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ORIGINAL ARTICLE

Impact of buried versus exposed flexible intramedullary nails osteosynthesis on pediatric forearm fractures

Impacto de los clavos intramedulares flexibles frente a los expuestos para osteosíntesis en fracturas pediátricas de antebrazo

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What do we know about the subject matter of this study?

The greatest concerns related to leaving the nail ends exposed are re-fractures and complications that will form with the removal of the nails because of infection before the fracture has healed. For this reason, it is believed that leaving the nail exposed increase the re-fracture rate due to early removal.

What does this study contribute to what is already known?

This study show that re-fracture is related more to the open reduction rate than to whether the nails are exposed or buried.

Abstract

In elastic stable intramedullary nailing (ESIN), there are different opinions among surgeons on whether to leave the nail buried in the same arm or to leave it exposed. **Objective:** To determine the risk of re-fracture in patients with a nail buried directly into the amr or left exposed as a treatment for forearm fractures, and to investigate postoperative complications. **Patients and Method:** The study included 113 pediatric patients with a forearm fracture of both diaphyses. Two groups were formed according to whether the nail was buried (Group B, n: 53) in the same arm or left exposed (Group E, n: 60). Data on the number of open reductions, the time to nail removal, the anesthesia type used for its removal, the number of re-fractures, skin infection, and nail entry site irritation were analyzed. **Results:** The mean union times between the groups were not significantly different ($P = 0.371$). The mean time of nail removal in group B (16.02 ± 1.29 weeks) was significantly longer than that of group E (6.65 ± 0.95 weeks) ($P < 0.001$). Open reduction rates were similar between groups ($P = 0.401$). The general anesthesia rate for nail removal in group B (77.4%) was significantly higher than group E (11.7%) ($P < 0.001$). The re-fracture rate was higher in patients who underwent open reduction in both groups ($P < 0.001$). **Conclusion:** The results of this study demonstrated that, despite the increased infection rate, leaving the nail exposed did not increase the re-fracture rate, which was associated with open reduction.

Keywords:
Intramedullary Nailing;
Forearm Fracture;
Buried;
Exposed;
Re-Fracture,
Pediatric Treatment

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Introduction

Forearm fractures are commonly seen fractures, constituting 5-14% of all fractures in the pediatric population and 30% of upper extremity fractures[1,2]. Traditionally, pediatric forearm fractures are treated conservatively with closed reduction and plaster casting. Indications for surgical treatment are unstable fractures, open fractures, and fractures that cannot be reduced by the closed method or have neurovascular damage[3]. Lascombes et al.[4] treated forearm diaphyseal fractures with elastic stable intramedullary nails (ESIN) and reported good results. This technique then became increasingly used and is still in widespread use worldwide[5]. The ease of applicability of the ESIN technique and that it leads to few complications has been confirmed in studies[6,7]. The complications reported most often after ESIN are refracture, damage to the superficial sensory branch of the radial nerve, and delayed union, respectively[8].

In ESIN applications, there are different opinions among surgeons on the subject of buried or exposed nail and this continues to be a matter of debate. The advantages and disadvantages of these two options have been reported at different rates in various publications. In some studies, it has been reported that a nail left exposed can be removed easily without any complications[9], while in others, it has been stated that a nail left exposed increases the risk of infection and since this is a reason for early removal, the risk of re-fracture is increased[10]. Fujihara et al.[11] reported that buried nails were necessary to reduce the risk of postoperative infection and re-fracture. In another previous study, there was reported to be a lower infection rate in the buried Kirschner wire (K-wire) method, and although this led to more removals of K-wires in the operating room compared to the method where it was left exposed, there was no significant difference between the groups in respect of early removal of K-wires[12].

The objective of this study was to determine the risk of re-fracture in patients with nail buried or left exposed in the ESIN treatment of forearm fractures, and to investigate postoperative complications. It was hypothesized that leaving the nail exposed would not increase the re-fracture rate due to early removal, and re-fracture rates would be associated more with open reduction.

Patients and Method

Study design

The study included a total of 113 pediatric patients with a forearm fracture of both diaphysis treated with ESIN a tertiary-level hospital between January 2017 and January 2022. Approval for the study was granted by the Ethics Committee of Hitit University (Decision Nº 31052023-07).

