Check for updates

ORIGINAL ARTICLE

Clinical effect analysis of different treatment schemes for children with ulnar and radial double fractures

Análisis del efecto clínico de diferentes esquemas de tratamiento para niños con fracturas dobles cubital y radial

*Jibin Liu, Zongpu Wang, Xiaowei Ma, and Jianchuan Wang**
Department of Orthopedics, Affiliated Zhongshan Hospital of Dalian University, Dalian, China

Abstract

Objective: *The objective of the study is to evaluate the safety and efficacy of three different treatment methods for pediatric ulnar and radial double fractures.* **Methods:** *120 children with ulnar and radial double fractures were included in the study. According to the different treatment plans, children were divided into three groups: manual reduction, splint external fixation, double elastic intramedullary fixation, and double plate fixation. Surgical indicators, radiological results, clinical efficacy, and complications were evaluated and compared among the groups.* **Results:** *The average hospital stay and operation time were significantly longer in the double plate internal fixation group compared to the other two groups. The double elastic intramedullary nailing group showed a higher fracture healing rate at 3 months compared to the other groups. There were no significant differences in clinical efficacy among the three groups. Complications were observed in all groups but did not show significant statistical differences.* **Conclusion:** *Double elastic intramedullary nailing fixation demonstrated favorable outcomes in terms of surgical indicators and fracture healing rates for pediatric ulnar and radial double fractures.*

Keywords: *Pediatric fractures. Ulnar and radial fractures. Treatment methods. Double elastic intramedullary nailing. Clinical outcomes.*

Resumen

Objetivo: *Evaluar la seguridad y eficacia de tres métodos de tratamiento diferentes para las fracturas dobles cubital y radial pediátricas.* **Métodos:** *Se incluyeron en el estudio 120 niños con fracturas dobles de cúbito y radio. Según los diferentes planes de tratamiento, los niños se dividieron en tres grupos: reducción manual, fijación externa con férula, fijación intramedular doble elástica y fijación con doble placa. Se evaluaron y compararon entre los grupos indicadores quirúrgicos, resultados radiológicos, eficacia clínica y complicaciones.* **Resultados:** *La estancia hospitalaria promedio y el tiempo de operación fueron significativamente más prolongados en el grupo de fijación interna con doble placa en comparación con los otros dos grupos. El grupo de clavo intramedular elástico doble mostró una mayor tasa de curación de la fractura a los 3 meses en comparación con los otros grupos. No hubo diferencias significativas en la eficacia clínica entre los tres grupos. Se observaron complicaciones en todos los grupos pero no mostraron diferencias estadísticas significativas.* **Conclusión:** *La fijación con clavo intramedular elástico doble demostró resultados favorables en términos de indicadores quirúrgicos y tasas de curación de fracturas pediátricas dobles cubital y radial.*

Palabras clave: *Fracturas pediátricas. Fracturas cubital y radial. Métodos de tratamiento. Clavado intramedular elástico doble. Resultados clínicos.*

***Correspondence:**
Jianchuan Wang
E-mail: wang_jianch99@126.com

Date of reception: 28-08-2023
Date of acceptance: 26-09-2023
DOI: 10.24875/CIRUE.M23000883

Cir Cir (Eng). 2025;93(5):515-524
Contents available at PubMed
www.cirugiaycirujanos.com

2444-0507/© 2023 Academia Mexicana de Cirugía. Published by Permanyer. This is an open access article under the terms of the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

Forearm fractures are the most common injury in children. In particular, forearm shaft fractures are one of the most common injuries in children[1]. Forearm double bone fracture accounts for 3.4% of children's fractures, and upper limb long bone fracture accounts for 26.6%[2]. In most children under the age of 10, forearm fractures can be effectively treated by closed reduction and splinting or gypsum because it has a considerable potential of bone remodeling, although in the case of children over the age of 10, conservative treatment is still a viable option. However, due to the reduced ability of mature bone remodeling, the potential of plaster to repair fracture is low in children aged 10 and in older teenagers[3]. If conservative treatment does not maintain reduction, internal fixation may be needed. It is well known that malunion occurs at a high rate with poor reconstruction of forearm diaphysis fractures[4]. Angular or rotational deformities can result in significantly reduced forearm pronation, especially in older children with bone remodeling potential[5]. Therefore, surgical treatment is required for open fractures with obvious soft tissue injury, unstable fractures with compartment syndrome, and fractures with unacceptable alignment after closed reduction.

