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ORIGINAL PAPER

The adjunct use of lateral hinged external fixator in the treatment of traumatic destabilizing elbow injuries

Ali Hassan Chamseddine[1] · Ali H. Asfour[1] · Mohammad Jawad H. Rahal[1] · Abbas A. Dib[1] · Hassan M. Wardani[1] · Mohammad O. Boushnak[1]

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Abstract

Purpose The purpose of this study is to evaluate the results of using a lateral hinged external fixator as an adjunct stabilizer in the treatment of a variety of acute destabilizing elbow injuries.

Methods A retrospective review was performed on the medical records of patients in whom a lateral monolateral elbow hinged external fixator was applied by the senior author. The indication to apply the fixator corresponded to a variety of acute injury patterns ranging from simple elbow trauma or dislocation to complex fracture–dislocation, and the decision was based on either the presence of recurrent or persistent instability in any direction and/or to secure a vulnerable or weak bony fixation or soft tissue repair as intra-operatively judged by the surgeon. The fixator was inserted in the same setting after the repair of the associated ligamentous and/or bony structures. Patients operated after one month of the trauma and those presented with open elbow injury or associated humeral or ulnar shaft fracture were excluded. Rehabilitation was immediately started and the fixator removed at six to eight weeks with elbow testing and gentle manipulation under general anaesthesia, and resuming of rehabilitation after removal. Clinical assessment was performed for all patients according to the Mayo Elbow Performance Score (MEPS) with evaluation of range of motion at regular intervals till the end of the post-operative first year, then at final follow-up for the purpose of the study with radiographic assessment for evaluation of elbow reduction and concentricity.

Results There were 13 patients with a mean age of 42 years. Two patients had instability secondary to LCL rupture; one patient had redislocation because of associated coronoid process fracture; one patient had radial head fracture with rupture of both collateral ligaments; five patients had terrible triad injury with variable association of collateral ligaments lesions; and four patients had posterior Monteggia fracture–dislocation. The mean MEPS was 90 at a mean follow-up of seven years with six excellent, six good, and one fair result. All patients had a concentrically reduced and stable elbow as assessed clinically and radiologically with a mean functional arc of motion of 132° for extension–flexion and 178° for pronation–supination.

Conclusion The hinged elbow external fixator represents a valuable adjunct in the therapeutic arsenal for the treatment of unstable elbows after bony and soft tissue repair. It provides satisfactory results in terms of stability and function and should be available in the operating room when a surgeon treats a complex elbow dislocation or fracture–dislocation.

Keywords Hinged elbow external fixator · Monteggia fracture–dislocation · Mayo Elbow Performance Score · Complex elbow dislocation · Terrible triad of the elbow

Introduction

Post-traumatic elbow instability may be distinguished in acute, chronic, and recurrent; it corresponds to the clinical sequellar manifestations of a wide spectrum of injuries ranging from ligamentous ruptures with or without elbow dislocation to fractures and fracture–dislocations [1, 2]. In the absence of appropriate treatment, destabilizing acute elbow injuries commonly lead to variable degree of disability in the form of chronic instability, secondary osteoarthritis and poor

✉ Ali Hassan Chamseddine
achamsedine@hotmail.com

[1] Division of Orthopaedic and Trauma Surgery, Sahel General Hospital, University Medical Centre, PO Box 99/25, Ghoubeiry, Beirut, Lebanon

functional outcomes [1–3]. Treatment of these injuries is very challenging and aims at restoring a concentrically reduced and stable elbow with painless functional range of motion; it involves surgical repair and reconstruction of the disrupted bony and/or ligamentous elbow restraints [4, 5]. Additional application of an articulated external fixator has shown beneficial effects in such circumstances [5–8]; the primary therapeutic objectives are to maintain concentric elbow reduction and stability by the spanning effect of the fixator and avoid joint stiffness by allowing early range of motion provided by the rotation around the axis of the fixator's hinge at the same time as protecting osseous and ligaments healing. Nevertheless, the application of this type of fixator is technically demanding. We aim at reporting our experience in using a lateral monolateral hinged external fixator in a variety of destabilizing elbow injuries; this analysis is like many previous studies, a retrospective review of a short case series [5, 8].

