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ORIGINAL ARTICLE

Implant removal associated complications in children with limb fractures due to trauma

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Abstract
Purpose The purpose of this study was to analyze the number and type of complications that occurred after fracture implant removal and to investigate whether implant removal should be performed routinely in children.
Methods In a retrospective study, patient records were used for the analyses of patient characteristics, surgery reports, and complications. Children under the age of 16 years with a limb fracture due to trauma, treated with either Kirschner wires (K-wires), elastic stable intramedullary nails (ESIN), or screw fixation between 2000 and 2007, were included. Exclusion criteria were as follows: refracture, pathological fracture, fracture of the hands and feet, or polytrauma patients (Injury Severity Score [ISS] > 15).
Results Three-hundred and nine fractures were analyzed. All K-wires (173) and ESIN (96) were removed as per standard procedure, resulting in 17/173 and 7/96 complications after removal, respectively. In 19/40 patients with screw fixation treatments, it was decided to remove the material after fracture consolidation, resulting in 4/19 complications. The decision in 21 treatments to leave the screw in situ led to four complications. No significant difference in complication rates could be found for the three groups after removal surgery (17/173, 7/96, and 4/19) or between hardware removal (4/19) and retention (4/21) in the case of screw fixation.
Conclusions The removal of K-wires, ESIN, and screws is considered to be a safe procedure in children and is, by definition, indicated for K-wires and ESIN after fracture healing.

Keywords Implant removal · Osteosynthesis material · Children · Trauma · Limb fractures

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Introduction

The majority of trauma-associated limb fractures in children can be treated with cast immobilization [1]. Fracture reduction and subsequent surgical fixation might be necessary if casting results in insufficient immobilization or inadequate reduction. A variety of fixation methods and materials can be used, depending on the fracture type and location. Once the fracture has healed, the metal implants can be removed.

Several studies have discussed the pros and cons of implant removal in children [2–13]. Whether metal implants in children should be removed routinely is controversial [2, 3, 5, 6, 10, 11, 13]. Up to 60% of the surgeons routinely remove hardware after bone healing [5, 10]. Operation-related complications due to implant removal play a key role in this discussion and no general agreement among surgeons exists about the need of hardware removal in children that are free of material-associated complaints [2–7, 10, 11, 13].

The aim of this study was to analyze the number and type of complications due to hardware removal in children with a (healed) limb fracture after trauma.

Patients and methods

In this retrospective analysis, all children under the age of 16 years with limb fractures due to trauma, who were admitted to our trauma center and were treated operatively with Kirschner wires (K-wires), elastic stable intramedullary nails (ESIN), or screw fixation between 1st January 2000 and 1st January 2007, were included. Excluded from the study were all children with refractures, pathological fractures, fractures of the hands or feet, and polytrauma patients (Injury Severity Score [ISS] > 15). The medical records from the Trauma Database of the Trauma Centre West of the Leiden University Medical Centre (LUMC) were used to collect patient data for analysis. If the postoperative follow-up was done in another hospital, the patient was categorized as lost to follow-up. The follow-up period of the children after the implant removal was 1 year. If the implant was not removed, the follow-up was continued until outpatient discharge. Data collected from the medical records were: diagnosis, comorbidity, information about the primary operation, complications with the material in situ, information about the implant removal operation, and complications after implant removal. Complications as described in the patient records during the follow-up were specified as minor or major. Minor complications were pain, irritation of the soft tissue or skin, superficial infection, unintentional protrusion or prominence of material, neurapraxia, and wound dehiscence. Prominence was defined as a combination of palpable material with pain, irritation, or an uncomfortable feeling. Major complications were deep infection, refracture, epiphysiodesis, nonunion, and malunion.

A database was constructed in Microsoft Access (Microsoft, Redmond, WA) and statistical analyses were performed using SPSS 17.0 (SPSS Inc., Chicago, IL). Fisher's exact test was used to investigate differences in the complication rate between groups. A p-value of <0.05 was considered to be significant for the statistical test.

