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# Abstract

# FEATURES OF ELASTIC STABLE INTRAMEDULLARY NAILING OF PEDIATRIC LONG BONE DIAPHYSEAL FRACTURES

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# CONTENTS OF THE THESYS

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**Long bones, diaphyseal fractures, elastic stable intramedullary nailing, closed surgery, simple bone cyst.**

# INTRODUCTION

A hundred years ago, infections were the main fatal cause in pediatric pathology of our society. Nowadays, their part had been taken by traumatic lesions. The new social conditions, nutrition, imunity and isolation of infection foci determined the reduction of this threat. Furthermore, social developement, the new environmental factors and especially the introduction of motorized transportation increased the risk of traumatic accidents [1]. The traumatisms, of any type, are the second main cause of hospitalization in children under 15 years old [2]. The accidents are the main death cause between the age of 1 and 18 years old [3]. Although seldom fatal, musculoskeletal traumas account for 10-25% of the childhood lesions [4]. Boys have a 50% risk and girls a 40% risk of suffering from a fracture before the age of 18 years old [5].

As the child gets older, the fracture rate grows and reaches a pick in early teenage. The new sports and recreational activities, like riding a bicycle, roller skating, skateboarding, had created new patterns of lesions, with a higher frequency for the distal fractures of the radal bone [5,6]. Luckily the majority of fractures are minore. Only 20% need orthopedic reduction and „greenstick" fractures and torus fractures account for aproximately 50% of all the fractures in children [7,8].

Therefore, fracture management in children is continuously changing; yet, one has to know exactly when to intervene or when to let nature take its course. The skeleton of a small childs act differently from the skeleton of a big child. There are

also musculoskeletal differences in biomechanics, anatomy and physiology between children and adults [9].

In his book „*Fractures in children"*, Walter Blount suggests that due to the growth, childrens' fractures have a great remodeling potential [10]. Furthermore, he very clearly defined the rules of repairing, showing the angular grade needed to be accepted in case of children fractures. In most cases, he was against surgical interventions for children fractures, especially regarding elastic stable intramedullary nailing (ESIN) for femural shaft fractures:

„Surgery is not necessary and, if it is performed, it has to be blamed. It can lead to unuseful inaesthetics and exposure of the bone ends, and can cause trauma to the whole medular cavity of the femur. There is no reason to do such a thing" [10].

Minimal tissue invasive management is more and more performed, with the passing of time and the improvement of the therapeutic methods for children fractures. This is why elastic stable intramedullary nailing (ESIN) has become more popular and has been accepted as first choice procedure for most of unstable shaft fractures in children. The indications for this technique are gradually raising. ESIN is based on the old principle of classic open intramedullary nailing, but approaches the bone in a less invasive way and apparently with much better results.

In the late 1970s, Dr. Jean-Paul Métaizeau (young chief rezident), Jean-Noël Ligier (resident) şi Prof. Prévot (Head of the Departament of Pediatric Orthopedics, University Hospital, Nancy) had discovered a way to stabilize femoral fractures in children. Eventually, on September 27, 1979, Hubert Lanternier and J.N. Ligier performed their first closed elastic stable intramedullary nailing on a 9-year-old child who had been hit by a car while riding a bicycle. Four 3 mm diameter stainless steel nails were used.

As early as 1980, ESIN indications expanded dramatically. It was first used in diaphyseal fractures: femur [11], and then tibia, both bones of the forearm [12], and humerus.

Therefore, ESIN method has gradually spread worldwide. The result of this popularity is that in many countries the acronym „ESIN" [13] has been changed to „FIN" (Flexible Intramedullary Nailing), which was then adopted to reach a consensual view. As a matter of fact, „stable" does not have the same connotation for all surgeons: some will consider meaning „stable equlibrium", while other will understand „stiffness".

The FIN method, also termed Métaizeau technique [14,15], Nancy technique [16,17], or ESIN technique (mainly in Europe) [18] was introduced in the 1980s through instructional course lectures and numerous published papers [19-22]. K. Parsch published, in the 1990s, a detailed history of this method in the treatment of femural fractures in childhood [23]. In this publication this technique is mentioned to be used in the 1970, by a team in Seville, Spain, conduted by Moroté Jurado. The technical protocol was identical to that used in Nancy. The study included 100 diaphyseal fractures of both bones of the forearm [24].

Almost 30 years after its introduction, the ESIN has now become a universal way of treating fractures. Early critisism and doubts were forgotten, and very important technological improvements were made. Now children can benefit from a low-morbiddity functional surgery, which does not interfere with the growth process. The advantages of ESIN over other fixation systems such as intramedullary locked nails, screw plates, and external fixators have long been recognized, although there are still specific indications for each of these systems.

# REASONS AND OBJECTIVES OF THE RES EARCH PAPER

## REASONS FOR CHOOSING THE RESEARCH TOPIC

Diaphyseal fractures of long bones in children are one of the most frequent lesions treated by the pediatric orthopaedic surgeon. Because the child's body is growing, the skeleton is also constantly changing and remodeling; therefore, even the most experienced orthopaedic surgeons can be challanged when facing such a fracture with a high complexity grade.

Most of these fractures can be treated by orthopaedic reduction and splint immobilization for a period of time. But this paper focuses on both the analytic aproach of these fractures and on studying the unstable ones or the fractures with the potential to displace that need surgical treatment.

Usually, the classical methods, including orthopaedic reduction according to case followed by continuous traction in the axis and then surgical intervention by opening the fracture focus or using an external fixator, are exagerated, uselles and sometimes does not bring the intended beneficial effect for the pediatric patient.

The elastic stable intramedullary nailing technique, also named ESIN and developed at the end of the last century by the French school, represents nowadays

the treatment of choice for this lesions in a growing number of clinics. This method has the advantage of being a simple technique, rapid healing and superior cosmetic appearance over other surgical procedures for osteosynthesis.

But, regardless of the therapeytical method that is being used, the final concern is to ensure a better evolution and prognosis for these lesions, that sometimes can be very serious; these are performed both on some theoretical arguments (morphopathological, patophysiological and biomechanical), and on the achieved clinical results.

**The aim** of the present paper is to ensure a better evolution and prognosis of diaphyseal fractures of long bones in childrem, by establishing the best therapeutical option for this type of fractures. Therefore, I wish to illustrate the advantages and desadvantages of the ESIN technique by showing its particularities in comparison with other surgical methods of osteosynthesis.