At present, there is much debate in the field of pediatric orthopedic surgery. Manual reduction splint external fixation has the advantages of simple operation, low pain, and quick healing, but some unstable fractures have the risk of redisplacement after reduction[6]. Open reduction plate internal fixation can achieve anatomic reduction, but the surgical dissection is large, the incision scar obviously destroys the blood supply of the fracture end, it is easy to cause delayed fracture union or non-union. Closed reduction flexible intramedullary nailing has the advantages of convenient operation, improved appearance, short operation time, stable blood supply to the fracture end, and convenient secondary removal[7]. Closed reduction flexible intramedullary nailing, as a pediatric orthopedic surgical technique, has many advantages, but it also has some drawbacks, such as the requirement for high technical skills and the risk of inadvertent injury to surrounding tissues, nerves, or blood vessels during the nailing process.

The objective of this retrospective cohort study was to evaluate the safety and effectiveness of three different treatment methods, namely manual reduction splint external fixation, double elastic intramedullary nailing, and double steel plate internal fixation, in the management of ulnar and radial double fractures in children aged 3-14 years.

Methods

Study population

The clinical data of 120 children with ulnar and radial double fractures treated by three treatment schemes, including manual reduction and splint external fixation, double elastic intramedullary pin fixation, and double plate fixation, were collected from January 2016 to December 2019 in the Department of Orthopedics of Pediatric Trauma, Zhongshan Hospital affiliated with Dalian University. There were 78 males and 42 females aged from 3 to 14 years old, with an average of 10.6 ± 2.8 years old, and the time from injury to operation was 1-7 days, with an average of 3.5 days. According to different treatment methods, they were divided into 3 groups: manual reduction splint external fixation group (48 cases, Group A). Forty patients (Group B) were treated with double elastic intramedullary nailing fixation. Thirty-two patients (Group C) were treated with double plate fixation. The study was retrospective and was grouped according to the type of surgery. In the sample size calculation, we set the significance level to 0.05, which is the probability threshold for accepting or rejecting the null hypothesis. The effect size was estimated based on previous research and practical considerations. We aimed to detect a moderate effect size and thus chose 0.3 as the effect size. To ensure that the study has the power to detect a true effect, we set the statistical power to 0.8. According to the sample size calculation formula for correlation analysis, we calculated that a minimum sample size of 30 is required.

Inclusion and exclusion criteria

The inclusion criteria were as follows: (i) 3~14 years old; (ii) the fracture was a transverse short oblique or comminuted double fracture of 1/3 of the radius and ulnar bone, either closed or open; (iii) after closed reduction, there were still more than 10 angular or more than 30 rotational deformities; and (iv) The treatment time was 7 days.

The exclusion criteria were as follows: (i) pathological fracture and forearm fracture; (ii) patients with neurovascular injury; (iii) associated wrist fracture dislocation or combination with fractures in other parts; and (iv) incomplete clinical data or loss during

follow-up. This retrospective study was approved by the Ethics Committee of the Affiliated Zhongshan Hospital of Dalian University (No. 6, Jiefang Street, Zhongshan District, Dalian). Informed written consent was obtained from all patients or their guardians.

Surgical method

Gimmick reset splint external fixation (Group A): Intravenous or general anesthesia, limb outreach in the C arm fluoroscopy stage and assistant traction elbow confrontation, easy traction with the forearm and wrist, correct rotating shift, and adoption of the folding roof reset correct before and after the shift. See the fracture under the C arm X-ray perspective, matched to the line. The forearm cotton pads were placed on the dorsal small splint for counter fixation, and then, external fixation was placed on the neutral elbow and wrist splint (Fig. 1, typical case).

Double elastic intramedullary nailing fixation group (Group B): the reduction and fixation under the C-arm fluoroscopy with positioning of the proximal ulna into the needlepoint; the selection of the ulnar olecranon for the lateral incision, ca. 1 cm long, is apart from the epiphyseal plate, 1.5 cm into the needle, and is suitable for the medullary cavity. A mouth opener was inserted into the vertical bone cortex at the lateral proximal end of the Lister tuberosity and gradually tilted 40°~60°. After penetrating the cortex, the head of the nail was inserted into the medullary cavity with a needle holder, and the elastic intramedullary nailing was rotated 180° and gradually advanced along the medullary cavity. Under C-arm fluoroscopy, the fracture end was reduced by a Traditional Chinese osteopath, the fracture end was continued to be advanced to the radial head, and elbow flexion was performed at 90° neutral positions with external fixation of the elbow and wrist plaster (Fig. 2, typical case).

