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Forearm fractures in children – follow-up study of 137 cases. Comparison and statistical analysis of surgical and conservative treatment

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A – Study Design, **B** – Data Collection, **C** – Statistical Analysis, **D** – Data Interpretation, **E** – Manuscript Preparation, **F** – Literature Search, **G** – Funds Collection

Summary **Background.** Upper limb fractures are a common issue in paediatric patients. Among the available methods, the most prevailing treatment is still closed reduction. The purpose of this study is to determine the best possible course of action in paediatric patients who sustained a forearm fracture.
Objectives. The aim is to evaluate the treatment results of patients with forearm fractures treated in one paediatric surgery centre in Poland.
Material and methods. 137 cases of forearm fractures were divided into groups according to the undertaken procedure and then compared using tools of statistical analysis. Several factors were analysed, with particular emphasis on the control of complications, exposure to ionising radiation, the nuisance of therapy and compliance with therapeutic recommendations.
Results. The comparison resulted in a statistically significant difference in reduction of X-ray pictures and a failure rate in favour of surgical treatment. Treatment time was significantly longer for surgical procedures than for conservative treatment. A higher failure rate was reported in the group of patients treated without stabilisation – 21.3%. For surgical procedures, the failure rate was up to 3.8%. Statistical analysis showed a significant difference in the number of interrupted observations between the surgical procedures and conservative treatment.
Conclusions. The shorter treatment time demonstrated for conservative methods and the associated lower financial expenditure, in the context of treatment of the general public, should be used whenever clinically possible. In more complex cases, it is worth taking into account the advantages of surgical methods.
Key words: child, X-rays, radiation, forearm.

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Background

Upper limb fractures are the most common fractures in children. Among them, the most frequent are forearm fractures [1–4]. In most cases, the standard of care is nonsurgical treatment. Changes in lifestyle, societal expectations, progress in implant design, the increasing problem of childhood obesity, greater interest in participating in sport events and the prevalence of motor vehicles have resulted in the growing popularity and, often, the need for primary surgical treatment [1, 3, 5]. However, the validity of the observed trend is questionable in many cases [6]. Initial medically-acceptable deformities are easily noticeable and rejected by patients and their families, resulting in their overtreatment (Table 1) [1–3, 5].

The forearm fracture incidence peak is between the ages of 10 and 14 (15.23 per 1,000 children). Between the ages of 0 and 19, the incidence is 9.47 per 1,000 children [4]. The risk of fractures is higher in boys than in girls; at the ages of 10–19, we observe a 2–3 times higher risk [4, 5]. The absolute risk of developing a fracture in childhood is 18% (180 per 1,000 children) [4]. The location of the fracture plays a role in influencing the prognosis of the healing process. Overall, 75–84% of fractures are observed in the distal, 15–18% in the middle and 1–7% in the proximal part of the limb [3]. Distal fractures of the forearms show a higher potential for remodelling, as distal cartilage shows a greater potential for growth compared to proximal cartilage (Table 2) [5]. Moreover, deformities occurring as a complication of treatment primarily affect the shaft and distal part of the radius, and they rarely affect the ulna. This results in a limitation of the range of hand motion [7].

Table 1. Therapeutic goals for the treatment of paediatric fractures

Aims of therapy in children
Reduction and maintenance of fracture reduction
Achieving the optimal position in the limb axis
Obtaining the optimal range of rotation and functionality
Avoiding damage to the growth plate at the epiphyses of the bone
Protection of soft tissues
Supporting wound healing
Early mobilisation
Avoiding complications

Table 2. Indications for therapy methods	
Nonsurgical treatment	**Surgical treatment**
Anticipated minor complications	Compound fracture
High remodelling ability (≥ 4 years of skeleton growth)	Multiple fragment fracture
Low risk of non-union	Multiple fractures
	Pathological fractures
	Co-occurring vascular injuries
	≤ 2 years of skeletal growth
	Accompanying ipsilateral fractures

Despite the conditions for a positive prognosis, the response to trauma in children is unpredictable. On the one hand, a child's skeleton has the ability to grow and adapt to biomechanical forces, but on the other hand, it is also possible to prematurely lose the epiphyses (growth plates), or to create osteochondrosis and necrosis [2]. The older the child is, the poorer the results of nonsurgical treatment [8]. By the age of 15, the skeleton matures, and in most children, the growth cartilages of the epiphyses close. After this age, the bone response to external forces is quite similar to that of adults. Girls are two years ahead of boys in terms of development in adolescence, especially over ten years of age, and therefore skeletal growth completes more quickly [2, 9].