Titanium elastic nails were applied to all the forearm diaphyseal fractures under C-arm fluoroscopy guidance. The study inclusion criteria were patient aged between 4 and 14 years and a forearm fracture of both diaphyses. Patients were excluded from the study if they had neurovascular damage, an isolated single diaphyseal forearm fracture, an open fracture, pathological fracture, were treated with surgical techniques other than ESIN, or were followed up for less than 6 months.

All the patients were evaluated preoperatively at the time of first presentation and postoperatively at 2, 6, and 12 weeks, 6 months and at the final follow-up examination. Two groups were formed according to the nail buried (Group B, n: 53) or left exposed (Group E, n: 60).

The demographic data, follow-up duration, operating time, time to union, operated side, fracture type, surgical method, and postoperative complications were retrospectively obtained from the hospital's computerized database. Analyses were performed with respect to the number of open reductions, the time to implant removal, the anesthesia type used for implant removal, number of re-fractures, postoperative neurovascular damage, skin infection, and nail entry site irritation. For the clinical evaluation, the system developed by Price CT et al.[3] was used. In this scale, the results based on pain status, and supination and pronation range of movement were evaluated as excellent, good, fair, or poor outcomes (table 1).

Surgical Technique

All the procedures were performed under general anesthesia with the patient positioned supine and the forearm in 90° flexion on an arm table under fluoroscopy guidance. No tourniquet was applied to any patient. The closed reduction maneuvre was attempted in all cases, and in those where closed reduction could not be obtained, a mini-open reduction was performed. After appropriate reduction was obtained, the standard surgical technique was applied as described by Lascombes et al.[4]. In all patients, 2, 2.5, and 3 mm titanium nails were pre-curved before introducing radius and ulna bone and were placed with mini incisions. In Group B, the nail ends were bent at 90° and cut then buried below the skin and in Group E, the nail ends were left exposed (figure 1). The wounds were closed with absorbable sutures and all patients were applied with an above-the-elbow brace, which was used for 2 weeks postoperatively. Except for patients whose nails were removed early, no brace was used after hardware removal procedure in any of the patients. Whether the tip of the nails was buried or exposed outside the skin was based on the surgeon's preference.

Statistical methods

The software SPSS (Version 22, SPSS Inc., Chicago, IL, USA, Software license: Hitit University) was used in order to perform statistical analysis of the data. For categorical data, descriptive statistics were presented as frequency and percentage. According to the sample size in the crosstab, the Pearson Chi-square test or Fisher's exact test was utilized to compare categorical variables between research groups. The assumption of normal distribution of numerical data was examined using the Shapiro-Wilk test and the Q-Q plot. Since the assumption of a normal distribution was met, descriptive statistics for numerical data were presented as mean±standard deviation (SD). In order to test the hypothesis of homogeneity of variances, Levene's test was performed. Student's t-test was utilized to compare numerical data between two independent groups since the parametric test assumptions were met. $P < 0.05$ was accepted for statistical significance in all comparisons.

Table 1. Criteria for assessment of result, according to Price CT et al.[13]

Outcomes	Symptoms	Loss of Forearm Rotation
Excellent	No complaints with strenuous activity	< 15°
Good	Mild complaints with strenuous activity	15°- 30°
Fair	Mild complaints with daily activities	31° - 90°
Poor	All other results	> 90°

