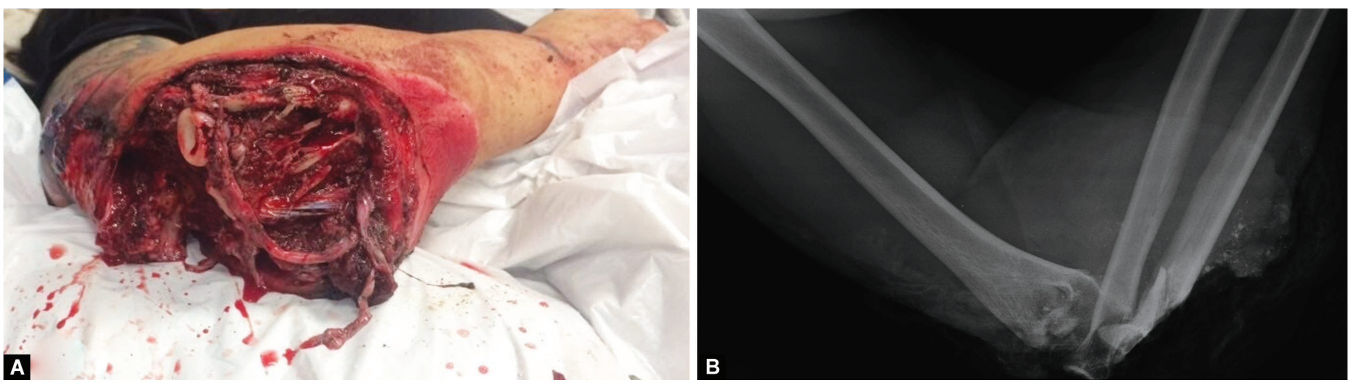
She had been initially referred to another hospital. She underwent damage control surgery for wound toilet, debridement, and unstable joint stabilisation by using a Kirschner wire (K-wire) for ulnar-trochlear temporary arthrodesis. Finally, a bridging external fixation (EF) was placed to provide bone stability (Fig. 2).

The patient refused amputation as a therapeutic solution based on the bone exposure and severe soft tissue damage.

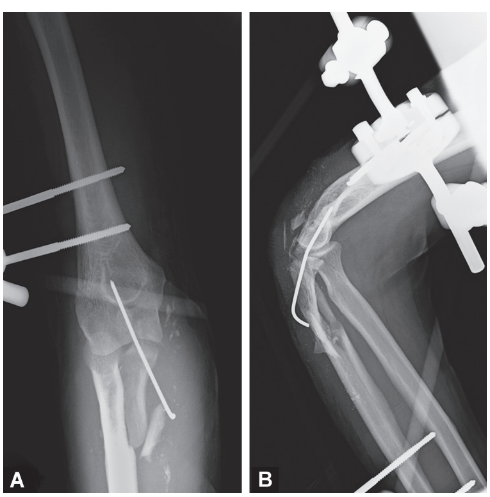
Ten days after the trauma, she was referred to our hospital. Declaration of Helsinki and guidelines for good clinical practice were applied, and the patient expressed informed consent for surgery, photos, and clinical follow-up.

She underwent surgical exploration, toilet, and debridement (Fig. 3). Wound exploration showed an ulnar nerve gap of over 7 cm. Cultural examinations were performed along with broad-spectrum antibiotic therapy.

Three days later, a third multidisciplinary plastic and orthopaedic surgical approach was performed: necrotic tissues including bone were debrided once again. Metaphyseal ulnar fracture was reduced by resorbable cerclage wiring, and the triceps tendon, completely detached, was sutured into the remaining part of the olecranon, covering the posterior distal humeral bone loss to obtain stability.



