Tension plate for treatment of olecranon fractures: new surgical technique and case series study

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Background: Our aim was to determine the effectiveness of a new surgical technique for olecranon fractures using a tension plate (TP) designed by the operating surgeon.

Methods: We included patients with olecranon fractures treated between September 2010 and August 2013 in our study. Treatment involved a new implant and operative technique, which combined the most favourable characteristics of 2 frequently used methods, tension band wiring and plate osteosynthesis, while eliminating their shortcomings. The new method was based on the newly constructed implant.

Results: Twenty patients participated in our study. We obtained the following functional results with our TP: median flexion 147.5° (interquartile range [IQR] 130°–155°), median extension 135°/deficit 10° (IQR 135°–145°), median pronation 90° (IQR 81.3°–90°), median supination 90° (IQR 80°–90°). Implant-related complications were noted in 1 patient, and implants were removed in 3 patients. The mean functional Mayo elbow performance score was 94.8 (range 65–100). The removal of the implant was considerably less frequent in patients operated using the new method and implant than in patients operated using conventional methods at our institution ($p < 0.001$). Mean duration of follow-up was 8 months.

Conclusion: Our TP for the treatment of olecranon fractures is safe and effective. Functional results are very good, with significantly decreased postoperative inconveniences and need to remove the implant. Less osteosynthetic material was used for TP construction, but stability was preserved.

Contexte : Notre but était de déterminer l'efficacité d'une nouvelle technique chirurgicale de réduction des fractures de l'olécrâne à l'aide d'un système à plaque et broches (SPE), conçue par le chirurgien pratiquant l'intervention.

Méthodes : Nous avons inclus dans notre étude des patients victimes d'une fracture de l'olécrâne traités entre septembre 2010 et août 2013. Le traitement reposait sur un implant et une technique chirurgicale d'un genre nouveau, réunissant les caractéristiques les plus utiles de 2 méthodes d'ostéosynthèse couramment employées, soit le brochage-haubanage et la pose de plaque, tout en permettant d'en éviter les inconvénients. La nouvelle méthode a recours à un implant de conception nouvelle.

Résultats : Vingt patients ont participé à notre étude. Nous avons obtenu les résultats fonctionnels suivants avec notre SPE : flexion médiane 147,5° (écart interquartile [ÉIQ] 130°–155°), extension médiane 135°/déficit 10° (ÉIQ 135°–145°), pronation médiane 90° (ÉIQ 81,3°–90°), supination médiane 90° (ÉIQ 80°–90°). Des complications liées à l'implant ont été notées chez 1 patient et les implants ont été retirés chez 3 patients. Le score fonctionnel moyen à l'échelle MEPS (Mayo elbow performance score) a été de 94,8 (entre 65 et 100). Les retraits d'implant ont été nettement moins fréquents chez les patients soumis au nouveau type d'intervention et implant que chez les patients soumis aux méthodes d'intervention classiques dans notre établissement ($p < 0,001$). Le suivi moyen a été de 8 mois.

Conclusion : Notre SPE pour le traitement des fractures de l'olécrâne est sécuritaire et efficace. Les résultats fonctionnels sont très bons et s'accompagnent d'un nombre significativement moindre de complications postopératoires et de retraits d'implants. La construction de cette SPE a nécessité moins de matériel d'ostéosynthèse, mais la stabilité a été préservée.

Olecranon fractures account for 10% of all fractures of the upper extremities.¹ These fractures occur in cases of direct hit in the elbow region or of a pull of the triceps brachii muscle through its distal attachment site on the olecranon during a fall on a partially stretched arm.^{1,2} Only 5%–7% of these fractures occur without substantial displacement of fractured fragments, while more than 93% include fragment dislocation that requires active surgical intervention.^{3–6} Given that these are intra-articular fractures, it is very important to achieve precise anatomic fragment reduction and stable osteosynthesis and to start with early mobilization and physical therapy. Nowadays a number of operative methods are used; 2 of the most frequent are tension band wiring and osteosynthesis with a plate and screws. The method of tension band wiring is the most frequently used method of surgical treatment in cases of olecranon fractures.^{6–11} Despite maximal care, precision of surgical work and the expertise of the surgeon, up to 60% of patients experience varying degrees of migration and protrusion of the osteosynthetic material and associated pain, personal unease and slow rehabilitation with reduced mobility.^{12,13} The second most frequently used operative technique is osteosynthesis with conventional plate and screws. It has been suggested that using this method to treat comminutive and/or unstable fractures (Mayo classification II B and III A and B), for which the use of tension band wiring is not advisable, reduces the frequency of complications related to the migration of osteosynthetic material and the associated pain and unease.¹⁴ Yet, the use of a large number of screws to achieve stability increases the probability of subcutaneous protrusion of screw heads (more pronounced subjective hardships and the need for earlier removal of the implant) and increases the possibility of tissue reaction against the considerable quantity of foreign objects implanted during the operation. The purpose of our study was to determine the effectiveness of a new technique of surgical treatment for olecranon fractures using a new tension plate (TP) designed by the operating surgeon (B.L.).