Double plate internal fixation group (Group C): conventional radial dorsal and ulnar approaches were adopted with two incisions of approximately 6-8 cm in length. Reconstruction plate screws were used for fixation. After elbow flexion at the 90° neutral position, external plaster of the elbow and wrist was applied with intravenous antibiotics for 3 days (Fig. 3, typical case).

Intraoperative and post-operative follow-up evaluation

After the operation, the affected limb was suspended with an elbow band, and external fixation was performed with plaster for 4-6 weeks. The tightness of external fixation was adjusted and strengthened in a timely manner in the outpatient clinic every week. Relevant indices were recorded.

Imaging evaluation

After 2 weeks, 4 weeks, 6 weeks, 8 weeks, and 12 months, the outpatient department regularly made follow-up visits and took films. We tentatively defined a fracture healing time over 3 months as “delayed healing” and a fracture healing time over 6 months as “non-healing”[8]. The fracture healing standard was the appearance of a bridging callus in three directions of the bone cortex, which was observed on the antero-posterior and lateral X-ray radiographs without tenderness at the fracture site. The fracture healing rate was recorded at 3 and 6 months to evaluate the wrist joint function according to Berton’s healing evaluation standard[9].

Clinical evaluation

There were regular follow-up visits at 2 weeks, 4 weeks, 6 weeks, 8 weeks, and 12 months after the operation, and the functional recovery of the forearm was checked according to the X-ray review. Grace and Eversman scoring criteria[10] are to evaluate the efficacy of forearm function as follows: excellent: fracture healing, with forearm rotation function greater than 90% of normal, 95~100 points; good: fracture healing, with forearm rotation function greater than 80% of normal, 80~94 points; medium: fracture healing, with forearm rotation function more than 60% of the normal, 60~79 points; and poor: non-union of the fracture or forearm rotation less than 60% of normal, 0-59 points. At the past follow-up visit, we tentatively determined that the pronation or supination angle of the affected forearm was < 10° or more than the rotation angle of the uninjured forearm on the opposite side, which could be considered limited forearm rotation of the affected limb.

Surgical complications

The post-operative complications were recorded.

Statistical analysis

SPSS 23.0 software was used for data analysis. Quantitative data were statistically described by

Figure 1. *Female child, 12 years of age, with a running fall causing a double shaft fracture of the left arm.* **A** *and* **B:** *the positive side of the X ray film.* **C** *and* **D:** *after admission, in the C arm machine perspective, with the administration of intravenous anesthesia and reset of the splint by external fixation with the elbow and wrist in neutral position for splint external fixation.* **E** *and* **F:** *splint external fixation for 6 weeks, demolition of the external fixation film and fracture healing;* **G:** *reset cubits. External observation of the wrist in neutral position with splint fixation.*

Figure 2. *Fourteen-year-old female child fell while roller skating and sustained a double shaft fracture of the left arm.* **A** *and* **B:** *the positive side of the X ray film.* **C** *and* **D:** *2 days after admission, general anesthesia in the C-arm machine perspective downward with closure by double elastic intramedullary nailing fixation.* **E** *and* **F:** *3 months after the operation, X-ray positive side in fracture healing.* **G-I:** *double elastic intramedullary nailing (post-operative outside view).*

Figure 3. *A 14-year-old male patient suffered a double fracture of the right radial diaphysis caused by a bicycle fall.* **A** *and* **B:** *orthographic and lateral radiographs at the time of injury.* **C** *and* **D:** *on the 2nd day after admission, open reduction and double-plate fixation were performed under general anesthesia.* **E** *and* **F:** *the 2nd year after surgery, he was readmitted to remove the plate internal fixation.* **G-I:** *the scar of the incision before internal fixation and the external observation after operation was removed.*

means ± standard deviation. Differences between the groups were assessed by Student's t-test (two groups) or one-way ANOVA (multiple groups). The count data were expressed as the number of cases/percentage (n/%) and tested by Chi-square test or Fisher exact test. $p < 0.05$ was considered statistically significant.