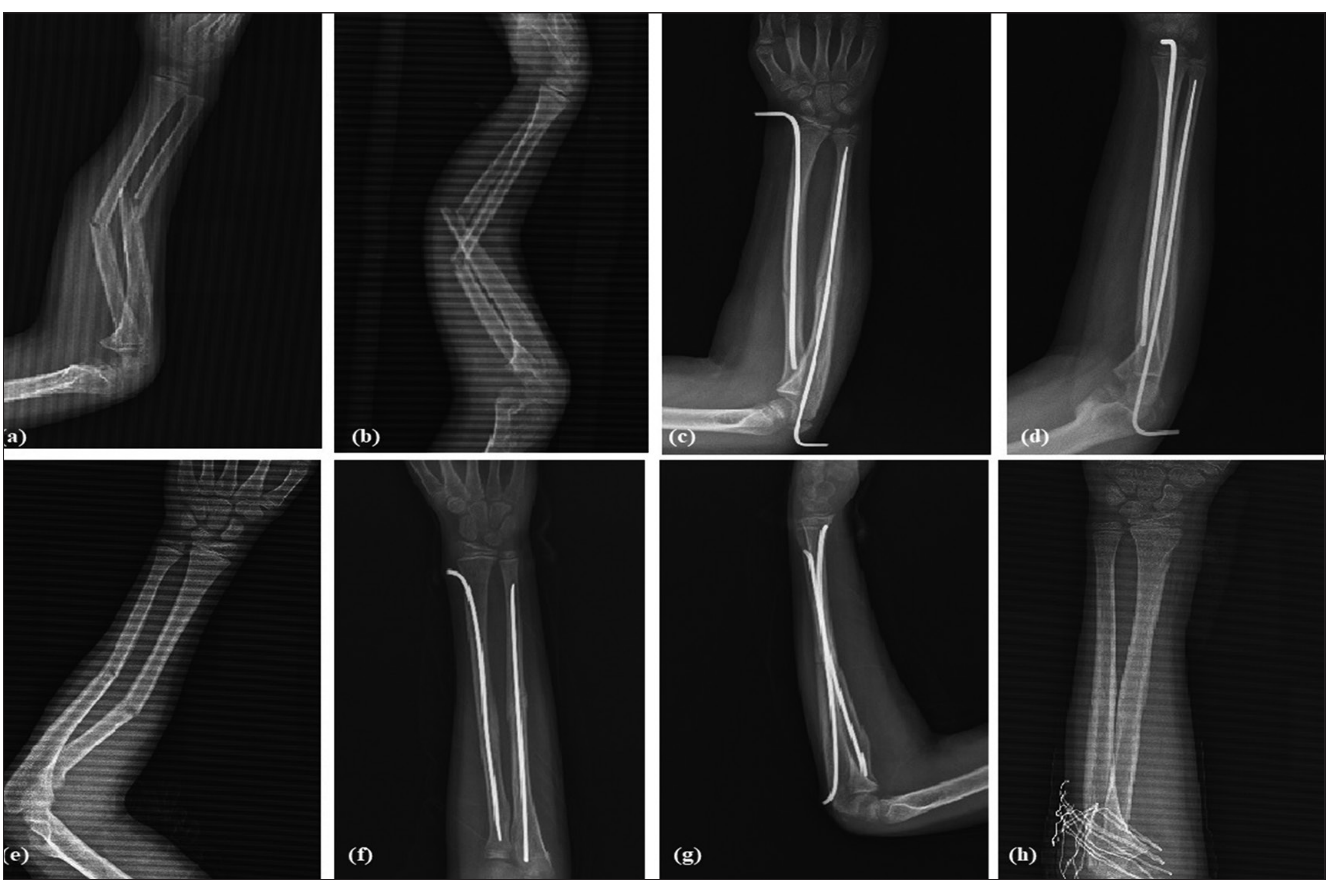

Figure 1. (a, b) Anteroposterior and lateral view of a 5-year-old boy who sustained both bone forearm fractures on the left side. **(c, d)** Anteroposterior and lateral view X-rays of forearms after ESIN, the nail ends were left exposed. **(e)** Post-operative radiograph at 5 months showing re-fracture. **(f, g)** Anteroposterior and lateral view X-rays of forearms after ESIN, the nail ends were left buried. **(h)** Post-operative radiograph after hardware removal at 8 months showing bony union.

Results

In the study, data from 113 patients, 53 (46.9%) in Group B (Buried) and 60 (53.1%) in Group E, were statistically analyzed. 57.5% (n = 65) of the patients were male and 42.5% (n = 48) were female. The mean age of the patients was 9.5 ± 2.17 years (range: 4-13). The mean operation time for all patients was 48.5 ± 3.61 (range: 41-56) minutes, the mean union time was 7.53 ± 0.85 (range: 6-9) weeks, the implant removal time was 11.04 ± 4.82 (range: 5-19) weeks, and the mean follow-up time was 9.47 ± 1.41 (range: 6-12) months.

Statistical findings for the comparison of demographic and clinical characteristics between research groups are presented in table 2. The distribution of sex ratios between the groups was statistically similar ($P = 0.853$). The distribution of forearm fracture sides was statistically similar between the groups ($P = 0.825$). The mean age was not significantly different between the groups ($P = 0.376$). The mean age of Group B was 9.3±2.27 years and the mean age of Group E was 9.67±2.08 years.