METHODS

Patients

We recruited patients presenting to the department of surgery, Split University Hospital Centre, Split, Croatia, for the surgical treatment of olecranon fractures between September 2010 and August 2013. Inclusion criteria were Mayo classification II–III olecranon fractures as well as fractures of the proximal ulna involving the region up to 3 cm distal to the trochlear notch. Exclusion criteria were pre-existing injuries of the elbow, distal brachial or proximal antebrachial region, pre-existing neurologic damage or illness of the arm involved, congenital deformities or diseases of the musculoskeletal system and systemic neurologic conditions.

Patients underwent the new surgical technique and received the newly developed implant (TP). The same surgeon (B.L.) performed all the operations. We compared the incidence of implant removal in the present cohort with that in 49 patients who had surgery using the conventional techniques, mostly tension band wiring, at our hospital between April 2006 and November 2012 (control group). We obtained informed consent from all patients, and the study protocol was approved by the Ethical Committee of Split University Hospital Centre.

Outcome measures

The primary aim of our study was to achieve adequate functional results (i.e., not worse than results of tension band wiring or conventional plating), with reduced difficulties related to the bulging and migration of osteosynthetic materials. We also aimed to reduce the quantity of inserted osteosynthetic material in relation to the quantity required for conventional plating. The functional range of movement in the operated elbow that we sought to achieve was flexion $\geq 128^\circ$, extension $\geq 116^\circ$, and pronation and supination $\geq 72^\circ$, which corresponds to the average functional status when the current surgical techniques are applied. Our goal was that 40% or more of our patients would have no marked subjective difficulties; this percentage is comparable to that for patients treated with tension band wiring or conventional plating.¹⁵ We compared the results obtained in the present cohort with those of our control group.

Surgery

Surgery was performed with the patient in prone position and under general anesthesia and without the application of a tourniquet. The fracture was exposed through a posterior midline incision curving around the tip of the olecranon. In case of more copious bleeding in the olecranon bursa, excision of the bursa was performed. The Kirschner wires were always “anchored” in the opposite (anterior) cortex of the ulna. After radiographic confirmation of the position of the fragments, the TP was introduced on the dorsal (posterior) surface of the ulna (Fig. 1). The TP forms the basis of the new operative technique. This implant has a number of innovations. The existence of 2 holes (diameter 2 mm) on the proximal part enables application of the Kirschner wires (diameter 1.8 mm) through the implant. The tip of the hook is narrower and shorter; the base width of the tip is 5 mm, it has a steep angle of 35° , and the base-to-tip length is 7 mm, allowing easier penetration in the bony structure of the olecranon without disturbing previously achieved fragment reduction. The curve of the plate is contoured according to the shape of the olecranon, and the body of the plate is slightly curved in a tubular manner, with the total length of the

plate measuring 82 mm, allowing it to be used in most cases of olecranon and proximal ulnar fractures. There is an opening for the distal “guiding” screw used to achieve

Fig. 1. Intraoperative placement of the tension plate.

Fig. 2. Tension plate (A) holes for distal “guiding” and for distal screw, and (B) 2 holes enabling application of the Kirschner wires.

interfragmentary compression. Finally there is only 1 hole (centered 6 mm proximal to the end of the plate) through which the distal screw fastens the plate onto the ulna (Fig. 2). Drainage of the operation area was regularly performed, with the drain usually being removed after 24 hours. Postoperative immobilization was never used.

