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Treatment of displaced supracondylar humeral fractures in children by humero-ulnar external fixation

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Abstract

Purpose Humero-ulnar external fixation has been proposed to treat complex supracondylar humeral fractures in children. It facilitates fracture reduction and reduces the risk of ulnar nerve lesion, which can occur after cross pinning.

Methods In a ten year period, 28 children have been operated on in our centre by humero-ulnar external fixation, for Lagrange-Rigault stages III and IV supracondylar humeral fractures. The data about fracture management and early follow-up were obtained from our medical database. The long-term evaluation was done at a minimum six months' follow-up. The range of motion and carrying angle measurements were classified according to Flynn. The final X-rays were evaluated for quality of reduction, presence of malunion, late infection signs, osteo-arthritis and myositis ossificans. The elbow function was evaluated by Mayo Elbow Performance Index (MEPI), Disabilities of the Arm, Shoulder and Hand (DASH) or modified DASH scores.

Results The treatment was well tolerated by children and parents. There was no neurological complication related to the insertion of the pins, and no Volkmann syndrome. The median duration of external fixation was 33.5 days. Twelve patients were reviewed after a median follow-up duration of seven years (mean, 7.5 years; range, 3–21 years). One child had a refracture, three years after his original fracture, which was treated non-operatively. This case ended up in a cubitus varus deformity with a pronation deficit. All other patients had excellent clinical and radiological results.

Conclusions For the treatment of complex supracondylar humeral fractures in children, humero-ulnar external fixation is a good alternative to lateral or crossed pinning. The advantages are the ease to obtain the reduction, the absence of neurological risk to the ulnar nerve and the possibility to obtain good stabilisation of the fracture with moderate elbow flexion.

Keywords Supracondylar fracture · Children · External fixation · Long-term evaluation

Introduction

The classical treatment of displaced paediatric supracondylar humeral fractures is closed reduction followed by percutaneous pinning [1–7]. Crossed-pin configuration provides better stability than lateral K-wiring, but carries the risk of iatrogenic injury to the ulnar nerve [5, 8–10]. Another complication is infection at the sites of pin insertion, which may be quite serious. It is not always easy to obtain and maintain with K-wires a good reduction, and insufficiency or loss of reduction may result in a rotational malunion, ending up in a cubitus varus deformity [3, 7].

Because of the limitations of pinning, alternative methods have been proposed, including external fixation (ExFix). There are actually two ExFix techniques described in the literature: the humero-ulnar elbow bridging technique, reported by Gris et al. [11, 12], and the lateral humero-humeral ExFix method proposed by Slongo et al. [13]. The first method is based on the principle of ligamentotaxis. A half-frame is constructed, with a first group of pins inserted above the fracture in the posterior aspect of humerus, and a second cluster of pins in the proximal ulnar diaphysis, well below the physis. After closed reduction in distraction and moderate elbow flexion, the fracture is

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maintained in place through the tension of the elbow collateral ligaments, by locking the connecting rod [12].

The purpose of this study was to assess the short- and long-term results and complications of humero-ulnar bridging ExFix.

Materials and methods

This monocentric retrospective study evaluated the short- and long-term clinical and radiological results of displaced supracondylar humeral fractures in children treated by closed reduction and humero-ulnar ExFix. As the Gartland classification has been modified several times over the years, which is a source of confusion [8, 14–17], we used in this study the Lagrange-Rigault system, comprising four stages (Fig. 1). According to this classification, patients included in this study had fractures either of stage III (fracture with substantial displacement) or IV (fracture with substantial displacement and no remaining contact between the bone fragments). All patients operated on at our institution between July 2001 and July 2011 were included. Twenty-eight ExFixes were implanted. All fractures were considered as highly unstable—during the same period, over 30 less displaced and more stable fractures were treated conservatively or by classical pinning at our institution.

