**Introduction**

The exceptional mobility of our upper extremity reflects the sum of a chain of very mobile joints. In this chain, a loss of function of the elbow joint is the most difficultly compensated. Moderate flexion, extension or pro/supination deficits affect activities of daily life: in case of a complete elbow stiffness there is a thorough change in quality of life.

With a ratio of 10% of all upper extremity lesions, the olecranon fracture is one of its most frequent entities. The lesion may be the result of an indirect or direct trauma; forced hyperextension of the elbow joint is considered a frequent mechanism. A number of classification systems has been developed but no one is generally accepted. In general, they are descriptive and based on localization of the mean fracture line and its morphological appearance. The degree of instability is also a marker. In this study, fractures were classified in accordance to the system of WADSWORTH (13), of HORNE and TANZER (1), of the Mayo clinic (7) and of SCHATZKER modified by SCHMELING (11-12). WADSWORTH distinguished three types of olecranon fractures (13): avulsion of a small fragment (Type 1), simple fracture with larger proximal fragment (Type 2) and multifragmental fracture (Type 3). HORNE and TANZER also described three different types (1): intraarticular fracture in the proximal third of the articular surface or small oblique extraarticular fracture (Type 1), fracture running through the middle third, subdivided into simple (Type 2a) and complex (Type 2b) and fracture running through the distal third of the olecranon fossa (Type 3). MORREY presents his Mayo classification (7). He correlated displacement with (in)stability and proposed three fracture types with two subtypes each. In the first type, the fractures are undisplaced. Type IA has a simple fracture type, type IB a complex one. In the second type, the fracture is displaced but the elbow joint is stable. Type IIA collects simple fracture types, type IIB complex ones. In the third type, the olecranon fracture is displaced and the elbow joint unstable. Type IIIA fractures have simple fracture types, type IIIB complex ones. Based on the classification of SCHATZKER (11), SCHMELING distinguished between transverse, oblique and plurifragmental fractures, the latter without or with dislocation (12). Among the transverse fractures, they
subclassify in simple (A1) and complex lesions with central impaction (A2). The oblique fractures are subdivided into proximal (B1) and distal types (B2). Plurifragmental fractures without (Type C) and with dislocation, combined with a radial head fracture (Type D) are the most severe.

The treatment of an olecranon fracture is always operative, since it is an intraarticular lesion with loss of the extension mechanism of the elbow joint. Tension band wiring has been introduced by WEBER and VASEY in 1963 (14) (Fig. 1a-c). The tension band principle has never been abandoned since then but several modifications, especially to avoid migration of the Kirschner wires, have been described. Intramedullary devices or plate and screws have also been promoted (3, 8).

Although the olecranon fracture is regarded as one of the simplest articular lesions and its operative treatment as straightforward, reports exist on a number of postoperative problems (2, 5, 9). Infection, delayed union and ulnar nerve palsy have been described in up to 10% of the cases. Specific complaints are related to the subcutaneous position of the Kirschner wires (4). Their migration may be responsible for secondary displacement, wound healing problems, local pain and a number of reinterventions.

In this retrospective study, the authors correlate radiological, subjective and functional outcome after operative treatment of olecranon fractures with fracture type, fracture classification, correctness of operative technique as well as with the presence and type of associated lesions.

Material and methods

Between March 1, 1992 and March 1, 2000, the authors performed open reduction and internal fixation of...
95 consecutive olecranon fractures. The medical charts and radiographs were reviewed for age, sex, fracture classification, associated lesions, comorbidity, timing and type of operative treatment, correctness of operative technique, postoperative complications and hardware removal. After an average of 36 months, 58 of 69 available patients (84.0%) could be reexamined clinically and/or radiologically. Twenty-three patients were lost to follow-up despite exhaustive search processes. Eleven patients refused control examination for different reasons (age, diseases, distance to hospital). Three patients had died. All patients were asked to fill in a questionnaire with questions referring to pain intensity and frequency, sensomotor disturbances as well as activities of daily life (especially lifting weights). All questions referred to the period before hardware removal and to the present time. Clinical examination consisted in measurement of elbow motion (comparison with the contralateral side), circumference of the upper and lower arm 15 cm above and 10 cm below the elbow joint) and measurement of grip strength (comparison with the contralateral side). Data were collected in a Microsoft SPSS® database. Boxplots and crosstabs were created to find out significant influences of different categories on outcome measurement data. Significant differences were defined at a level of \( p < 0.05 \).