## THE OBJECTIVES OF THE RESEARCH

**The research hypotesis** consists of the fact that nowadays especially in our country there are numerous therapeutical techniques for the management of diaphyseal fractures in children, without a treatment of choise. In other European countries and not only ESIN represents the main method in treating these kinds of fractures, in particular the instable ones or with a possible potential to displace. The advantages and disadvantages of this procedure are not strictly limited, and there are both followers and disputants.

In order to demonstrate the research hypotesis we performed the following actions:

A. Consulting speciality literature and comparative description of the ESIN procedure used by me and my colleagues in the Departament of Pediatric Surgery, County Emergency Clinical Hospital, Constanța;
B. Clinical research in surgical treatment using ESIN technique for diaphyseal fractures of long bones in children.

**The novelty of this research** consists in the way how the paper is made; there was a premiere in the research of the advantages and disadvantages of the ESIN technique, in comparison with the other therapeutic procedures, which was performed on a complex batch of patients with diaphyseal fractures and aproaching all the long bones of the appendicular skeleton.

**The consequence of the research** includes a better understanding in therapeutic management for diaphyseal fractures of long bones in children. The results of this study can also be used to establish specific therapies for these conditions, in order to obtain complete postoperatory results, or as close to normal as possible.

# MATERIALS AND METHODS

## THE RESEARCH METHODOLOGY

The present paper started as a personal initiative, also encouraged by my colleagues in the Departament of Pediatric Surgery, County Emergency Clinical Hospital, Constanța, regarding the therapeutic management for diaphyseal fractures of long bones in children. More exactly, it describes the advantages and disadvantages of using the closed elastic stable intramedullary nailing technique in treating this type of fractures. I intended to analyze the management of this fractures in improving the follow up and prognosis using both theoretical (morphopathological, patophysiological and biomechanical) arguments, and the achieved clinical results.

The present research is based on a complex study composed of two parts:

i. Comparative description of the ESIN procedures used by both me and my colleagues in the Departament of Pediatric Surgery, County Emergency Clinical Hospital, Constanța;
ii. Analytical part, consisting in a prospective, interventional, randomized clinical study, on the therapeutic management of diaphyseal fractures of long bones in children.

## RESEARCH CONDUCTED DIRECTIONS (STUDIES)

The thesis is an integrated research mainly based on a clinical study, and preceded by a theoretical study (fig. 1).

In the theoretical part, which was performed on a period of time of aproximately 12 months (during the year 2008), we established a parallelism between the technical procedures used in the ESIN method in centers around the world (which published conclusive data regarding the subject mentioned above) and

the way how they were put into practice in the Departament of Pediatric Surgery, County Emergency Clinical Hospital, Constanța.

## RESEARCH COMPONENTS

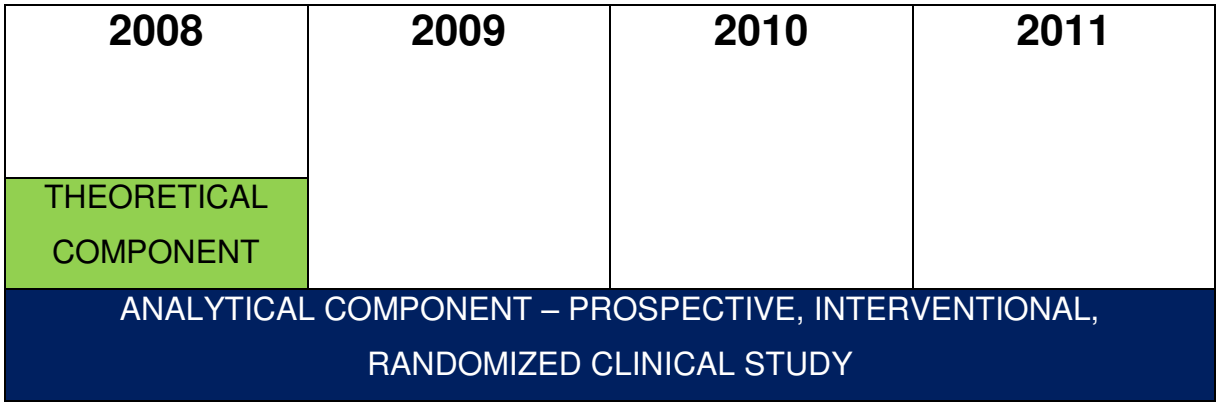


**Figure 1** – Study components regarding the specific features of the elastic stable intramedullary nailing in diaphyseal fractures of children

A prospective, interventional, randomized clinical study was conducted in the analytical component, that was extended on a four year interval (between 2008-2011), in which I analysed the clinical aspects and the surgical therapeutical methods used in treating diaphyseal fractures of long bones in children. I also composed a strategy of illustrating the advantages and disadvantages of the ESIN technique in the therapeutical management.

## PROTOCOL FOR THE PROSPECTIVE, INTERVENTIONAL, RANDOMIZED CLINICAL STUDY

My study was performed on a total number of 1131 cases, incuding:

- 32 cases with diaphyseal fractures of the humerus;
- 849 cases with diaphyseal fractures of the forearm bones;
- 116 cases with diaphyseal fractures of the femur;
- 134 cases with diaphyseal fractures of the leg bones, particularly the tibial diaphyseal fractures, because this is the bone that was taken into consideration in the present study.

The subjects that entered the study were patients of the Departament of Pediatric and Orthopaedic Surgery, County Emergency Clinical Hospital, Constanța, who were hospitalized and treated between 01.01.2008 – 31.12.2011. This interval consists in the first hospitalization and orthopaedic or surgical repair. Part of these

patients were also followed in 2012, especially the ones who needed the extraction of the osteosynthesis material.

The study is of the prospective, interventional, randomized clinical type, was performed on a period of 4 years (between 2008 and 2011) and includes a comparison between the classical therapeutical methods, both orthopaedical and surgical, for diaphyseal fractures of long bones in children and elastic stable intramedullary nailing (ESIN).

I took the therapeutical decission (orthopaedic reduction or surgical intervention) the methods discussed above according to the following:

- A diaphyseal fracture is operated when it is instable;
- It is operated when it does not reduce after repeated attempts;
- Age of the patient;
- It is operated in case of an older child with a low remodelling potential;
- Displacement degree of the fracture;
- Polytraumatized patient;
- Multiple organ lesions or several diaphyseal fractures;
- Opened fractures;
- Compartment syndrome;
- Additional indications – a dominant upper limb, used in sporting performance activities, playing a musical instrument. In case of teenagers all of these aspects have to be taken in consideration;
- Spasticity due to cerebral lesions;
- In some cases it was the surgeon's option.

