

ORIGINAL ARTICLE

Pediatric Forearm Fractures: TEN (Titanium Elastic Nail) Versus Plate Screw Fixation for Surgical Treatment

Pediatric Ön Kol Kırıklarının Cerrahi Tedavisinde TEN (Titanyum Elastik Çivi) ile Plak Vida Tespitinin Karşılaştırılması

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ABSTRACT

Background/Aims: In pediatric forearm fractures, the choice of surgical technique and fixation method can be challenging. Surgically treated pediatric patients younger than 14 years with Titanium Elastic Nails (TEN) or Plate Screw Fixation (PSF) were compared clinically, in cost, and in terms of postoperative outcomes.

Method: In the retrospective case-control study, pediatric forearm fractures operated on at a level I trauma center between 2017 and 2022 were examined. Surgically treated forearm fractures in pediatric patients under 14 years of age were included in this study group.

Results: The mean age of 109 patients was 10.83 ± 3.28 years. The PSF group (12.87±2.76 years) was 3.17 (95% CI 2.02 - 4.33) years older than the TEN group (9.7±3 years) (p<0.001; student's t-test). The median implant cost in the TEN group (85 [IQR 64 - 120] dollars) was significantly lower than in the PSF group (258 [IQR 205 - 336] dollars) (p<0.001; Mann-Whitney-U). The day callus tissue observed on the X-ray differed significantly between the groups (p<0.001; chi-square test).

Conclusion: In younger children, surgeons preferred TEN due to the likelihood of remodeling associated with growth, the possibility of forming a callus sooner, and the lower cost compared to PSF.

Key words: Pediatric Forearm Fracture, TEN, Plate Screw Fixation, Cost

ÖZ

Amaç: Pediatrik önkol kırıklarında cerrahi teknik ve tespit yöntemi seçimi zor olabilir. Titanyum Elastik Çivilerle (TEN) veya Plak Vida Tespiti (PSF) ile cerrahi olarak tedavi edilen 14 yaşından küçük pediatrik hastalar klinik, maliyet ve postoperatif sonuçlar açısından karşılaştırıldı.

Yöntemler: Retrospektif vaka-kontrol çalışmasında 2017-2022 yılları arasında I. seviye bir travma merkezinde opere edilen pediatrik önkol kırıkları incelenmiştir. Bu çalışma grubuna 14 yaş altı pediatrik hastalarda cerrahi olarak tedavi edilen ön kol kırıkları dahil edildi.

Sonuçlar: 109 hastanın ortalama yaşı 10,83 ± 3,28 bulundu. PSF grubu (12,87±2,76 yıl), TEN grubundan (9,7±3 yıl) 3,17 (%95 GA 2,02 - 4,33) yıl daha büyüktü (p<0,001; student's t-testi). TEN grubunda medyan implant maliyeti (85 [IQR 64 - 120] dolar), PSF grubundan (258 [IQR 205 - 336] dolar) anlamlı derecede düşüktü (p<0,001; Mann-Whitney-U). Röntgende kallus dokusunun görüldüğü gün gruplar arasında anlamlı farklılık gösterdi (p<0,001; ki-kare testi).

Tartışma: Ortopedistler küçük yaşta çocuklarda, büyüme ile ilişkili yeniden şekillenme olasılığı, daha erken bir kallus oluşturma olasılığı ve PSF ile karşılaştırıldığında daha düşük maliyet nedeniyle TEN tercih ettiler.

Anahtar kelimeler: Pediatrik Ön Kol Kırığı, Titanyum Elastik Çivi, Plak Vida Tespiti, Maliyet

Introduction

Among childhood fractures, forearm fractures are common (1). The elasticity of the child's bones and the potential for remodeling make conservative treatment possible. However, the number of surgeries has increased in recent years (2). The treatment of forearm fractures depends on the mechanism, shape, and localization of the fracture (1).

In pediatric forearm fractures, it is important to maintain proper length, alignment, and rotation. An arc of supination-pronation of 100° is required for optimal forearm function.

Surgical treatment of forearm fractures is recommended in cases of unacceptable angles after reduction, irreducible fractures, fractures with reduction loss, and fractures with vascular-nerve injuries (3). It is possible to fix these problems surgically with an intramedullary nail, plating, or hybrid fixation (2,4).

