UDC 616.718.4-001.5-089.819.84
DOI – https://doi.org/10.14300/mnnc.2024.19026
ISSN – 2073-8137

APPLICATION OF ELASTIC OSTEOSYNTHESIS TENS IN CHILDREN WITH DIAPHYSEAL FRACTURES

B. M. Ch. Evers [1], A. V. Isaeva [2, 4], S. V. Minaev [2, 4], N. K. Barova [3, 5], Yu. V. Pozharsky [2, 4], A. A. Edidzhi [3, 5], M. Sh. Ushveridze [4], M. S. Bagdasaryan [2]

[1] Hannover Medical School, Germany
[2] Stavropol State Medical University, Russian Federation
[3] Kuban State Medical University, Krasnodar, Russian Federation
[4] Regional Children's Clinical Hospital, Stavropol, Russian Federation
[5] Children's Regional Clinical Hospital, Krasnodar, Russian Federation

ПРИМЕНЕНИЕ ЭЛАСТИЧНОГО ОСТЕОСИНТЕЗА В ЛЕЧЕНИИ ДИАФИЗАРНЫХ ПЕРЕЛОМОВ У ДЕТЕЙ

Б. М. Х. Эверс [1], А. В. Исаева [2, 4], С. В. Минаев [2, 4], Н. К. Барова [3, 5], Ю. В. Пожарский [2, 4], А. А. Едиджи [3, 5], М. Ш. Ушверидзе [4], М. С. Багдасарян [2]

[1] Ганноверская медицинская школа, Германия
[2] Ставропольский государственный медицинский университет, Российская Федерация
[3] Кубанский государственный медицинский университет, Краснодар, Российская Федерация
[4] Краевая детская клиническая больница, Ставрополь, Российская Федерация
[5] Детская краевая клиническая больница, Краснодар, Российская Федерация

A multicenter study analyzes the use of elastic stable intramedullary nailing (ESIN) in 142 fractures of the femoral, tibia, and humerus shaft in children. Flexible rods are introduced through the distal metaphyseal area to develop a bridging callus. Early load on the limb is possible and is recommended. Complications were minimal. Compared with osteosynthesis with extracortical plates in 208 patients, ESIN obviates the need for prolonged bed rest and protects soft tissue without disrupting the blood supply to bone tissue.

Keywords: diaphyseal bone fracture, elastic osteosynthesis, ESIN, TEN, children

В многоцентровом исследовании проанализировано применение эластичных стабильных интрамедуллярных стержней (ЭСИН) при 142 переломах диафизов бедренной, большеберцовой и плечевой костей у детей. Гибкие стержни вводились через дистальную метафизарную область для формирования мостовидной мозоли. Проводилась ранняя нагрузка на поврежденную конечность. Осложнения были минимальными. В сравнении с остеосинтезом экстракортикальными пластинами у 208 пациентов ЭСИН позволил избежать необходимости длительной госпитализации и обеспечил защиту мягких тканей, не нарушая кровоснабжение костной ткани у детей.

Ключевые слова: перелом диафизарной кости, эластичный остеосинтез, ESIN, TEN, дети

For citation: Evers B. M. Ch., Isaeva A. V., Minaev S. V., Barova N. K., Pozharsky Yu. V., Edidzhi A. A., Ushveridze M. Sh., Bagdasaryan M. S. Application of elastic osteosynthesis tens in children with diaphyseal fractures. *Medical News of North Caucasus*. 2024;19(2):117-120. DOI – https://doi.org/10.14300/mnnc.2024.19026

Для цитирования: Эверс Б. М. Х., Исаева А. В., Минаев С. В., Барова Н. К., Пожарский Ю. В., Едиджи А. А., Ушверидзе М. Ш., Багдасарян М. С. Применение эластичного остеосинтеза в лечении диафизарных переломов у детей. *Медицинский вестник Северного Кавказа.* 2024;19(2):117-120. DOI – https://doi.org/10.14300/mnnc.2024.19026