Results

Patient and treatment characteristics

During a period of 7 years, a total of 308 children with limb fractures were treated operatively by four trauma surgeons. Ten children were lost to follow-up. A total of 309 limb fractures, in the remaining 298 children (180 boys and 118 girls), were treated with a form of osteosynthesis (Fig. 1). The average patient age was 9.1 years (range 1.2–15.9 years). Fractures were mainly located in the radius and ulna shaft (39%) and in the distal humerus (31%) (Fig. 2).

K-wires

In 173/309 fracture treatments, K-wires were used as the fixation material and the removal of K-wires after fracture healing was standard procedure. K-wires were implanted in such a manner (the tips were situated percutaneously) that early planned removal surgery would be a minimal intervention. After a mean period of 40 days (range 17–409 days), all K-wires were removed.

During the follow-up period of 74 days after removal surgery, six major, ten minor, and one other complication occurred in 17/173 removal treatments (10%) (Table 1). The six major complications that occurred were three times an epiphysiodesis, two refractures, and one deep infection. All epiphysiodeses were due to the trauma mechanism and not as a consequence of removal surgery. Two refractures occurred 2 and 4 months after removal surgery due to minor trauma. In both forearm fractures, the K-wires were

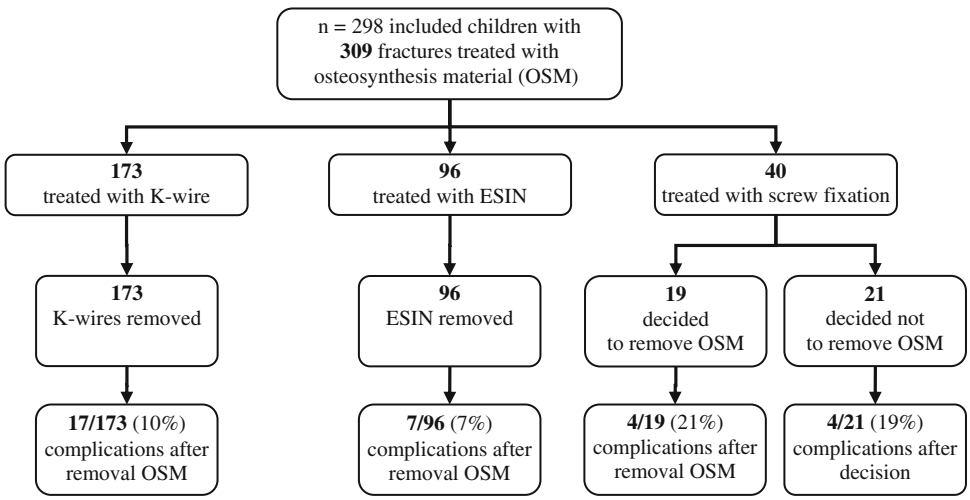

Fig. 1 Flowchart of the study population. The *bold numbers* indicate the number of treated limb fractures