The TEN (Titanium Elastic Nail) method relies on relative fixation. TEN are usually preferred by surgeons in younger children because of a higher probability of remodeling associated with growth (5). The advantages of TEN include a better cosmetic appearance, less bone periosteum removal, minimal disruption of the fracture hematoma, smaller incisions, a lower risk of vascular and nerve damage, and a cheaper alternative to other surgical procedures (5,6). Although complications such as skin irritation, migration, compartment syndrome, and failed fixation have been reported, there are relatively high rates of delayed union, longer immobilization period, and pseudoarthrosis compared with plate screw fixation (7,8).

Using Plate Screw Fixation (PSF), a method that includes open reductions and plate osteosynthesis should be used in children whose skeletal systems

have completed or near completion. By using the device, radial inclination and malrotations can be corrected as well as anatomical reduction and rigid fixation (3,4). The PSF method delays the formation of calluses because more bone periosteum and fracture hematoma are removed. Compared to other surgical procedures, this procedure has a number of disadvantages, including higher cost, larger incisions, worsening cosmetic appearance, and increased risk of vascular and nerve damage (6,7,9,10).

It is usually necessary to surgically treat displaced fractures in patients older than 11 years of age in females or 13 years of age in males (as there is much smaller remodeling potential) (11). There is no universal consensus on how to treat forearm fractures surgically. Particularly for children younger than 14 years old, the decision of fixation method can still be challenging and controversial (1-3,11). Thus, the purpose of this study was to compare the clinical characteristics and outcomes of pediatric patients younger than 14 years who were treated surgically with PSF or TEN for forearm fractures. Also, the study compared the costs of using TEN versus PSF.

Material and Methods

In this retrospective case-control study, pediatric forearm fractures operated at a level 1 trauma center between 2017 and 2022 were examined. This study group included surgically-treated forearm fractures in pediatric patients under 14 years of age. Patients, whose information was insufficient on the hospital system, were excluded from the study. A Helsinki Declaration-compliant ethics committee approval and institutional permission were obtained

(Decision Date: 13 January 2023 No: 314).

Data such as demographics, surgery time, surgeon experience, and operation reports were analyzed. An examination of radiographs was conducted to determine fracture characteristics: the type of fracture, and the location of the fracture (radius or ulna or both). Various intraoperative variables were assessed, including fixation method, cost of implants, and reduction type (open vs closed). Radiographic union of the fractures (callus formation), duration of cast immobilization, and recurrent fractures during the follow-up period with the post-op cast were determined as primary outcomes.

Patients in the study were divided into groups based on the surgical method they underwent (PSF or TEN). PSF procedure includes open reduction and osteosynthesis of the plates. A TEN procedure involved closed reduction and elastically-stable intramedullary nailing. Surgeries in the TEN group were performed by a senior surgeon, while those in the PSF group were performed by the other senior surgeon. For Plate Screw and TEN, the cost was extracted from the Billing Unit's (Faturalandırma Birimi) database from 2017 to 2022. A cost calculation was performed in local currency (TRY), which was converted to U.S. dollars according to the National Bank of Türkiye's exchange rate for each year.

Statistical analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences version 27 for Mac (SPSS Inc., Chicago, IL, USA). For descriptive statistics, continuous variables were presented as mean (+ standard deviation) or median values (interquartile range [IQR]), and nominal and categorical variables were presented as percentages and counts. Univariate analyses were performed using Fisher's exact test, χ^2 test, and independent sample t-test or student's t-test. The alpha significance value was set at $p < 0.05$.