Figs 1A and B: Initial presentation of open elbow fracture-dislocation with loss of important bones, olecranon articular surface and posterior distal humerus. (A). Soft tissue envelope damage with muscle and skin loss. The lesion was classified as type IIIB according to modified Gustilo classification; (B). X-ray



Figs 2A and B: Immediate damage control surgery consisting of one Kirschner wire (K-wire) for ulnar-trochlear temporary arthrodesis and a bridging external fixation (EF) placed to provide bone stability: (A). AP X-ray; (B). LL X-ray

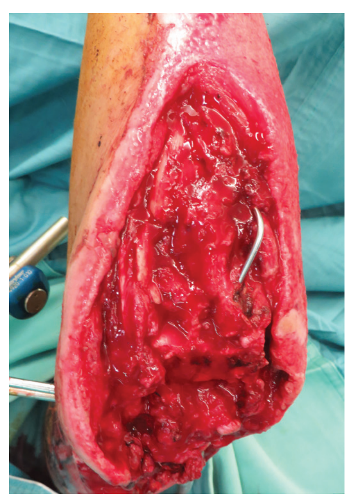


Fig. 3: Ten days after the trauma, the patient went to surgery for surgical exploration, toilet, and debridement. The picture reveals important soft tissues. Immediate skin coverage cannot be provided

The K-wire was removed, and EF was replaced by a dynamic external fixator (DEF) to allow elbow flexion-extension movement. Vacuum-assisted closure (VAC) therapy was applied. Specific antibiotic and hyperbaric therapies were started.

Therefore, the reconstructive orthoplastic strategy was planned. The aims were firstly to provide an adequate soft tissue and skin coverage, and secondly to pursue elbow stability and bone gap restoration, in order to restore articular joint surface and mobility.

One month after the trauma, the infection was eradicated. She underwent plastic surgery to provide soft tissue coverage with a musculocutaneous latissimus dorsi rotational flap. Ulnar nerve gap was restored by harvesting the homolateral sural nerve, which was duplicated and end-to-end sutured, covered by the amniotic membrane (Fig. 4).

Hand and wrist splints were placed to prevent claw hand. Elbow active flexion-extension ROM was from 40 to 90° and ten days after surgery prono-supination was unlocked. An intensive rehabilitative physio-kinetic therapy program was started.

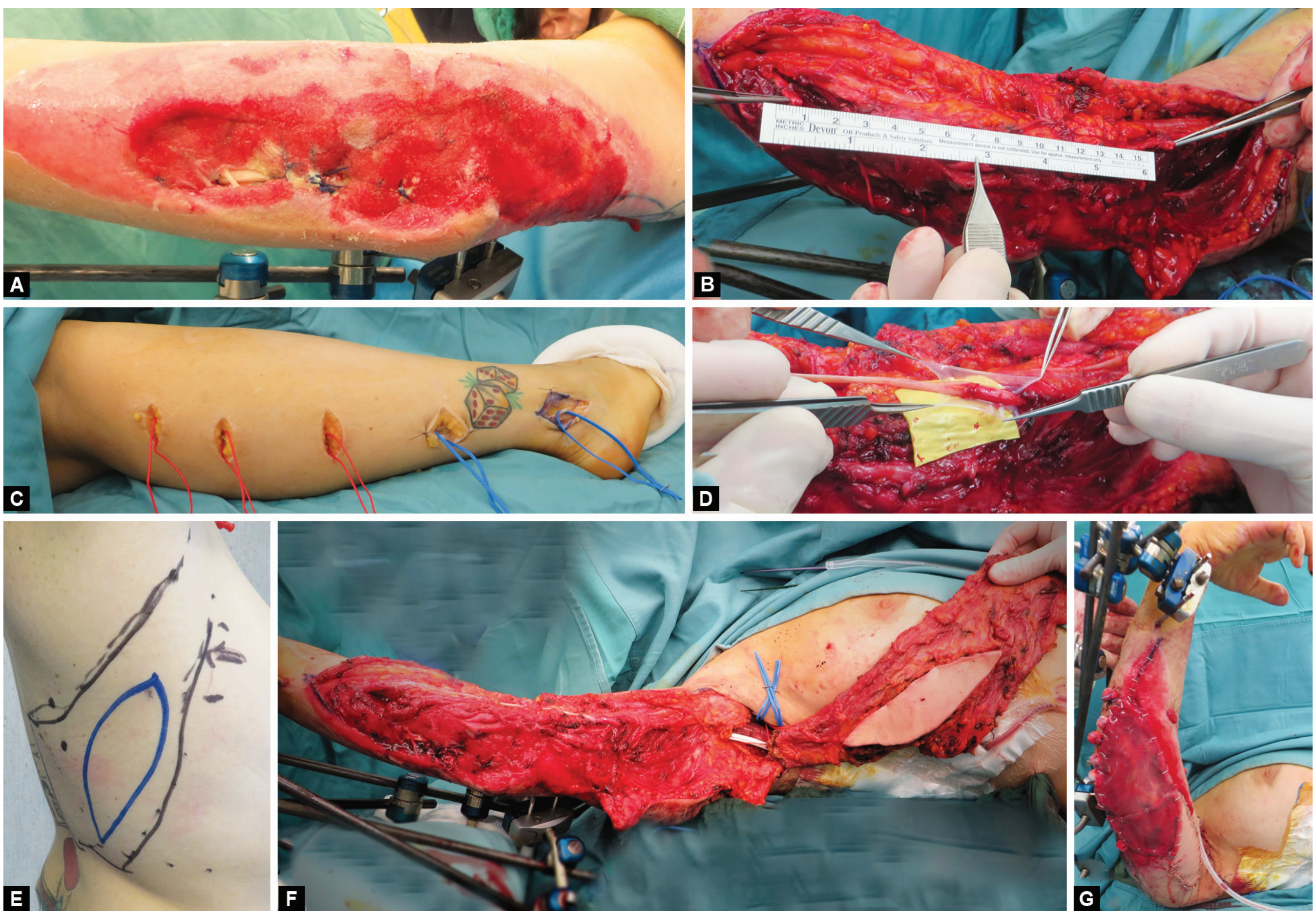
The patient underwent periodic clinical and functional examinations as an outpatient to assess flap taking, scar quality, articular finger wrist and elbow mobility, muscle tropism, musculotendinous retraction, and finger position. A constant improvement was registered.