The mean union times between the groups were not significantly different ($P = 0.371$). The mean union time of group B was 7.45 ± 0.95 weeks and the mean of union time of group E was 7.6 ± 0.76 weeks. The mean follow-up times were not significantly different between the groups ($P = 0.190$). The mean follow-up times of the B group were 14.28 ± 1.3 months and the mean of the E group was 14.63 ± 1.49 months. The

Table 2. Statistical results for the comparison of demographic and clinical characteristics of the patients

		Groups		P values
		B (Buried) (n = 53)	E (Exposed) (n = 60)	
Gender	Male	30 (56.6%)	35 (58.3%)	0.853[a]
	Female	23 (43.4%)	25 (41.7%)	
Side	Right	32 (60.4%)	35 (58.3%)	0.825[a]
	Left	21 (39.6%)	25 (41.7%)	
Open reduction	No	46 (86.8%)	55 (91.7%)	0.401[a]
	Yes	7 (13.2%)	5 (8.3%)	
Anesthesia	General	41 (77.4%)	7 (11.7%)	< 0.001[a]
	Local	12 (22.6%)	53 (88.3%)	
Re-fracture	No	51 (96.2%)	56 (93.3%)	0.683[b]
	Yes	2 (3.8%)	4 (6.7%)	
Nail entry site infection	No	52 (98.1%)	56 (93.3%)	0.369[b]
	Yes	1 (1.9%)	4 (6.7%)	
Skin irritation	No	48 (90.6%)	58 (96.7%)	0.250[b]
	Yes	5 (9.4%)	2 (3.3%)	
Nerve injury	No	52 (98.1%)	60 (100%)	0.469[b]
	Yes	1 (1.9%)	0 (0%)	
Delayed union	No	52 (98.1%)	60 (100%)	0.469[b]
	Yes	1 (1.9%)	0 (0%)	
Tendon ruptured	No	53 (100%)	60 (100%)	-
	Yes	0 (0%)	0 (0%)	
Age		9.3 ± 2.27	9.67 ± 2.08	0.376[c]
Operation time (minute)		50.04 ± 3.42	47.15 ± 3.24	< 0.001[c]
Union time (week)		7.45 ± 0.95	7.6 ± 0.76	0.371[c]
Follow-up time (month)		9.28 ± 1.3	9.63 ± 1.49	0.190[c]
Time to implant removal (week)		16.02 ± 1.29	6.65 ± 0.95	< 0.001[c]

[a]Chi-square test with n (%). [b]Fisher exact test with n (%). [c]Student's t-test with mean ± standard deviation (SD).