Results

In the study, 109 patients with forearm fractures were included. The mean age of the patients was 10.83 \pm 3.28 years. The majority of patients were male (86.2%) (n=94). Based on the surgical technique they underwent, there were two groups of patients: PSF (n=39, 35.8%) and TEN (n=70, 64.2%) (Table 1). The PSF group (12.87 \pm 2.76 years) was 3.17 (95% CI 2.02- 4.33) years older than the TEN group (9.7 \pm 3 years) ($p < 0.001$; student's t-test). The gender ratios between the groups did not differ significantly ($p = 0.051$; chi-square test). In this study, 71 patients (65.1%) had both radius and ulna fractures, 19 patients (17.4%) had isolated radius fractures, and 19 patients (17.4%) had isolated ulna fractures. In terms of fractured bones, there was no significant difference between groups ($p = 0.3419$; chi-square test). Monteggia fractures were present in 14 patients (12.8%), and there was no significant difference between the groups in the presence of these fractures ($p = 0.378$; chi-square test). The median time to undergo surgery from fracture was 2 days (IQR 1- 2) and there was no significant difference between groups ($p = 0.819$; Mann-Whitney U). The mean years of experience of surgeons in the PSF group (5.77 \pm 3.4 years) and the TEN group (5.56 \pm 2.96 years) did not differ statistically significantly ($p = 0.735$; student's t-test). The median implant cost in the TEN group (85 [IQR 64 - 120] dollars) was significantly lower than in the PSF group (258 [IQR 205 - 336] dollars) ($p < 0.001$; Mann-Whitney-U).

As shown on Table 2, the day callus tissue was observed on the X-ray differed significantly between the groups ($p < 0.001$; chi-square test). In the PSF group, no callus formation was observed on the 15th day. However, 6 patients (15.4%) had callus formation on the 30th day, 6 patients (15.4%) on the 45th day, and 27 patients (69.2%) on the 60th day. Callus formation was observed in 2 patients (2.9%) on Day 15, 18 patients (25.7%) on Day 30, 30 patients (42.9%) on Day 45, and 20 patients (28.6%) on Day 60 in the TEN group. Casting was applied for 15 days in the PSF group (n=25, 64.1%), while it was frequently applied for 30 days in the TEN group (n=55, 78.6%) ($p < 0.001$; chi-square test). In the PSF group, no refracture was observed in the casting period, whereas in the TEN group, refracture was observed in 8 patients (11.4%) in the casting period ($p < 0.001$; chi-square test).

Table 1. Comparison of demographic and fracture characteristics of the groups

Variable	Total (n=109)	Plate Screw Fixation Group(n=39)	Titanium Elastic Nails Group(n=70)	p value	
Age (in years)	10.83±3.28	12.87±2.76	9.7±3	<0.001	
sex	Male	94 (86.2%)	37 (94.9%)	57 (81.4%)	0.051
	Female	15 (13.8%)	2 (5.4%)	13 (18.6%)	
Fractured bone	Radius	19 (17.4%)	9 (23.1%)	10 (14.3%)	0.341
	Ulna	19 (17.4%)	8 (20.5%)	11 (15.7%)	
	Both	71 (65.1%)	22 (56.4%)	49 (70%)	
Monteggia fracture	14 (12.8%)	6 (42.9%)	8 (57.1%)	0.378	
Time to surgery (in days)	2 (1 - 2)	2 (1 - 2)	2 (1 - 2)	0.819	
Experience of surgeon (in years)	5.63±3.11	5.77±3.4	5.56±2.96	0.735	
Implant cost (\$)	205 (120 - 282)	258 (205 - 336)	85 (64 - 120)	<0.001	

Table 2. Comparison of the characteristics of the postoperative period according to the groups

Variable	Plate Screw Fixation Group (n=39)	Titanium Elastic Nails Group(n=70)	P value	
Callous formation on x-ray	Day 15	0 (0%)	2 (2.9%)	<0.001
	Day 30	6 (15.4%)	18 (25.7%)	
	Day 45	6 (15.4%)	30 (42.9%)	
	Day 60	27 (69.2%)	20 (28.6%)	
Duration of cast immobilization (day)	7	8 (20.5%)	0 (0%)	<0.001
	15	25 (64.1%)	11 (15.7%)	
	30	6 (15.4%)	55 (78.6%)	
	45	0 (0%)	4 (5.7%)	
Refracture during casting	0 (0%)	8 (11.4%)	0.025	

Discussion

Choosing the right surgical technique and fixation method for pediatric forearm fractures remains challenging, especially for children younger than 14 years old. A surgeon may use intramedullary nails, plating, or hybrid fixation depending on their experience, preference, and patient's age and type of forearm fracture (1-4). In selecting an intervention, age, and remodeling potential are the most relevant factors to consider (9).