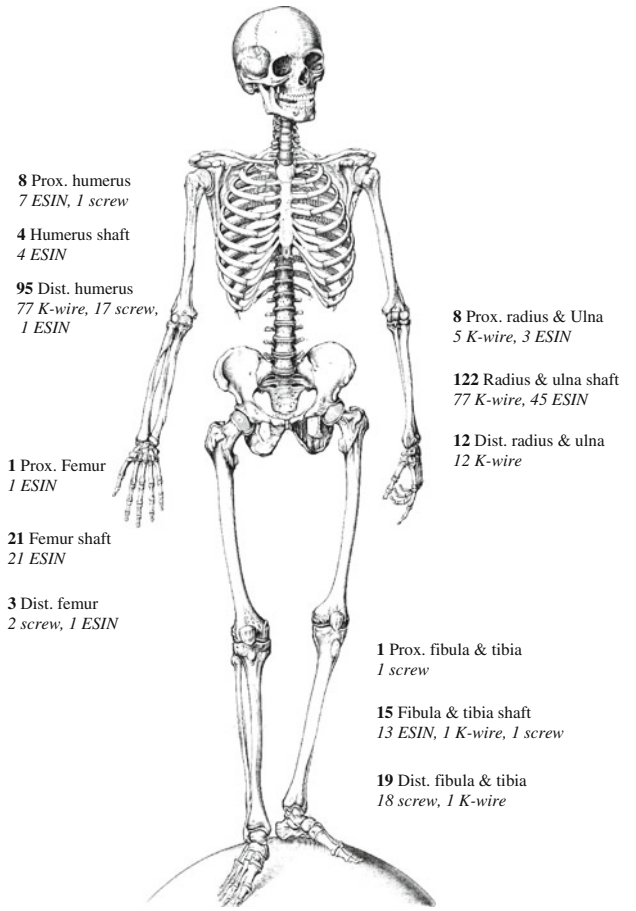

Fig. 2 Fracture location and treatment of 309 fractures. The *bold numbers* indicate the number of fractures. The number and type of treatments for the specific fractures are given in *italics*

removed according to protocol after 45 and 55 days, respectively. The deep infection that persisted after hardware removal resulted from the primary fracture fixation. Except for one neurapraxia, all complications were temporary and gave no irreversible restrictions.

ESIN

In 96/309 fracture treatments, ESIN were used as the fixation material and the removal of ESIN after fracture healing was standard procedure. The nails were implanted in such a manner (tips were situated just outside the cortical bone) that early planned removal surgery would be a minimal intervention. After a mean period of 119 days (range 28–471 days), all ESIN were removed. In one patient, increased bleeding in the bone marrow occurred during the removal of the ESIN and the use of Surgicel® was necessary to stop the bleeding.

During the follow-up period of 60 days after removal surgery, two major and five minor complications occurred in 7/96 removal treatments (7%) (Table 1). One refracture

Table 1 Complications in 269 limb fractures treated with K-wires or ESIN after implant removal surgery

Material	Complication	*n*	Type
K-wires	Pain	5	Minor
	Epiphysiodesis	3[a]	Major
	Neurapraxia	3	Minor
	Refracture	2	Major
	Superficial infection	2	Minor
	Deep infection (pre-existent)	1[a]	Major
	Other OSM-related	1	–
	Subtotal	17	
ESIN	Pain	2	Minor
	Refracture	2	Major
	Superficial infection	2	Minor
	Wound dehiscence	1	Minor
	Subtotal	7	
Total		24	

[a] Trauma-related or pre-existent before implant removal ($n = 4$)

of the femur, in which ESIN was electively removed after 100 days, occurred almost 12 months after removal and was treated in another hospital. One refracture of the distal radius, in which ESIN was electively removed after 88 days, occurred due to a fall from a small height 5 months after removal. All minor complications were temporary and gave no irreversible restrictions. No difference in the complication rates was found between the removal of ESIN fixation (7/96) and the removal of K-wires (17/173) after fracture healing ($p = 0.656$).

Screw fixation

Hardware removal

In 19 of the 40 fractures that were treated with screws, the material was removed after a mean duration of 190 days (range 44–516 days) (Fig. 1, Table 2). The average age of this group was 12.9 years (range 5.9–15.8 years). During one implant removal, a part of a screw could not be entirely removed. Table 2 shows the four complications that occurred after 19 screw removal operations (21%). After implant removal, the average follow-up in the outpatient clinic was 75 days (range 1–661 days). No difference in the complications rates was found between the removal of screw fixation (4/19) and the removal of K-wires (17/173) ($p = 0.13$) or ESIN (7/96) ($p = 0.08$) after fracture healing.

One major complication, epiphysiodesis, occurred after removal surgery. This epiphysiodesis was most probably due to the trauma mechanism or the primary fixation and not as a consequence of the removal surgery. The three

Table 2 Complications in 40 limb fractures treated with screw fixation after hardware removal or retention

Four complications after screw fixation removal in 19/40 treatments			Four complications after screw fixation retention in 21/40 treatments		
Complication	*n*	Type	Complication	*n*	Type
Epiphysiodesis	1[a]	Major	Prominence	3	Minor
Superficial infection	2	Minor	Pain	1	Minor
Pain	1	Minor			
	4			4	

[a] Trauma-related or pre-existent before implant removal ($n = 1$)

minor complications, two superficial infections and one complaint about pain, were temporary and gave no irreversible restrictions.

