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## Summary of the general overviews

Antiquity has shown that there has been an early interest in the study of fracture repair and consolidation, generated by some doubts on bone regeneration capacity. A bone fracture triggers a series of complex repair stages, based on a strict temporospatial sequence that ends in the union of bone fragments without a scar.

Chapter I-“Callus-Pathophysiology” focuses on fracture consolidation mechanisms, early and contemporary insights on callus formation, evolution phases on callus formation and important factors that have a strong influence on fracture healing.

Chapter II-“Classification of tibial diaphyseal fractures” is a synthesis of tibial diaphyseal fractures carried out since early times up to date. Moreover, a special interest is shown to the clinical-therapeutical importance, relevance of evolution, and the prognosis of most commonly used classifications in everyday practice.

Chapter III-„ Therapeutic algorithm in Open Diaphyseal Tibial Fractures” highlights important phases in open diaphyseal lower leg fractures therapy. Attention is shown to ethics at the scene of the accident, in the emergency room and operating room. This section is a detailed description of the treatment process and of the methods made use of while managing fracture/wound sites closure with the positive and negative aspects involved. Open fracture repair is a complex process due to lesion complexity and trauma, and needs a multidisciplinary team: an anaesthesia and intensive care specialist, surgeon, vascular surgeon, neurosurgeon, plastic surgeon, orthopaedic surgeon)

Chapter IV-„ Modern Treatment Methods to Stimulate Bone Fracture Healing” is a thorough presentation of the methods that stimulate fracture repair, that highlights up-to-date procedures used in everyday practice and experimental ones. Thus, these methods have been classified as it follows:

- Biological methods
- Biomechanical methods
- Biophysical methods

**Keywords:** open fracture, fracture healing, pseudarthrosis, cold ultrasound, tibia, callus

## **Summary of the thesis**

### **CHAPTER V**

#### **RETROSPECTIVE STUDY ON OPEN FRACTURES IN THE LOWER LIMB BASED ON ORTHOPAEDIC CASUISTRY 2006-2008**

##### **V.1 Introduction to the research**

A successful evolution of open fractures in the lower limb that does not involve any risks depends on a correct treatment that is carried out taking into consideration all phases, starting with providing first aid at the scene, during transportation and especially after hospitalization. The ideal hospital is one that provides specialized modern technical equipment and an experienced multidisciplinary team. The team will keep a constant contact with the patient and re-evaluate the patient periodically in order to choose the appropriate therapeutic techniques for every evolution phase.

##### **V.2 The purpose of the research**

This study aims to provide a correct interpretation of the lesion degree, of the sequence of stages, the quality of care during the treatment period, that are important factors in achieving healing of open fractures in the lower limb without risks or complications.

##### **V.3 Materials and methods used during the research**

The retrospective study has been conducted at the Clinical County Emergency Hospital from Sibiu, in the Clinical Department Of Orthopaedics and Traumatology and includes all cases of open fractures in the lower leg bones between 2006-2008. The study does not include patients with open fractures of the lower leg strictly localized to the proximal or distal epiphysis.

The current study has made use of the following documents to collect the necessary data:

- ✓ The database of Orthopaedics and Traumatology Department (at that time)
- ✓ Observation sheets of the patients
- ✓ Operating room register
- ✓ Scans from the archive

##### **V.4 Research results/findings**

Between 2006-2008, at the Clinical County Emergency Hospital from Sibiu, in the Clinical Department Of Orthopaedics and Traumatology, 5108 patients have been hospitalized, and a number of 224 patients presented diaphyseal fractures of the

lower leg bones. Only 48 of these patients suffered from open fractures of the lower leg bones, the rest of the patients-176 presented closed fractures. Over a period of three years the study has shown the following information:

- 2006-76 patients out of whom only 20 cases of open fracture;
- 2007-77 patients out of whom 10 cases of open fracture;
- 2008-71 patients out of whom 10 cases of open fracture;

From 48 studied cases, 38(79%) were men. The average age of the subjects in the current case is 44, the youngest patient was 18 years old, the eldest 90 years old. The ethiology of open fractures is varied: traffic accidents(52%), household accidents(27%), accidents at work(11%), violence cases(4%).