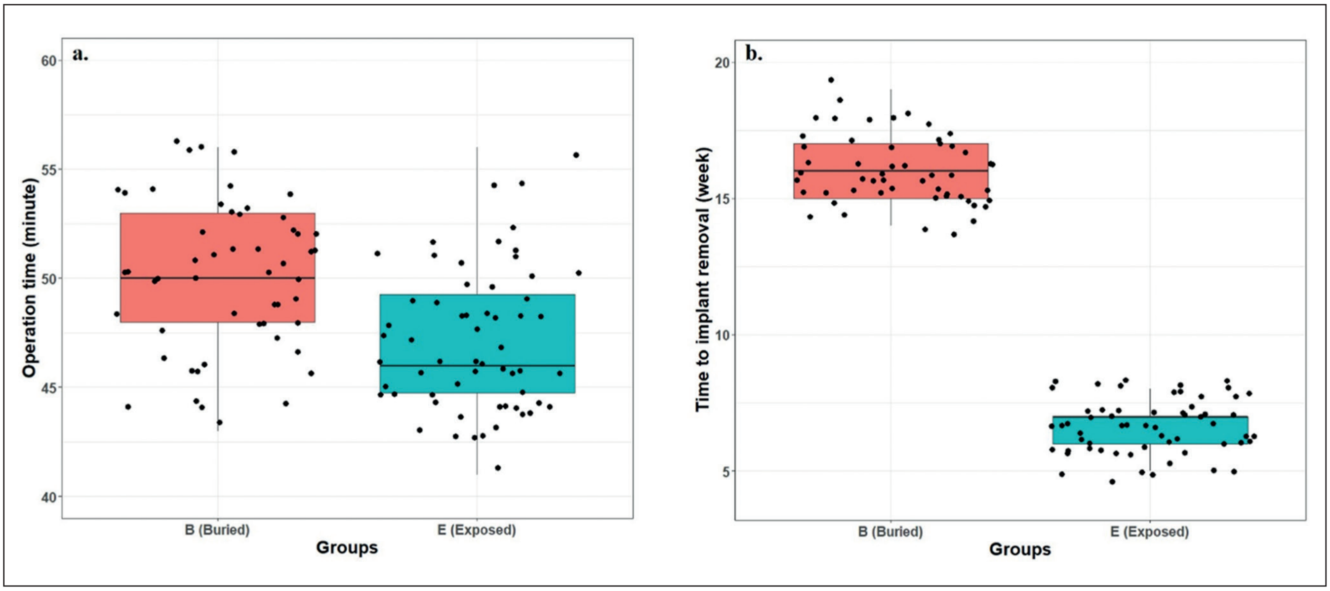

Figure 2. Boxplot with jitters showing operation times (minutes) **(a.)** and time to implant removal (week) **(b.)** between research groups.

Table 3. Statistical results for the relationship between open reduction and re-fracture between groups

Groups			Re-fracture			P values
			No	Yes	Total	
B (Buried)	Open reduction	No	46 (100%)	0 (0%)	46	0.015[b]
		Yes	5 (71.4%)	2 (28.6%)	7	
E (Exposed)	Open reduction	No	54 (98.2%)	1 (1.8%)	55	0.001[b]
		Yes	2 (40%)	3 (60%)	5	

[b]Fisher exact test with n (%).

mean operation time of group B (50.04 ± 3.42 min) was significantly higher than that of group E (47.15 ± 3.24 min) ($P < 0.001$). The mean time of implant removal in group B (16.02 ± 1.29 weeks) was significantly higher than that of group E (6.65 ± 0.95 weeks) ($P < 0.001$). Box plots showing the distribution of operation and implant removal times between groups are presented in figure 2.

Open reduction rates were similar between the groups ($P = 0.401$, table 3). The distributions of general and local anesthesia rates for implant removal were significantly different between the groups ($P < 0.001$). The general anesthesia rate in group B (77.4%) was significantly higher than group E (11.7%) (figure 3). The rates of re-fracture, nail entry site infection, skin irritation, nerve injury and delayed union were similar between the groups ($P = 0.683$, $P = 0.369$, $P = 0.250$, $P = 0.469$, $P = 0.469$, respectively, table 2). There was no ruptured tendon in any patient in either group. In Group E, 4 patients had nail entry side infection. In these patients, the nails were removed before union occurred and all patients were applied with an above-the-elbow brace for risk of refracture.

Statistical results regarding the relationship between open reduction and re-fracture in the groups are presented in table 3. The re-fracture rate was higher in patients who underwent open reduction in both groups (figure 4). In group B, the re-fracture rate (28.6%) in patients with open reduction was significantly higher than that in patients without open reduction (0%) ($P = 0.015$). In group E, the re-fracture rate (60%) in patients with open reduction was significantly higher than that in patients without open reduction (1.8%) ($P = 0.001$).

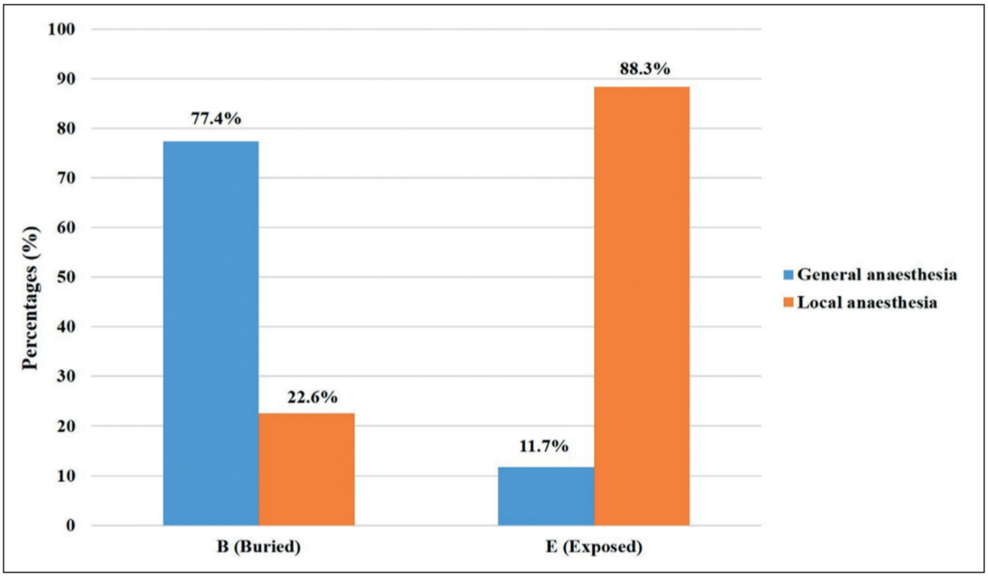

Figure 3. Bar chart showing the distribution of local and general anaesthesia in research groups.

