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Original article

# Advantages of expulsion-proof pins in the treatment of olecranon fractures with tension band wiring: Comparison with a control group

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ABSTRACT

*Introduction:* Tension band wiring is considered the standard treatment for transverse olecranon fractures. Its main complications are pin migration and discomfort caused by the hardware. We have designed and used "expulsion-proof" pins (EPP) that are shaped to prevent migration and reduce discomfort. This study compared the complication rate between our device and Kirschner pins (controls).
*Hypothesis:* We hypothesised that EPP would have lower migration rates and fewer complications than standard Kirschner pins.
*Materials and methods:* This retrospective, single-center, multi-operator, observational, study examined data from January 1996 to December 2014. The primary outcome was the occurrence of pin migration. Secondary outcomes were the occurrence of one or more additional complications and the hardware removal rate.
*Results:* The study enrolled 101 patients: 53 (52.4%) with expulsion-proof pins and 48 (47.6%) controls. The mean follow-up was 240.6 days in the EPP group and 268.9 days in the control group. No cases of migration (0%) were found in the EPP group versus 21 (43.7%) cases in the controls ($p < 0.05$). One or more complications occurred in 18 (33.9%) patients in the EPP group versus 46 (95.8%) controls ($p < 0.05$). There was material discomfort in 13 (24.5%) cases and 1 (1.9%) case of secondary displacement in the EPP group, compared with 38 (79.2%) and 7 (14.6%) cases, respectively, in the controls ($p < 0.05$). The rate of delayed consolidation was statistically identical in the two groups ($p = 0.103$). The hardware was removed in 13 (24.5%) cases in the EPP group compared with 36 (75%) controls ($p < 0.05$).
*Conclusion:* EPPs are useful for management of olecranon fractures treated via TBW: the pins do not migrate and can reduce complications, discomfort, secondary displacement, and the hardware removal rate.
*Level of evidence:* Level III, retrospective comparative study.



## 1. Abbreviations

| | |
|---|---|
| AO | German for Association for the Study of Internal Fixation |
| BMI | body mass index |
| DMI | department of medical information |
| EPP | "expulsion-proof" pins |
| K-pins | Kirschner pins |
| TBW | tension band wiring |

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## 2. Introduction

Olecranon fractures constitute 1–10% of all upper limb fractures. The sex ratio is close to unity, and the fractures are often caused by low-energy impacts [1–3]. Usually, such fractures are closed and isolated. Most treatments are surgical [4]; many options are available, including plate fixation, tension band wiring (TBW), intramedullary nailing, and intramedullary screwing [2–8]. Nonsurgical treatment may also be appropriate in some cases [8,9]. The first olecranon fracture osteosynthesis was described by Lister in 1883 [10]. TBW was introduced by Weber in 1963 [11], based on the biomechanical principles established by Pauwels in 1935 [12]. Originally, two Kirschner pins (K-pins) were introduced via the top of the olecranon into the medullary ulnar canal. Surgical assembly featured a steel wire resting on the proximal pin,

**Fig. 1.** Elbow x-rays (profile views) showing the various implanted devices: a: osteosynthesis using K-pins and the Association for Osteosynthesis (AO) technique; b: osteosynthesis using intramedullary K-pins; c: osteosynthesis using expulsion-proof pins (EPPs).

proceeding through a trans-osseous tunnel in the distal ulnar crest, forming an "eight" figure. The aim was to transform the tensile force of the triceps brachii muscle into a joint force compressing the fracture site [12]. Later, the Association for Osteosynthesis (AO) advocated oblique insertion of K-pins to transfix the anterior cortical region of the proximal ulna [13]; this increased the stability of assembly and rendered migration unlikely [13,14]. However, possible complications inherent after transfixion of the anterior cortical ulna included neurological, vascular, and pronosupination issues [15–19]. Some authors thus advocated intramedullary, ulnar pin insertion [7,20,21]. However, up to 75% of discomfort and 80% of migration were reported with K-pins [4,6,7,22–24]. Migration also triggered skin perforation and hardware externalization, in turn promoting infection. Also, secondary displacements, delayed consolidation, and non-union were reported [4,25–29]. In 2014, Matar et al. [4] reported a K-pins migration rate > 40%. To prevent hardware migration and associated complications, we designed an expulsion-proof pin (EPP) in which the proximal end bears a welded ring through which the strapping wire passes. Our principal objectives were:

- to compare the migration rate of our device to that of classical K-pins;
- to compare complications associated with the use of the two pins.