Without taking into consideration 5 cm proximal and distal parts that correspond to the epiphysis of the lower leg bones, the diaphysis was separated in three equal parts that have established the main fracture site closure. Those three diaphyseal fractures were named: 1/3 proximal fraction, 1/3 middle, 1/3 distal. The classification of the patients under study based on the main fracture site closure: 1/3 proximal diaphyseal fraction-10 cases ,1/3 middle-26 cases, 1/3 distal-12 cases.

The classification of cases of open fractures of the lower leg takes into consideration skin lesions and soft-tissue injury and is based on the well-known study of Gustilo-Anderson:I-20 cases, II 19 cases, IIIA 7 cases, IIIB 2 cases, IIIC 0 cases.

A part of the open fractures of the lower leg have occurred in a plurilesional or polytraumatic context. Thus, 15 cases presented other lesions,5 cases presented an association of multiple injuries in the open fracture of the lower leg. Perilesional associations found in the research are presented in table 1.

Table 1.Trauma related diagnoses

<b>Association lesion</b>	<b>Number of cases</b>
Craniocerebral trauma	5
Thoracic trauma	4
Maleolar fracture	1
Tibial plateau fracture.	1
Scapula fracture	1
Metatarsal fracture	1
Foreleg amputation trauma	1
Craniofacial trauma	1
Scapulo-humeral luxation	1
Clavicle fracture	1
Distal radial epiphyseal fracture	1
Open femoral fracture	1
Proximal humerus fracture	1

Treatment and prognosis of open lower limb fractures is strongly influenced by the biological status of the patient, and, thus patient's medical history has been taken into consideration. In the case studies, related diseases have been met in 12 cases:

arterial hypertension (6), diabetes mellitus (3), ischemic heart disease (3), chronic hepatitis B (1), homolateral ankle arthrosis (1) COPD (1), chronic atrial fibrillation (1).

Fracture site type has been interpreted in terms of the AO ASIF classification. Taking into consideration all factors this classification is based upon, 27(56%) of the subject cases presented a simple fracture (42A-based on AO-ASIF classification), and 21(44%) presented a comminuted fracture (42B or 42C-based on AO-ASIF classification).

Therapeutic treatment plan has been designed based on different lesions taking in consideration the appropriate stages in terms of the local lesion degree, associated lesions and clinical context of contusions and trauma.

Initial assessment and stabilisation of fracture included the following aspects:

- Plaster cast immobilisation-8 cases;
- Trans-calcaneal extension-33 cases;
- External fixation with osteosynthesis-7 cases.

Previous data has shown that initial stabilisation of fracture that was used more often is the trans-calcaneal extension, while plaster cast immobilisation was used only in type I and II open fractures, and external fixation was used in type III open fractures.

Final stabilisation of the fracture included:

- Orthopaedic methods;
- Surgical methods.

Definitive stabilisation of the fracture included:

- immobilisation of the fracture with the initial plaster cast until fracture consolidation;
- trans-calcaneal conversion(after a previous scanning of the fracture)in plaster cast immobilisation until fracture healing;

Definitive surgical stabilisation of the fracture made use of different methods:

- Centro-medular nailing osteosynthesis;
- External fixation osteosynthesis;
- Screw and plate osteosynthesis. (table 2)

Table2 Type of Final stabilisation of the fracture

Type of Final stabilisation of the fracture	No. Of cases	Method	No. of cases
Orthopaedic	17	immobilisation of the fracture with the initial plaster cast until fracture consolidation	8
		trans-calcaneal conversion in plaster cast immobilisation	9
Surgical	31	Centro-medular nailing osteosynthesis	22
		External fixation osteosynthesis	8
		Screw and plate osteosynthesis	1

Definitive surgical fracture stabilisation methods have been differentiated (table 3):

- intramedullary Kuntscher nailing osteosynthesis without diaphyseal reaming-22 cases;
- reamed and locked intramedullary nailing osteosynthesis-1 case,
- plate and screws osteosynthesis-1 case;
- external fixation osteosynthesis-7 cases.