Data about fracture management, early complications and results were obtained from our medical database. The quality of reduction was judged "anatomical" if perfect, "acceptable" if not anatomical but the surgeon believed that it would not lead to clinical malunion, or "insufficient" in other cases. All patients were invited to participate in a long-term medical and radiological evaluation of their elbow, conducted by an independent observer (A.B.). The clinical examination consisted of the measurement of the carrying angle (CA) and of the active range of motion (ROM). Based on CA and ROM values, the patients could be classified according to Flynn as excellent, good, fair or poor results—in this classification, the cubitus varus deformity is always considered as a poor result [18]. The patients had a careful neurological evaluation. The global elbow function was estimated by the Mayo Elbow Performance Index (MEPI), which consists of four parts, evaluating pain, ulno-humeral motion, stability and ability to perform five functional tasks. The total score ranges from 5 to 100 points; higher points indicating better function. Scores over 90 points are considered excellent, between 75 and 89 good, between 60 and 74 fair, and less than 60 points poor [19]. The upper extremity disability was assessed by the Disabilities of the Arm, Shoulder and Hand (DASH) score if the patient had become an adult at final evaluation, or using the modified Disabilities of the Arm, Shoulder and Hand (mDASH) score if the patient was still a child. Indeed, the standard DASH is not appropriate in a paediatric population. This not well-validated mDASH consists of ten questions concerning symptoms and disabilities of an upper limb and
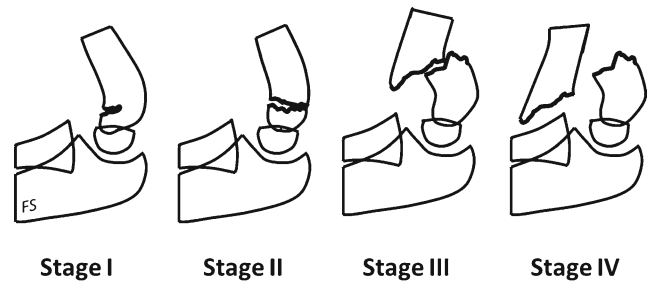

Fig. 1 Scheme illustrating the Lagrange and Rigault classification. Stage I, undisplaced fracture; only the anterior cortex is disrupted. Stage II, both cortices are fractured with no or minimal displacement. Stage III, fracture with substantial displacement. Stage IV, fracture with substantial displacement and no remaining contact between the bone fragments

answered by the child or parent [20]. Both scores range from 0 (no disability) to 100 (severe disability).

On final X-rays, the quality of reduction, bone healing and normal development of the elbow joint were evaluated. In patients with still open physis, the shaft-physeal Baumann angle was measured and, in all patients, the metaphyseal-diaphyseal angle (<90° with valgus). In addition, on profile views the location of the capitulum relative to the anterior humeral line (Rogers line) was evaluated [21]. Signs of late infection, particularly at pins insertion sites, osteo-arthrosis and/or myositis ossificans were also searched for.

Surgical technique (Fig. 2)

Humero-ulnar ExFix is performed under general anaesthesia, in dorsal or lateral decubitus. A C-arm is used throughout the procedure; care is taken to minimise the X-ray dose to the child. The arm is sterilised like for any open surgical procedure. Below the radial nerve crossing and above the fracture, two 3-mm pins are first screwed through two stab-wounds in the two cortices of the humerus, perpendicular to the bone, following a posterio-anterior direction. Following identical technique, two similar pins are inserted into the ulnar diaphysis, well below the proximal ulnar physis. The pins are fixed in Hoffmann clamps. The reduction is then performed, by closed manipulation of the fracture through the external fixation clamps. Distraction, moderate flexion and pronation manoeuvres are usually helpful. When the reduction seems acceptable, it is maintained by locking the connecting rod, fixing the elbow in distraction and moderate elbow flexion (optimal position, about 70° elbow flexion—Fig. 3). If the radiological images on the C-arm are not acceptable, the whole reduction procedure is started again, until a perfect result is obtained.

Post-operative care

No plaster cast is used, and the child can immediately use his/ her hand and do pronation-supination movements. The