## 3. Materials and methods

### 3.1. Materials

The AO recommends [13,14] insertion of two parallel K-wires 1.6 mm in diameter after fracture reduction using a pointed forceps. The pins must be obliquely inserted at the posteriorly in the olecranon, and must point anteriorly, to transfix the anterior cortical region of the proximal ulna; the pins must pass as close as possible to the joint. After completion of the eight figure, the proximal ends of the pins must be bent and buried to minimize soft tissue conflicts (Fig. 1a).

Another technique using intramedullary K-pins (Fig. 1b) is similar to that recommended by the AO, but differs in one key point: K-pins are inserted into the ulna via the top of the olecranon, and thereafter remain intramedullary (Fig. 1c); cortical transfixion is thus lacking, but the perpendicular relationship to the fracture line is retained. The trans-osseous tunnel and the eight figure are identical to those in the AO technique.

EPPs were developed in 1990 by Lefèvre of the Brest Hospital of France (Aked, 44c, rue de Bray, 35510 Cesson-Sevigne, France). The pins are made of stainless steel, the proximal ends are pointed, and the pins have a curvature of 180°, allowing insertion into the top of the olecranon (Fig. 2a). The proximal end features a concave ring that accepts a steel wire 1.5 mm in diameter, allowing strapping (Fig. 2b). The distal end is pointed, as is the end of the K-pin. Pins of lengths 50, 80, and 130 mm are available; their respective diameters are 1.5, 2, and 2.5 mm. The pins are motor-inserted into the olecranon using a chamber mandrel containing the pre-curved proximal pin ends (Fig. 2c). Pins are inserted perpendicular to the fracture line and are always intramedullary in location.

## 4. Methods

This was an observational, retrospective, monocentric, continuous multi-operator study.

We enrolled all patients with olecranon fractures treated via surgical TBW as recorded by our Department of Medical Information (DMI) from January 1996 to December 2014. The exclusion criteria were: management in a center other than our Center; missing records; treatment other than TBW; and TBW combined with placement of non-exclusively intramedullary EPPs.

### 4.1. Measurement methods

All data were collected by a single investigator by reference to medical records, emergency visits, hospitalizations, operative and anesthesia reports, consultations, and X-rays performed during follow-up. The variables gathered were:

- demographics: sex, age at time of fracture, body mass index (BMI);
- traumatological fracture type according to the Morrey classification [30]: affected side, open or closed fracture, isolated or associated fracture (in the same or another limb);
- date of intervention, type of TBW;
- postoperative follow-up: pin migration and complication status, type of complication and time to onset thereof;
- postoperative long-term follow-up: follow-up delay, removal or not of hardware, ablation delay.

All patients were divided into two groups by TBW type. The 'case' group contained patients who underwent surgery with placement