Follow-up

Obligatory radiological and clinical follow-ups were carried out 1, 3 and 6 months after the surgery. During these visits, we obtained anteroposterior and lateral radiographs of the operated elbow (Fig. 3). Classical goniometry was used to evaluate postoperative range of motion of the injured and healthy elbow joints. We assessed the function of the extremity by measuring the range of flexion, extension, pronation and supination of the forearm, and we compared these values with those for the uninjured extremity of the same patient and with the reference values in literature to assess the success of the operative method and of the implant applied.^{16–18} Approximately 6 months after the surgery, the patients were interviewed about their general impression and their possible difficulties (hardships present or not); in the presence of hardships we tried to assess them quantitatively (mild, moderate, intense). For this investigation we used the Mayo elbow performance score questionnaire, which takes into consideration objective (range of motion, stability of the joint) as well as subjective (existence and intensity of pain, daily functions of the joint) parameters for the appraisal of joint function.

Statistical analysis

We analyzed the data using Microsoft Excel version 11.0 for Windows. The normality of the distribution of continuous variables was tested using the Shapiro–Wilk test. Medians and interquartile ranges (IQRs) were used as measures of central tendency and variability when the distribution significantly deviated from normal. We used the χ^2 test to analyze the significance of between-group differences in frequency of categorical variables, and the ϕ coefficient of association was used as the standardized measure of effect size in case of statistically significant differences. Group difference is continuous, but variables that were not normally distributed were analyzed using the Mann–Whitney *U* test. The Shapiro–Wilk test did not indicate a significant difference in age distribution, so means and standard deviations were used as measures of central tendency and variability. To make our results more comparable to those from other studies (for the sake of possible future meta-analysis), we used means with 95% confidence intervals (CIs) for comparison with noninferiority margins. We considered results to be significant at $p < 0.05$.

RESULTS

A total of 26 patients were surgically treated for olecranon fractures during our study period. Six of them were excluded: 4 patients met 1 or more exclusion criteria and 2 refused to participate. Our final sample comprised 20 patients (10 men and 10 women) with a mean age of 49.2 (range 19–84) years. Ten patients had fractured the left and 10 had fractured the right olecranon. Fourteen patients had Mayo classification IIA, 4 had IIB and 1 had IIIB fractures; the remaining patient had a Monteggia fracture on the ulna just distal to the trochlear notch. Patient demographic and clinical characteristics are summarized in Table 1. The mean duration of follow-up was 8 (range 3–24) months.

In case of all functional tests, maximum values were at the level of physiologic maximum. The average time required for fractures to heal was 9 (range 8–14) weeks. The best results were obtained for pronation and supination, for which mean values were close to and median values were at the level of physiologic maximum. Mean flexion was above the noninferiority margin, while its lower limit was only 0.1° below the noninferiority margin. For all other functional test results, the lower limits of the CIs were above the noninferiority margin (Tables 2 and 3). To examine further functional test results, we determined the proportion of patients whose functional test results were at or above the noninferiority margin (functional loss of $\leq 20\%$; Table 4). Proportions of patients whose functional test results were at the levels of

physiologic maximums were also determined. The mean functional Mayo elbow performance score was 94.8 (range 65–100). None of the patients had extension deficit of more than 20%, and 7 of 20 had no extension deficit at all (35.0%, 95% CI 12.1%–57.9%). Complete recovery of pronation and supination was achieved in 14 of 20 patients (70.0%, 95% CI 48.0%–92.0%). Three patients reported subjective problems (15.0%, 95% CI 0.0%–32.2%). In the postoperative period, 1 patient experienced a surgical site infection. In another patient with an accompanying comminutive fracture of the coronoid, a hypertrophic callus developed in the coronoid region, and extensive ectopic calcifications in the joint region were observed. Although these changes had no direct influence on the successful healing of the olecranon fracture, the final functional outcome was compromised, so we decided to remove the implant. One patient reported typical objective and subjective symptoms of the migration of osteosynthetic material, and after the implant removal he achieved a satisfactory functional result. We compared the prevalence of implant extraction in this cohort with that in our control group. In the control group, 23 of 49 patients (46.9%) were men, 28 of 49 (57.1%) had a left elbow injury, and the median age was 47 (IQR 29–62) years. The implants were removed in 3 patients who underwent the new operative treatment, while hardware was extracted in 31 patients in the control group (Table 5). Implant extraction was significantly less prevalent in patients from the present series than in the control group ($p < 0.001$).

Fig. 3. Radiographs of a patient with a Monteggia fracture: (A) preoperative radiograph, (B) lateral radiograph 3 months after the surgery, and (C) anteroposterior radiograph 3 months after the surgery.