Between the two surgical options (open technique and ESIN technique), and taking into consideration the earlier described indications for the study protocol, we always first chose the ESIN method. We preffered open surgery only when it was impossible to reduce the fracture before beginning the intervention.

The batch of patients was diveded into four groups, according to the involved anatomical segment: arm, forearm, thigh, shank. The following general variables were considered for each of the four subtypes:

- Age;
- Age group;
- Sex;
- Year of presentation;

- Month of presentation;
- Environmental origin;
- Affected bone (only for diaphyseal fractures of the forearms);
- Affected segment (right or left);
- Fracture type;
- Fracture pattern;
- Affected diaphyseal area;
- Circumstances in which the fractures were produced;
- Concurrent lesions;
- Type of treatment;
- Open/close fracture;
- Per primam/iterative fracture;
- Secondary complications;
- Period of time for wearing the splint.

After describing the four subbatches according to the above mentioned general variables, we passed to comparing the ESIN technique to the other classical surgical procedure. Subsequently, we analyzed the patients treated with ESIN method exclusively, and concluded with the advantages and disadvantages of this technique. To perform this part of the study, we took into consideration the following features, according to each subbatch:

- Type of the performed technique;
- Type of approach;
- Single bone/both bones osteosynthesis (only for the diaphyseal fractures of the forearm bones);
- Cutaneous complications;
- Bone complications;
- Period of time for maintaining the osteosynthesis material.

The data was rendered (both in tabular and graphical methods) in absolute and percentage values, and as an average. *p value,* calculated with the IBM SPSS Statistics 19 programme, was used to explain the statistical value. We used Relative Risk (RR) and Odds Ratio (OR) to illustrate the features related to the advantages and disadvantages of the ESIN technique [6,8]. Both indicators were calculated by grouping the data in contingency tables and the statistical assessement was performed with the help of the IBM SPSS Statistics 19 programme.

## DESCRIPTION OF THE INVESTIGATION TOOLS USED AT THE PROSPECTIVE, INTERVENTIONAL, RANDOMIZED CLINICAL STUDY

**A data chart** was filled for every patient who entered the study, using the clinical chart owend by the Departament of Pediatric and Orthopaedic Surgery, County Emergency Clinical Hospital, Constanța. Demographical, clinical, paraclinical, therapeutical and assessment data of the patients included in the study were introduced in the chart.

**Performing a X-ray examination of the affected limb.** The radiological images assessed were the ones obtained in hospital admition (to include in one of the subbatches, to establish the fracture type and the therapeutical method), during and after the surgical intervention (to assess the quality of the orthopaedic reduction or of the surgical intervention that was performed) and further follow ups, when the presence of the callus, the quality of the assembly and the possible bone complications are assessed.

A Canon PowerShot SX10IS **camera** that can storage over 1000 photographs was used to record the osteosynthesis materials that were used, different scenes during the surgical interventions, and the functional and cosmetic results after the healing if the diaphyseal fractures of long bones had occured.

## STATISTICAL ASSESSMENT OF THE DATA FROM THE PROSPECTIVE, INTERVENTIONAL, RANDOMIZED CLINICAL STUDY

Classical descriptive assay was performed for all the variables as follows:

- The average and standard deviation were calculated for the numeric variables;
- The qualitative/dichotomous variables were divided into two classes corresponding to „1” and „0” (respectively M/F, U/R, +/-);
- The proportion was shown in percentage.

It is important to observe that only the cases with collected data (which means that absent data were not marked with an „0”, but with „blank”) have been included in the statistical analysis of each variable.

A data base was composed in order to perform the statistical analysis, which subsequently permited their analysis with the help of specialized softwares. Microsoft Office Access 2010 was used to compose and manage the data base. It is obvious that during the process of colecting and elaborating data identification information, including PNC, exact address and others were not modified. Once the necessary data were colected and introduced in the matrix, it was easy to export them to the specialized softwares for the statistics analysis.

Special statistical softwares were needed for the descriptive analysis of the followed batches of this paper; for performing statistical analysis in order to observe whether the noted differences hace a statistical value or not; and for the graphic reprezentation of the results. These softwares included: *Microsoft Office Excel 2010, IBM SPSS Statistics 19.* The reason for this great number is that it is imperative to use the best accounting and displaying method for every statistical analysis that was made.

There were several types of statistical analysis that were applyed to this paper. It was first necessary to use the descriptive statistical methods in order to show the batches features (frequencies, averages, standard deviation, maximal values, minimal values etc).

More advanced statistical methods based on the probability theory were used, according to the researched sample. Therefore it was possible to estimate the situation for the entire population that holds these features. The methods are based on testing the differences encountered between the studied batches, usually one batch is exposed to the researched phenomenon and the other is exposed to a comparative phenomenon (which can be, for example, a different treatment). Subsequently, it was necessary to perform some statistical tests to establish whether the differences that were encountered between the two batches had a statistical value or not.

For the statistical analysis, one always starts with the hypothesis that the differences encountered between the two batches do not have statistical value, and emerge because of the fluctuation in selecting the batches. This hypothesis is called null hypothesis. Different types of statistical analysis intend to demonstrate whether this hypothesis is null or false. If this hypothesis is true, then the differences that emerge between the batches are not due to the phenomenon to which they were exposed. In contrast, if this hypothesis is false, then the alternative hypothesis will be accepted and one can confirm that the notable differences have statistical value.

Using the following types of statistical analysis it has been performed the comparison between different groups:

- ***Student's t-test*** [25-28]. The significance of this test was: $p > 0,05$ – without statistical value (NS), $p < 0,05$ – statistical value, $p < 0,01$ – high statistical value (FS), $p < 0,001$ – very high statistical value (ES).
- ***Levene test for the equality of variances*** [29];
- ***Chi-squared test*** [30-32];
- ***Cramer's V/Phi coefficient*** [33-35];
- ***Shapiro-Wilk and Kolmogorov-Smirnov tests*** [36-45];
- ***Mann-Whitney U test*** (also named ***Mann-Whitney-Wilcoxon – MWW***, **Wilcoxon rank-sum test** or **Wilcoxon–Mann–Whitney test**) [46-48];
- ***Risk analysis*** was used to measure the degree of association between two parameters. To this effect ***Relative Risk (RR)*** [49-51] and ***Odds Ratio (OR)*** were calculated. The explanation for the values of relative risk test was as following: RR>1 positive signifiance, RR<1 negative signifiance and for the odds ratio: OR = 1 there is no statistical signifiance, OR > 1 there is a statistical signifiance.
- ***ANOVA test (analysis of variance)*** used to compare two percentages.