**Results**

**Operative treatment and postoperative follow-up**

There were 47 men and 48 women. Their average age was 47.7 years. Nearly half of the men (44.7%) were between 21 and 40 years of age, 39.6% of women were between 61 and 80 years. Ninety-two sets of preoperative radiographs could be evaluated. In the classification system of Wadsworth (13), 33 fractures (36%) belonged to type I, 8 fractures (9%) to type 2 and 51 (55%) to type 3. Twelve fractures (13%) were classified as type I lesions in the classification of Horne and Tanzer (1), 21 fractures (23%) as type IIa lesions, 51 (55%) as type IIb and 8 (9%) as type III lesions. The distribution of the lesions in the Mayo-classification (7) was as follows: 13 (14%) belonged to type I, 7 (8%) to type II, 18 (20%) to type IIIA, 27 to type IIIB (29%), 10 (11%) to type IIIB and 17 (19%) to type IIIB. In accordance to the Schatzker-Schmeling classification (11-12), 20 fractures (22%) belonged to type A, 14 (15%) to type B, 41 (45%) to type C and 17 (19%) to type D. Twenty-eight (30%) patients suffered one or more additional lesions of the ipsilateral upper extremity, at the proximal radius in 16 and at the humerus, lower arm or hand in 12. In fifteen patients (16%) comorbidity (pulmonary, cardiovascular, oncological diseases) was noted.

In 72 patients (76%), operative treatment was performed within the first 48 hours. Fifteen other patients (16%) were operated within the first week and eight (8%) more than one week after trauma. In 77 patients (81%), a classical tension band wiring was carried out, in 10 patients (11%), a tension band wiring with additional lag screws, in three (3%) a tension band wiring with osteosynthesis of the proximal radius and in 5 (5%) a plate osteosynthesis. The other 13 proximal radius lesions were treated non-operatively. Of all operative procedures, 77.4% were assessed as correct and 22.6% as suboptimal. The operative technique was regarded as suboptimal if the Kirschner wires were not inserted parallel or if they did not perforate the opposite cortex of the proximal ulna.

In 8 patients (8.4%) migration of the implants was observed. Four of them needed revision surgery, the other 4 did not. Ten other reinterventions were necessary, 3 of them due to delayed healing and 2 due to infection. One patient underwent neurolysis of the ulnar nerve, another re-osteosynthesis due to implant loosening after a new trauma. Other patients needed revisions because of severe pain, inadequate implant positioning and staged reconstruction of a severe elbow trauma. This brings the rate of implant migration to 9.5%, the rate of delayed healing to 3.2%, the rate of infection to 2.1% and the rate of reinterventions to 14.7%.

In 62 patients (65%) hardware removal was performed after an average of 12 months.

**Long-term follow-up**

Forty-eight patients completely filled in the questionnaire. Of these, 37% reported no pain before, and 53% after hardware removal. On the other hand, 24% reported pain at rest before and only 13% after hardware removal. Pain intensity was situated between 0 and 4 in a numeric scale from 0 to 10 in 78% before and in 90% after hardware removal. Functional deficits in the activities of daily life were documented in 32% of patients before and in only 15% after hardware removal. The rate of patients, who declared to have unlimited function, was 38% before and 41% after hardware removal. Forty percent of patients did not feel dysesthesia around the previous fracture site before and 46% after hardware removal, all others recorded different types of discomfort (Fig. 2a-c).

Fifty-eight patients were examined clinically and radiologically by two of the authors (SRU and RM), who were not involved in any of the surgical procedures. Only 12 patients (21%) had no extension deficit. Nineteen patients (33%) had a deficit below 10°. Twenty-one patients (36%) showed an extension deficit between 10° and 20°. In 6 patients (10%) the deficit was larger than 20°. Thirty-one patients (53%) showed no flexion deficit. A deficit below 10° was present in 17 patients (29%). A flexion deficit between 10° and 20° resp. above 20° was present in 5 patients (9%) each.
Pronation was normal or showed less than 10° deficit in 56 (97%) of patients, supination in 53 (91%). In 14 patients (25%) there was a diminution of circumference of the upper arm of at least one centimeter, in one patient with fracture-dislocation of the elbow joint the difference was 3.5 cm. There was a diminution of circumference of at least one centimeter of the lower arm in 16 (29%). Only 50% of patients showed an elbow extension force of at least 90% of the contralateral side, 63% had a flexion force of at least 90%.