Results

General Information

There were 75 males and 45 females aged from 3 to 14 years old, with an average of 10.6 ± 2.8 years old. Specific clinical general information for the three groups of patients is presented in Supplementary Table 1. General information did not differ between the three groups and could be used for subsequent comparisons ($p > 0.05$).

Comparison of surgical indicators

Length of hospital stay

There was no significant difference between Group A and Group B ($p > 0.05$). There were statistically significant differences between Groups B and C, and there were statistically significant differences between Groups A and C ($p < 0.05$). Group C had the longest average hospital stay.

Operation time

There was no significant difference between Group A and Group B ($p > 0.05$). There were statistically significant differences between Groups B and C and statistically significant differences between Groups A and C ($p < 0.05$). Group C had the longest average operation time.

Intraoperative blood loss

There was no significant difference between Group A and Group B ($p > 0.05$). There were statistically significant differences between Groups B and C and statistically significant differences between Groups A and C ($p < 0.05$). The average blood loss in Group C was the highest.

Incision length

There was no significant difference between Group A and Group B ($p > 0.05$). There were statistically significant differences between Groups B and C and statistically significant differences between Groups A and C ($p < 0.05$). Group C had the longest average incision length.

Treatment cost

There was no significant difference between Group A and Group B ($p > 0.05$). There were statistically significant differences between Groups B and C and statistically significant differences between Groups A and C ($p < 0.05$). Group C had the highest average treatment cost (Table 1).

Radiological results

Comparison of the fracture union rate 3 months after operation: in Group A, 39 cases had complete fracture union; there were 37 cases of complete union in Group B and 27 cases in Group C. The fracture healing rate of Group B was higher than that of Group A and Group C at 3 months. The difference between Group B and Groups A and C was statistically significant ($p < 0.05$), and there was no significant difference between Group A and Group C ($p > 0.05$) in terms of the number of non-union cases involving ulnar fracture.

Comparison of the fracture union rate 6 months after the operation: there were 47 cases, 40 cases, and 31 cases of fracture union, respectively, among the 3 groups.

Clinical efficacy results

The forearm function of the three groups was evaluated by the Grace and Eversman evaluation criteria at the 3-month follow-up after surgery. The excellent and good rates of Group A, Group B, and Group C were 87.6% (42/48 cases), 97.5% (39/40 cases), and 93.6% (29/32 cases), respectively. According to the Berton healing evaluation standard, the excellent and good rates of Group A, Group B, and Group C were 91.6% (44/48 cases), 95% (38/40 cases), and 93.6% (30/32 cases), respectively. There was no significant difference in the excellent and good rate assessed by the forearm rotation wrist function score among the three groups ($p > 0.05$) (Table 2).

Table 1. Comparison of perioperative data

	Group A	Group B	Group C	χ^2/F value	p
Hospitalization days (day)	3.2 ± 1.2	3.3 ± 1.1	10.6 ± 1.3	6.213	0.001
Operation time (min)	32.1 ± 4.3	35.3 ± 3.5	58.4 ± 5.2	9.942	0.001
Blood loss (mL)	0	5.5 ± 1.1	25.2 ± 9.8	8.652	0.001
Length of incision (cm)	0	1.0 ± 0.3	9.2 ± 1.3	6.431	0.001
Cost of treatment (yuan)	2300 ± 430.3	5000 ± 121.4	18000 ± 200.5	44.252	0.001

Complication results

In Group A, there were 2 children with fracture displacement 2 weeks after surgery, and their families required conservative treatment and finally malunion within the acceptable angle range. There was 1 case of needletail irritation in Group B; 1 case of incision infection in Group C, which was healed by dressing changes; 1 case of delayed healing; and 1 case of refracture, which was healed by iliac bone regrafting. There was no statistical significance in pairings among Groups A, B, and C ($p > 0.05$).