## DISCUSSION AND CONCLUSIONS OF THE STUDY OF HUMERAL SHAFT FRACTURE PATIENTS

During the present study the number of annual admissions has decreased with predominance in the cold season, with more patients from rural areas. It was an even distribution by age, except between 0-3 years where there was only one case.

Most fractures were transverse and displaced in the proximal and middle third. From the point of view of therapeutic management, most of them have been treated conservatively or by ESIN technique. In the present study the frequency of the two methods of treatment where equal. Only 2 cases were resolved by opening the fracture site. The literature states that the majority of diaphyseal humeral fractures are treated conservatively [52,53].

The ESIN technique was used especially for age groups 7-9 years and 14-16 years, for most displaced transverse fractures from proximal to midshaft.

The insertion of the rods was predominantly retrograde, to avoid iatrogenic fractures of the distal diaphyseal third and nerve damage. Others (Garg et al. [53])

prefer bilateral approach, medial and lateral, but I used only the unilateral approach, on the side, above the external epicondyle.

The literature does not recommend gypsum immobilization after surgery [6]. However, we have used it in most cases for 3-4 weeks. Only one third of patients operated with ESIN were left without plaster.

Osteosynthesis material was removed after 3-5 months postoperatively. Literature calls about the same period – 4-6 months [53].

I had no major complications. In 3 cases of 16 operated I had an angulation of the fragments after fixation, which was only observed radiologically and not clinically or functionally. There was a case of delay in union where I left the rods in place for 7 months, resolved without repercussions. Lascombes [55] states that the rate of this complication is higher in the humerus than the weight bearing leg.

There was no nerve or vascular complications. Literature indicating intraoperative injury of the radial nerve [55,56] or vascular trauma fracture resulting from high energy [54].

As final conclusions from the study of diaphyseal humeral fractures in children, I can say that conservative treatment remains the main method of choice to address these injuries. During this period there is potential for significant remodeling of bone, which decreases with age.

If surgery is necessary, the preferred method is ESIN, an ideal procedure that ensures fracture stability and allows early mobilization of the limb.

Gypsum immobilization after surgery I thought was necessary, contrary to the principles of ESIN, due to postoperative comfort and reduced patient compliance. Because of the small number of subjects in the study group, there was not possible to draw a statistical conclusion upon complications rate between the patients with plaster immobilization and those without.

This technique is accessible and easy to perform both for humeral diaphyseal fractures and also in other long bones in children [12,57-63].

## DISCUSSION AND CONCLUSIONS IN THE STUDY FOR BONE SHAFT FOREARM FRACTURES

In this study there was an annual decrease in the number of cases admitted and treated for diaphyseal fractures of the forearm bones. Most of the admissions have been made in summer.

The mean age of the subjects was 8.94 years, an sex ratio male: female of 2.52 (similar to the literature [54.64]) ($p < 0.001$). Most patients were in the categories of preschoolers and adolescents.

The range of age was more extended on boys than on girls. For girls the age distribution was equal to the average. For the males there were more cases over the average age.

In terms of methods of treatment, as the patients were smaller on age, first choice was orthopedic reduction and then ESIN technique, and last choice was open surgery, for older patients. Therefore, the majority were treated by closed reduction.

Typical for this age, there were more cases of diaphyseal fractures with angulation than displacement. The fractures with angulation were mainly treated by closed reduction ($p < 0.001$). Fractures of the distal third are displacing easier than angulating, compared to the middle or the proximal third ($p < 0.001$).

Angulation fractures often occur because of a fall from the same level, while displaced fractures occur from a fall from other level ($p = 0.005$).

Distal third fractures are usually transverse or short oblique fractures, from middle third to proximal third of the shaft they become long oblique "green-stick" or comminuted fractures ($p < 0.001$).

Open fractures were mostly resolved by opening the fracture site ($p < 0.001$) and the same for the iterative ones ($p = 0.021$).

On older children are more common distal third fractures ($p = 0.037$). “green-stick” fractures predominate at early ages, while the most complex occur on older children ($p = 0.005$). Complex fractures occur mainly by fall from another level ($p = 0.001$).

Both bones of the forearm fracture more often than one bone, when it comes to diaphyseal segment ($p = 0.001$).

During the study ESIN technique was becoming widely used, reporting on our years of study. Most surgical patients belonged to the age group of 10-13 years.

The age of male children who underwent surgery is significantly higher than those of females ($p = 0.028$).

There have been operated more displaced fractures than angulated ones. When the fracture is more complex, probabilty to be operated also increases.

Iterative fractures weren’t treated by ESIN technique due to changes in the permeability of medular canal.

ESIN basic principle is the lack of plaster immobilization, but for various reasons, especially protection, we used gypsum immobilization in most cases. The period of immobilization was shorter than in open surgery ($p = 0.02$). The bigger the child is the cast is more menteind after surgery ($p = 0.002$).

Literature [65-68] recommends that osteosynthesis material should be kept for 4-6 months. In the present study, in 50 of 80 cases treated we kept the osteosynthesis material less than 3 months (not statistically significant - $p = 0.354$).

The rate of complications was the same in relation to the area of origin of the patients. But were three times more complications in males, without statistical significance ($p = .0.25$).

On the age groups in this study, there were more complications during 0-6 years without statistical significance ($p = 0.848$).

As the fracture was more complex, the likelihood of complications is greater ($p <0.001$). The rate of complications is greater for the open surgery than for the ESIN technique. The fewest appear during orthopedic reduction ($p = 0.007$).

Comparing the two fixation options, the classic one has more complications than target technique ($p = 0.032$).

## DISCUSSION AND CONCLUSIONS OF THE STUDY OF FEMURAL SHAFT FRACTURE PATIENTS

This study was conducted over a period of 4 years. There were included in the group a number of 116 children, aged between 0 and 16.

There were considered three methods of treatment of these fractures: orthopedic reduction, ESIN technique and other methods of fixation by open surgery.

A significant percentage of the total fractures was treated conservatively by closed reduction (49 cases out of 116) ($p <0.001$).