Material and methods

A retrospective review was performed on the medical records of patients in whom a lateral monolateral elbow hinged external fixator (Orthofix; Orthofix Orthopedics International, Bussolengo, Verona, Italy) was applied by the senior author between February 1999 and February 2019. The rationale for the application of the fixator was to start early motion while maintaining elbow reduction and protecting bony and/or ligamentous repair or reconstruction. Regan and Morrey [9] classification was used to describe associated coronoid fractures. Patients operated within 1 month after trauma were only included whereas those who were treated more than four weeks after the initial injury were considered chronic and therefore excluded. Patients with open elbow dislocation or open fracture–dislocation were also excluded, as well as patients with additional ipsilateral humeral or ulnar shaft fracture. Surgical repair of fractures and/or ligamentous injuries was first achieved, followed by application of the hinged fixator using standard surgical techniques [6, 10]. The indication to apply the fixator corresponded to a variety of injury patterns ranging from simple elbow trauma or dislocation to complex fracture–dislocation, and the decision was based on either the recurrence or persistence of instability in any direction and/or to secure a vulnerable or weak bony fixation or soft tissue repair as intra-operatively judged by the surgeon. Immediate rehabilitation was started under close supervision of an occupational therapist in daily sessions from the day after the operation; elbow extension was intentionally kept 30° short of its full range for the first four weeks. The fixator was removed at six to eight weeks under general anaesthesia with testing of elbow stability and gentle manipulation as needed. Rehabilitation was then continued for 3 to 6 months to reinforce and consolidate range of motion. All patients were treated and regularly followed up by the senior author; they were clinically evaluated according to the Mayo Elbow Performance Score (MEPS) [11] at regular intervals of two to three months until the end of the post-operative first year, then at the final follow-up. MEPS is formed by four parameters with a total of 100 points: 45 points for absence of pain, 20 points for an arc of motion more than 100°, 10 points for stability, and 25 points for daily function. The result is excellent for a total score of 90–100, good for 75–89, fair for 60–74, and poor for less than 60. Elbow active range of motion was evaluated using standard goniometer; in addition to arc of extension–flexion, arc of pronation–supination was also assessed. Full range of extension–flexion was attributed 0°/145° (full arc 145°) whereas a full range of pronation–supination was attributed 90°/90° (full arc 180°). Radiographic assessment with AP and lateral views for evaluation of elbow reduction and concentricity was performed for all cases at the occasion of the final follow-up for the purpose of this study.

Technique of insertion of the hinged external fixator

The application of the hinged fixator followed the technical steps previously described by many authors [6, 10]; it is accomplished after intra-operative identification of two landmarks on strict fluoroscopic lateral view of the elbow: the first landmark is achieved when the dense line of the distal humerus is at one third of the distance from the posterior to the anterior humeral cortex; the second landmark is achieved when the margins of the trochlea and capitellum delineate two concentric circles. A pin is then drilled from the lateral epicondyle in the center of the two concentric circles; caution is made not to penetrate the medial epicondyle in order to avoid injury to the ulnar nerve. The pin should appear as a spot on the fluoroscopic lateral elbow view; on antero-posterior view, it should be parallel to the joint line to reproduce the valgus angulation of the distal humerus. The pin materializes the axis of elbow rotation, and the hinge of the fixator is consequently mounted over it. The humeral screws of the fixator are inserted at the humeral-distal insertion of the deltoid tubercle by direct surgical exposure of the bone as the radial nerve is posterior at this location and consequently out of harm; ulnar screws are inserted at the postero-lateral aspect of the mid ulnar shaft. Concentric joint reduction is maintained during final tightening of the fixator under fluoroscopic control. The correct alignment of the axis of the fixator with the elbow axis of rotation is clinically checked after final tightening of the fixator in place: repetitive flexion–extension movements should be smoothly achieved without resistance or accident. The pin axis is removed after the application of the fixator is completed.