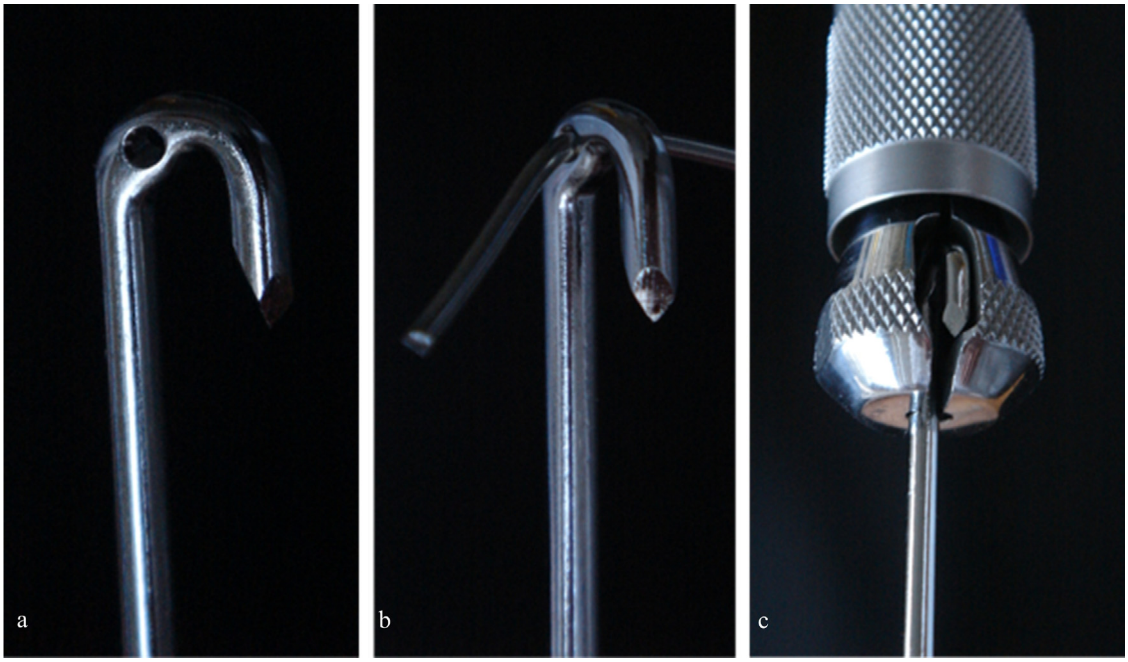


**Fig. 2.** a: photograph of proximal expulsion-proof pins (EPP) ends exhibiting 180° of curvature; b: photograph of the ring that accepts the steel wire; c: photograph of the chamber mandrel containing the pre-curved, proximal pin ends.

of EPPs (the EPP group). Those receiving Kirschner pins constituted the control group. Patients were considered lost to follow-up if they underwent strapping of either type but their follow-up data were inadequate (few or no X-rays, no consultations, no medical follow-ups elsewhere).

The primary endpoint was pin migration (or not). The secondary endpoints were delayed hardware migration, development and timing of other complications, and the need for hardware removal. The assessments were realised until the last follow-up for each patient.

### *4.2. Statistical methods*

All statistical analyses were performed with the aid of MedCalc Software. Quantitative variables were compared using Student's *t*-test, or the Mann–Whitney test when variables were not normally distributed. Categorical qualitative variables were compared with the aid of the $Chi^2$ test, or the exact Fisher test if the numbers were < 5. To be able to measure at least a 50% lower rate of pin migration/complications at the risk $\alpha$ of 5% and $\beta$ of 10%, 40 patients were required in each group. Survival (probability) curves were drawn using the Kaplan–Meier method.

## 5. Results

Our DMI identified 219 patients who may have had olecranon fractures during the study period, of whom 68 were excluded: 39 because they were treated elsewhere and 29 whose records were lost. Of the remaining 151, 40 were excluded because they underwent alternative treatments. Ultimately, 111 records were subjected to analysis (average of 5.8 TBW treatments annually) (Fig. 3).

Of these patients, 61 (55%) were treated using EPPs, 15 (13.5%) employing Kirschner pins and the conventional AO technique, and 35 (31.5%) using intramedullary Kirschner pins; 1 patient (0.9%) who received non-intramedullary EPPs was excluded. The control group was therefore composed of 50 patients (45.1%) who underwent TBW without placement of EPPs (15 + 35). Nine patients (8.1%) were lost to follow-up: 7 in the EPP group (11.6%) and 2 in the control group (4%). The number of patients for whom data were available for analysis and comparison was therefore 101: 53 (52.4%) in the EPP group and 48 (47.6%) controls. The mean follow-up time was 240.6 days (± 173, 53–780, 95% CI [192.9, 288.3 days]) in the EPP group and 268.9 days (± 196, 56–971, 95% CI [211.3, 326.6 days]) in the controls. The two groups did not differ significantly in terms of mean follow-up duration ($p = 0.4769$) (Table 1).

The gender ratio did not differ significantly between the groups ($p = 0.7837$); neither did age ($p = 0.4029$) or BMI ($p = 0.7441$).