The group included 74 male patients and 42 female with a sex ratio of 1.76.

Mean age was 5.6 years, most patients being within 0-3 years.

Depending on the affected part of the diaphysis, most of them were at the midshaft, statistically significant ($p = 0.036$).

Most of them have been displaced transverse fractures ($p <0.001$) produced by the fall from another level ($p = 0.003$). If the fracture is more complex, is more likely produced by fall from another level ($p <0.001$).

When referring to the principles of ESIN with no immobilization, in this study they were not met, most children were wearing a cast after surgery ($p<0.001$). The fracture is more complex, the cast was held longer ($p <0.001$).

If the fracture was solved by open surgery, then cast the device was worn longer (Odds ratio = 8.166 [CI 95% 2.634-25.322] and $p<0.001$).

From the point of view of complications, percentual, there were more in females, the rate of complications depending on the model of fracture ($p = 0.006$).

Also percentual, I can say that in this study there were more complications in patients treated by open surgery than by ESIN technique, but without statistical significance ($p = 0.167$). The fewest complications were recorded for orthopedic reduction.

Also skin complications were higher with opensurgery than with ESIN procedure ($p=0.001$).

## DISCUSSION AND CONCLUSIONS OF THE STUDY OF TIBIAL SHAFT FRACTURE PATIENTS

There were more males with tibial shaft fractures in the study, the gender ratio being 2:1. The average age was about 8.6 years. The data are consistent with the literature [37]. Most children were in age groups 4-6 years and 10-13 years.

There were more diaphyseal fractures in the middle third then the distal one, most of them being transverse.

I applied conservative treatment in most cases, exactly as the instructions I found in the literature [69-73].

If surgery was needed, ESIN was the preferred technique, 14 of 17 operated patients have benefited from this. It is a basic indication of other authors [16,61,74-76].

I used exclusively bilateral anterograde approach. I didn't operate the fibula in either of cases. Lascombes [54] is one of those who mention this possibility.

In 3 cases of 14 operated with ESIN I used cast immobilization. There were no differences in the healing to others without cast. In literature there is controversy on this point. Lascombes argues that the lack of gypsum is the basic condition of healing after ESIN [54]. Other authors prefer immobilization for comminuted fractures and thise potentially unstable with the osteosynthesis material [77]. Immobilization was used 3-4 weeks on average.

When the age of patients is less, the gypsum period of wear is shorter. Immobilization was longer in complex fractures (comminuted, oblique long, etc).

All patients, regardless of whether or not were immobilised, we're-assessed at intervals of 7 days, 3 weeks, 6 weeks, 3 months. Depending on the amount of callus on the front and profile radiographs, after 3 months postoperatively, we consider the removal of osteosynthesis material.

Fractures were reported consolidated if the front and profile radiographs and there was evidence of bridging callus formation in at least 3 of 4 corticis [78].

Fractures that required six months or more to strengthen, but who had evidence of consolidation on serial radiographs were defined as fractures with delayed consolidation [79-82].

Fractures witch were associated with absence of pain and movements at the fracture site, combined with the lack of callus on serial radiographs in 3 to 6 months after intervention, were declared pseudoarthrosis [79-81].

At 7-10 days after the removal of osteosynthesis material, the ablation of the skin sutures was performed and a further revaluation.

The most displaced fractures were in the age group 4-6 years, however, the most surgical procedures are in the range 7-9.

But during this interval prevailed other technique, contrary to expectations such as ESIN would be first choice for this age [54,83].

The preferred type of surgery was ESIN technique. Most common intraoperative complication was difficulty in reducing the fracture site.

Percentual, complications were 5 times more for open surgery (of any kind) than by orthopedic reduction ($p=0.015$). Thus, from my study, the conservative treatment is the choice that remains.

Complications are twice the percentage on the rural areas. Also, they are more frequent with increasing in age.

Most complications also occur depending on the complexity of the fracture (the comminuted ones or with high potential of movement).

From the point of view of the surgical treatment used, the probability of complications is equal to this group ($p = 1$ in the Fischer test).

# DISCUSSION AND CONCLUSIONS OF THE STUDY OF PATIENTS WITH SIMPLE BONE CYSTS TREATED WITH ESIN

Mechanical treatment of large and active bone cysts using ESIN technique is effective for cannulation and cyst decompression cyst, also for stabilising it.

X-ray cystic ratio can be used as an alternative to already known cystic index for selecting patients who can be treated using this method.

ESIN has two advantages: continuous decompression of the cyst and its immediate stability, allowing early mobilization of the affected limb and return to normal daily activities without any major restriction besides avoiding local trauma and excessive effort.

# CONCLUSIONS

Since the beginning of the XXIst century, every orthopaedic surgeon or traumatologist has to know the Schenk rule: „If the surgeon acts «logicaly», «bio» will do the rest" [1]

All tissues, including the bone, heal spontaneously, with or without sequelae. It has been long known that the most important principle for treating a lesion, including bone lesion, consists in creating a focal best situation for the healing process. Different kinds of osteosynthesis and correct orthopedic reduction allow healing of the bone, especially in pediatric cases.

Because of the increasing popularity of the ESIN technique and its wide spread among the pediatric orthopedic surgeons from all around the world, the present study holds its limits regarding the inovations and improvements brought to this method itself. The originality of the study consists in combined description according the anatomic segments of the advantages and disadvantafes of this technique in comparison with the other therapeutic possibilities. Therefore, the particularities of this method for every segment have been illustrated during a certain period of time.

There still are certain questions and controversies in the special literature about the ESIN technique:

- Which is the exact age interval for the use of this method?
- Which is the maximum weight limit per age for percutaneous osteosynthesis without cast immobilisation for the treatment of inferior limbs fractures?
- Is the ESIN technique a clear advantage in comparison to the opened Kirshner wire osteosynthesis for the shaft of the forearm bones in children?
- How long the osteosynthesis matherial should be kept for every limb and segment?
- The complications of this technique shadow its advantages?

I have managed to offer relevant answers to part of the abouve, but for certain these leaves room for further comentaries and debates:

- The growing child's organism has an extraordinary ability to remodel the bones and, in many cases, the trace of a faulty consolidated fracture will disappear. This is why the orthopedic reductions remain the election method for the treatment of this kind of fractures. However, the accepted maximum residual deformity after such a fracture to be smaller than that typically thought, especially for the forearm to permit the wide range of movements, and also for the older children, in which case the remodeling is lower.