Results

There were 16 patients for whom a lateral monolateral articulated elbow external fixator was applied. Three patients were excluded: one patient had open elbow dislocation with humeral artery injury, one had terrible triad injury associated with complex fractures of distal radial and ulnar shafts, and one had elbow subluxation of ten week duration secondary to terrible triad injury. As a result, the final number of patients that were included and analyzed for this study was 13. Tables 1, 2, and 3 recapitulate the characteristics of the series, the individual active range of motion and the individual MEPS respectively. There were nine men and four women ranging in age between 23 and 67 years (mean 42). The left side was affected in seven patients and the right side in six. All patients were operated on within one day to four weeks after the causative trauma. In two patients, the surgical procedure consisted of lateral collateral ligament (LCL) reinsertion through standard Kocher lateral approach: one patient had posterolateral rotatory instability (case 1) operated one month after the initial trauma and the other patient had irreducible perched dislocation of the elbow after two weeks of cast immobilization (case 2) and was operated upon three weeks after the injury. One patient was operated on at five days post-injury for elbow redislocation into cast (case 3) related to an initially undiagnosed type II coronoid fracture using open reduction and internal fixation (ORIF) with antero-posterior screw fixation of the coronoid process through anterior elbow approach. In one patient (case 4), radial head prosthesis with LCL and medial collateral ligament (MCL) repair were performed for comminuted radial head and neck fracture with important instability secondary to LCL and MCL rupture, through double lateral and medial approach. Five patients had terrible triad injury (cases 5 to 9) corresponding to elbow dislocation with fractures of the radial head and coronoid process and variable collateral ligaments injuries; four of them were operated on within one week of the injury (cases 5 to 8) (Fig. 1) and one patient at four weeks (case 9) (Fig. 2); combination of lateral and medial approach was used for three patients (cases 5, 6, and 8) (Fig. 1) whereas a combined lateral and anterior approach was performed for the remaining two patients (cases 7 and 9) (Fig. 2). All patients with terrible triad injury received radial head prosthesis; type I coronoid fracture was not repaired (cases 5 and 6) (Fig. 1), whereas types II and III underwent ORIF with either antero-posterior screw through a direct anterior approach (cases 7 and 9) (Fig. 2) or postero-anterior screw (case 8); repair of LCL was performed in all five patients (cases 5 to 9) and MCL repair in three (cases 5, 6, and 8) (Fig. 1). Four patients had posterior olecranon fracture–dislocation corresponding to type II posterior Monteggia lesion (cases 10 to 13); surgical repair involved ORIF of the olecranon fracture with plate and screws in all four patients, radial head ORIF in one patient (case 10) and radial head prosthesis in three patients (cases 11 to 13) with LCL repair in two of them (cases 11 and 13), and coronoid process reconstruction either by postero-anterior fixation (cases 10 and 13) or bone graft (cases 11 and 12). One of the patients with posterior Monteggia lesion (case 11) (Fig. 3) had a primary surgery in another institution with ORIF of the proximal ulna and radial head resection through posterior approach; he underwent secondary repair at four weeks in our institution because of elbow stiffness and posterior dislocation of the proximal radial stump: radial head prosthesis with LCL repair through lateral approach and reconstruction of the coronoid process with iliac bone graft through anterior approach were performed. This patient (case 11) developed post-operative numbness in the ulnar nerve territory related to irritation of the nerve by the tip of the antero-posterior screw inserted to fix the iliac bone graft for coronoid reconstruction; he was completely relieved after he was re-operated upon six months later with exploration-neurolysis of the ulnar nerve and cut off the tip of the screw with a pin cutter. The same patient underwent an additional surgery 14 months later for proximal ulnar fracture with plate breakage after a car accident: removal of the old plate with new ORIF was subsequently performed. Elbow testing under general anaesthesia after removal of the fixator concluded that all 13 elbows were stable. The radio-clinical assessment was available at a mean final follow-up of seven years, ranging from two to 18 years. All patients had concentrically reduced and stable elbow with a very satisfactory functional arc of motion for both extension–flexion and pronation–supination as detailed in Table 2. The mean arc of extension–flexion was 132°, with 142° of mean flexion and 9.6° of mean extension deficit. The mean arc of pronation–supination was 178°, with mean of 88° pronation and 90° supination. Only one patient reported pain requiring medication especially during moderate and heavy duty (case 11). Table 3 represents the details of MEPS for all patients of the series: the mean MEPS was 90 and there were six excellent results, six good and one fair. Excellent results correspond to the following patients: patient with posterolateral rotatory instability (case 1), patient with irreducible perched dislocation (case 2), patient with unstable elbow dislocation and coronoid fracture (case 3), patient with terrible triad injury (case 9), and two patients with posterior Monteggia fracture (cases 10 and 13). Good results correspond to the following patients: one patient with radial head fracture and both collateral ligaments injury (case 4), four patients with terrible triad injury (case 5, 6, 7, and 8), and one patient with posterior Monteggia lesion (case 12). Finally, fair result is seen in a patient with posterior Monteggia lesion (case 11)

Table 1 Summary of characteristics and results of the series. *TS*, time of surgery; *SA*, surgical approach; *MEPS*, Mayo Elbow Performance Score; *F-Up*, follow-up; *PLRI*, postero-lateral rotatory instability; *CFD*, complex fracture–dislocation; *LCL*, lateral collateral ligament; *MCL*, medial collateral ligament; *RH*, radial head; *TOF*, trans-osseous fixation; *LE*, lateral epicondyle; *ORIF*, open reduction and internal fixation; *P&S*, plate and screws; *Lat*, lateral; *Med*, medial; *Ant*, anterior; *Post*, posterior; *d*, day; *w*, week; *y*, year

Case	Side	Age	Sex	Diagnosis	Anatomic injuries	Treatment	TS	SA	MEPS	F-Up
1	Left	23 y	Male	PLRI	LCL	LCL repair (TOF)	4 w	Lat	100 excellent	10 y
2	Left	45 y	Female	Irreducible perched dislocation	LCL	LCL repair (TOF)	3 w	Lat	100 excellent	9 y
3	Left	41 y	Female	Unstable dislocation	Fracture coronoid	Coronoid AP screw fixation	5 d	Ant	100 excellent	18 y
4	Right	26 y	Female	CFD (dislocation + RH fracture)	RH fracture LCL MCL	RH prosthesis LCL repair (TOF) MCL repair (suture)	3 d	Lat + Med	85 good	5 y
5	Left	52 y	Male	CFD (terrible triad)	Fracture RH & neck Fracture coronoid type I LCL + Fracture LE MCL	RH prosthesis Coronoid tip not repaired LCL repair + LE fixation MCL repair (Anchor)	1 w	Lat + Med	85 good	3 y
6	Right	42 y	Male	CFD (terrible triad)	Fracture RH & neck Fracture coronoid type I LCL MCL	RH prosthesis + cerclage Coronoid tip not repaired LCL repair (Anchor) MCL repair (Anchor)	3 d	Lat + Med	85 good	2 y
7	Left	62 y	Female	CFD (terrible triad)	Fracture RH Fracture coronoid type III LCL	RH Prosthesis Coronoid AP screw fixation LCL repair (TOF)	1 d	Lat + Ant	85 good	7 y
8	Right	36 y	Male	CFD (terrible triad)	Fracture RH & neck Fracture coronoid type II LCL MCL	RH prosthesis Coronoid PA screw fixation LCL repair (Anchor) MCL repair (Anchor)	1 d	Lat + Med	75 good	3 y
9	Right	67 y	Male	CFD (terrible triad)	Fracture RH + Fracture coronoid type II LCL	RH prosthesis Coronoid AP screw fixation LCL repair (TOF)	4 w	Lat + Ant	100 excellent	13 y
10	Left	45 y	Male	CFD (posterior Monteggia)	Fracture proximal Ulna Fracture coronoid type II Fracture RH	ORIF ulna (P&S) PA coronoid fixation ORIF RH (screws)	4 d	Post	100 excellent	2 y
11	Right	36 y	Male	CFD (posterior Monteggia)	Fracture proximal ulna Fracture coronoid type II Fracture RH	Initial treatment: ORIF ulna (P&S) Excision RH Final treatment: RH prosthesis Coronoid graft (Iliac bone) LCL repair (Anchor)	1 d 4 w	Post Lat + Ant	70 fair	5 y
12	Left	32 y	Male	CFD (posterior Monteggia)	Fracture proximal ulna Fracture coronoid type II Fracture RH	ORIF ulna (P&S) Coronoid graft (RH fragment) RH prosthesis	1 d	Post	85 good	14 y
13	Right	40 y	Male	CFD (posterior Monteggia)	Fracture proximal ulna Fracture coronoid type II Fracture RH	ORIF ulna P&S PA fixation coronoid RH prosthesis LCL repair (TOF)	2 d	Post	100 excellent	2 y
Mean		42 y							90	7 y