In the EPP group, the average duration of immobilization was 21.4 days (± 9.8, 0–45, 95% CI [18.6, 24.1 days]), and patients commenced rehabilitation at a mean of 6 days postoperatively (± 11.4, 0–45, 95% CI [2.9, 9.1 days]). In controls, the mean duration of immobilization was 25.3 days (± 10.3, 0–45, 95% CI [22.3, 28.2 days]) and rehabilitation commenced at a mean of 7.5 postoperative days (± 12.9, 0–45, 95% CI [3.7, 11.2 days]). The two groups did not differ significantly in terms of the length of immobilization ($p = 0.0518$) or time to commencement of rehabilitation ($p = 0.5294$).

In the EPP group, no pin migration was noted, but 21 controls (43.7%) exhibited Kirschner pin migration ($p < 0.000001$).

In the control group, the mean time to pin migration was 123.2 days (± 22.2, 95% CI [79.8, 166.6 days]) and the median time was 54 days (95% CI [23.1, 25.2 days]) (Fig. 4).

In the EPP group, 18 patients (33.9%) developed one or more complications, compared to 46 controls (95.8%) ($p < 0.000001$) (Table 2).

The mean time to development of a complication was 197.1 days in the EPP group (± 36.5, 95% CI [125.6; 268.5 days]) and 56.2 days in controls (± 9.6, 95% CI [37.4, 75.1 days]). The median time to development of a complication was 213 days (95% CI [66; 281 days]) in the EPP group and 30 days (95% CI [25; 44 days]) in controls ($p < 0.0001$) (Fig. 5).

We encountered 13 hardware removal cases (24.5%) in the EPP group and 36 (75%) in controls ($p < 0.0001$).