A significant factor in the final effect of nonsurgical therapy is the quality and accuracy of the orthopaedic cast [10]. The biggest challenge in conservative treatment is to keep the fracture on the adequate axis. Plaster, together with the initial setting of bone fragments, plays a leading role [7, 11]. In addition, the risk of wound infection is an important factor. Among the nonsurgical methods, these complications play practically no role and are negligible in scientific reports. Surgical treatment is associated with an average risk of 1.9% for wound infection [12].

Materials and methods

The aim of the study is to evaluate the treatment results of patients with forearm fractures treated in one paediatric surgery centre in Poland between January and December of 2019, with particular emphasis on the control of complications, exposure to ionising radiation, the inconvenience to the patient (patient nuisance) and compliance with therapeutic recommendations. Patient nuisance was indirectly assessed by taking into consideration the number of X-ray pictures, the length of the therapy and the number of visits in the clinic. The degree of curvature was assessed at the follow-up visit by a paediatric surgeon based on X-rays pictures. The selection of patients did not refer to the indications for the selection of the therapeutic method. The procedures performed included: closed reduction of the fracture without internal fixation, closed reduction of the fracture with internal fixation and open reduction of the fracture with internal fixation (according to ICD-9-CM: 79.02, 79.12 and 79.32, respectively). The evaluation of treatment results was carried out depending on the type of treatment. The patients were classified into three main groups based on the type of procedure performed. The follow-up consisted of patients' visits to the clinic, during which a paediatric surgeon evaluated the effectiveness of the healing process based on localised changes and X-ray images.

Fourteen cases were excluded from the statistical analysis. The exclusion criteria were the inability to conduct a long-term follow-up due to inspection outside the clinic and high complexity of a fracture not in line with the typical treatment and convalescence process. Monteggia and Galeazzi injuries, isolated olecranon fractures, comminuted fractures and compound fractures were excluded from the analysis. The intraoperative radiation dose was considered statistically insignificant and was omitted from the analysis.

The groups were compared and statistically analysed in terms of differences in the selected parameters. The ANOVA Kruskal-Wallis test was used to compare the number of X-rays, treatment time and immobilisation time. The post-hoc tests performed were the Dunn-Bonferonni test and the Jonckheere-Terpst test to analyse the trend. The Mann-Whitney test was used to collectively compare the number of X-rays for surgical and nonsurgical procedures, with the number of X-ray images being compared solely for completed observations (thus excluding interrupted observations and treatments terminated prematurely due to failure). The treatment time was counted from the time of fracture to discharge from the clinic or to a lost follow-up. The immobilisation time was counted as the time spent in an orthopaedic cast or orthosis, excluding cases requiring a readjustment. The number of failures for individual procedures was then examined. For comparison, Fisher's exact test was used. Further analysis was performed, using multiple comparisons of the columns with the Benjamini-Hochberg correction. Failure was identified as the presence of clinically significant displacement or union in an incorrect setting that required re-readjustment or reoperation. For fractures in children less than 9 years of age, complete displacement, 15 degrees of angulation and 45 degrees of malrotation were acceptable. In children 9 years of age and older, 30 degrees of malrotation was acceptable, with 10 degrees of angulation for proximal fractures and 15 degrees for more distal fractures [13]. The incidence of complications was compared using the Pearson Chi-square test. The Cochran-Armitage test was used to investigate the trend. In order to indirectly assess compliance, the Pearson Chi-square test was used to compare the number of losses to the follow-up of patients treated conservatively and the total number of losses to the follow-up in surgical procedures. To perform the statistical analysis, the PQStat version 1.8.2 program was used.