Magnetotherapy was prescribed 8 hours/day for eight weeks.

Electromyography was conducted three months after trauma, showing ulnar axonotmesis.

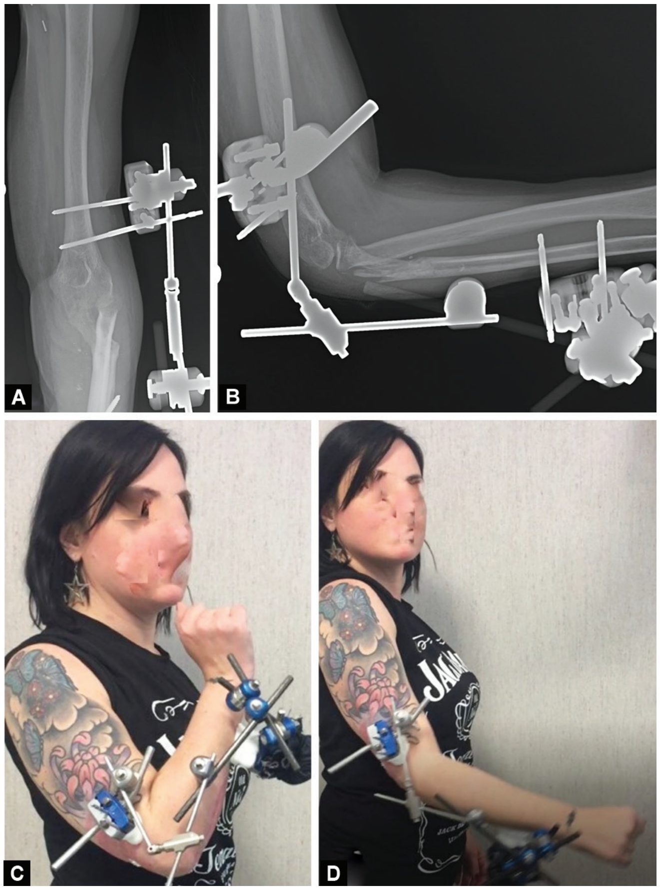
Six months after the trauma, the second step of elbow reconstruction was started. At that time, elbow active ROM in flexion-extension was 30–100° and ROM in pronosupination 30–40° (Fig. 5). The quick disabilities of the arm, shoulder, and hand (DASH) questionnaire[22] was performed, the result was 93.2 points. Due to young age, total elbow replacement was avoided.