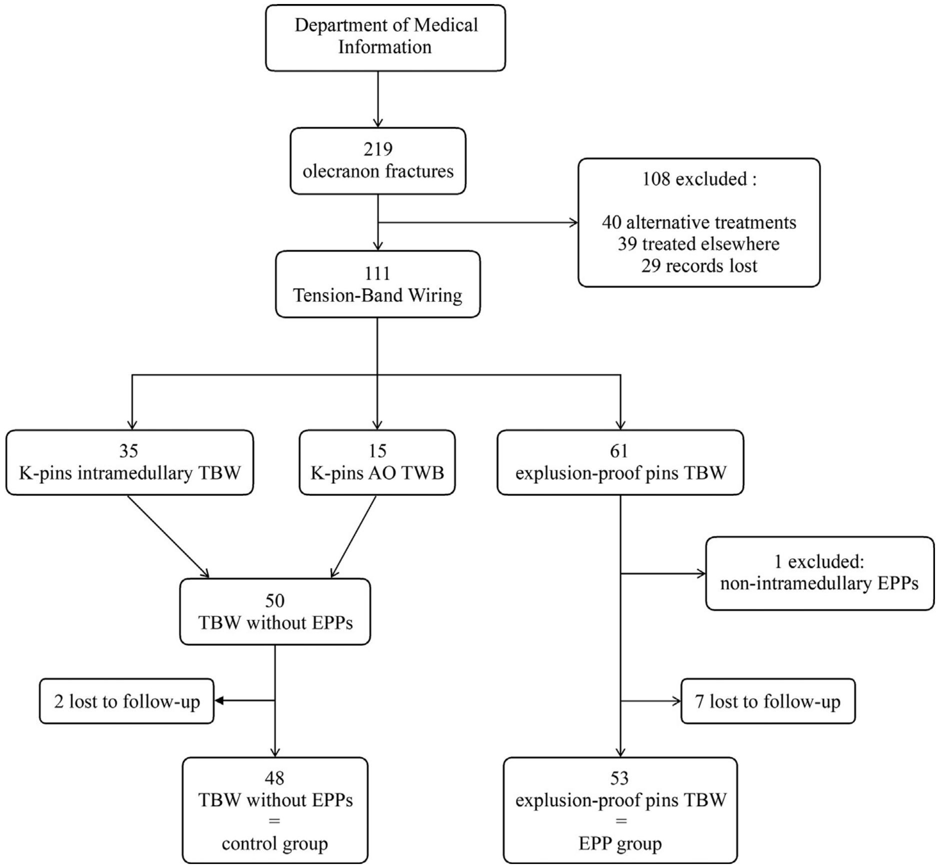


**Fig. 3.** Flow chart of patient enrolment. TBW: tension band wiring; EPP: expulsion-proof pins.

**Table 1**
Demographic, trauma, treatment, and postoperative outcome data of the EPP group and controls.

| | | EPP group | Control group | *p*-value |
|---|---|---|---|---|
| Patients | *n* (%) | 53 (52.4) | 48 (47.6) | – |
| Sex | *n* (%) | | | 0.7837[b] |
| Male | | 29 (54.7) | 24 (50) | – |
| Female | | 24 (45.3) | 24 (50) | – |
| Mean age | years (min to max; SD) | 51.8 (16–96; 22.4) | 55.8 (16–96; 23.9) | 0.4029[a] |
| Mean BMI | kg/m$^2$ (min to max; SD) | 23.9(17.9–32.8; 3.5) | 24.2(17.3–36.7; 3.6) | 0.7441[a] |
| Mean follow-up time | days (min to max; SD) | 240.6(53–780; 173) | 268.9(56–971; 196) | 0.4769[a] |
| Type of fracture | *n* (%) | | | 0.5304[b] |
| IA | | 1 (1.9) | 1 (2.1) | – |
| IB | | 0 (0) | 0 (0) | – |
| IIA | | 36 (67.9) | 31 (64.6) | – |
| IIB | | 15 (28.3) | 13 (27.1) | – |
| IIIA | | 1 (1.9) | 3 (6.2) | – |
| IIIB | | 0 (0) | 0 (0) | – |
| Affected side | *n* (%) | | | 0.1411[b] |
| Right | | 32 (60.4) | 21 (42.7) | – |
| Left | | 21 (39.6) | 27 (56.3) | – |
| Skin status | *n* (%) | | | 0.9295[b] |
| Closed fracture | | 46 (86.8) | 41 (85.4) | – |
| Open fracture | | 7 (13.2) | 7 (14.6) | – |
| Associated fractures | *n* (%) | | | 0.3161[b] |
| No | | 40 (75.5) | 41 (85.4) | – |
| Yes | | 13 (24.5) | 7 (14.6) | – |
| Mean duration of immobilization | days (min to max; SD) | 21.4 (0–45; 9.79) | 25.3 (0–45; 10.28) | 0.0518[c] |
| Mean time to commencement of rehabilitation | days (min to max; SD) | 6 (0–45; 11.4) | 7.5 (0–45; 12.9) | 0.5294[a] |

EPP: expulsion-proof pins; *n*: number; BMI: body mass index; SD: standard deviation.
[a] Mann–Whitney U-test.
[b] Chi$^2$ test.
[c] Student's *t*-test.

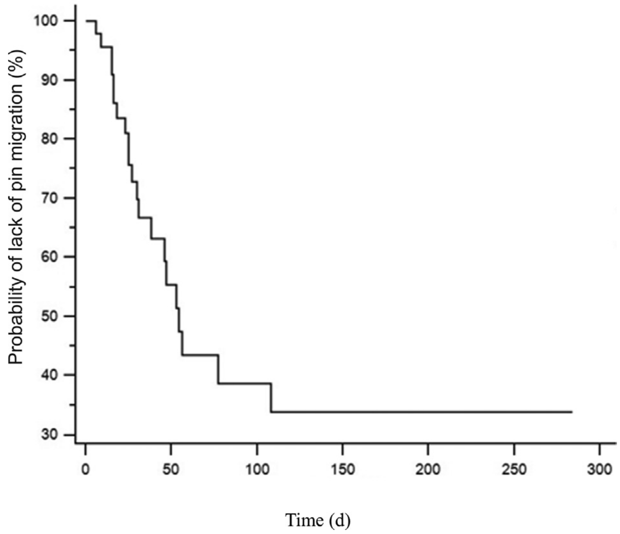


**Fig. 4.** Probability of lack of pin migration (%) in the control group (as a function of time) as revealed by Kaplan–Meier analysis (d = days).

The post-hoc calculation of the statistical power was > 99% considering pin migration rates, complications rates, including hardware removal rates.

## 6. Discussion

The aim of this study was to:

- to compare the migration rate of our EPP to classical K-pins;
- to compare complications associated with the use of the two pins either for EPP or classical K-pins.

