Elastic stable intramedullary nailing versus Kirschner wire pinning: outcome of severely displaced proximal humeral fractures in juvenile patients

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Background: Significantly displaced juvenile proximal humeral fractures (Neer-Horowitz type 3 and 4) usually require reduction and fixation. The most commonly used fixation methods are Kirschner wire (K-wire) pinning or retrograde elastic stable intramedullary nailing (ESIN). However, results comparing the long-term outcome of both methods are absent in the literature. The aim of this study was to provide an outcome comparison of both techniques.

Methods: Included were 40 patients treated between 1998 and 2008 and who had complete records concerning operation time, duration of hospital stay, and time until implant removal. The assessment of clinical (Disabilities of Arm, Shoulder and Hand [DASH] and Constant-Murley scores) and radiologic long-term outcome was possible in 31 patients (78%). Preoperative, postoperative and follow-up radiographs of these patients were evaluated for angular deformity, reduction, and remodeling.

Results: The mean follow-up of the 31 patients (16 ESIN; 15 K-wire) was 5.8 ± 3.6 (standard deviation) years. The operative time of the primary fixation procedure was shorter in the ESIN group (P < .001), but the hospital stay and the time until implant removal were significantly longer. No significant difference was seen between the groups at follow-up for the mean DASH (ESIN, 1.44; K-wire, 1.66) or Constant-Murley (ESIN, 89.5; K-wire, 92) scores. The neck-shaft angle was significantly improved by reduction in both groups (P < .001) and remained unchanged at follow-up.

Conclusions: ESIN and K-wire pinning have a favorable and comparable functional outcome and therefore seem to be adequate methods for treating Neer-Horowitz type 3 and 4 proximal humeral fractures in juvenile patients. The initially achieved improvement of the neck-shaft angle can be maintained at long-term follow-up.

Level of evidence: Level III, Retrospective Cohort Study, Treatment Study.

Keywords: growing skeleton; proximal humeral fractures; displaced

Fractures of the proximal humerus are rare in children, accounting for only 3% of all physeal injuries; however, these fractures still represent the most common physeal injuries of the shoulder and upper arm. In 1965, Neer and Horowitz introduced a classification system grading these fractures into types I through V.
injuries according to their displacement (type 1: <5 mm; type 2: <1/3 shaft width; type 3: >1/3 and <2/3 shaft width; and type 4: >2/3 shaft width).

The physis of the proximal humerus is responsible for approximately 80% of the humeral growth.\(^7\) This unique structure is responsible for the high remodeling potential of proximal humeral fractures and the widespread acceptance that most proximal humeral fractures can be treated conservatively, depending on the degree of displacement, angulation, rotation, or translation.\(^3,\)\(^4,\)\(^8,\)\(^9,\)\(^10,\)\(^19\)

However, remodeling has been clearly identified as being age-dependent and recognized as an important factor in determining the treatment regimen of juvenile proximal humeral fractures.\(^6,\)\(^11,\)\(^12,\)\(^17\) Adolescents have a limited correction potential of proximal humeral fractures because remodeling capacity in this age group is already limited compared with younger children with a greater opportunity for remodeling. Several authors therefore favor a surgical approach in adolescents with Neer-Horowitz type 3 and 4 fractures with axial deformities of more than 30° varus and more than 10° valgus.\(^6,\)\(^12\)

Operative management includes closed or open reduction, followed by fixation with variable options.\(^31\) The use of percutaneously placed pins has been well described.\(^6,\)\(^11\) Nevertheless, retrograde elastic stable intramedullary nailing (ESIN) using flexible titanium or stainless steel implants\(^7,\)\(^12\) has been strongly supported in recent years, although studies comparing the outcome of both techniques are rare. Hutchinson et al.\(^14\) compared the early postoperative outcome of skeletally immature patients treated for displaced proximal humeral fractures by ESIN or Kirschner wire (K-wire) pinning and reported no differences between the methods.\(^14\) However, longer-term results of ESIN vs K-wire pinning for proximal humeral fractures have not been reported so far. Thus, the hypothesis of the present study was that the functional and radiologic long-term results of proximal humeral fractures treated with ESIN or K-wire pinning do not differ significantly.