Table 2 Details of range of motion of the series. *ROM*, range of motion; *E/F*, arc of extension-flexion; *P/S*, arc of pronation–supination

ROM	Case													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
E/F	0/145	0/145	0/145	0/145	−10/135	−20/145	−10/140	−20/130	−15/145	−5/135	−35/145	−10/145	0/145	132
P/S	180 (90/90)	180 (90/90)	180 (90/90)	180 (90/90)	170 (80/90)	180 (90/90)	180 (90/90)	170 (80/90)	180 (90/90)	180 (90/90)	180 (90/90)	180 (90/90)	180 (90/90)	178 (88/90)

who was operated 4 weeks after failure of initial treatment performed in another institution and who underwent two additional surgeries as abovementioned. None of the 13 patients developed complications at the surgical site or related to the application of the hinged external fixator.

Discussion

The elbow is an inherently stable restrained joint with two degrees of mobility: flexion–extension movement compared to a hinge joint and pronation–supination. The particular anatomic configuration of the joint surfaces combined with the anatomic topography of the capsulo-ligamentous structures confers to the elbow its stable and harmonious range of motion [1, 2]. O'Driscoll et al. [2] consider that elbow constraints can be distinguished in primary and secondary stabilizers arranged in two lines of defenses similar to a fortress construction; however, a secondary stabilizer such as the radial head becomes of primary importance for elbow stability when a primary stabilizer such as the MCL or the coronoid process is disrupted. For Ring and Jupiter [1], elbow constraints are organized in four components or columns of stabilizers according to a ring configuration; the risk to develop chronic or recurrent instability increases with the number of injured columns; furthermore, when one component is injured, such as comminuted fracture of the radial head, rupture of another component of the ring, such as the medial collateral ligament, should be expected.

Post-traumatic elbow instability is a complex condition corresponding to a wide spectrum of anatomic lesions including capsulo-ligamentous injuries and/or fractures of the articular stabilizing components; it can clinically manifest as subtle instability, or either recurrent or permanent subluxation or dislocation of the elbow [1, 2]. Unstable elbow fractures and fracture–dislocations represent a group of injury patterns including posterior dislocation of the elbow associated with fracture of the radial head or coronoid process or both (so-called terrible triad), anterior trans-olecranon fracture–dislocation, and posterior olecranon fracture–dislocation equivalent to posterior Monteggia lesion [1]; yet many of these unstable fractures and fracture–dislocations also include different patterns of disruption of one or both collateral ligaments [12]. In elbow with intact bony components, functional stability requires structural integrity of LCL and MCL [13]; accordingly, ulnohumeral instability can occur after elbow sprain or dislocation as a result of ligaments insufficiency [13]. O'Driscoll [13] described the "posterolateral rotatory instability" secondary to insufficiency of LCL, mainly its ulnar bundle, as the most subtle clinical manifestation and the first stage of the spectrum of postero-lateral elbow dislocation. The second stage, the so-called perched dislocation, corresponds to injury of the entire LCL with the anterior and posterior capsule and

Table 3 Detailed results of the Mayo Elbow Performance Score of the series (MEPS)

Case	MEPS						
	Pain/45	Mobility/20	Stability/10	Function/25	Total/100	Result	Follow-up
1	45	20	10	25	100	Excellent	10 years
2	45	20	10	25	100	Excellent	9 years
3	45	20	10	25	100	Excellent	18 years
4	30	20	10	25	85	Good	5 years
5	30	20	10	25	85	Good	3 years
6	30	20	10	25	85	Good	2 years
7	30	20	10	25	85	Good	7 years
8	30	20	10	15	75	Good	3 years
9	45	20	10	25	100	Excellent	13 years
10	45	20	10	25	100	Excellent	2 years
11	15	20	10	25	70	Fair	5 years
12	30	20	10	25	85	Good	14 years
13	45	20	10	25	100	Excellent	2 years
Mean	35.7	20	10	24.2	90		7 years