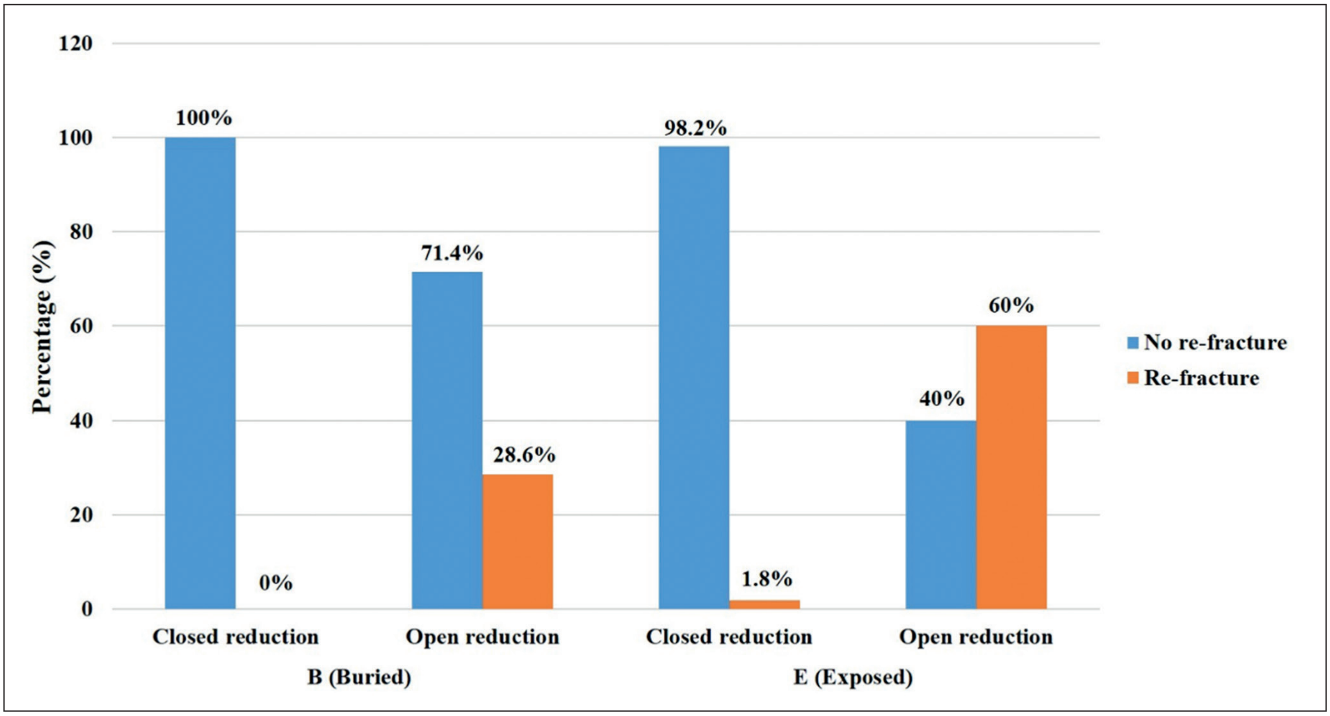

Figure 4. Bar graph showing re-fracture rates in patients with and without open reduction in research groups.

Discussion

The objective of this study was to determine the clinical results of ESIN applied in the treatment of forearm diaphyseal fractures and to evaluate the advantages and disadvantages of buried and exposed nail ends. The basic treatment of most pediatric forearm fractures is closed reduction and plaster casting[14]. When the closed reduction and plaster casting method is not successful, surgical treatment methods are applied. The intramedullary nailing method is a more minimally invasive method than the plate fixation method and is widely used in the surgical treatment of pediatric forearm fractures[15]. Although titanium elastic nails are an excellent option in the treatment of paediatric forearm diaphyseal fractures, many complications have been reported at different rates[16,17].