Radiological examination revealed normal condition in 60%, intra-articular steps without arthrosis in 7%, light to moderate arthrosis in 20%, severe arthrosis in 12% and pseudarthrosis in 1%.

Factors influencing outcome

The classification system of Wadsworth (13) and the system of Horne and Tanzer (1) had no predictive value for the flexion or extension deficit in their different types.

There was a difference in flexion and in extension deficit between fractures of the type D in the classification system of Schatzker-Schmeling (11, 12) and the types A - C. Patients with a fracture of the type C or D had a higher rate of arthrosis (light, moderate and severe) than fractures of the type A or B. Patients with type III lesions in the Mayo classification (7) had a higher deficit in extension and in flexion than patients with lesions of type I or II.

There was a correlation between suboptimal osteosynthesis and arthrosis. The risk of arthrosis in a patient with suboptimal osteosynthesis was 3.35 as high as in optimal osteosynthesis (95% confidence interval : 1.16 – 9.71). There was no correlation between suboptimal osteosynthesis and implant loosening or reintervention.

Patients with an additional trauma of the ipsilateral upper extremity had a higher extension and flexion deficit of the elbow joint than patients with isolated olecranon fractures. The risk of an extension deficit of more than 10° was 6.27 higher in patients with an additional lesion than in patients without (95% confidence interval : 1.72 – 22.84). The risk of a flexion deficit of more
Olecranon Fractures in Adults

than 10° was 5.05 times higher in the same patient group (95% confidence interval: 1.2 – 21.15). Patients with an additional lesion of the proximal radius (part of the previous group) had a 8.53 times higher risk of extension deficit above 10° than patients with isolated olecranon fractures (95% confidence interval: 1.67 – 43.61) (Fig. 3a-c). Additional lesions in other skeletal regions or comorbidity had no influence on the elbow extension and flexion. Age also had no influence.

Discussion

Olecranon fractures seem to be straightforward lesions. Their clinical picture is obvious, conventional radiographs are sufficient to make the diagnosis and understand the lesion. There are very few controversies concerning indication and technique of treatment. They are always articular lesions – with the exception of the very proximal avulsion fracture – with disruption of the extension mechanism of the elbow. Through the pull of the triceps muscle, displacement of the proximal fracture fragment is the rule (6). As in other articular fractures, goals of treatment will be restoration of anatomy and joint stability. This is possible only with open reduction and internal fixation. The tension band wiring technique described in 1963 by Weber and Vasey (14) has found general acceptance and widespread use. Although it is
clearly depicted and consists only of few consecutive steps, there may be different reasons for suboptimal osteosynthesis. Especially the correct insertion of the Kirschner wires proves to be difficult. Ideally, these wires are inserted parallel to each other at the tip of the olecranon, cross the reduced fracture obliquely and perforate the opposite cortex in the proximal ulnar diaphysis. The cerclage wire is placed as a tension band, connecting the most proximal and distal fragment through a figure-of-eight. Proximally, the loop runs through the triceps muscle tendon behind the insertion point of the Kirschner wires. Distally, the wire runs through a bone canal prepared with a 2.5 mm drill. When the cerclage wire is tightened, the whole construct acts as a tension band system. Flexion of the elbow joint is converted into compression of the fracture site (15).