**Methods**

The Department of Pediatric and Adolescent Surgery, Medical University of Graz, Austria, is the only level 1 pediatric trauma center within a catchment area covering the entire State of Styria that takes care of children and adolescents up to the age of 18 years. A retrospective analysis of the hospital’s trauma database was performed to identify children and adolescents (up to the age of 18 years) treated for displaced proximal humeral fractures, Neer and Horowitz type 3 and 4, between 1998 and 2008 and treated by K-wire pinning or ESIN.

Inclusion criteria were the diagnosis of proximal humeral fractures, Neer-Horowitz type 3 and 4, confirmed by x-ray imaging, complete clinical data sets with information about age, sex, trauma mechanism, type of treatment, operation time for primary operation, duration of hospital stay, operation time for implant removal, and time to implant removal.

Exclusion criteria were proximal humeral fractures due to bone tumors (eg, juvenile or aneurysmatic bone cysts), patients with other underlying diseases affecting bone density, and patients with neurologic disorders unable to complete Disabilities of Arm, Shoulder and Hand (DASH) and Constant-Murley scores.

All patients were invited to a follow-up examination to assess the long-term functional and radiographic outcomes.

Angulation was assessed in radiographs at three time points (time of the injury, first follow-up visit, and final follow-up). The neck-shaft angle in anteroposterior radiographs, as described by Agudelo et al.\(^1\) was measured preoperatively, postoperatively, and at follow-up.

The Constant-Murley and the DASH scores, as approved tools to evaluate the treatment results of upper extremity injuries, were assessed at follow-up.\(^2,\)\(^20\) Both scores were completed in all patients.

For statistical analysis, IBM SPSS Statistics 20 software (IBM Corp, Armonk, NY, USA) was used. The independent sample \(t\) test was applied to compare the functional outcomes between the 2 groups. The Kruskal-Wallis test was used to compare the neck-shaft angles, according to Agudelo et al,\(^1\) because the data did not show normal distribution according to the Kolmogorov-Smirnov test. Values are expressed as means ± standard deviations and ranges. A \(P\) value of <.05 was considered to be statistically significant.

**Surgical techniques**

Choice of surgical technique was the surgeon’s choice.

A 2-nail technique was used for ESIN. A skin incision of at least 2 cm in length was performed just above the lateral epicondyle of the humerus. The bone was opened with an awl in an oblique manner, without perforating the opposite cortex. Nail diameter was chosen according to the diameter of the bone marrow space: each of the 2 nails had a diameter of one-third of the bone marrow space.\(^16\) The nail was inserted and brought up to the fracture site. By traction, abduction, and 90° external rotation, the fracture was reduced under fluorographic control; then, the nail was passed into the proximal fragment. A second nail was inserted into the humerus using the same insertion site. The nails were cut about 10 mm from the cortex.

Postoperative treatment included early functional treatment without immobilization. ESIN removal was performed at least 4 weeks postoperatively when callus formation was visible on control x-ray images. Because immobilization is not required and the nail ends usually do not irritate the soft tissue, planning for implant removal can be more flexible, taking into account each patient’s personal circumstances.

For pinning, K-wires with a diameter between 2.0 and 2.5 mm were used. By traction, abduction, and 90° external rotation, the fracture was reduced. The correct reduction was checked by using fluoroscopy. The first pin was inserted into the distal fracture fragment close to the deltoid tuberosity. The K-wire was passed across the fracture site in a superomedial direction using a wire driver. To avoid intra-articular placement and to check stability, the shoulder joint was moved under fluoroscopy. A second K wire was positioned more anteriorly or posteriorly as needed. Because bending has to be avoided during fixation and for accurate stability of the fracture fragments, we use 2.0-mm or 2.5-mm K-wires according to the protocol in our department. Pins were cut under the skin.
Postoperative treatment included bandage immobilization\(^6\) until implant removal to obviate compliance problems and secure good results, although a stable osteosynthesis would not require additional external fixation.\(^3\) Metal removal in the K-wire group was performed when callus formation was visible on the x-ray image, 4 to 8 weeks after osteosynthesis.