CRCH – Children's Regional Clinical Hospital
EOC – electronic optical converter
ESIN – elastic stable intramedullary nailing
HMS – Hannover Medical School
RCCH – Regional Children's Clinical Hospital
TEN – titanium endomedullary nails

Diaphyseal fractures of the femur occur on average in 27.6–32.8 % of cases, the humerus in 5.3–7.9 %, and the tibia in 28.9–42.5 % [1, 2]. Of these, 42.9–50.2 % of preschool-aged patients are under seven years of age, and the rest are older [3]. Therefore, there is undoubtedly an increasing need to choose treatment methods for diaphyseal fractures in children. Of course,

conservative treatment of diaphyseal fractures of tubular bones is preferred. However, given the fracture type, surgical treatment is gaining importance. Given the variety of metal fixators, minimally invasive surgical treatment methods in children are favored [4]. They minimize trauma to adjacent soft tissues and eliminate exposure to bone fragments. In addition, the duration of surgical treatment is shortened, and the medical and social rehabilitation of the child is improved.

One of the minimally invasive methods of surgical treatment of tubular bones in children is elastic stable intramedullary nailing (ESIN). This method was developed by French surgeons J. P. Metaze and J. Pevotin in 1979. [5]. This method has become recognized and actively used in pediatric traumatology in the last decade. This method retains the principles formulated by the «World Association of Osteosynthesis»: no intervention in the fracture area with preservation of blood supply to the injured segment, anatomical repositioning, and stable-functional fixation. One of the most important aspects is the cosmetic result with early restoration of the function of the wounded limb [6].

The ESIN technique is designed to fix diaphyseal fractures of long tubular bones when the medullary canal is narrow, and implant flexibility is paramount. The basic principles of ESIN are based on the geometric principles of the fracture [2, 4]. Ideally, the osteosynthesis should be two counter-bent rods in the medullary canal at the end of the surgical intervention. The apexes of the bends of each rod should be at the fracture level and unidirectional. Of course, intramedullary osteosynthesis with flexible titanium rods is contraindicated in unstable fractures [1, 5].

This work aims to evaluate the effectiveness and advantages of intramedullary elastic osteosynthesis with flexible titanium rods in treating diaphyseal fractures of long tubular bones in children in a multicenter study.

Material and Methods. A retrospective analysis of the children's treatment for the period from 2018 to 2023 at the Hannover Medical School – HMS (Hannover, Germany), Regional Children's Clinical Hospital – RCCH (Stavropol, Russia), and Children's Regional Clinical Hospital – CRCH (Krasnodar, Russia) treated for fracture of long tubular bones was performed. The ages of the patients ranged from 3 to 18 years (Table).

Table

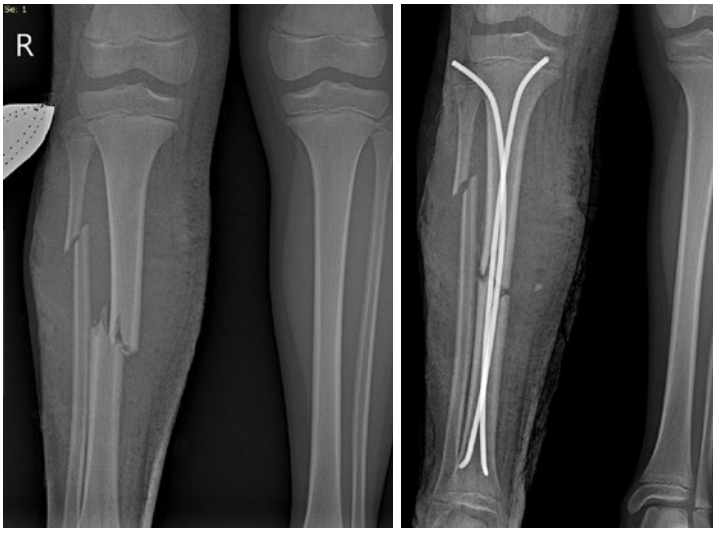
Age range and gender difference of children with diaphyseal fractures