- Considering the approach for the surgical treatment of displaced or potentially displaced shaft fractures, there is the possibility of opening the site of fracture and resolving it by the classic technique and there is also the mentioned technique – ESIN. There is the tendency to prefer the opened site for the present batch. This method has the advantage of direct approach of the site of the fracture followed by its anatomic osteosynthesis (which is not necessarily nedeed in pediatric cases that have a great remodeling potential); the disadvantage that was described in the present study is mostly cosmetic.

- Oblique, spiroid or comminuted shaft fractures almost always are displaced and very unstable. In the present study ESIN represented the main method for their treatment. However there were two major complications. The most frequent one was the presence of skin rash with granulation tissue and ulcerations at the incision sites, because of the distal outer ends of the wires. A subsequent intervention to shorten them and treat the skin was needed in some cases. But we did not find any deep infection or osteitis because of the osteosynthesis

matherial. Other complications present in the study included the delayed union and malunion.

- The postoperatory cast immobilisation is not mentioned in the original description of the ESIN technique for this type of fractures. Most of the patients with fractures included in the present study were immobilised for safety and to prevent pain. There were not any statistical differences among the ones with cast and the ones without a cast, regarding the evolution.

- Statistically, in the present study, I have the proof of the advantage in using the ESIN technique in comparison to other methods only for the shaft fractures of the forearm bones regarding the incidence of the complications.

- Elastic stable intramedullary nailing (ESIN) seems to succsesfully cope with the therapeutic charges in many ways. ESIN is a cheap, safe and simple method for the surgical treatment of the shaft fractuers in children. It does not interfere with the growth process, has little complications, short hospitalization period and rapid return to the daily activities. However, these are the characteristics of a correct orthopedic reduction with cast immobilisation also. Therefore, this important aspect of the conservatory treatment must not be forgotten.

- In the adolescent cases, where the sponatenous correction of the consolidation deffects is lower or unlikely, ESIN reached its limits in the present study also.

- In conclusion to all of the above, one can mention that most of the pediatric shaft fractures are treated in a conservatory way, but the ESIN method is chosen when the surgical intervention is being considered. Clear indications for the intervention and the correctly performed operatory technique allow this procedure to be an optimal choice for the therapeutic management of the discussed pediatric pathology.

- Because of the indubitable benefits of the percutaneous elastic osteosynthesis, one must make sure that the ability to manipulate fractures and cast immobilisation are not lost over time.

- ESIN technique has two advantages in the mechanical treatment of simple bone cysts: continuous decompression and immediate stability of the cyst. This permits early mobilization of the affected limb and return to current activities without any other major restriction, except avoiding local trauma and excesiv movements.

## REFERENCES


1. WESSON D.E., COOPER A., SCHERER III T., STYLIANOS S., TUGGLE D.W. Pediatric Trauma - Pathophysiology, Diagnosis, and Treatment. Taylor & Francis Group, LLC, 2006, 1, pag. 1.
2. IRWIN C.J., CATALDO M., MATHENY A. Jr, et al. Health consequences of behaviors: injury as a model. Pediatrics, 1992, 90, pag. 798.
3. Leading causes of death reports. In: National conference for injury prevention and control. Atlanta, GA: Center for Disease Control and Prevention, 2003.
4. LANDIN L.A. Epidemiology of children's fractures. J Pediatr Orthop, 1997, 6B, pag. 79.
5. JONES I.E., WILLIAMS S.M., DOW N., et al. How many children remain fracture-free during growth? A longitudinal study of children and adolescents participating in the Dunedin Multidisciplinary Health and Development Study. Osteoporos Int, 2002, 13(12), pag. 990-995.
6. KHOSLA S., MELTON L.J. III, DEKUTOSKI M.B., et al. Incidence of childhood distal forearm fractures over 30 years: a population-based study. JAMA, 2003, 290(11), pag. 1479-1485.
7. WORLOCK P., STOWER M. Fracture patterns in Nottingham children. J Pediatr Orthop, 1986, 6B, pag. 656-660.
8. BRUDVIK C., HOVE L.M. Childhood fractures in Bergen, Norway: identifying high-risk groups and activities. J Pediatr Orthop, 2003, 23(5), pag. 629-634.
9. MORRISSY R.T., WEINSTEIN S.L. Lovell & Winter's Pediatric Orthopaedics, 6th Edition. Lippincott Williams & Wilkins, 2006, pag. 1430-1431.
10. BLOUNT W.P. Fractures in children. Baltimore: Williams & Wilkins, 1955.
11. LIGIER J.N., MÉTAIZEAU J.P., PRÉVOT J., LASCOMBES P. Flexible Intramedullary Nailing of femoral shaft fractures in children. J Bone Joint Surg, 1988, 70B, pag. 74-77.

12. LASCOMBES P., PRÉVOT J., LIGIER J.N., MÉTAIZEAU J.P., PONCELET T. Flexible intramedullary nailing in forearm shaft fractures in children: 85 cases. J Pediatr Orthop, 1990, 10, pag. 167-171.
13. DIETZ H.G., SCHMITTENBECHER P.G., SLONGO T., WILKINS K.E. AO Manual of Fracture Management–Elastic Stable Intramedullary Nailing (ESIN) in Children. AO Publishing, 2006, pag. 233.
14. MÉTAIZEAU J.P. L'ostéosynthèse de l'enfant: techniques et indications. Rev Chir Orthop, 1983, 69, pag. 495-511.
15. MÉTAIZEAU J.P. Ostéosynthèse chez l'enfant: flexible intramedullary nailing. Sauramps Médical, Montpellier, 1988.
16. PRÉVOT J., LASCOMBES P., LIGIER J.N. L'ECMES comme procédé d'ostéosynthèse des fractures des membres chez l'enfant. Principe, application sur le fémur. À propos de 250 fractures suivies depuis 1979. Chirurgie, 1993–94, 119, pag. 473-476.
17. PRÉVOT J., MÉTAIZEAU J.P., LIGIER J.N., LASCOMBES P., LESURE E., DAUTEL G. Flexible intramedullary nailing. Encycl Med Chir (Elsevier SAS, Paris), Techniques Chirurgicales-Orthopédie- Traumatologie, 44-018, 1993, pag. 13.
18. LASCOMBES P., HAUMONT T., JOURNEAU P. Use and abuse of flexible intramedullary nailing in children and adolescents. J Pediatr Orthop, 2006, 26, pag. 827-834.
19. BOUR P. L'embrochage descendant dans le traitement des fractures supracondyliennes du coude chez l'enfant (method originale). Thèse de médecine, Nancy I, 1983.
20. ALTERMATT P. L'embrochage centromédullaire dans les fractures de l'enfant. Thèse de médecine, Nancy I, 1980.
21. BLANQUART D. L'embrochage élastique stable des fractures du fémur chez l'enfant. Thèse de médecine, Nancy I, 1987.
22. GENET GENTZBITTEL F. Embrochage centromédullaire dans les fractures déplacées du col du radius chez l'enfant. À propos de 13 observations. Thèse de médecine, Nancy I, 1981.
23. PARSCH K.D. Modern trends in internal fixation of femoral shaft fractures in children. A critical review. J Pediatr Orthop, 1997, 6B, pag. 117-125.
24. PÉREZ SICILIA J.E., MOROTE JURADO J.L., CORBACHO GIRONÉS J.M., HERNÁNDEZ CABRERA J.A., GONZÁLES BUENDÍA R. Osteosíntesis