Fig. 2 Humero-ulnar elbow bridging with ExFix. Six-year-old boy, Lagrange-Rigault type IV closed fracture (**a**). Forty-one days of ExFix (**b** and **c**)—elbow flexion could be less, as has been applied in this case. Full recovery of elbow joint motion, anatomical reduction at final evaluation (58 months post fracture—**d** and **e**)
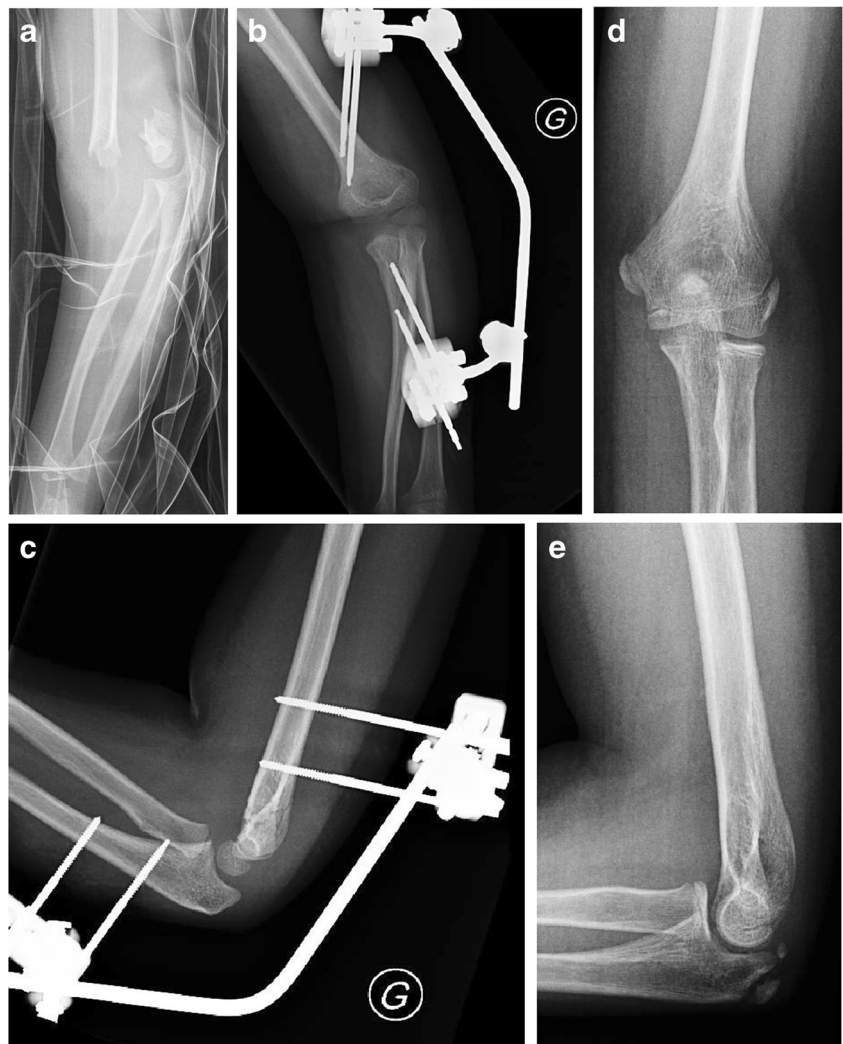
classical skin care is conducted, to prevent infection of the pins, avoiding alcohol with young children. After four to six weeks, when there is evidence of early fracture healing, the ExFix is removed in the day clinic, under minute anaesthesia. Usually a Blount collar is then used for some weeks, and no physiotherapy is prescribed. Most children recover good elbow joint motion quickly.

Results

There were 15 boys and 13 girls, with a median age of six years (mean 6.2 years; range, 2–12 years) and an even distribution between right and left sides. All fractures were closed. One child had signs of high median nerve palsy, affecting the anterior interosseous nerve (AIN); in another child, the fracture was complicated by acute arterial ischaemia and radial nerve palsy. In two cases, a fracture of the medial epicondyle complicated the supracondylar humeral fracture (Fig. 3). In two other cases, there was an associated distal radius fracture (Salter and Harris

classification: one type I and one type II), treated by pinning in addition to the humero-ulnar ExFix.

Humero-ulnar ExFix was the primary treatment in 25 patients (89.3 %), operated within 24 hours of the traumatism, within eight hours in most cases; in three patients, the operation was performed after a few days, after a first unsuccessful attempt at closed reduction and plaster immobilisation; one of these three children had developed dysesthesiae in the ulnar dermatome under plaster immobilisation, which persisted initially under ExFix but finally spontaneously disappeared. The case with acute arterial ischaemia had spontaneous hand revascularisation after fracture reduction; the two children who had presented neurological problems at admission had full spontaneous recovery within three months.