DISCUSSION

The aim of operative treatment for olecranon fractures is to establish normal anatomy and function in the elbow joint in such a way that the newly established regular intra-articular and extra-articular relations are stably fixed. This enables early mobilization of the elbow involved, thus contributing to a decrease of posttraumatic stiffness of the joint. There are a number of methods to achieve this; among them, the most frequently used are tension band wiring and the conventional plating method.⁵ The most widely adopted method of tension band wiring achieves healing by transforming the posterior pulling force (created by the triceps muscle during contraction) into an anterior intra-articular interfragmentary compression on the joint surface.⁶⁻¹⁰ The usual complications of this method are infections, delayed healing, fracture healing in an unfavourable position and, somewhat less frequently, ulnar nerve palsy. However, the most frequent complication is a migration of the Kirschner wires and subcutaneous protrusion of knots on the tension band wiring, which causes pain, weakened function, interruption in physical therapy and problems with the healing of the surgical wound. Although the fracture healing and functional results are usually satisfactory, the frequent difficulties experienced by the patients, most commonly caused by the migration of the osteosynthetic material, substantially compromise this method and lead to an additional opera-

tion to remove the implant.¹¹⁻¹⁵ With the conventional olecranon plate, these disturbances are usually accompanied by an intense local reaction due to the use of a substantial quantity of osteosynthetic material (especially the use of many screws), which also causes a feeling of unease and often leads to the subsequent removal of the implant. For osteosynthesis with plate and screws, somewhat more frequent is a secondary dislocation of the proximal fragment with the loss of correct intra-articular relations.

With this information in mind, our aim was to achieve a state of adequate reposition, stable fixation and interfragmentary compression, together with reduction of difficulties caused by subsequent migration of the implant, which could lead to another operation for removal of osteosynthetic material, by introducing innovation in the construction of the implant as well as in operative technique. We regularly penetrated Kirschner wires into the opposite cortex of the ulna, since our earlier experience was in agreement with that reported in studies by Mullett and colleagues¹⁹ and Huang and colleagues.²⁰ These studies showed that this procedure almost doubles the firmness of the construction itself. In the present study, we observed no secondary loss of the reposition of the proximal fragment, which was held in position by 3 pivotal points (the tip of the TP plate and 2 Kirschner wires). The absence of postoperative dislocation of the fragments is especially important when one bears in mind that postoperative immobilization was never used (except the standard bandaging material during the first 24 h after the surgery), although the use of a removable splint is widely adopted manner of aftercare in similar fracture cases.²¹ In addition, there were no signs of a postponed or delayed healing process, nor of late dislocation of the fragments. Since we considered the olecranon bursa to be a sort of natural "buffer zone" between the olecranon and the support on which the patient rested the elbow, we removed it only in cases of a marked haemorrhage into the bursa or of penetrating injuries with the penetration channel passing through the bursa itself. However, the results of our study indicate the somewhat exaggerated importance of the bursa in mechanical protection of the elbow; of the 5 patients in whom we had to remove the olecranon bursa during the operation, only 1 experienced mechanical irritation from the osteosynthetic material when resting the elbow on a solid support. On the contrary, the only patient who reported subjective difficulties caused by the migration of the osteosynthetic material had an intact bursa.

Table 1. Demographic and clinical characteristics of the study cohort (n = 20)

Variable	No. (%)
Sex	
Male	10 (50)
Female	10 (50)
Fracture type	
IIA	14 (70)
IIB	4 (20)
IIIB	1 (5)
Monteggia	1 (5)
Side	
Left	10 (50)
Right	10 (50)
Bursa removed	
No	15 (75)
Yes	5 (25)

Table 2. Results of functional tests

Result	Min.	Max.	Median (IQR)	Mean ± SD (95% CI)
Flexion	90	160	147.5 (130.0–155.0)	138.5 ± 20.91 (128.7–148.3)
Extension	125	145	135.0 (135.0–145.0)	137.3 ± 6.58 (134.2–140.3)
Pronation	50	90	90.0 (81.3–90.0)	85.3 ± 9.93 (80.6–89.9)
Supination	50	90	90.0 (80.0–90.0)	85.0 ± 10.0 (80.3–89.7)

CI = confidence interval; IQR = interquartile range; SD = standard deviation.