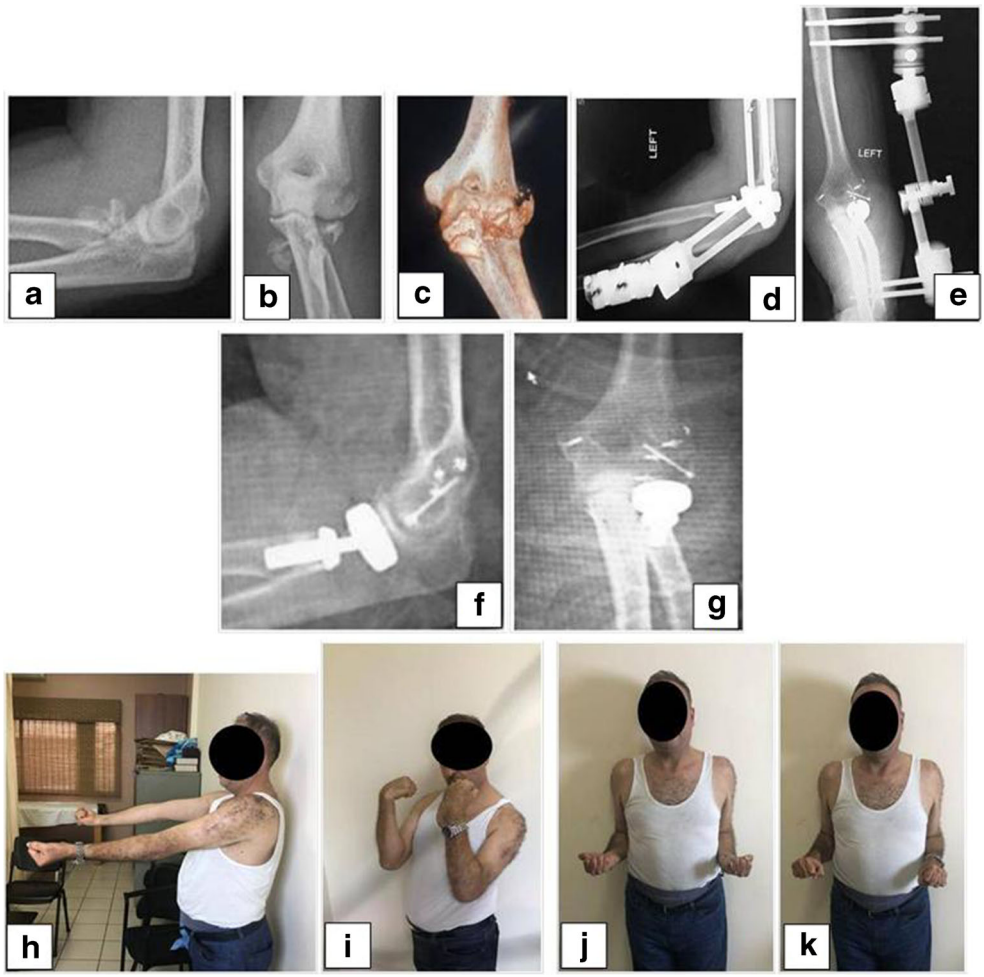

Fig. 1 Case 5. **a**, **b** Antero-posterior with lateral radiographs and **c** 3-D CT scan view of a terrible triad injury after closed reduction; **d**, **e** post-operative radiographs showing the hinged fixator with radial head replacement, LCL fixation using anchors and headless screw for the lateral epicondyle, and MCL reinsertion with anchor suture; **f**, **g** radiographs after removal of the fixator showing a concentrically reduced elbow; **h**, **i**, **j**, **k** photographs of the same patient at 3-year follow-up with almost full range of motion