On the early post-operative radiograms after ExFix, the reduction was considered anatomical in 24 (85.7 %), acceptable in two and insufficient in two. These two latter cases had a remanipulation of the fracture under general anaesthesia within three days, keeping the ExFix, which finally allowed in both cases an excellent reduction; there were, therefore, in

Fig. 3 Lagrange-Rigault type IV closed supracondylar humeral fracture with associated fracture of the medial epicondyle. Note that the elbow is fixed in about 70° flexion (**a**–**c**). Early radiological result, 82 days after the fracture (**d** and **e**)
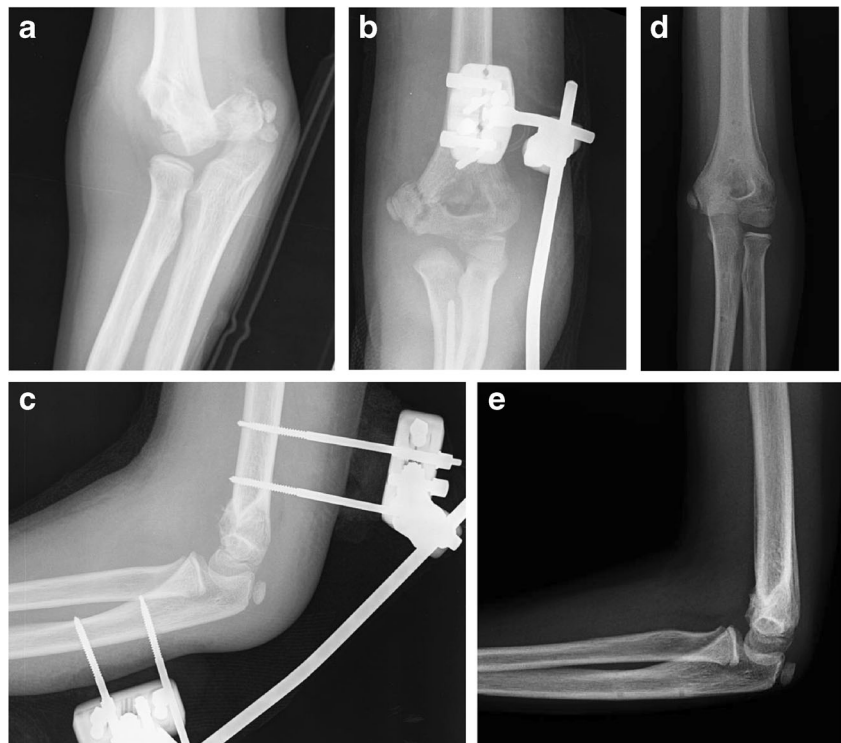
total 26 excellent reductions. Some early complications were noted. One turbulent child had a violent fall on his fixator and broke his humerus just above the most proximal humeral pin. A new operation was necessary to reposition the humeral pins above the new fracture, and this case finally ended by healing of both fractures in an anatomical position. One child had untightening of a fixator clamp, just before removal of the fixator, without loss of fracture reduction. Two children had skin infection at their pins' exit sites, which resolved under oral antibiotics. All children and their parents tolerated very well the ExFix; none complained. The median duration of ExFix was 33.5 days (mean, 35.3 days; range, 26–52 days). One 2-year-old child, with initially an unacceptable reduction under plaster immobilisation, treated after a few days by ExFix with an anatomical reduction, suffered a new supracondylar, mildly displaced, fracture three years later, which was then treated conservatively. The new fracture line was not related to the external fixation holes. This case ended up in a cubitus varus deformity, which was probably the consequence of the second fracture. Another child with originally a reduction judged acceptable, developed a cubitus varus deformity after removal of his fixator (kept in total 40 days)—a purely cosmetic problem as there was no limitation of his active elbow joint mobility. This patient had a corrective osteotomy at skeletal maturity. There was no case of a Volkmann contracture.

Only 12 patients accepted the long-term evaluation: seven males and five females. All were right-handed and in six cases the fracture had concerned the dominant upper extremity. No patient had any significant comorbidity. One patient had, however, suffered a supracondylar fracture of his contralateral elbow, treated with reduction and pin fixation. Another child in the long-term evaluation was the one with the supracondylar refracture of ipsilateral elbow who developed a cubitus varus, probably related to the second fracture. The original fracture was classified as Lagrange-Rigault stage III in four patients and stage IV in eight patients. One of the reviewed children was one of the two of the original series, presenting an associated intra-articular fracture detaching the medial epicondyle. The long-term evaluation concerned also the two children who presented an associated fracture of the distal radius; the one who presented at the time of the fracture a palsy affecting the AIN and the other child who had signs of ulnar nerve deficit related to the initial plaster cast immobilisation. Among the 12 patients were three who did not have ExFix as the primary treatment but were firstly treated by non-operative technique. One of the 12 patients was one of the two who needed a new reduction, untightening the fixator and retightening it after remanipulation. Thus, the 12 patients reviewed on the long-term comprised the most difficult cases of the original series, probably those who especially remembered their fracture. It is likely that for many others who were lost for follow-up, their fracture was an almost forgotten story.