Results

The study group included 137 cases of forearm fractures in patients of the clinic aged 2 to 18 years between January and December of 2019. Both the gender distribution and the location of the fractures were consistent with the expected epidemiological values – 69.9% of the fractures concerned boys and 30.1% girls. Fractures most commonly occurred in both forearm bones (72.9%), followed by 24.8% in the radius and 2.4% in the ulna. In the study group, 24.6% of cases were lost to follow-up, of which 73.3% were caused by lack of appearance for the follow-up visit after orthopaedic cast removal or internal fixation (Table 3). Most X-ray images were taken for procedure 79.02 (average 8.22), followed by procedure 79.32 (average 7.25), with the least for procedure 79.12 (average 6.39) (Figure 1). This difference was statistically significant, while post-hoc analysis indicated that significant differences were observed

Table 3. Reasons for losses to follow-up and distribution between surgical procedures and conservative treatment ($p = 0.34$)

	Failed to appear	Refraction	Incomplete documentation	Other
Conservative treatment	6	1	0	2
Surgical treatment	16	2	1	1

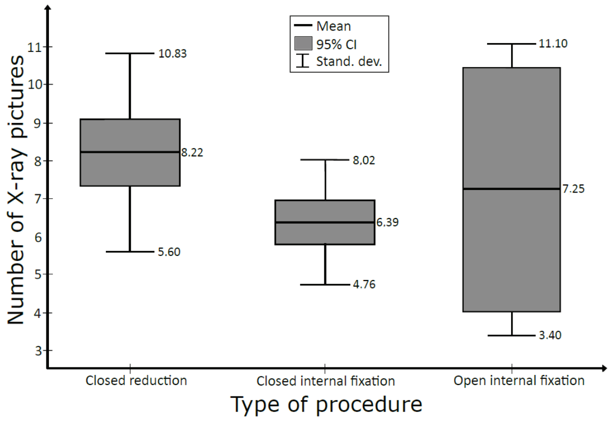

Figure 1. Comparison of X-ray quantity for procedures 79.02, 79.12 and 79.32 for the whole treatment (X-rays taken during the operation were not included) ($p = 0.009$)

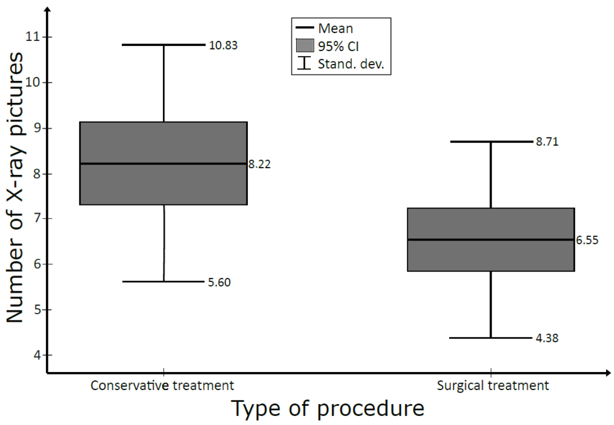

Figure 2. Mean, confidence interval and standard deviation of the X-ray image number taken for conservative and surgical treatment ($p = 0.002$)

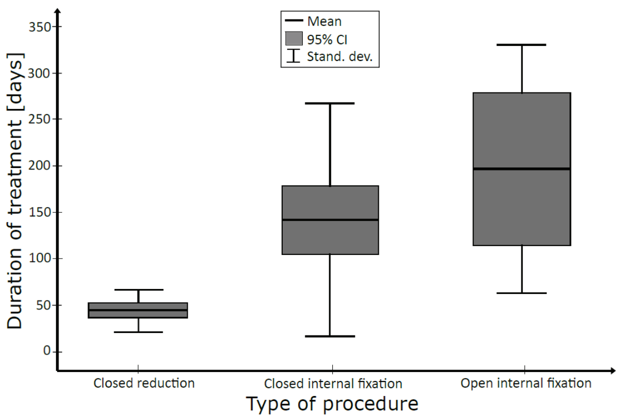

Figure 3. Duration of treatment for procedures 79.02, 79.12 and 79.32 ($p < 0.001$)

between conservative treatment and closed stabilisation ($p = 0.0087$). This trend was also confirmed ($p = 0.0019$). There was also a significant difference when comparing the surgical procedures with combined conservative treatments (Figure 2).