In a study conducted in the USA between 2000 and 2012, Cruz et al(12) reviewed pediatric forearm fractures. As a result, the rate of surgery choice decreased with age, with the lowest rate occurring in children 0-4 years old (15.4%) and the highest rate occurring in adolescents 15-20 years old (79.2%). In a

population-based study from Finland, Helenius et al. (13) showed that the most dramatic increases in the surgical treatment of forearm fractures were seen among 8-14-year-olds (78%), followed by 15-17-year-olds (90%). In the present study, the mean age of the included patients was 10.83 ± 3.28 years. The mean age of patients treated surgically was compatible with the literature. In terms of age, the PSF and TEN groups differed statistically significantly (12.87±2.76 vs. 9.7±3 years). The PSF group had significantly older ages (3.17 years) than the TEN group (p<0.001; student's t-test). Providing rigid fixation in older children is the main reason why the PSF group is preferred, as children's bone remodeling rate decreases with age.

No significant differences were observed between groups in terms of gender, fractured bones, presence of Monteggia fractures, surgery time, or surgeon experiences. These findings showed that TEN or PSF methods were chosen by surgeons according to their preferences for pediatric forearm fractures.

Cost is one of the most important factors when choosing one treatment option over another in any medical system (14). In the TEN group, the median implant cost was 85 dollars (IQR 64-120), significantly less than in the PSF group (258 dollars, IQR 205-336) (p<0.001). The majority of patients were treated with TEN (n=70, 64.2%) in this study. Based on these findings, surgeons have considered cost-effectiveness when choosing forearm fracture treatment methods.

In terms of callus tissue, TEN groups formed calluses significantly earlier than PSF groups (p<0.001). This difference was due to less bone periosteum removal, and minimal disruption of the fracture hematoma in the TEN method (5). Additionally, the PSF method involves open reduction and removal of fracture hematoma, which delays callus formation (7,9). Since absolute fixation is performed with PSF and relative fixation is performed with TEN, callus appearance occurs more with TEN. It is a natural and expected result that callus appearance is higher in patients treated with TEN. Even callus tissue may not be visible in PSF. After surgery, TEN groups spent significantly more days immobilized than PSF groups. Firstly, by using a plate and screw, the PSF method provides a rigid fixation for fracture treatment (3,4). Second, the TEN method involves relative fixation (5). These main differences are responsible for postoperative cast immobilization duration differences. Refracture rates have been reported between 0% and 4.4% after surgery with TEN(4,8). However, the refracture rate observed was 11.4% in the post-operative cast immobilization period in TEN groups.

Limitations

Some limitations were present in this study. First, it was performed in a single-center and small-size cohort. Second, it was designed retrospectively. So, neither clinical nor functional outcomes were correlated with radiographic outcomes and there were no measures of patient-related outcomes. In terms of using fluoroscopy and radiation safety during the

intervention, PSF and TEN methods can be compared in a prospective study. The achievement of similar aims and objectives will require additional large-scale and prospective research.

Conclusion

In pediatric forearm fractures remain challenging to decide on methods for surgery and fixation. Consideration should be given to age, remodeling potential, and implant cost before surgery. In younger children, surgeons preferred TEN due to the likelihood of remodeling associated with growth, the possibility of forming a callus sooner, and the lower cost compared to PSF.

Statements and Declarations

Conflict of interest: The authors declare that they have no conflict of interest.

Funding: This study was not funded by any grant.

Ethics approval: This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Gazi Yasargil Training and Research Hospital Ethical Committee before the study (Decision Date: 13 January 2023 No: 314).

Consent to participate: As this study has a retrospective design, the need for informed consent was waived by the institutional review board.

Availability of data and material: The dataset used and analyzed during the current study is available from the corresponding author on reasonable request.

Author contributions: ALTINTAŞ M, OZEL M: Design of the work, acquisition, analysis, interpretation of data for the work, and accountability for all aspects of the work. ALTINTAŞ M: Revising the work critically for important intellectual content, data collection, interpretation, and drafting the work. TATLIPARMAK AC: Analysis and interpretation of data, revising the work critically. All the authors have approved the final version of the manuscript to be published and are equally accountable for all aspects of the work.

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