Table 2. Clinical efficacy results of the three groups

Group	Excellent and good rate according to the Berton score (wrist)	Excellent and good rate according to the Grace score
Group A	91. 6% (44/48)	87.6% (42/48)
Group B	95% (38/40)	97.5% (39/40)
Group C	93.6% (30/32)	93.6% (29/32)
χ^2/F value	0.235	0.276
p	0.868	0.967

Discussion

In this study, we conducted a comprehensive evaluation of three different surgical treatment methods for pediatric diaphyseal forearm fractures, focusing on their clinical outcomes and complications. Significant differences were observed among the three groups in terms of surgical indicators, including hospital stay, operation time, intraoperative blood loss, incision length, and treatment cost. Radiographic results also revealed variations in fracture healing rates among the three groups. Furthermore, clinical efficacy assessments demonstrated differences in forearm function evaluations. However, no significant statistical differences were observed in terms of complications.

Forearm fractures in children can be treated with non-surgical methods such as manual reduction splints or plaster external fixation[11]. However, these methods have limitations in achieving anatomical reduction and may result in treatment failure[12]. Surgical intervention is recommended for patients with significant rotation deformities after closed reduction[13,14]. The traditional fixation method is open reduction and plate internal fixation, which can ensure anatomical reduction but has drawbacks such as surgical trauma, increased risk of non-union and infection, and aesthetic concerns[15,16]. Therefore, there is a need for a better fixation method for pediatric forearm shaft fractures.

The application of elastic intramedullary nailing in the fixation of double bone fractures of the forearm in children has shown promising functional and imaging results, making it the preferred method due to its simplicity, minimal damage to the blood supply, esthetic incisions, and easy nail removal[17]. This technique utilizes small incisions and the insertion of elastic nails to provide three-point support within the long bone cavity, maintaining fracture stability[9,18,19]. Closed reduction and elastic intramedullary nailing therapy are designed to cause the foot radius to obtain anatomical reduction that is maintained in the process of healing fracture alignment. Ligier et al.[20] believed that the elasticity of elastic intramedullary nailing could transform shear force into compression force and traction force, thus promoting the formation of early callus. Furlan et al.[21] retrospectively analyzed 175 cases of long bone fracture fixed by elastic intramedullary nailing in 2011, with an average follow-up of 41.3 months. All patients achieved complete union, with an average healing time of 7.5 weeks, and 11 patients (6.3%) had complications. Lu et al.[22] found that elastic intramedullary nail

has multiple advantages of mini-invasiveness, quicker healing, and excellent function recovery in the treatment of both ulna and radius fractures in children. Antabak et al.[23] retrospectively analyzed the efficacy and imaging manifestations of elastic intramedullary nailing for the treatment of double fractures of the forearm diaphysis in children and concluded that elastic intramedullary nailing is an effective technique universally recognized for the fixation of double fractures of the forearm diaphysis in children, which is conducive to the recovery their forearm function. Richter et al.[24] reported that 30 children with forearm fractures were treated with elastic intramedullary nailing, and the results were excellent in 24 cases, good in 5 cases, and moderate in 1 case after 6 months of follow-up. Our study aligns with previous research, demonstrating improved surgical indicators and higher fracture healing rates in the group treated with elastic intramedullary nailing. These findings support the effectiveness of this method in pediatric forearm fractures.

However, it is important to acknowledge the potential complications associated with elastic intramedullary nailing. Although the flexible intramedullary nailing technique has many advantages, such as no injury to the epiphyseal vessels, safety, low infection rate, and convenience for early rehabilitation and exercise, its complications still need to be given attention[25]. Elastic intramedullary nailing can be complicated by wound infection, nerve injury, skin irritation, and refracture, with an average complication rate of approximately 10 to 15%[26]. In our study, we also observed potential complications associated with elastic intramedullary nailing in the treatment of double bone fractures of the forearm in children. Some complications may be attributed to surgeon-related factors, such as poor reduction skills or disruption of the blood supply during open reduction, increasing the risk of delayed union or non-union. Open reduction can also lead to local periosteal destruction, reduced blood supply, and delayed callus formation. Some complications can be attributed to surgical-related factors[27-29].

A single intramedullary nail or open and mixed fixation method has been reported to reduce operative time, fluoroscopy time, and soft tissue dissection. Colaris's study[30] warns against using single-bone fixation in all double-bone fractures of the forearm, as it significantly reduces the operation time. However, this may lead to increased clinical outcomes of redisplacement and may not provide rotational stability. Our study employed experienced traditional Chinese medicine osteosetters who performed closed reduction without compromising the blood supply at the fracture site. Therefore, the duration of surgery and fluoroscopy time should be interpreted in the context of individual surgeon expertise and fracture complexity.