The median follow-up duration was seven years (mean, 7.5 years; range, 3–21 years) and the median age of the patient at long-term evaluation was 12 years (mean, 13.6 years; range, 7–27 years)—two adults and ten children (however, only seven children still presented open elbow physes).

The final carrying angles and elbow range of motion are summarised in Table 1. All patients had symmetrical and normal CA and ROM, in flexion-extension and in pronation-supination, except the child who developed cubitus varus after his refracture; his carrying angle was 20° in varus. Although his flexion-extension and supination ROM were normal, the patient had no more than 30° active pronation. The Flynn score was excellent in 11 patients and poor in the patient with the cubitus varus deformity. The neurological examination of the upper limb was normal in all patients. The X-ray examinations did not show the presence of osteo-arthrosis, myositis ossificans or late signs of infection. The Baumann (shaft-physeal) angle could be measured in seven patients with capitulum open physes. Six children presented normal Baumann angle and one child—the child with the cubitus varus deformity—an angle of 100°; the median value of the Baumann angle was 60° (mean ± SD, 68° ± 14°; range, 100–55°). The median value of metaphyseal-diaphyseal angle was 86° (mean ± SD, 84.3° ± 6.7°; range, 71–92°). The anterior humeral line (Rogers line) passed through the middle third of the capitulum in ten (83.3 %), and through the proximal third in two (16.7 %). Only in one child, and only for one ulnar pin, could a pin hole site still be seen on these late X-rays; in all other cases, there was no radiological trace of the previous ExFix implantation. For two adult patients, the median and the mean DASH were 2.5 (range, 5–0; SD, 2.5). The mDASH, which was performed in the paediatric population, showed a median score of 0 (mean ± SD, 4.3 ± 11.1; range, 35-0). The median overall DASH/mDASH score was 0 (mean ± SD, 4.0 ± 10.1). The MEPI score showed ten excellent and two good results (median score, 100 points; mean ± SD, 96.3 ± 6.1 points; range, 85–100 points).

Discussion

Supracondylar humeral fractures are common in children, and account for 13–16 % of all paediatric fractures and 60 % of fractures about the elbow [1, 22]. The peak age is between five and eight years, with predominance in boys at a ratio of 3:2 [23, 24]. The most common injury mechanism (95 %) is a fall on an outstretched hand, with the elbow in full extension and the arm pronated, resulting in posterio-medial displacement with internal rotation of the distal fragment [8, 23, 24]. In 15 %, displaced supracondylar humeral fractures are complicated by a peripheral nerve injury [9, 25], usually neuropraxy [9, 17, 25]. Radial nerve lesion occurs with posterio-medial displacement, and median nerve injury, mainly affecting the AIN, from posterio-lateral fracture displacement [8, 9, 24, 25]. Vascular injuries are found in up to 14 % [9, 26], corresponding either to a spasm of the brachial artery, which usually recovers after reduction and fracture stabilisation, to brachial artery fracture entrapment, to thrombosis due to intimal injury, or to total section [8, 9, 26]; compartment syndrome may lead to Volkmann's ischaemic contracture [24, 27]. Indeed, the most feared complication of supracondylar humeral fractures in children is compartment syndrome. Battaglia et al. observed a significant pressure elevation when the elbow was immobilised in flexion, beyond 90°, a position to be avoided [27].