pecutánea en fracturas diafisarias de antebrazo en niños y adolescentes. Rev Esp de Cir Ost, 1977, 12, pag. 321-334.

25. MANKIEWICZ R. The Story of Mathematics. Princeton University Press, 2004, pag. 158.
26. O'CONNOR J.J., ROBERTSON E.F. Student's t-test, MacTutor History of Mathematics archive, University of St Andrews,1996, pag. 55.
27. FISHER BOX J. Guinness, Gosset, Fisher, and Small Samples. Statistical Science, 1987, 2(1), pag. 45-52.
28. RAJU T.N. William Sealy Gosset and William A. Silverman: two "students" of science. Pediatrics, 2005, 116(3), 732-735.
29. LEVENE H. Robust tests for equality of variances. În Ingram Olkin, Harold Hotelling, et alia. Stanford University Press, 1960, pag. 278-292.
30. CORDER G.W., FOREMAN D.I. Nonparametric Statistics for Non-Statisticians: A Step-by-Step Approach. Wiley, 2009.
31. GREENWOOD P.E., NIKULIN M.S. A guide to chi-squared testing. Wiley, New York, 1996.
32. FIELD A. Discovering Statistics Using SPSS, 3rd Ed. Sage Publications, 2009.
33. CRAMÉR H. Mathematical Methods of Statistics. Princeton: Princeton University Press, 1946, pag. 282.
34. SHESKIN D.J. Handbook of Parametric and Nonparametric Statistical Procedures. Boca Raton. CRC Press, 1997.
35. LIEBETRAU A.M. Measures of association. Newbury Park, CA: Sage Publications. Quantitative Applications in the Social Sciences Series, 1983, 32, pag. 15-16.
36. SHAPIRO S.S., WILK M.B. An analysis of variance test for normality (complete samples). Biometrika, 1965, 52(3-4), pag. 591-611.
37. STEPHENS M.A. EDF Statistics for Goodness of Fit and Some Comparisons. Journal of the American Statistical Association (American Statistical Association), 1974, 69(347), pag. 730-737.
38. MARSAGLIA G., TSANG W.W., WANG J. Journal of Statistical Software, 2003, 8(18), pag. 1-4.
39. KOLMOGOROV A. Sulla determinazione empirica di una legge di distribuzione. G. Inst. Ital. Attuari, 1933, 4, pag. 83.
40. SMIRNOV N.V. Tables for estimating the goodness of fit of empirical distributions. Annals of Mathematical Statistics, 1948, 19, pag. 279.

41. PEARSON E.S., HARTLEY H.O. Biometrika Tables for Statisticians. Cambridge University Press, 1972, pag. 117-123, Tabelele 54, 55.
42. SHORACK G.R., WELLNER J.A. Empirical Processes with Applications to Statistics. Wiley, 1986, pag. 239.
43. PEACOCK J.A. Two-dimensional goodness-of-fit testing in astronomy. Monthly Notices of the Royal Astronomical Society, 1983, 202, pag. 615-627.
44. FASANO G., FRANCESCHINI A. A multidimensional version of the Kolmogorov–Smirnov test. Monthly Notices of the Royal Astronomical Society, 1987, 225, pag. 155-170.
45. LOPES R.H.C., REID I., HOBSON P.R. The two-dimensional Kolmogorov-Smirnov test. XI International Workshop on Advanced Computing and Analysis Techniques in Physics Research. Amsterdam, the Netherlands, 2007.
46. KRUSKAL W.H. Historical Notes on the Wilcoxon Unpaired Two-Sample Test. Journal of the American Statistical Association, 1957, 52(279), pag. 356-360.
47. WILCOXON F. Individual comparisons by ranking methods. Biometrics Bulletin, 1945, 1(6), pag. 80-83.
48. MANN H.B., WHITNEY D.R. On a Test of Whether one of Two Random Variables is Stochastically Larger than the Other. Annals of Mathematical Statistics, 1947, 18(1), pag. 50-60.
49. CORNFIELD J. A Method for Estimating Comparative Rates from Clinical Data. Applications to Cancer of the Lung, Breast, and Cervix. Journal of the National Cancer Institute, 1951, 11, pag. 1269-1275.
50. MOSTELLER F. Association and Estimation in Contingency Tables. Journal of the American Statistical Association (American Statistical Association), 1968, 63(321), pag. 1-28.
51. EDWARDS A.W.F. The measure of association in a 2x2 table. Journal of the Royal Statistical Society, Series A (Blackwell Publishing), 1963, 126(1), pag. 109-114.
52. WEBB L., MOONEY J. Fractures and dislocations about the shoulder. In: GREEN N., SWIONTKOWSKI M. (eds) Skeletal trauma in children. W.B. Saunders, Philadelphia, 2003, pag. 322-343.
53. GARG S., DOBBS M.B., SCHOENECKER P.L., LUHMANN S.J., GORDON J.E. Surgical treatment of traumatic pediatric humeral diaphzseal fractures with titanium elastic nails. J Child Orthop, 2009, 3, pag. 121-127.