This study has several limitations. First, it adopted a retrospective design, which may introduce recall bias and incomplete information. Second, the sample size was relatively small, which may affect the reliability and generalizability of the results. Third, the study only included data from one hospital, which may limit the generalizability of the findings due to regional and institutional differences. Finally, the study did not consider individual differences and pre-operative conditions that may influence treatment outcomes, which could have an impact on the results.

Conclusions

Double elastic intramedullary nailing fixation shows favorable outcomes in terms of surgical indicators and fracture healing rates for ulnar and radial double fractures in children aged 3 to 14 years. These findings provide important guidance for clinicians in selecting appropriate surgical treatment methods.

Acknowledgments

The authors would like to thank Zhongshan Hospital, affiliated with Dalian University, for its support of this study.

Funding

The authors declare that they have not received funding.

Conflicts of interest

The authors declare no conflicts of interest.

Ethical considerations

Protection of human and animal subjects. The authors declare that the procedures followed complied with the ethical standards of the responsible human experimentation committee and adhered to the World Medical Association and the Declaration of Helsinki. The procedures were approved by the institutional Ethics Committee.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's

confidentiality protocols, obtained informed consent from patients, and received approval from the Ethics Committee. The SAGER guidelines were followed according to the nature of the study.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing of this manuscript.

Supplementary data

Supplementary data are available at DOI: 10.24875/CIRU.23000426. These data are provided by the corresponding author and published online for the benefit of the reader. The contents of supplementary data are the sole responsibility of the authors.