Displaced fractures (Lagrange-Rigault stages III and IV) require good reduction and appropriate stabilisation to prevent late malunion. The classical technique is closed reduction followed by percutaneous crossed or lateral pinning and plaster cast immobilisation. The reduction is not always easy to achieve [28] and not always stable, especially after lateral pinning. For these reasons, pinning may end in malunion, most commonly in cubitus varus. The occurrence of this complication is estimated after pinning to be 3 % [24, 29]. The other complication is iatrogenic ulnar nerve injury. After cross-pinning, it occurs in 4–10 % [10, 22, 30] and, to prevent this lesion, open insertion of the medial pin has been recommended [31]. Infection at the pins' exit sites is not infrequent. Finally, as a plaster cast is used, there is some risk of Volkmann, especially if the cast maintains the elbow in excessive flexion, which is not recommended and is not necessary after pinning.

Table 1 Long-term evaluation, carrying angle (CA) and elbow range of motion (ROM)

	Affected side				Normal side			
CA (degrees) (valgus is positive, varus negative)	Median	Mean	Range	SD	Median	Mean	Range	SD
	10	6.8	−20 to 20	9.5	10	8.5	0–20	5.1
ROM (degrees)	Median	Mean	Range	SD	Median	Mean	Range	SD
Flexion	140	137.5	130-150	6.2	140	136.3	120–140	6.4
Extension	10	12.1	5-30	7.8	10	9.4	−2 to 20	4.9
Arc of flexion-extension motion	147.5	149.6	135-170	10.1	150	145.7	128-150	6.8
Pronation	90	85	30-90	17.3	90	90	90-90	0
Supination	90	80	50-90	18.1	90	80	50-90	18.1
Arc of pronation-supination	180	165	120-180	22.8	180	170	140-180	18.1

Humero-ulnar ExFix can also provide good stabilisation of complex supracondylar humeral fractures in children. Compared with classical pinning, the reduction is facilitated by direct manipulation of the humerus and ulna through the pins and clamps. If the reduction is not optimal, it can be redone easily. We obtained an anatomical reduction in most of the patients, in a few an acceptable reduction. One child in the series ended up with a cubitus varus deformity, but obviously related to a refracture which occurred 3 years later. Compared with pinning, there is no risk of iatrogenic injury to the ulnar nerve. Finally, because no plaster cast is used, and because the elbow is immobilised in moderate elbow flexion, the risk of Volkmann is minimal. In this ExFix series, there was no case of a compartment syndrome.

Humero-ulnar ExFix brings its own risks, of course. The nerve which is potentially in danger is not the ulnar, but the radial nerve, at the site of its crossing the posterior aspect of the humerus. The humeral pins must therefore be inserted precisely in the region just above the fracture, not more proximally. In the series, there was no case of radial nerve injury related to ExFix. Infections may occur at the pins' skin exit sites. Indeed, there were two cases of superficial pin track infection, which did not influence neither the duration of ExFix nor the healing of the fracture, and had no long-term consequences. Another potential complication is elbow stiffness related to prolonged traction on the paediatric elbow ligaments. In this series, all children were able to quickly regain their range of joint motion, without physiotherapy. The non-bridging humeral lateral ExFix construction of Slongo et al. [13] is not based on the ligamentotaxis effect; elbow bridging is avoided, which could possibly be advantageous to prevent this potential problem of elbow stiffness, which we did not observe. We have no experience of this method of ExFix.

In this article, we evaluated the short- and long-term results of humero-ulnar ExFix. This study has significant limitations: it is not a prospective, randomised trial comparing ExFix to pinning; the choice to use ExFix was done by the surgeon based on his/her subjective appreciation of the instability of the fracture; the long-term results were assessed on a relatively small sample of the original series—however, probably those with the most significant original lesions.

Conclusions

Humero-ulnar ExFix represents a good alternative to treat complex supracondylar fractures of the humerus in children. The best indications are open fractures, and probably also fractures occurring in spastic patients—no cases in this series of closed fractures. But ExFix is also an excellent alternative to treat closed supracondylar fractures in children, especially when there is marked displacement of the bone fragments, and the technique could even be used in more simple displaced

fractures. The advantages of ExFix are the ease to achieve the reduction, whatever the complexity of the fracture, the absence of neurological risk to the ulnar nerve, and the possibility to obtain good stabilisation of the fracture with moderate elbow flexion, decreasing therefore the risk of compartment syndrome. Another probably minor advantage, is the possibility for the child to actively perform pronation-supination after the operation, which is not possible in the case of plaster immobilisation. The drawbacks of ExFix are the infectious bone and skin reactions. The radial nerve can be at risk in case of too proximal humeral pin implantation.

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