Treatment time was significantly longer for procedures 79.32 and 79.12 than for conservative treatment ($p < 0.001$). The mean and median durations of treatment in days were 44.5 and 41 for procedure 79.02, 141 and 117 for 79.12 and 197 and 141 for 79.32 (Figure 3).

There was no statistically significant difference in the time of immobilisation (Figure 4). These tests also did not show a trend ($p = 0.54$).

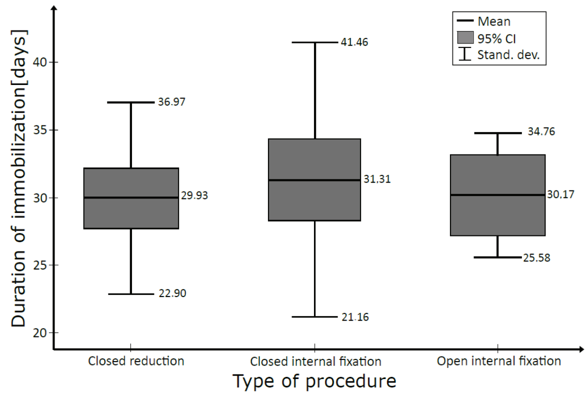

Figure 4. Duration of immobilisation for procedures 79.02, 79.12 and 79.32 ($p = 0.77$)

A higher failure rate (21.3%) was reported in the group of patients treated without stabilisation. For procedure 79.12, the failure rate was 3.8%, and for 79.3,2 no failures were observed. The differences between the groups are statistically significant at $p = 0.011$ (Figure 5). Multiple column comparison showed that there is a significant difference between procedures 79.02 and 79.12 ($p = 0.029$).

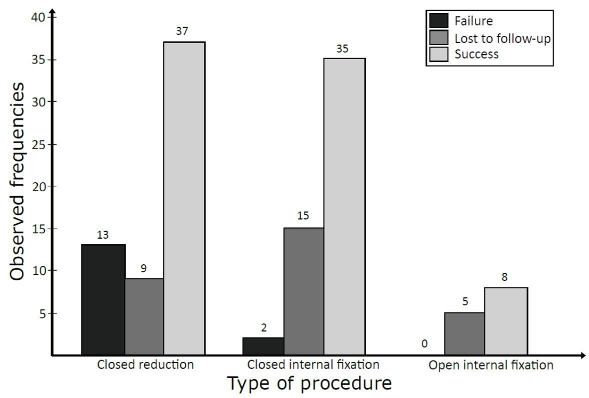

Figure 5. Observed frequencies of successes, failures and losses to follow-up (p = 0.011)

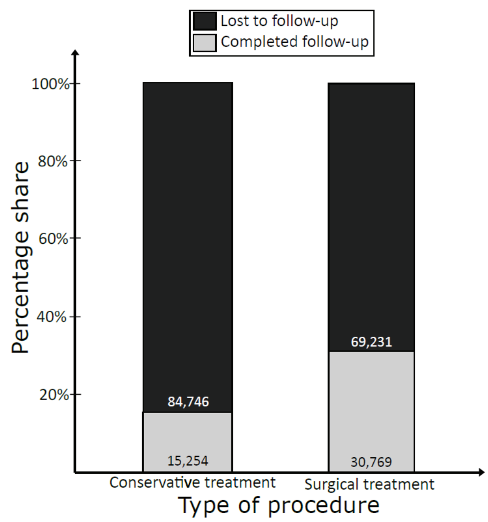

Figure 6. Percentage share of losses to follow-up and complete observations among surgical procedures and conservative treatment ($p = 0.042$)

There were 30 observations lost to follow-up, which constituted 24.19% of the study group. Statistical analysis showed a significant difference in the number of interrupted observations between the surgical procedures and conservative treatment (Figure 6). The majority of interrupted observations resulted from the patient's absence at the follow-up visit after removal of the K-wire or orthopaedic cast. For surgical procedures, this percentage was 24.61%, and for conservative treatment, this was 12.24% of the described cases. However, the analysis did not show a statistically significant difference in the reasons for losses to follow-up.