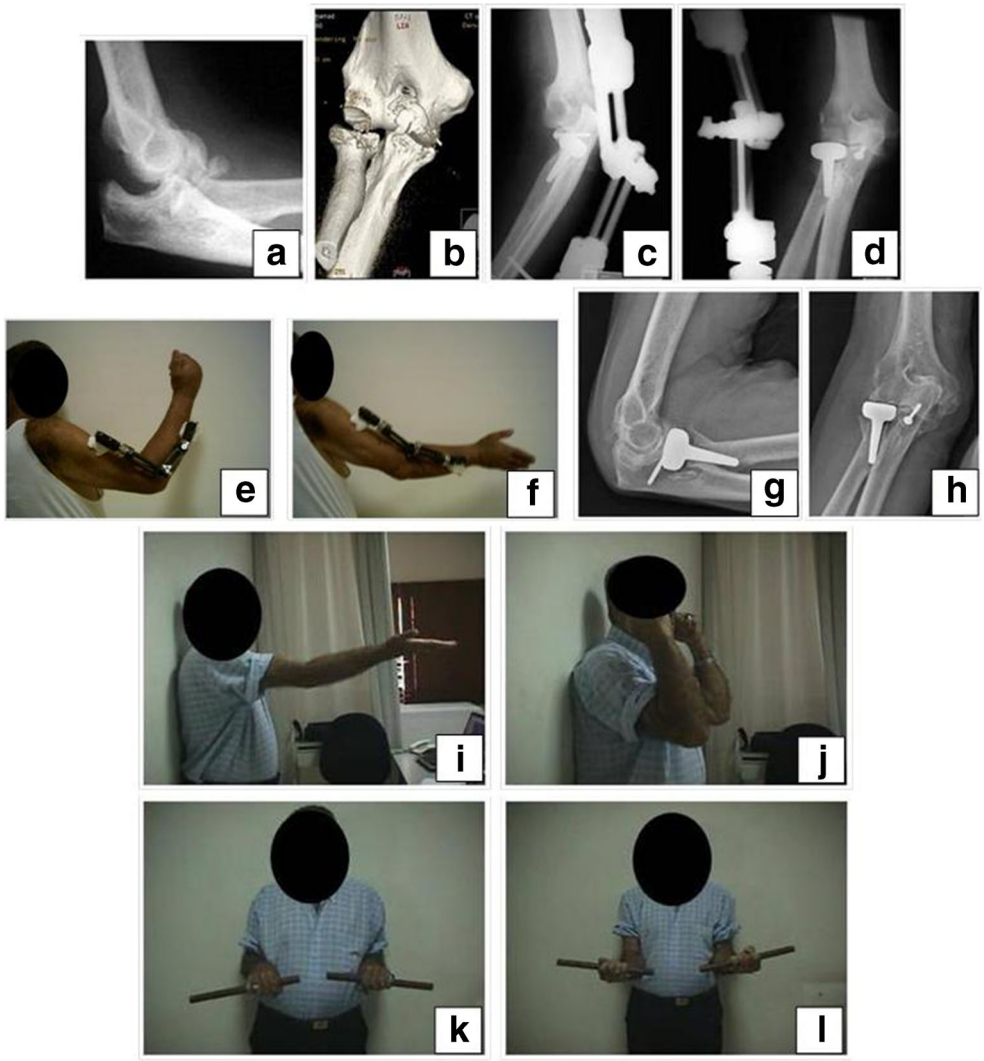

Fig. 2 Case 9. **a** Lateral radiograph and **b** 3-D CT scan view of a terrible triad injury of 1 month duration; **c**, **d** post-operative radiographs after elbow reduction and radial head replacement, trans-osseous reinsertion of the LCL, antero-posterior coronoid fixation, and insertion of hinged external fixator; **e**, **f** radiographs of the same patient showing early range of motion protected by the fixator; **g**, **h** elbow radiographs 13 years after repair showing only mild arthritic changes with concentrically reduced elbow; **i**, **j**, **k**, **l** photographs of the same patient showing nearly complete range of motion excepted for a 15° lack of extension

represents an incomplete dislocation where the coronoid process is "perched" under the trochlea and for which little force is needed to completely dislocate or to reduce the elbow [13]; intra-articular osteochondral entrapment and soft tissue interposition were reported in association with such presentation [14]. Surgical treatment of these two entities consists of repair and reconstruction of the LCL [15]. For post-operative period, Nestor et al. [15] advised 4 weeks of cast immobilization at 90° flexion with forearm pronated, followed by six weeks of hinged splint or brace with a stop at 30° short of full extension, followed by additional four to six weeks of hinged splint without stop. We believe such post-operative regimen is relatively long and requires a high degree of compliance and obedience from the patient. Alternatively, the use of hinged external fixator has been proposed in such circumstances for the protection of the LCL repair with early restoration of range of motion [16], as it was performed for cases 1 and 2. In addition, Hopf et al. [17] reported good and very good objective and subjective results in 26 patients presenting unstable elbow dislocation with isolated unidirectional or multidirectional instability treated using only closed reduction and application of hinged external fixator. The failure rate of 50% was reported in elbow fracture–dislocations treated without adjunct hinged external fixator [18] whereas the use of prolonged cast immobilization to sustain stable reduction was associated with a high incidence of stiffness [3]. To improve outcomes in terms of stability and function, many authors proposed the use of hinged external fixator in addition to bony and ligamentous repair. For Hildebrand et al. [19], treatment of complex elbow fracture–dislocations is based on the reduction of the dislocation with concomitant specific treatment of each associated fracture; they advise ligament repair if the elbow is unstable within an arc of motion from 60° to full flexion, followed by insertion of a hinged external fixator. In their algorithm for management of complex fracture–dislocations—"the terrible triad injury"—Zeiders and Patel [20]