Age group	Hannover Medical School		Regional Children's Clinical Hospital, Stavropol		Children's Regional Clinical Hospital, Krasnodar	
	boys	girls	boys	girls	boys	girls
3–7 years	10; 9.1 %	3; 2.7 %	21; 17.3 %	12; 9.9 %	12; 10.1 %	9; 7.6 %
7–14 years	46; 41.8 %	21; 19.1 %	35; 28.9 %	17; 14.4 %	39; 32.8 %	12; 10.1 %
14–18 years	22; 20.0 %	8; 7.3 %	23; 19.0 %	13; 10.7 %	32; 26.9 %	15; 12.6 %
Total	110 children		121 children		119 children	

Inclusion Criteria: children from the age of three to eighteen with diaphyseal closed fractures of the femur, tibia, and humerus; both genders; no infectious diseases; no genetic diseases; no use of hormonal medications.

Exclusion Criteria: patients who did not want to undergo surgery; patients with open fractures; old fractures; pathologic fractures; patients taking cytotoxic drugs; and patients with congenital bone pathology.

All children were divided into two groups: the main group – 142 children and the control group – 208 children. In the main group, flexible elastic osteosynthesis with flexible titanium rods was used for fractures of tubular bones (Fig. 1). Osteosynthesis with extracortical plates was used in the control group.



A B

Fig. 1. Treatment of a fractured leg bone in a child using the ESIN technique: A – preoperative X-ray of the girl with a right closed oblique diaphyseal fracture of the shin; B – postoperative X-ray showing good fixation by TEN of tibia fracture

The treatment of 110 children with diaphyseal fractures using the HMS technique was analyzed. There were 65 (59.1 %) children with tibia fractures, 38 (34.5 %) with femur fractures, and 7 (6.4 %) with humerus fractures. There were 76 (69.1 %) boys and 34 (30.9 %) girls. There were 47 (42.3 %) children in the main group and 63 (57.3 %) in the control group. ESIN technique was used for tibial fracture in 24 (21.8 %) patients, femur – 23 (20.9 %), and humerus – 3 (2.7 %).

In RCCH, 121 children were treated for fractures of long tubular bones during the study period. There were 79 (62.3 %) boys and 42 (34.7 %) girls. Femur fracture was in 38 (31.4 %), humerus fracture in 19 (15.7 %), and tibia fracture was observed in 62 (51.2 %). The main group included 43 (35.6 %) children, and the control group included 78 (64.5 %). Of the total number of observations, the ESIN technique was used for femur fracture in 9 (7.4 %) children, humerus fracture in 7 (5.8 %), and tibia fracture in 27 (22.3 %).

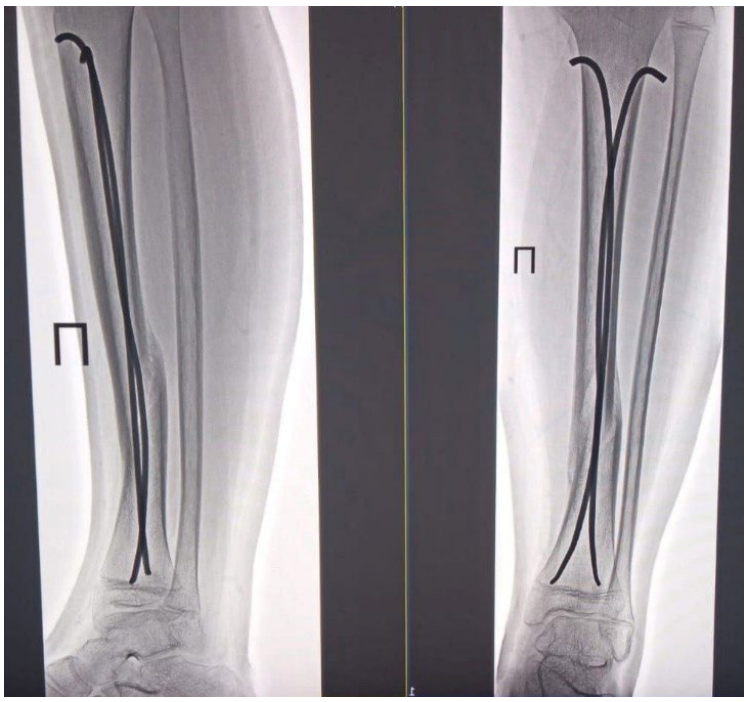
During the study period, 119 children were treated for fractures of long tubular bones in CRCH. There were 83 (69.7 %) boys and 36 (30.3 %) girls. Femur fracture was in 32 (26.9 %) patients, humerus fracture – in 23 (19.3 %), and tibia fracture – in 64 (53.8 %). The main group included 52 (43.7 %) children, and the control group 67 (56.3 %). Of the total number of observations, the ESIN technique was used for femur fracture in