Radiographic examples for both techniques at the 3 different time points are presented in Figures 1 and 2.

**Results**

Between 1998 and 2008, 40 patients with Neer-Horowitz type 3 and 4 proximal humeral fractures were treated and invited for the follow-up assessment. However, 9 patients were lost for follow-up: 5 due to an incorrect postal address and 4 declined to participate in the study. Therefore, 31 patients (78%) participated in the follow-up examination after a mean of 5.8 ± 3.6 years (range, 13 months-12.5 years). There were 18 boys and 13 girls, with a mean age of 11.3 ± 3.7 years (range, 3-16 years) at the time of the injury. In 19 patients the left arm was injured, and 12 fractures occurred on the right side.

The mechanism of injury was sports-related (trampoline, skiing, and snowboarding) in 13 patients; of which, 9 children were injured while playing outside, and 4 sustained playground injuries. Three patients were involved in bicycle accidents, and 2 teenaged boys were involved in a fight. All injuries were closed injuries, without damage to neurovascular structures.

Treatment was with K-wire osteosynthesis in 16 patients and with ESIN in 15 patients. A comparison of patient demographics and osteosynthesis-related data is presented in Table I.

One superficial infection with irritation of the soft tissue occurred within the group of patients treated with K-wires. As a consequence, the K-wires were immediately removed 3.5 weeks after osteosynthesis.

The total operative time was 89 ± 34.8 minutes (range, 16-135 min) in the ESIN group and 88 ± 24.4 minutes (range, 54-150 min) in the K-wire group and was not statistically different (\(P = .53\)).

The mean preoperative neck-shaft angle was 126 ± 14° in the ESIN group compared with 112 ± 29° in the K-wire group (\(P = .632\)). Osteosynthesis led to a significant improvement of the neck-shaft angle in both groups (\(P < .001\)). This improvement was maintained at follow-up (ESIN group, \(P = .14\); K-wire group: \(P = .664\); Fig. 3).

At follow-up, the DASH score did not show statistically significant differences between the 2 groups (\(P = .85\)). The mean DASH score was 1.44 ± 3.06 (range, 0-12.5) for the K-wire–treated patients and 1.66 ± 4.44 (range, 0-17.5) for the ESIN–treated patients. The most common limitation in patients with higher DASH scores was performing heavy work. Likewise, the Constant-Murley score did not differ between the 2 groups (\(P = .26\), with a mean of 92 ± 6.15 (range, 81-100) for the K-wire group and 89.5 ± 6.15 (range, 80-100) for the ESIN group.

**Discussion**

In older children with Neer-Horowitz type 3 and 4 proximal humeral fractures, operative treatment with fracture reduction and fixation is generally required to optimize fracture healing and prevent deformity that may adversely affect future shoulder function. Available techniques include K-wire pinning or retrograde ESIN. The ESIN technique allows early postoperative mobilization; however, for implantation using the technique described in this report, a larger skin incision for opening the cortex is necessary.