A commonly seen problem is intramedullary positioning of the distal part of the wires or wires crossing each other instead of being drilled parallel. K-wires, which are intramedullary positioned only perforate one cortex and tend to migrate when active motion of the elbow joint is started. This can lead to secondary displacement of fracture fragments with intraarticular steps or gaps. When K-wires cross each other at the level of the fracture, they do not offer the ideal structure to convert flexion into fracture compression. Due to lower stability, secondary displacement may occur or fracture healing may be disturbed (2-4, 10). In our study, there was suboptimal osteosynthesis in 22.6%, implant migration in 9.5% and reintervention ratio in 14.7%. But there was no correlation between suboptimal osteosynthesis and implant loosening. However, there was a correlation between suboptimal osteosynthesis and arthrosis. As arthrosis was more frequently present in fractures of type C or D in the classification of Schatzker-Schmeling (11-12), suboptimal osteosynthesis seems to be more related with complex fracture patterns than with improper placement of the implants.

On the one hand, the olecranon is directly covered by a bursa, subcutaneous tissue and skin: this makes access to the fracture site easy. On the other hand, the implants must be located subcutaneously. The answers received to the questions in the questionnaire made it very clear that localization of the implants was responsible for subjective complaints and loss of elbow function in many patients. One quarter of the patients reported pain at rest; pain intensity was higher in patients before hardware removal; functional deficits in the activities of daily life were more than twice as frequent before than after hardware removal. These are clear arguments for hardware removal after fracture healing. In our series, it was performed in two-thirds of the patients after an average of 12 months. After one year, fracture healing is solid enough to resist traction forces of the elbow flexion and extension.

Subjective complaints after olecranon fracture received objective support with the measurement of the circumferences and the muscle force: at least one fourth of the patients had a reduction in the circumference of the upper and lower arm of one centimeter or more, nearly 50% of the patients had a decrease in force of at least 10%.

Additional lesions in the ipsilateral extremity had a negative influence on the elbow joint function. This was proven by the higher risks of extension and flexion deficit in these patients: 6.27 times higher risk of extension deficit and 5.05 times higher risk of flexion deficit above 10°. There even was a more important negative influence of additional lesions of the proximal radius on elbow extension: 8.53 times higher risk of an extension deficit above 10°.

In our study, only the classification systems of the Mayo clinic (7) and of Schatzker-Schmeling (11-12) had a predictive value for elbow function. In both systems, elbow instability is a criterion for classification. In the Mayo classification (7), unstable lesions belong to type III, in the Schatzker-Schmeling classification (11-12), they belong to type D. The additional fracture of the proximal radius is an indirect sign of instability, mostly it is also combined with more complex fracture patterns of the olecranon. There was no correlation between the classification system of Wadsworth (14) or the system of Horne and Tanzer (1) on the one hand and elbow function on the other hand. These classification systems are purely descriptive. Their criteria are complexity and localization of the fracture. We may conclude that fracture pattern of an olecranon fracture is not decisive for elbow function after its open reduction and internal fixation. The classification systems of the Mayo clinic (7) and Schatzker-Schmeling (11-12) incorporate primary (in)stability as a criterion. In both systems, we found that only this criterion is a prognostic factor for elbow function. The classification system of the Mayo clinic (7) also incorporates displacement and fracture morphology, the system of Schatzker-Schmeling (11, 12) only fracture morphology.

Fracture morphology was an important factor for development of arthrosis in the system of Schatzker-Schmeling: plurifragmental fractures (type C and D) developed more often arthrosis than simple fracture types (type A and B). While the Mayo system is somewhat more academic than the Schatzker-Schmeling classification, both can be used as an instrument for evaluation of prognosis.

**Conclusion**

Olecranon fractures are treated with open reduction and internal fixation. Tension band wiring is the technique most frequently used. Because the implants are located subcutaneously close to a very mobile joint, many
patients report subjective complaints and loss of function in activities of daily life before hardware removal. The more complex the fracture pattern, the more difficult the osteosynthesis. There is a correlation between fracture pattern and development of arthrosis and between suboptimal osteosynthesis and arthrosis. There is no correlation between suboptimal osteosynthesis, implant loosening and secondary procedures. There is no correlation between suboptimal osteosynthesis and elbow function. Elbow function is more likely to be diminished in olecranon fractures, combined with lesions of the ipsilateral upper extremity, especially extension in proximal radius lesions. As proximal radius fractures are an indirect expression of elbow instability, this criterion is an important factor for prognosis of elbow function. We recommend the classification systems of the Mayo clinic and of Schatzker-Schmeling as instruments for evaluation of prognosis of elbow function after olecranon fracture.

References


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