Considering the olecranon bone loss, we planned the reconstructive phase by using a cadaver elbow allograft, proper sized with "ad hoc" harvesting by National Tissue Bank. Moreover, bilateral elbow CT was performed in view of the bone reconstruction surgery, 3D model production, and bone loss specific evaluation.



Figs 4A to G: The reconstructive orthoplastic strategy was planned: the primary purpose was to provide an adequate soft tissue and skin coverage. The patient underwent plastic surgery to provide soft tissue coverage with a musculocutaneous latissimus dorsi rotational flap. (A). After VAC and hyperbaric therapy, a good and clean granulation tissue was achieved and definitive skin coverage could be provided. Skin elbow situation before skin coverage surgery; (B). Ulnar nerve gap (7 cm); (C). Harvesting of homolateral sural nerve; (D). Ulnar nerve gap was restored by harvesting homolateral sural nerve, which was duplicated and sutured end to end using microsurgical technique. It was covered by amniotic membrane; (E). Musculocutaneous latissimus dorsi rotational flap preoperative drawing; (F). Musculocutaneous latissimus dorsi rotational flap was harvested and rotated to cover the receiving area; (G). Final outcome

Being the percentage of olecranon articular surface bone loss was greater than 70%, a contralateral elbow was used to obtain affordable measures for ad hoc harvesting. For this purpose, we employed mirroring technique, producing a mirroring virtual model of the healthy elbow.[14,23]



Figs 5A to D: Six months after trauma: (A). AP x-ray; (B). LL x-ray; (C). Elbow active ROM in flexion of 100°; (D). Elbow active ROM in extension of 30°

3D Printing and VR Applicated to This Case

CT files of each elbow were imported on the software syngo.via Frontier (Siemens). We performed a semi-automatic segmentation by threshold and we exported each elbow 3D model for 3D printing (Fig. 6).

The healthy left elbow model was imported on the software Meshmixer (Autodesk) in order to use "mirror" function. Thus, the mirror image was produced with respect to the sagittal plane of the left elbow, i.e., obtaining a healthy copy of the right elbow (Fig. 6C).

We printed the thermoplastic right elbow and mirrored elbow 3D models by 3D printer Fortus (250mc Stratasys) (Fig. 6D and E).

The duration of printing was 18.53 hours. The material cost was € 58.69.

The olecranon bone loss on VR was quantified by importing 3D models on software MiniMagics (Materialise) and Meshmixer. We chose landmarks to measure the healthy elbow 3D model (Table 1).

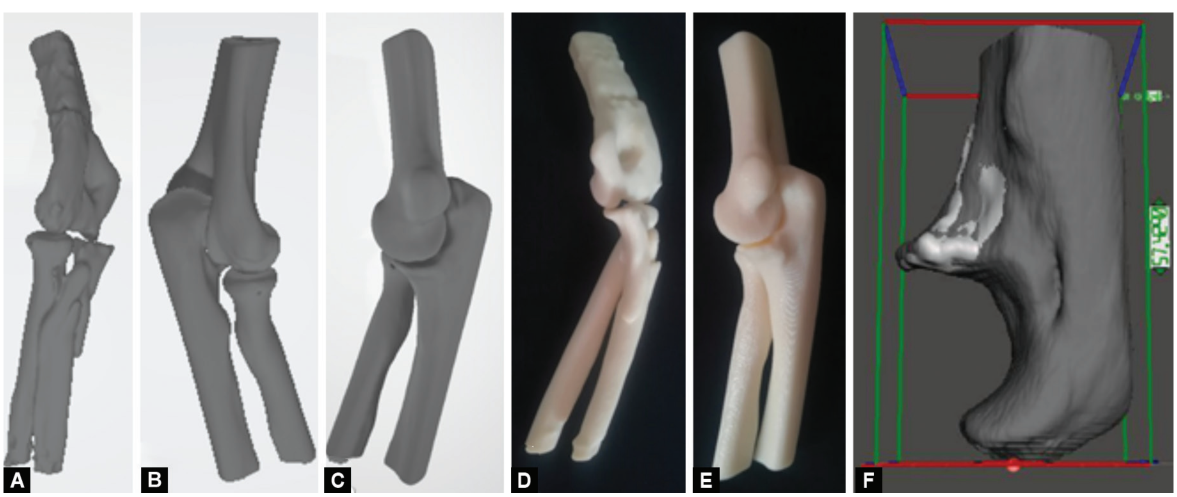
Finally, right injured 3D model and mirrored healthy 3D model were imported on the Meshmixer software to perform "Boolean subtraction," thus producing a new 3D model subtracting the right injured 3D model from the mirrored healthy 3D model. The two geometries were overlapped by using landmarks on coronoid (Fig. 6F). It allowed to obtain a proximal ulnar bone loss 3D model, in order to visualise the gap and to plan the graft surgery. (Fig. 6F) shows the bone loss measurement.