16 (3.1 %) children, humerus fracture in 10 (1.9 %), and tibia fracture in 26 (5.1 %).

The ESIN technique was performed using two rods of the same diameter. The intramedullary rods were inserted retrogradely to the level of the fracture line. Then, closed repositioning was performed under EOP control. Next, an immobilization dressing was applied to the broken limb at the osteosynthesis site. This mobilization did not cause torsional forces at the fracture site.

We evaluated the effectiveness of the ESIN method according to the following parameters: duration of surgical intervention, use of postoperative immobilization, patient activation in the postoperative period, presence of postoperative complications, time of fracture consolidation, length of hospital stay, and restoration of motor activity of the broken limb.

Statistical processing was performed using Statistica 10.0 (StatSoft Inc., USA) software packages. The Mann – Whitney U-test was applied, taking into account the sample's normal distribution. The qualitative data of the two groups was compared using tables from Fisher's exact test. A p-value <0.05 was considered statistically significant.



A B

Fig. 2. Postoperative X-ray of a child with a right middle tibia diaphyseal fracture treated with TEN. X-rays in the third month showed satisfactory length, angulation, and rotation recovery:
A – lateral position; B – direct projection

Results and Discussion. The analysis of the leading performance indicators of the ESIN technique in the main group showed the following indicators. According to HMS, the surgical intervention duration was 40.3±7.8 minutes, RCCH – 38.6±8.2, and CRCH – 41.5±7.2. In the control group, the duration of operative intervention according to HMS data was 49.1±3.4 minutes, RCCH – 48.7±4.9, and CRCH – 51.2±5.3. The main group's immobilization period was HMS – 3.7±1.5 weeks, RCCH – 4.6±1.1, and CRCH – 4.5±1.2. In the control group, the immobilization period was HMS – 5.7±0.5 weeks, RCCH – 6.2±1.2, CRCH – 6.5±1.1. Consolidation time was in the main group, according to radiography data of three centers, on average 4.5±0.6 weeks (Fig. 2). In the control group, 6.1±0.5 weeks. At the same time, the decrease in immobilization time contributed to reducing the possible development of contractures, which improved the patient's quality of life.

According to HMS, no complications were observed in any child after ESIN. According to RCCH, delayed consolidation and nonunion of the femur fracture were observed in 1 (0.7 %) adolescent. According to CRCH: 1 (0.7 %) patient had a femur fracture minor skin ulceration caused by the end of the rod.

In the control group, after extracortical osteosynthesis, the development of local complications was noted in 5 (2.4 %) cases. There was one bone infection and no delayed union in all hospitals. The development of hypertrophic scars was also reported in 1 case at RCCH and CRCH hospitals.

The average duration of hospitalization in the main group, according to HMS – was 3.1±1.1 days, RCCH – 5.2±1.2, and CRCH – 5.1±1.3. In the control group, the average duration of hospitalization according to HMS – 6.3±1.9 days, RCCH – 9.1±1.4, and CRCH – 8.9±2.1.