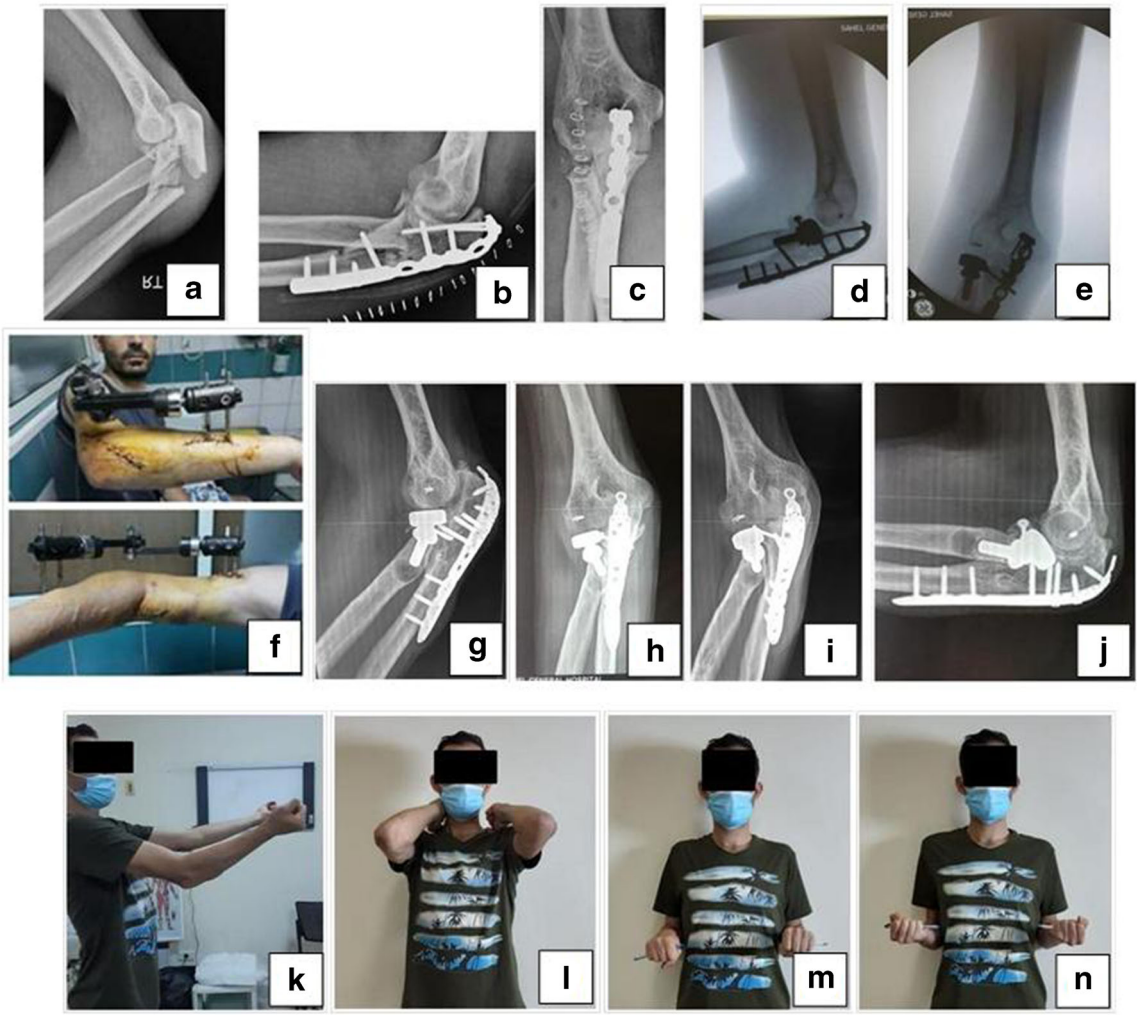

Fig. 3 Case 11. **a** Post-traumatic lateral radiograph showing a posterior Monteggia fracture; **b**, **c** post-operative radiographs of the first operation with fixation of the olecranon fracture associated to radial head excision without coronoid process repair; **d**, **e** intra-operative radiographs of the revision surgery showing elbow reduction after radial head replacement, LCL reinsertion with anchor suture and anterior iliac bone graft to restitute the coronoid deficit; **f** post-operative photographs showing the hinged external fixator with the lateral and the anterior skin incisions; **g**, **h**, **i**, **j** elbow radiographs 5 years after surgery showing mild arthritic changes with concentric and well reduced elbow joint: note that the ulnar plate was exchanged after the revision surgery and the coronoid graft is consolidated, but there is an alarming intra-medullary osteolysis at the tip of the stem of the radial head prosthesis; **k**, **l**, **m**, **n** photographs of the same patient showing complete range of motion excepted for a 35° lack of extension

recommend using a hinged external fixator if the elbow is not stable enough for unrestricted mobilization after bone and ligamentous repair and restoration of the stabilizing effect of the radio-capitellar contact by either ORIF or replacement of the radial head; this would allow early motion and improve functional outcome. In a multicenter prospective study over a two year period grouping 27 patients from 11 centres, Iordens et al. [7] concluded that the use of hinged external fixator provides sufficient stability to start early motion after an acute complex elbow dislocation and residual instability and gives good functional outcomes with minimal disability. Reconstruction of the coronoid process and restitution of the radial head are crucial steps to obtain anatomical restoration; the repaired structures should be protected to allow uneventful bony and ligamentous healing, and a protective external fixator offers a logical alternative to achieve this objective [4, 7]. Pizzoli et al. [21] recently reported satisfactory results in 32 patients in whom an articulated external fixator was used for the treatment of complex elbow injuries including dislocations and fracture–dislocations. Cobb and Morrey [22] achieved good results in six of seven patients for whom they applied a hinged external fixator for persistent elbow instability secondary to traumatic posterior dislocation associated with fracture of the coronoid process; coronoid and ligamentous reconstruction were associated as needed. McKee et al. [8] reported promising results after using a hinged external

fixator in 16 patients with recurrent complex elbow instability; associated fractures and ligamentous injuries were first repaired or reconstructed; the fixator was applied at the time of the primary surgery in two patients and during revision surgery after failure of the initial treatment in 14 patients.