The greatest concerns related to leaving the nail ends exposed are re-fractures and complications that will form with the removal of the nails because of infection before the fracture has healed. As several studies have reported a higher infection rate with exposed nail ends, it has been reported that the nails should not be kept in place for longer than 8 weeks[18,19]. In the current study, the infection rates were found to be 6.7% in Group E and 1.9% in Group B. Although the infection rate was higher in the exposed nail group than in those where the nail ends were buried, the difference was not significant ($p = 0.369$). The infections seen in Group E ($n = 4$) were mostly superficial infections that were brought under control with appropriate antibiotic therapy, and therefore this did not lead to the need for early implant removal in any case. Similar to previous studies, the implants of almost all the cases in Group E were removed before 8 weeks.

Lascombes et al.[20] reported skin irritation complications at an 8% rate, and stated that when these complications are seen before the fracture has healed they will cause an increase in the rate of general anaesthesia and costs. In the current study, skin irritations were seen in 3.3% of Group E and in 9.4% of Group B. In the 3 patients in Group B with skin irritation, the implants were removed early in the 4th month under general anaesthesia in the operating room. In Group E, skin irritation was seen in only 2 patients in the 5th week, and as the fractures were seen to have healed on the radiographs taken in the 6th week, the implants were removed in the outpatient clinic with no need for local or general anesthesia. As the nails with exposed were ends were removed in the outpatient clinic, extra costs were not incurred for general anaesthesia and additional working time as in the cases with buried nails[21]. The implants were removed under general anesthesia in 41 (77.4%) of the Group B and only in 7 (11.7%) of the Group E, with the remainder removed in the outpatient clinic (< 0.001). Thus it can be said that Group E was more advantageous than Group B in respect of implant removal.

In a study by Dinçer et al.[9], the re-fracture rates were reported to be 3.1% in the group with buried nails and 2.1% in the exposed group, and the exposed method was stated to be reliable. Many studies have reported that re-fracture occurs in the first 2-8 months after the original fracture[22,23]. All the re-fractures in both groups of the current study (6.7%) were seen to occur within 8 months of the first fracture. In all the patients who developed re-fracture, the first fractures were seen to have healed on the previously taken anteroposterior and lateral radiographs.

The re-fracture rate within the first year after implant removal was determined to be 3.8% (n:2) in Group B and 6.7% (n:4) in Group E. Although the number of cases with re-fracture was greater in Group E than in Group B, the difference was not statistically significant and the results were similar to those of Dinçer et al. In another study by Flynn et al.[15], re-fracture rates were reported to be higher in open fractures and forearm fractures applied with open reduction. Similar to that study, when the patients in both groups who developed re-fracture were examined in the current study, it was determined that open reduction was applied to the 2 patients in Group B who developed re-fracture, and to 3 of the 4 patients in Group E. This suggests that re-fracture is related more to the open reduction rate than to whether the nails are exposed or buried. In the open reduction method, the periosteum is damaged and the fracture hematoma is drained, and this can cause the fracture healing process and thereby remodelling to continue for months and even sometimes for years.

Damage to the superficial branch of the radial nerve was seen in only one patient in Group E. Especially when a lateral approach to the radius is made, care must be taken in the identification and protection of the nerve, but it has been reported that the nerve usually heals spontaneously[24].

There were some limitations to this study, primarily the retrospective design, which meant that data collection was limited to the recorded data, to which there may have been limited access. A further limitation was the low number of patients in the second group. Finally, that the surgical procedures were performed by different surgeons could also be considered a limitation.

In conclusion, the results of this study demonstrated that despite the increased infection rate, leaving the nail ends exposed did not increase the re-fracture rate, which was seen to be more associated with open reduction. The removal of exposed nails did not require additional general anesthesia and working time and therefore did not incur extra costs. It should be kept in mind that open fractures and open reduction increase the risk of re-fracture and great care should be taken explaining this to the family.

Ethical Responsibilities

Human Beings and animals protection: Disclosure the authors state that the procedures were followed according to the Declaration of Helsinki and the World Medical Association regarding human experimentation developed for the medical community.

Data confidentiality: The authors state that they have followed the protocols of their Center and Local regulations on the publication of patient data.

Rights to privacy and informed consent: The authors have obtained the informed consent of the patients and/or subjects referred to in the article. This document is in the possession of the correspondence author.

Conflicts of Interest

Authors declare no conflict of interest regarding the present study.

Financial Disclosure

Authors state that no economic support has been associated with the present study.

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