K-wire pins, in contrast to ESIN, are inserted percutaneously and require postoperative immobilization, according to current guidelines.\(^2\) In addition, protruding K-wires can irritate the muscles and soft tissues and have a considerable risk of migration.\(^14\) There are even reports of K-wires migrating from the proximal humerus to the aorta, with consecutive perforation.\(^15,18\)

With the exception of the study of Hutchinson et al,\(^14\) previous reports have only studied the outcome of ESIN or K-wire pinning, without a direct comparison of both techniques. Burgos-Flores et al,\(^6\) for example, reported excellent results in 22 patients with Neer-Horowitz type 3 and 4 proximal humeral fractures treated with K-wire fixation at a mean follow-up of 6.8 years. They recommended a more aggressive approach to correct the initial displacement and angulation in children aged older than 13 years.\(^6\)

Rajan et al\(^22\) reported 14 patients treated with ESIN at a mean follow-up of 30 months. The Neer shoulder score was 96.79 and the mean DASH score was 2.26. Six patients required open reduction, and 1 patient showed transient radial nerve irritation. Postoperative soft tissue irritation was observed in 3 patients; at follow-up, however, there was no residual deformity. The authors recommended stabilization by ESIN in juvenile proximal humeral fractures as a safe and stable minimal invasive surgical procedure.\(^22\)

These favorable outcomes were confirmed by Fernandez et al,\(^12\) who reported 35 children with Neer-Horowitz type 3 and 4 proximal humeral fractures and recommended ESIN as a safe and stable minimal invasive surgical procedure. Their study reported a mean surgery time of 54 minutes and a mean hospital stay of 4.1 days.\(^12\)

In the present study, the mean operation time for ESIN was 50 minutes and significantly shorter compared with a mean of 57 minutes for K-wire pinning (compare Table I). Although a surgical approach to the bone must be performed for the introduction of ESIN, this technique may simplify reduction because the proximal fragment can be moved by rotation of the ESIN, thereby making reduction easier.\(^12\) Nevertheless, a mean difference of 7 minutes does
not seem to be significant enough to influence a surgeon’s decision for or against one of both possible techniques.

Our data revealed that patients of the ESIN group stayed significantly longer in hospital than patients of the K-wire group. However, whether a mean difference of 0.4 days—although statistically different—is of any clinical significance is questionable. The early postoperative mobilization performed in the ESIN group might cause pain and, therefore, might lengthen the initial hospital stay.

Hutchinson et al. compared the outcome of ESIN vs K-wire pinning. Marked differences between the techniques were the lower complication rate but longer surgery times and increased blood loss when ESIN was used. The authors concluded that both techniques are effective for stabilization of Neer-Horowitz type 3 and 4 proximal humeral fractures with improvement of angulation. Nevertheless, follow-up time was only 9 months.

In the present study, with a mean follow-up of 5.8 years, we corroborate that both techniques are effective in stabilization and that there is no significant difference in the functional and radiologic outcome of ESIN vs K-wire pinning. Significant improvement of the neck-shaft angle was achieved with both techniques immediately after the operation and was maintained at follow-up.

Additionally, a low complication rate, without pin migration and 1 pin tract infection in the K-wire group (3%), was seen. In their study, Hutchinson et al. reported complications in 11 of 27 patients (41%) treated with percutaneous pinning, including pin migration and infection. In contrast to Hutchinson et al., we cut the K-wires under the skin. Buried wires seem to have significantly lower infection rates than K-wires left through the skin. However, by burying the pins under the skin, the advantage of pin removal in sedation, without the necessity of a second anesthesia, is lost.
In all patients included in the present report, the DASH and Constant-Murley scores demonstrated excellent clinical outcome. Both scores were chosen because they represent universally accepted evaluation tools enabling comparisons with other reports. However, we are aware that the Constant-Murley and the DASH score were developed and validated for adults, which was a limitation of this study. Nevertheless, no valid score for measuring the outcome of children sustaining injuries of the upper limb is available. Further limitations were the retrospective design of the study that did not allow randomization of the patients. The number of patients was low, and the patients were treated by different surgeons.

Conclusions

Either K-wire pinning or ESIN can be recommended for the treatment of Neer-Horowitz type 3 and 4 proximal humeral fractures in juvenile patients. Both methods lead to good functional and radiologic long-term results. Although fracture fixation using ESIN showed a significant lower operative time than fracture fixation by percutaneous pinning, the overall operative time (primary fixation time plus implant removal time) was similar in both methods.

References