Hardware retention

In 21 children, for various reasons, it was decided not to remove the material after fracture consolidation (Fig. 1). The average age of this group was 14.2 years (range 11.2–15.9 years). After it had been decided not to remove the material, four patients (19%) returned to the hospital with material-associated complaints (Table 2). In two of these four cases, the decision was reconsidered and the material was still removed. No complications were registered after removal surgery. No difference in the complication rates was found between the removal of screw fixation (4/19) and the retention of screws (4/21) after fracture healing ($p = 1.0$).

Discussion

Analyzing the number and type of complications that occurred after implant removal, we aimed to determine whether hardware removal in children could be performed safely and as a routine procedure. The study population existed of children with fractures treated with K-wires, ESIN, or screw fixation. In the groups treated with K-wires or ESIN, removal surgery was performed routinely, unlike the group treated with screw fixation. No significant differences in the complication rates could be found between the three groups after removal surgery (17/173, 7/96, and 4/19) or between hardware removal (4/19) and retention (4/21) in the case of screw fixation.

Our results showed, overall, 28 complications after 288 hardware removal operations: nine major, 18 minor, and one other material-related complication. Of these nine major complications, four epiphysiodesis were due to the trauma mechanism and one deep infection was already present when the material was in situ. In the case of the four refractures, all materials were removed according protocol after a sufficient time of being in situ. This low number of four refractures, after 288 removal surgeries (1%), rather reinforces the arguments pro removal of implants, than providing arguments not to remove the material. All minor complications and one material-related complication were temporary, except for one case of neurapraxia. Given these results on complications that occurred after implant removal and the fact that only two complications occurred during the removal procedure itself, implant removal surgery of K-wires, ESIN, and screws can be put forward as a safe intervention.

Although a standard procedure in many hospitals, routine hardware removal in children remains controversial. Currently, no evidence-based guideline exists on the topic of hardware removal in children. Arguments against removal would be the potential for complications from the surgery, the repeated anesthesia, and increased medical costs. Since pins and K-wires can be removed in an outpatient situation under local anesthesia, these arguments do apply to a lesser extent for percutaneously inserted and removed metal wires.

Four previous studies investigated complications after hardware removal in children. It remains unclear in these studies whether these fractures were all due to trauma or also included pathological fractures [4, 12–14]. Rosson and Shearer [12] investigated the incidence of refractures after plate removal from the forearm in children. No refractures were reported after the removal of 43 plates in 29 patients. Also, Kim et al. [13] investigated complications after forearm plate removal. One superficial wound infection and three refractures were reported, two in the same child, after the removal of 44 plates in 43 children. The removal of K-wires in 119 fractures was studied by Symons et al. [14]. They primarily investigated complaints of pain after the removal of K-wires. They also documented one ulnar nerve neurapraxia, four superficial wound infections, and 11 overgranulations of the wound after removal of the K-wires. Simanovsky et al. [4] studied the removal of flexible titanium nails in 143 children after femur or forearm fracture fixation. No postoperative infections or neurovascular injuries associated with nail removal were registered. Two refractures were documented, both in the forearm group. In comparison, the current study has not

been restricted to one fracture location, or outcome parameter, and, therefore, relates the results in a wider perspective.

We also looked into the consequences of material retention after fracture consolidation in children, a topic that has not been widely investigated. The only results published on the topic showed higher numbers of treatments in which the primary decision for metal retention was reconsidered [3]. But they all concerned femoral fractures treated with ESIN, in children between 6.5 and 13 years of age. In our study, ESIN was routinely removed.

A limitation of our study is the retrospective follow-up design. Children, who experienced complaints or a refracture, may also have presented elsewhere and were lost to follow-up.

In conclusion, hardware removal of K-wires, ESIN, or screws in children is considered to be a safe procedure. The removal of K-wires or ESIN is, by definition, indicated after fracture healing in children.

Conflict of interest None.

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