According to the literature, experts have preferred surgical intervention during the last decade, which provides rapid recovery, shortened rehabilitation, and immobilization [5, 6]. In addition, it is more easily tolerated by children psychologically. Many authors note that TENS is preferable to other surgical techniques [7, 8]. At the same time, it singles out the most preferable age group – 6–14 years old. Since the rods do not interfere with the growth zone, they better retain the fragments and improve patients' quality of life in the postoperative period. Ligier J. N. et al. analyzed the treatment results of 123 diaphyseal fractures in children using the ESIN technique [9]. The data obtained showed the undoubtedly better result of treatment in comparison with other methods of fixation [10]. Flynn J. M. et al. analyzed 49 diaphyseal fractures and found significant effectiveness of TENS application, which reduced the time of fracture consolidation [11]. Similar results were described by Venkataramana P. et al. when analyzing 30 diaphyseal fractures of the femur [12]. Postoperative immobilization after osteosynthesis with elastic rods is different [13, 14]. Ligier J. N. et al. did not use any means of immobilization, while Flynn J. M. et al. used coxite plaster cast in femoral diaphysis fracture. In our study, immobilization in hip fractures was in the form of a degloving boot.

Conclusion. Thus, ESIN in treating diaphyseal fractures of long tubular bones in children showed a high level of efficacy. This minimally invasive procedure protects soft tissues without disrupting the blood supply to the bone tissue. At the same time, a significant advantage of this method is the absence of trauma to the growth zone and avascular necrosis of the metaphysis. These patients do not require long-term hospitalization.

Disclosures: The authors declare no conflict of interest.

References

1. Lascombes P., Journeau P., Popkov D. A. Use of flexible nails in children diaphyseal fractures. Five questions and answers. *Genij Ortopedii.* 2021;27(4):413-417. https://doi.org/10.18019/1028-4427-2021-27-4-413-417
2. Heffernan M. J., Gordon J. E., Sabatini C. S., Keeler K. A., Lehmann C. L. [et al.] Treatment of femur fractures in young children: a multicenter comparison of flexible intramedullary nails to spica casting in young children aged 2 to 6 years. *J. Pediatr. Orthop.* 2014;35(2):26-129. https://doi.org/10.1097/BPO.0000000000000268
3. Borshchevskaya V. N., Kopylov A. V., Kolomoets I. A., Sasko S. S., Bachurin S. S. [et al.] Morphological characteristics of the vascular-capillary bed of soft tissues in the fracture region of long tubular bones depending on the carriage of single-nucleotide polymorphisms in the methylenetetrahydrofolate reductase (MTHFR) gene. *Medical News of North Caucasus.* 2023;18(3):299-303. https://doi.org/10.14300/mnnc.2023.18070
4. Denis D., Maucort B. D., Suchier Y., Mamadou T. B., Metaizeau J. D. Biomechanical and Clinical Comparative Study of the New Elastic Stable Intramedullary Nailing «MJ-FLEX Orthofix». *J. Pediatr. Orthop*. 2020;40(3):149-155. https://doi.org/10.1097/BPO.0000000000001206
5. Shaha J., Cage J. M., Black S., Wimberly R. L., Shaha St. H. [et al.] Flexible intramedullary nails for femur fractures in pediatric patients heavier than 100 pounds. *J. Pediatr. Orthop*. 2018;38(2):88-93. https://doi.org/10.1097/BPO.0000000000000775
6. Khanna M., Wadhwani J., Batra A., Yadav S., Iman S. [et al.] TENS for the surgical management of femoral shaft fractures in 6–14 years age group children. *Pediatric traumatology, orthopaedics and reconstructive surgery*. 2017;5(2):13-21. https://doi.org/10.17816/PTORS5213-21
7. Luo Y., Wang L., Zhao L. H., Wang Y. C., Chen M. J. [et al.] Elastic stable titanium flexible intramedullary nails versus plates in treating low grade comminuted femur shaft fractures in children. *Orthop. Surg.* 2019;11(4):664-670. https://doi.org/10.1111/os.12514
8. Huang J., Pan J., Xu M., Xu S. Successful open reduction and internal fixation for displaced femoral fracture in a patient with osteopetrosis: Case report and lessons learned. *Medicine (Baltimore).* 2017;96(33):e7777. https://doi.org/10.1097/MD.0000000000007777
9. Ligier J. N., Metaizeau J. P., Prévot J., Lascombes P. Elastic stable intramedullary nailing of femoral shaft fractures in children. *J. Bone Joint Surg. Br.* 1988;70(1):74-77. https://doi.org/10.1302/0301-620X.70B1.3339064
10. O'Shaughnessy M. A., Parry J. A., Liu H., Stans A. A., Larson A. N. [et al.] Management of paediatric humeral shaft fractures and associated nerve palsy. *J. Child. Orthop*. 2019;13(5):508-515. https://doi.org/10.1302/1863-2548.13.190012
11. Flynn J. M., Hresko T., Reynolds R. A., Blaiser R. D., Davidson R., Kasser J. Titanium elastic nails for pediatric femur fractures-a multicenter study of early results with analysis of complications. *J. Pediatric Orthop.* 2001;21(1):4-8.
12. Venkataramana P., Mahesh S. A prospective study of surgical management of diaphyseal fractures of femur & tibia in children aged between 5 to 16 years using elastic stable intra medullary nailing. *International Journal of Orthopaedics Sciences*. 2016;2:31-35. https://doi.org/10.22271/ortho.2016.v2.i4.007
13. Seibold B. T., Quan T., Pizzarro J., Farley B., Tabaie S. Comparing pediatric femoral shaft fracture repair patient outcomes between pediatric and non-pediatric orthopedic surgeons. *Eur. J. Orthop. Surg. Traumatol.* 2024;34(2):809-814. https://doi.org/10.1007/s00590-023-03717-5
14. Patil Ch., Amar J. Study of the outcome of titanium elastic nail system (Tens) in diaphyseal fractures of femur and tibia in children. *International Journal of Orthopaedics Sciences.* 2019;5:617-620. https://doi.org/10.22271/ortho.2019.v5.i3k.1599