References

1. Kruppa C, Bunge P, Schildhauer TA, Dudda M. Low complication rate of elastic stable intramedullary nailing (ESIN) of pediatric forearm fractures: a retrospective study of 202 cases. Medicine (Baltimore). 2017;96:e6669.
2. Landin LA. Fracture patterns in children. Analysis of 8,682 fractures with special reference to incidence, etiology and secular changes in a Swedish urban population 1950-1979. Acta Orthop Scand Suppl. 1983;202:1-109.
3. Barnett SA, Song BM, Yan J, Leonardi C, Gonzales JA, Heffernan MJ. Intraoperative burden of flexible intramedullary nailing and spica casting for femur fractures in young children. J Pediatr Orthop. 2021;41:e499-505.
4. Soumekh L, Sylvanus T, Karlen A, Wahl C, Huser AJ, Truong WH. Refracture rate of both bone forearm fractures: a retrospective comparison of casting alone versus casting and extended functional bracing. J Pediatr Orthop. 2021;41:267-72.
5. Chen C, Xie L, Zheng W, Chen H, Cai L. Evaluating the safety and feasibility of a new surgical treatment for forearm fractures in older children: study protocol for a randomised controlled trial. Trials. 2019;20:320.
6. López S, Vilar JM, Sopena JJ, Damià E, Chicharro D, Carrillo JM, et al. Assessment of the efficacy of platelet-rich plasma in the treatment of traumatic canine fractures. Int J Mol Sci. 2019;20:1075.
7. Yang X, Li L, Tang X, Xiang B, Wen T. Can intraoperative ultrasound visualize the closed reduction and elastic intramedullary nail fixation processes of double forearm fractures in children? Medicine (Baltimore). 2021;100:e24324.
8. Reinhardt KR, Feldman DS, Green DW, Sala DA, Widmann RF, Scher DM. Comparison of intramedullary nailing to plating for both-bone forearm fractures in older children. J Pediatr Orthop. 2008 28:403-9.
9. Yong B, Yuan Z, Li J, Li Y, Southern EP, Canavese F, et al. Single bone fixation versus both bone fixation for pediatric unstable forearm fractures: a systematic review and metaanalysis. Indian J Orthop. 2018;52:529-35.
10. Grace TG, Eversmann WW Jr. Forearm fractures: treatment by rigid fixation with early motion. J Bone Joint Surg Am. 1980;62:433-8.
11. Sinikumpu JJ, Lautamo A, Pokka T, Serlo W. The increasing incidence of paediatric diaphyseal both-bone forearm fractures and their internal fixation during the last decade. Injury. 2012;43:362-6.
12. Dittmer AJ, Molina D 4th, Jacobs CA, Walker J, Muchow RD. Pediatric forearm fractures are effectively immobilized with a sugar-tong splint following closed reduction. J Pediatr Orthop. 2019;39:e245-7.
13. Papamerkouriou YM, Christodoulou M, Krallis P, Rajan R, Anastasopoulos J. Retrograde fixation of the ulna in pediatric forearm fractures treated with elastic stable intramedullary nailing. Cureus. 2020;12:e8182.
14. Freese KP, Faulk LW, Palmer C, Baschal RM, Sibbel SE. A comparison of fixation methods in adolescent patients with diaphyseal forearm fractures. Injury. 2018;49:2053-7.
15. Fernandez FF, Egenolf M, Carsten C, Holz F, Schneider S, Wentzensen A. Unstable diaphyseal fractures of both bones of the forearm in children: plate fixation versus intramedullary nailing. Injury. 2005;36:1210-6.
16. Fernandez FF, Eberhardt O, Langendörfer M, Wirth T. Nonunion of forearm shaft fractures in children after intramedullary nailing. J Pediatr Orthop B. 2009;18:289-95.
17. Cintean R, Eickhoff A, Pankratz C, Strauss B, Gebhard F, Schütze K. Radial vs. dorsal approach for elastic stable internal nailing in pediatric radius fractures-a 10 year review. J Clin Med. 2022;11:4478.
18. Vasilescu DE, Cosma D. Elastic stable intramedullary nailing for fractures in children - principles, indications, surgical technique. Clujul Med. 2014;87:91-4.
19. Smith VA, Goodman HJ, Strongwater A, Smith B. Treatment of pediatric both-bone forearm fractures: a comparison of operative techniques. J Pediatr Orthop. 2005;25:309-13.
20. Ligier JN, Metaizeau JP, Prévot J, Lascombes P. Elastic stable intramedullary nailing of femoral shaft fractures in children. J Bone Joint Surg Br. 1988;70:74-7.
21. Furlan D, Pogorelić Z, Biočić M, Jurić I, Budimir D, Todorić J, et al. Elastic stable intramedullary nailing for pediatric long bone fractures: experience with 175 fractures. Scand J Surg. 2011;100:208-15.
22. Lu B, Liu P, Wang Y. Application of elastic intramedullary nail in the treatment of both ulna and radius fractures in children. Zhonghua Yi Xue Za Zhi. 2014;94:1882-5.
23. Antabak A, Luetic T, Ivo S, Karlo R, Cavar S, Bogovic M, et al. Treatment outcomes of both-bone diaphyseal paediatric forearm fractures. Injury. 2013;44 Suppl 3:S11-5.
24. Richter D, Ostermann PA, Ekkernkamp A, Muhr G, Hahn MP. Elastic intramedullary nailing: a minimally invasive concept in the treatment of unstable forearm fractures in children. J Pediatr Orthop. 1998;18:457-61.
25. Slongo TF. Complications and failures of the ESIN technique. Injury. 2005;36 Suppl 1:A78-85.
26. Makki D, Matar HE, Webb M, Wright DM, James LA, Ricketts DM. Elastic stable intramedullary nailing in paediatric forearm fractures: the rate of open reduction and complications. J Pediatr Orthop B. 2017;26:412-6.
27. Elia G, Blood T, Got C. The management of pediatric open forearm fractures. J Hand Surg Am. 2020;45:523-7.
28. Mania S, Zindel C, Götschi T, Carrillo F, Fürnstahl P, Schweizer A. Malunion deformity of the forearm: three-dimensional length variation of interosseous membrane and bone collision. J Orthop Res. 2023;41:727-36.
29. Poutoglidou F, Metaxiotis D, Kazas C, Alvanos D, Mpeletsiotis A. Flexible intramedullary nailing in the treatment of forearm fractures in children and adolescents, a systematic review. J Orthop. 2020;20:125-30.
30. Colaris J, Reijman M, Allema JH, Kraan G, van Winterswijk P, de Vries M, et al. Single-bone intramedullary fixation of unstable both-bone diaphyseal forearm fractures in children leads to increased re-displacement: a multicentre randomised controlled trial. Arch Orthop Trauma Surg. 2013;133:1079-87.