In the EPP group, no pin migration was noted, while 21 case of the control group (43.7%) exhibited Kirschner pin migration ($p < 0.000001$). In the EPP group, 18 patients (33.9%) developed one or more complications, compared to 46 cases in the control group (95.8%) ($p < 0.000001$). The two groups were comparable for the demographic parameters. Even if the study implied small cohorts, the post-hoc statistical power of the study was computed to be > 99%. It may be explained by the high differences concerning migration rates and complications rates in the two groups. These

**Table 2**
Pin migration rates, types and rates of other complications, and hardware removal rates of the EPP group and controls.

| | EPP group*n* (%) | Control group*n* (%) | *p*-value |
|---|---|---|---|
| Pin migration | 0 (0) | 21 (43.7) | < 0.000001[a] |
| Other complications | 18 (33.9) | 46 (95.8) | < 0.000001[a] |
| Hardware discomfort | 13 (24.5) | 38 (79.2) | < 0.000001[a] |
| Secondary displacement | 1 (1.9) | 7 (14.6) | 0.025[a] |
| Externalization | 0 (0) | 4 (8.3) | 0.117[a] |
| Infection of the operative site | 1 (1.9) | 4 (8.3) | 0.188[a] |
| Equipment disassembly | 0 (0) | 3 (6.2) | 0.103[a] |
| Steel wire breakage | 1 (1.9) | 0 (0) | 1.00[a] |
| Assembly relaxation | 0 (0) | 1 (2.1) | 0.475[a] |
| RSDS | 1 (1.9) | 0 (0) | 1.00[a] |
| Uninfected hygroma | 1 (1.9) | 5 (10.4) | 0.099[a] |
| Post-traumatic cicatricial disunity | 1 (1.9) | 0 (0) | 1.00[a] |
| Prior conflict | 0 (0) | 1 (2.1) | 0.475[a] |
| Delayed consolidation | 0 (0) | 3 (6.2) | 0.103[a] |
| Hardware removal | 13 (24.5) | 36 (75) | < 0.0001[b] |

EPP: expulsion-proof pins; RSDS: reflex sympathetic dystrophy syndrome.
[a] Fisher's exact test.
[b] $Chi^2$ test.

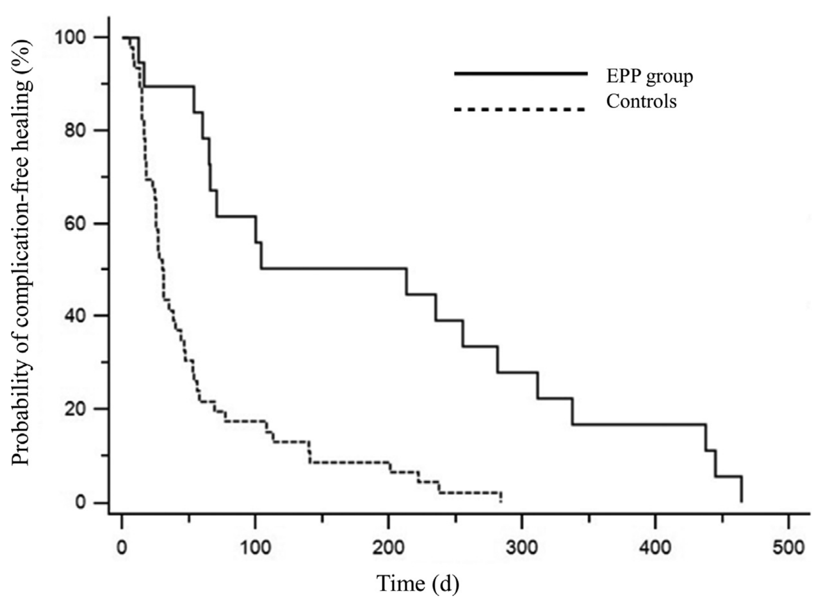


**Fig. 5.** Probability of complication-free healing (%) in the expulsion-proof pins (EPP) group and controls (as functions of time) as revealed by Kaplan–Meier analysis (d = days).

results confirm that EPP is a relevant technique for the management of olecranon fractures.

TBW has been used for olecranon fracture fixation for many years. The biomechanical basis of the procedure is well-established and good results were obtained in long-term series [5,18,31–34]. However, complications associated with the subcutaneous prominence of Kirschner pins are common.