54. LASCOMBES P. – Flexible Intramedullary Nailing in Children - The Nancy University Manual, Springer-Verlag Berlin Heidelberg, 2010, pag. 20; 99-109; 159-183; 197-251.
55. SCHMITTENBECHER P.P., BLUM J., DAVID S., KNORR P., MARZI I., SCHLICKEWEI W., SCHONECKER G. Treatment of humeral shaft and subcapital fractures in children. Consensus report of the child trauma section of the DGU. Unfallchirurg, 2004, 107, pag. 8-14.
56. AMILLO S., BARRIOS R.H., MARTINEZ-PERIC R., LOSADA J.I. Surgical treatment of the radial nerve lesions associated with fractures of the humerus. J Orthop Trauma, 1993, 7, pag. 211-215.
57. WILLIAMS P.R., SHEWRING D. Use of an elastic intramedullary nail in difficult humeral fractures. Injury, 1998, 29, pag. 661-670.
58. FLYNN J.M., HRESKO T., REYNOLDS R.A., BLASIER R.D., DAVIDSON R., KASSER J. Titanium elastic nails for pediatric femur fractures: a multicenter study of early results with analysis of complications. J Pediatr Orthop, 2001, 21, pag. 4-8.
59. FLYNN J.M., SCHWEND R.M. Management at pediatric femoral shaft fractures. J Am Acad Orthop Surg, 2004, 12, pag. 347-359.
60. GORDON J.E., GREGUSH R.V., SCHOENECKER P.L., DOBBS M.B., LUHMANN S.J. Complications after titanium elastic nailing af pediatric tibial fractures. J Pediatr Orthop, 2007, 27, Pag. 442-446.
61. LIGIER J.N., METAIZEAU J.P., PREVOT J., LASCOMBES P. Elastic stable intramedullary pinning of long bone shaft fractures in children. Z Kinderchir, 1985, 40, pag. 209-212.
62. LUHMANN S.J., SCHOOTMAN M., SCHOENECKER P.L., DOBBS M.B., GORDON J.E. Complications of titanium elastic nails for pediatric femoral shaft fractures. J Pediatr Orthop, 2003, 23, pag. 443-447.
63. KUBIAK E.N., EGOL K.A., SCHER D., WASSERMAN B., FELDMAN D., KOYAL K.J. Operative treatment of tibial fractures in children: are elastic stable intramedutllary nails an improvement over external fixation? J Bone Joint Surg Am, 2005, 87, pag. 1761-1768.
64. FERNANDEZ F.F., LANGENDORFER M., WIRTH T., EBERHARDT O. Failures and complications in intramedullary nailing of children's forearm fractures, J Child Orthop, 2010, 4, pag.159-167.

65. OGONDA L., WONG-CHUNG J., WRAY R., CANAVAN B. Delayed union and non-union of the ulna following intramedullary nailing in children. J Pediatr Orthop, 2004, 13, pag. 330-333.
66. GREENBAUM B., ZIONTS L.E., EBRAMZADEH E. Open fractures of the forearm in children. J Orthop Trauma, 2001, 15, pag. 111-118.
67. LIGIER J.N., MÉTAIZEAU J.P., LASCOMBES P., PONCELET T., PRÉVOT J. – Traitement des fractures diaphysaires des deux os de l'avantbras de l'enfant par embrochage élastique stable. Rev Chir Orthop, 1987, 73(Suppl 2), pag. 149-151.
68. LUHMANN S.J., GORDON J.E., SCHOENECKER P.L. Intramedullary fixation of unstable both-bone forearm fractures in children. J Pediatr Ortho, 1998, 18, pag. 451-456.
69. SWINDELLS M.G., RAJAN R.A. – Elastic intramedullary nailing in unstable fracture of the paediatric tibial diaphysis: a systematic review. J Child Orthop, 2010, 4, pag. 45-51.
70. WEBER B.G., BRUNNER C., FREULER F., editors – Treatment of fractures in children and adolescents. New York: Springer, 1980.
71. OGDEN J.A., editor – Skeletal injury in the child. Philadelphia: Lea and Febiger, 1982.
72. SHANNAK A.O. – Tibial fractures in children: follow-up study. J Pediatr Orthop, 1988, 8, pag. 306–310.
73. THOMPSON G.H., WILDER J.H., MARCUS R.E. - Internal fixation of fractures in children and adolescents. Clin Orthop, 1984, 188, pag. 10–20.
74. HUBER R.I., KELLER H.W., HUBER P.M., REHM K.E. – Flexible intramedullary nailing as fracture treatment in children. J Pediatr Orthop, 1996, 16, pag. 602–605.
75. LIGIER J.N., METAIZEAU J.P., Prevot J. L'embrochage elastique stable a foyer ferme en traumatologie infantile. Chir Pediatr, 1983, 24, pag. 383-385.
76. METAIZEAU J.P., LIGIER J.N. Le traitement chirugical des fractures des os longs chez l'enfant. J Chirurg, 1984, 121, pag. 527-537.
77. SRIVASTAVA A.K., MEHLMAN C.T., WALL E.J., DO T.T. – Elastic stable intramedullary nailing of tibial shaft fractures in children. J Pediatr Orthop, 2008, 28(2), pag. 152-158.

78. SKAGGS D.L., LEET A.I., MONEY M.D., SHAW B.A., HALE J.M., Tolo V.T. Secondary fractures associated with external fixation in pediatric femur fractures. J Pediatr Orthop. 1999, 19, pag. 582-586.
79. BARTLETT C.S. 3rd, WEINER L.S., YANG E.C. Treatment of type II and type III open tibia fractures in children. J Orthop Trauma, 1997, 11, pag. 357-362.
80. ROBERTSON P., KAROL L.A., RAB G.T. Open fractures of the tibia and femur in children. J Pediatr Orthop. 1996, 16, pag. 621-626.
81. BUCKLEY S.L., SMITH G.R., SPONSELLER P.D., THOMPSON J.D., ROBERTSON W.W. Jr., GRIFFIN P.P. Severe (type III) open fractures of the tibia in children. J Pediatr Orthop. 1996, 16, pag. 627-634.
82. LIOW R.Y., MONTGOMERY R.J. Treatment of established and anticipated nonunion of the tibia in childhood. J Pediatr Orthop. 2002, 22, 754-760.
83. O'BRIEN T., WEISMAN D.S., RONCHETTI P., PILLER C.P., MALONEY M. – Flexible Titanium Nailing for the Treatment of the Unstable Pediatric Tibial Fracture. J Pediatr Orthop, 2004, 24(6), pag. 601-609.
84. SCHENK R., WILLENEGGER H. Morphological findings in primary fracture healing: callus formation. Simp Biol Hungarica, 1967; 7; pag. 75.