Final Outcomes of the Clinical Case

To avoid bone infection prior to performing the orthopaedic surgery, DEF was removed ten months after the trauma: during forearm flexion movements over arm and biceps contraction, the ulna was still anteriorly dislocated. The articulated brace was positioned, granting flexion-extension and prono-supination.

Three months later, with the choice of proper cadaveric allograft from the National Tissue Bank and the request of second check for the harvesting phase, the patient refused the treatment, reporting no limitations in no-articulated brace activities.

Thirteen months after the trauma, at clinical examination, she presented intrinsic hand muscle ipotrophy, good finger recovery, and elbow active ROM: flexion-extension reached 10–120°, prono-supination was 40–55°. X-rays were performed, showing complete



Figs 6A to F: (A). Right elbow 3D model (the pathologic one); (B). Left elbow 3D model (the healthy one); (C). Mirror image with respect to the sagittal plane of the left elbow, i.e., the healthy copy of the right elbow; (D). Right elbow 3D printed model (the pathologic one); (E). Mirrored left elbow 3D printed model (the healthy one); (F). "Boolean subtraction" of right injured 3D model and mirrored healthy 3D model. Landmarks on coronoid have been used to overlap the two geometries. We obtained a 3D model of the proximal ulnar bone loss and we measured the bone loss healing of the fractures. Quick DASH score[22] resulted 75 points and Broberg-Morrey score[24] resulted 33.5 points.

The flap showed a steady morphological resemblance to the surrounding tissues, as it progressively integrated into the receiving area. There was an edema regression and a scar enhancement; despite that, the scar remained hypertrophic in the proximal forearm.

The patient about two years after the trauma underwent a flap-defatting revision surgery.

Table 1: Measurements performed importing 3D models on free software MiniMagics and on Meshmixer. On MiniMagics, we used "distance" function, whereas in Meshmixer "measure" function was employed

Landmarks	*MiniMagics*	*Meshmixer*
Coronoid-olecranon top	27.62 mm	26.41 mm
Coronoid-olecranon posterior aspect	32.23 mm	32.25 mm
Maximum lateral-medial articular olecranon	18.09 mm	18.67 mm
Maximum lateral-medial posterior olecranon	18.06 mm	16.49 mm

Eighteen months from the DEF removal and almost two and a half years from the trauma, she did not complain of elbow instability, lifting low weights easily and resuming daily activities. Elbow active ROM in flexion-extension reached 5–130° and pronosupination was 45–60°. Elbow radiographs showed initial humeroulnar signs of arthrosis and modicum proximal radioulnar diastasis (Fig. 7).

Quick DASH Score[22] calculation was 93.2. Broberg-Morrey score[24] was performed with a result of 71.5.