In 1985 and 1986, Macko and Szabo [22] and Jensen and Olsen [25] reported pin migration rates of 40 and 45%, respectively. Although the rate was < 15% in several series [1,26,28,35–37], migration attained 80% in other series [7]. The pin migration rate in our control group (43.7%) was close to that observed by Van der Linden et al. [23] in a series of 59 TBW patients (38.9%). However, we recorded no EPP migration.

Macko and Szabo [22] and Jensen and Olsen [25] reported externalization rates of 20 and 18.8% respectively; generally, the rate is < 10% [21,32,38–42]. We encountered four cases of externalization (8.3%) in controls and none in the EPP group; however, the difference was not significant, probably because of the small study population ($p = 0.117$).

Discomfort caused by subcutaneous hardware is common: the rate is usually > 30% [2,22–29,34–39,43]. The discomfort rate in our control group was 79.2%, similar to that recorded by Chaladis et al. [2] in 2008 (82.3%). The rate was 24.5% in the EPP group, similar to that reported in the recent Chan and Donnelly [40] series (20.6%).

The consolidation delay rate after TBW ranges from 0 to 10% [1,2,22,28,29,34–37,39–41]. We encountered three cases of delayed consolidation (6.2%) in the EPP group and none in the controls; the difference was not significant ($p = 0.103$).

The secondary displacement rate is usually < 10% [22,29,35–37,42]. The highest rates were reported by Helm et al. [26] and Hume and Wiss [28] (20.5 and 52.6%, respectively). We encountered only one case (1.9%) of secondary displacement in the EPP group and seven (14.6%) in the control group ($p = 0.025$).

TBW is associated with a high hardware removal rate, often > 60% [1,21,22,25,26,29], as was the case in our control group (75%). Of series reported in the last 10 years, the highest rates were recorded by Chaladis et al. [2] and Flintermann et al. [42] (82 and 92%, respectively). Huang et al. [21] systematically removed hardware. The use of EPPs was associated with a lower hardware removal rate (24.5%), averting the need for a second intervention.

In 1982, Netz and Strömberg [44] developed a spindle that could not recoil. No instance of pin migration or discomfort was recorded in patients treated with this device. The Larsen and Jensen series [43] (20 TBW patients fitted with Netz pins) did not report any migration or externalization, but it reported nine cases of discomfort or pain (45%), one secondary displacement (5%), and one infection (5%).

In 2013, Kim et al. [45] developed a pin that is very similar to the Netz pin. The distal end is pointed, and the proximal end bears a 1.1-mm-diameter eyelet, extended on a breakable segment used for insertion into the motor. Kim et al.'s series of 44 patients reported no instances of pin migration, secondary displacement, infection, or externalization, but it reported nine cases of discomfort or pain (20.4%).

The present study is retrospective in nature. Although differences in the primary endpoint and some secondary endpoints were apparent, a prospective study is required. All analyses were performed by a single observer; evaluation bias may be in play. We identified 219 patients by the codes assigned by our DIM. Some errors could occur.

## 7. Conclusion

EPPs are useful for management of olecranon fractures treated via TBW: the pins do not migrate and can reduce complications, discomfort, secondary displacement, and the hardware removal rate.

## Disclosure of interest

The authors declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Pr. Lefèvre is involved in the conception of the EPP device that may be considered like a link of interest. However, he does not have any financial interest that may be considered as a conflict of interest. The other authors declare that they have no competing interest.

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## Contributor roles

Remi Di Francia, M.D. (data curation; formal analysis; visualization; writing – original draft; statistical analysis; writing – review & editing).

Hoel Letissier M.D, M.Sc. (statistical analysis; writing – review & editing).

Dominique Le Nen, MD Ph.D. (validation; supervision, reviewing & editing).

Christian Lefèvre, MD, Ph.D. (conceptualization; device conception, supervision; reviewing & editing).

Fredéric Dubrana, MD, Ph.D. (supervision; reviewing & editing).

Eric Stindel, MD, Ph.D. (conceptualization; formal analysis; methodology; supervision; validation; reviewing & editing).

## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.otsr.2019.08.020.

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