Indications of the hinged external fixation in traumatic elbow disorders include a wide variety of injuries ranging from instability after simple dislocation to complex fracture–dislocations. For O'Driscoll et al [2], the primary indications are represented by (1) persistent instability after ligamentous and bony repair or reconstruction of an acute fracture–dislocation; (2) instability in a patient who is not a candidate for surgery; and (3) deferred treatment of a dislocated and stiff elbow presented more than four weeks after the injury. Relative indication corresponds to the need to protect elbow stability and fracture fixation throughout the early rehabilitation period after surgical repair of an unstable elbow [2]. We advise that hinged external fixator should be available in the operative theater at the time of surgery when treating unstable elbow and complex elbow fracture–dislocations; decision to apply the fixator is usually intra-operative and is typically made after testing of elbow stability following bony and ligamentous repair. In our cases, the surgeon judged necessary the application of the fixator for residual instability in some patients and for protection of the repaired structures in the others. We believe the rigid spanning effect of the fixator provides concentric elbow reduction and immediate stability and protects bony and ligamentous repair from undue harmful stress during healing period by neutralizing antero-posterior and latero-medial forces applied to the elbow; at the same time, alignment of the axis of the fixator's hinge with the axis of rotation of the elbow allows a safe and early smooth range of motion, promoting ligament healing, and avoiding stiffness as well.

Several designs of hinged external fixator are available and their use is generally technically demanding. The main factor for accurate application of any articulated external fixator is the exact placement of the axis pin which requires the recognition of the axis of rotation of the elbow and its appropriate alignment with the axis of the hinge of the fixator [6]. This step is based on the intra-operative identification of two specific landmarks on fluoroscopic strict lateral view of the elbow as detailed above: the dense line of the distal humerus and the center of the capitellum [6, 10]. Recreating the anatomic axis of rotation of the elbow with a hinged fixator allows co-axial and concentric elbow flexion–extension. The normal elbow roughly resembles a simple hinged joint with one axis of rotation which moves slightly by 1 to 2 mm during flexion–extension within a tight axode [10]; consequently, an applied axis of rotation within this range is well accepted and does not disturb elbow motion [10]. On the other hand, if the applied axis of rotation of the hinged fixator is off by more than 3–4 mm from the ideal physiologic mechanical axis of elbow rotation, a cam effect is created into the joint with subsequent alternation of articular compression–distraction during movement; hence, the articular resistance to flexion–extension is increased and concentric elbow motion is impaired with consequent limited arc of motion, cartilage erosion, and loosening of the pins of the fixator secondary to excessive stress on its frame. Madey et al. [23] reported a crucial increase of resistance to elbow movement when the hinge was experimentally set off the best-fit elbow axis by more than 5-mm translation (antero-posterior and proximo-distal) or more than 5° mismatch orientation (internal–external rotation and inversion–eversion). Bigazzi et al. [24] recently reported the use of a new dynamic autocentering elbow hinged external fixator applied without the need to use an axis pin to determine the center of elbow rotation; their preliminary results in seven patients were promising and without any complication. Yet Iordens et al. [7] recognized the occurrence of fixator-related complications in 37% of their patients, Tan et al. [6] stated in a review paper that the true incidence of complications is difficult to determine and they enumerated the following: superficial to deep pin tract infection with possible osteomyelitis, loss of elbow reduction during rehabilitation because of incorrect placement or breakage of the fixator, pin loosening, ulnar nerve injury during the placement of the axis pin by over-penetration of the medial epicondyle or caused by a penetrating distal humeral pin, radial nerve injury by penetrating proximal humeral pin, fracture of the ulna because of large diameter ulnar pins, and reflex sympathetic dystrophy. We recommend—for humeral pins insertion—performing direct open approach of the lateral aspect of the humerus at the level of the distal insertion of the deltoid muscle—deltoid tubercle—which corresponds to the junction proximal mid-third of the bone above the level of emergence of the radial nerve from the lateral intermuscular septum; at this level, the radial nerve is posterior and remains out of harm. On the other hand, high degree of caution should be maintained during insertion of the axis pin in the lateral epicondyle in order not to penetrate the medial epicondyle and to avoid aggression to the ulnar nerve.

In conclusion, despite the fact that our report is a retrospective review of a relatively small number of patients with different patterns of destabilizing elbow injuries, we consider like many other authors that hinged external fixator has a wide variety of indications in complex elbow dislocations and fracture–dislocations. It should be regarded as a valuable adjunct to stabilize unstable elbows and to protect bony and soft tissue repair and healing during the early postoperative period of restitution of range of motion; in these circumstances, satisfactory results in terms of stability and function can be expected. We believe this device should be available in the operating room and ready to use when a surgeon deals with complex elbow dislocation or fracture–dislocation; however, its application is challenging and surgically demanding.

Author contribution A.H.C.: conception of the study, data analysis and interpretation, drafting and writing the article, and final approval of the version to be published.

A.H.A., M.J.H.R., A.A.D., H. M.W., and M.O. B: equal participation in data collection, data analysis, literature analysis, and final approval of the version to be published.

Declarations

Ethical approval The authors declare that the current study was approved by the Ethical Committee of their institution.

Participation consent The authors declare that an informed consent was obtained from all patients to participate in the current study and that the data will be subject for publication.

Publication consent The authors agree and give their consent to publish the current manuscript in "International Orthopaedics."

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