The average time required for fracture healing was 9 (range 8–14) weeks, which is in accordance with the results reported in the literature. Oh and colleagues²² reported an average healing time of 10 weeks for comminuted olecranon fractures. We compared the functional results of the present cohort with those reported by Rommens and colleagues,¹⁶ who reported a considerably higher frequency of subjective difficulties in 58 patients with surgically treated olecranon fractures (before their implant was removed). Given the results of bone grafting reported by Cervera-Irimia and colleagues²³ in patients with comminuted fractures, we considered doing the same in 3 patients with significant comminution but opted against bone grafting as the degree of comminution in our patients was not sufficient to warrant this procedure. Erturur and colleagues¹⁷

Table 3. Results of functional tests: physiologic maximums, noninferiority margins and median values of obtained results

Result	Physiologic maximum	Noninferiority margin	Median (95% CI)
Flexion	160	128	147.5 (130.0–155.0)
Extension	145	116	135.0 (135.0–145.0)
Pronation	90	72	90.0 (85.0–90.0)
Supination	90	72	90.0 (80.0–90.0)

CI = confidence interval.

Table 4. Proportion of patients with functional deficit of 20% or less, and those with no deficit

Result	Deficit 20% or less, <i>n</i> = 20	No deficit, <i>n</i> = 20
	No. (%) [95% CI]	No. (%) [95% CI]
Flexion	16 (80.0) [60.8–99.2]	3 (15.0) [0.0–32.2]
Extension	20 (100.0) [99.8–100.0]	7 (35.0) [12.1–57.9]
Pronation	18 (90.0) [75.6–100.0]	14 (70.0) [48.0–92.0]
Supination	18 (90.0) [75.6–100.0]	14 (70.0) [48.0–92.0]

CI = confidence interval.

Table 5. Operative treatment by sex, side of an injured elbow and implant extraction

	Group; no. (%)			
Variable	New treatment	Conventional surgery	<i>p</i> value*	Effect size†
Sex				
Male	10 (50.0)	23 (46.9)	0.82	
Female	10 (50.0)	26 (53.1)		
Total	20 (100)	49 (100)		
Side				
Left	10 (50.0)	28 (57.1)	0.59	
Right	10 (50.0)	21 (42.9)		
Total	20 (100)	49 (100)		
Extraction				
No	17 (85.0)	18 (36.7)	< 0.001	0.44
Yes	3 (15.0)	31 (63.3)		
Total	20 (100)	49 (100)		

* χ^2 test.
†Standardized measure of effect size; ϕ coefficient of association.

used the conventional plate for the treatment of olecranon fractures classified as Mayo IIB and IIIB fractures. They obtained an average flexion and extension of 116° (our result was 138°), and an average pronation and supination of 126° (our result was 170.3°).

Data from the Mayo elbow performance score questionnaire indicate that our patients' symptoms (when the material was lodged) related to mild pain in the region of the incision early in the follow-up period (4 patients, 20%) and to smaller hardships during the maintenance of personal hygiene (e.g., more arduous elbow flexion when washing the back; 2 patients, 10%). These hardships usually disappeared before the last mandatory follow-up examination 6 months after the operation.

We compared the incidence of implant removal in the present cohort with that in the 49 patients in our control group, who underwent conventional surgical treatment for olecranon fractures at our hospital between 2006 and 2012. In the control group 31 of 49 patients had their implants removed compared with 3 of 20 in the present cohort. Given that in our hospital, the only indications for osteosynthetic material removal are objective or subjective troubles concerning the implant, we can easily conclude that these 31 control patients (63.3%) experienced some degree of implant-related discomfort. This finding appears to be in agreement with data from the literature. Rommens and colleagues¹³ reported that 40% of patients experienced no hardships in the fracture area before the removal of the implant, whereas most reported various hardships. Only 15% of patients in the present cohort had their implants removed, compared with 63.3% in our control group, indicating that substantially fewer patients who received our new implant and surgical procedure had to have their implant removed than patients who underwent conventional treatment. In view of all the results discussed, it is reasonable to conclude that use of the TP and the new operative method can achieve considerably less frequent and intense subjective hardships and equally good functional outcomes as the implants and operative techniques used previously. This conclusion is supported by the previously mentioned Mayo elbow performance scores.

CONCLUSION

Use of a TP for the treatment of olecranon fractures is safe and effective. Functional results are very good, with a significant decrease of postoperative subjective inconveniences and of the need to remove the implant. In addition, less osteosynthetic material is required to achieve a stable construction.

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