Table 4. Types and numbers of observed complications

Type of complication	Observed frequencies
None	36
Restriction of active and/or passive mobility	72
Curvature	6
Displacement of the fragments	6
Skin perforation by wire	3
Inflammation around the wire	1
Incomplete union	1
Limb shortening	1
Required tendon plasty	1
Compression of the orthopaedic cast	1

Complications were observed in 87 patients. The characteristics of these complications are summarised in Table 4. There was no statistically significant difference in the incidence of complications between the procedures (p = 0.074) (Figure 7), and no trend was observed (p = 0.055).

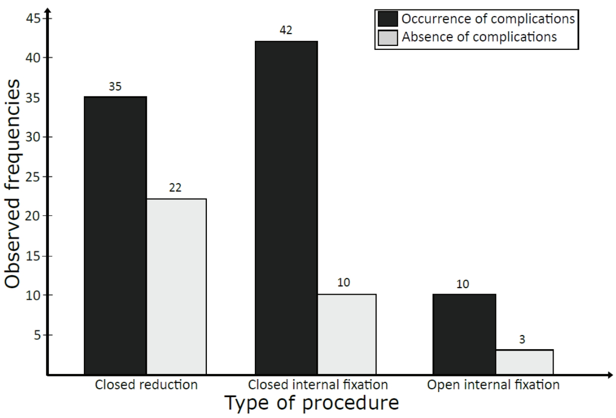

Figure 7. Observed frequencies of occurrence or absence of complications (p = 0.074)

Discussion

The obtained results suggest several valid issues that require more detailed discussion. The visualised, statistically significant difference in the number of upper limb X-rays in the context of the very young age of patients and the radiological principles of ALARA (As Low As Reasonably Achievable) indicates the advantage of internal fixation. Nonetheless, considering the dose of X-ray radiation to which the patient is exposed during a single image, this difference does not seem to be clinically important [14–16]. However, in the case of patients who require repeated imaging using ionising radiation for other reasons, this factor may be noteworthy (Table 5) [17].

Table 5. Dose of radiation absorbed by the body during X-ray examination

X-ray image	Radiation dose (mSv)	Time in which the dose equivalent is absorbed by the body from background radiation
Extremities	0.001	< 1 day
Chest	0.1	10 days
Abdomen	1.2	5 months
Lumbar spine	0.7	3 months

Additionally, another important aspect is the difference in the failure rates of primary operative therapy versus conservative therapy. In the study, we noted a clear advantage for surgical methods, despite the fact that they are used in more complicated cases by choice. Similar data can be observed in the references, where the occurrence of complications during conservative versus operative therapy was estimated at 58% and 24%, respectively [11]. The complications of the treatment process include:

- reoperation,
- displacement of the fracture,
- re-fracture,
- delayed union,
- nerve damage,
- non-union,
- a cosmetic effect unacceptable to the patient.

Moreover, the authors showed that 75% of surgically treated patients did not feel any pain after the end of therapy compared to 57% of those treated conservatively [11, 18]. It is worth emphasising that the most common mild complications of therapy, such as limited active or passive mobility, did not occur in patients who completed treatment. On the other hand, more major complications, including displacement or excessive curvature, occurred much more often in patients treated conservatively. Attention is drawn to the high percentage of observations that were discontinued due to failure to appear for a follow-up visit. Increasing the study group size could be helpful in finding the cause of this phenomenon, although it may be presumed that the difference in the disadvantages of the surgical procedures results from the difference in treatment time itself. It is worth considering that a selection bias might have occurred regarding older children, in which open reduction and internal fixation tend to be more commonly recommended.

Conclusions

The significantly shorter treatment time demonstrated for conservative methods might be valuable in counselling families but should not be considered as a deciding factor in determining the method. Moreover, the association of conservative treatment with lower financial expenditure, in the context of treatment of the general public, points to using these methods whenever clinically possible. However, in relation to cases of higher complexity, it is worth taking into account the advantages of surgical methods due to their lower radiation exposure, lower risk of severe complications and reduction in pain after the completion of therapy. In more difficult cases, it seems necessary to consult a more experienced doctor and transfer the patient to a tertiary referral hospital. In further future studies, it would be interesting to have a stratification of patients more accurate regarding their age.

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