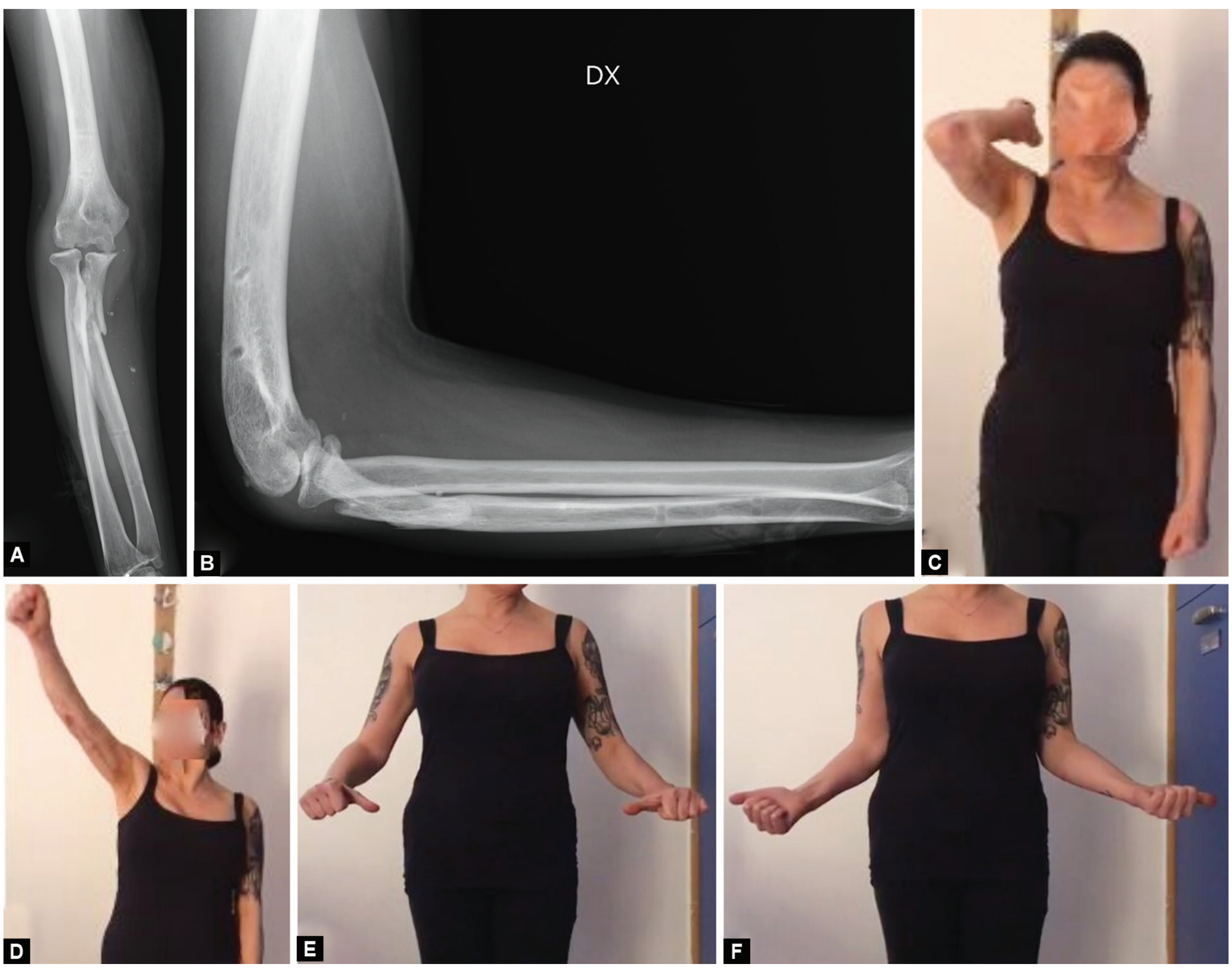
Discussion

In CEI, it is mandatory to deeply understand the injured structures in order to manage and apply proper treatment.

The complexity of the joint anatomy surely involves biomechanical elements.