Received 22.07.2023

About authors:

Evers Burkhard Martin Christian, orthopedic traumatologist;
tel.: +4917617131493; e-mail: burkhard.m.c.evers@gmail.com; https://orcid.org/0009-0000-0977-3008

Isaeva Alesya Vasilievna, PhD, Associate Professor of the Department of Pediatric Surgery, orthopedic traumatologist;
tel.: +79624454073; e-mail: isaeva_alesya@mail.ru; https://orcid.org/0000-0002-3638-4881

Minaev Sergey Viktorovich, MD, PhD, Professor, Head of the Department of Pediatric Surgery, pediatric surgeon;
tel.: +79624507653; e-mail: sminaev@yandex.ru; https://orcid.org/0000-0002-8405-6022

Barova Natusya Kaplanovna, PhD, Head of the Department of Surgical Diseases of Children, Head of Surgical Department № 1;
tel.: +79882420449; e-mail: nbarova@yandex.ru; https://orcid.org/0000-0001-5857-2296

Pozharsky Yuri Vasilievich, Assistant of Professor of the Department of Pediatric Surgery, orthopedic traumatologist;
tel.: +79886262442; e-mail: dr_pozharsky@mail.ru; https://orcid.org/0009-0002-4533-6379

Edidzhi Aliy Askerovich, Assistant of Professor of the Department of Surgical Diseases of Children, orthopedic traumatologist;
tel.: +79180303995; e-mail: Alkes16@mail.ru; https://orcid.org/0000-0001-3664-7359

Ushveridze Mamuka Shalvovich, orthopedic traumatologist;
tel.: +79624011712; e-mail: sirius.rino@gmail.com; https://orcid.org/0009-0003-0473-1468

Bagdasaryan Maria Sergeevna, resident;
tel.: +79283265416; e-mail: bagdasaryanms@yandex.ru; https://orcid.org/0009-0006-4199-0532