Olecranon with coronoid, medial collateral, and lateral collateral ligaments are considered the primary elbow constraints.[3] The secondary constraints are posterior capsule, trochlea, medial epicondylar muscles, anterior capsule, radial head, capitellum, and lateral epicondylar muscles.[25]

Doornberg assumed that in olecranon fracture-dislocations, it is mandatory to treat the coronoid fracture to restore the trochlear notch and to avoid sequels.[26]



Figs 7A to F: Close to two years from DEF removal and almost three years from the trauma, X-rays were performed, showing complete healing of fractures. Moreover, we reported initial humeroulnar signs of arthrosis and modicum proximal radioulnar diastasis. (A). AP X-ray; (B). LL X-ray; (C). Elbow active ROM in flexion of 130°; (D). Elbow active ROM in extension of 5°; (E). Elbow active ROM in pronation 45°; (F). Elbow active ROM in supination 60°

Fragment excision in high-comminuted capitellum and trochlea fractures has been described, too.[27] Despite some authors assessed that capitellum excision causes instability and ROM reduction, Dushuttle et al. showed that it did not provide valgus instability if the medial ligament was intact.[28] Alvarez et al.[29] and Garner et al.[30] illustrated good results in selected cases, saving the lateral ulnar collateral ligament.

An et al.[31] analyzed the proximal ulna partial removal outcomes in elbow constraint. He assessed that the humeral trochlea and the coronoid process integrity is not affected by the removal of half of the olecranon joint surface, avoiding any elbow instability. In 1947, McKeever affirmed that comminuted, old ununited or elderly olecranon fractures should be treated by fragment excision and repair of the triceps tendon. It permits to avoid prolonged immobilisation, preventing the necessity of bone grafting, consequently improving the elbow motion range. He assessed there would be no elbow instability without a fracture of the coronoid and 20% of the semilunar notch. He did not observe any severe triceps power reduction.[32]

Sullivan reported conservative management of type II olecranon fractures in elderly patients that allowed an acceptable function.[33]

In our case, the coronoid process and the anterior humeral trochlea were intact, whereas the olecranon and the distal posterior humerus were lost.

As previously stated, our first strategy was to replace the olecranon bone loss by a cadaveric allograft to provide stability. In such case, imaging is necessary for surgical planning to understand the injury.

Öztürkmen focused on the preoperative planning of olecranon fracture-dislocations, demonstrating that X-rays are inadequate, while the 3D CT allows to study the fracture pattern.[9]

Yang et al.[13] demonstrated that 3D printing contributed to reduce surgery duration and blood loss, thus producing better outcomes.

In this study, we described how 3D printing and VR in clinical practice can help to manage CEI associated with the loss of important substances, bones, and soft tissues. These new technologies have been helpful to study the entity of bone loss, focusing on olecranon gap and humeral–ulnar–radial relationships. Moreover, it has been possible to make a surgical planning for olecranon reconstruction by using bone grafts.

Despite the negative conditions, the patient refused surgical treatment because her joint stability seemed acceptable, performing daily life activities, such as doing housework, carrying water bottle boxes, and going to work.

Elbow stability, according to McKeever and Buck[32], might be replaced by triceps reinsertion and scar tissue formation. Moreover, DEF allowed an early recovery of ROM, making this condition acceptable for the patient. EF is indeed recommended in CEI because it provides joint stability by allowing the bone and the soft tissues to heal. Furthermore, it permits early motion, which is strongly recommended in CEI.[34]

Conclusion

Approaching this case, we conclude that olecranon and distal posterior humeral loss with the coronoid process and the anterior humeral trochlea integrity did not prejudice the whole joint stability, probably replaced by triceps reinsertion and by scar tissue formation.

That replacement can allow acceptable functions in common daily life activities. Of course, a high-demanding patient would not be benefitted by this treatment.

3D printing and VR approaches in clinical practice can be useful in the management of CEI associated with loss of important substances, bones, and soft tissues. The manufacturing of 3D models requires time, resources, and a multidisciplinary approach, and it must be justified by the complexity of the case. Future improvements in technologies can address these issues by reducing the duration and the cost of building a 3D printing model, thus simplifying the production process.

Acknowledgments

The authors would like to thank Pediatric and Specialistic Radiology Department (Ospedali Riuniti Ancona) for the support in TC scan process, Health Physics Department (Ospedali Riuniti Ancona) for the support in 3D model production and Virtual Reality process and Department of Industrial Engineering and Mathematical Sciences (UNIVPM) for 3D printing.

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