Table 3 Definitive surgical fracture stabilisation methods

Definitive surgical fracture stabilisation method	Type I	Type II	Type IIIA	Type IIIB
Intermedullary nailing	12	8	3	0
Plate and screws	1	0	0	0
External fixation (FE)	1	2	2	2

Management of posttraumatic wounds and skin defects includes multiple and complex interventions, and sometimes requires collaboration with a plastic surgeon. (fig. no. 1)

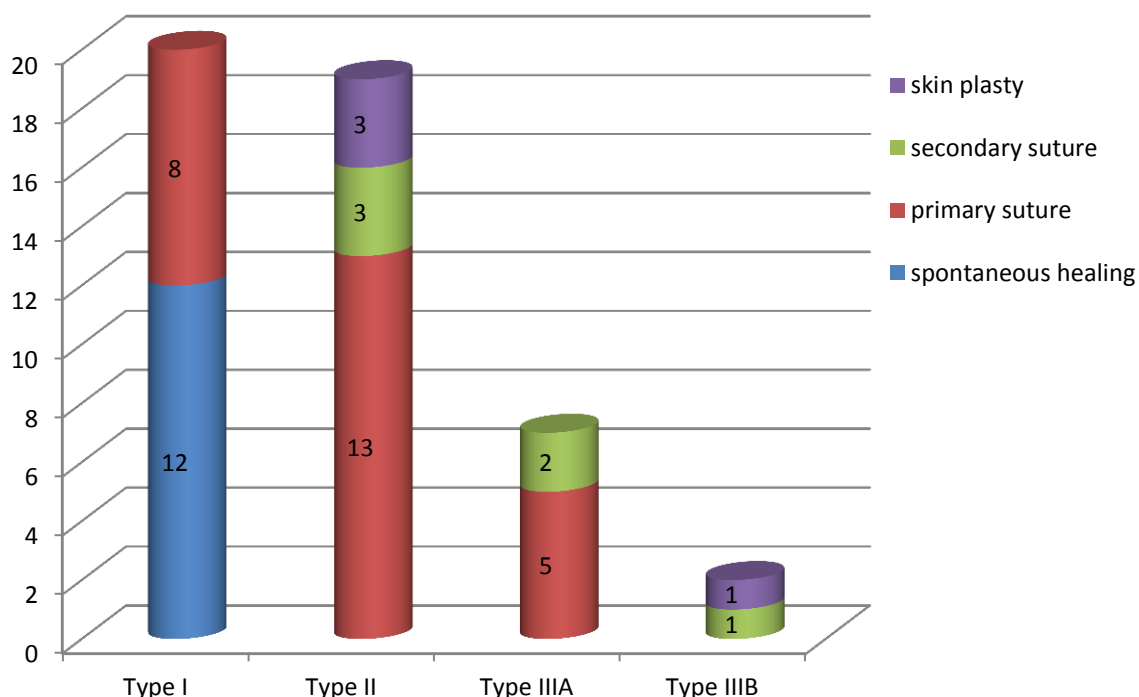


Fig. no. 1 Case classification based on the procedures used to close the fracture site

Study cases have reached a number of 1005 hospitalisation days, with an average of 21 days, and a period that spanned between 7 and 57 days. This is a classification based on the total and average hospitalisation period. (table no. 4):



Table no. 4 Classification of cases based on hospitalisation period

Gustillo-Anderson classification	Total number of hospitalisation days	Average number of hospitalisation days
Type I	301	15
Type II	460	24,2
Type III	244	27,1

Based on Gustillo-Anderson classification ,taking into consideration lesion degree, the average duration of antibiotic prophylaxis has shown the following:

- ✓ Type I-7,8 days;
- ✓ Type II-10,9 days;
- ✓ Type III-15,6days.

Studied cases involved postoperative immediate and late complications. An analysis of the database of the hospital has highlighted the fact that no extreme complications,such as pulmonary embolism or shock occurred. As far as immediate local complications are concerned, there was not any record of compartment syndrome and acute osteomyelitis. In 9 of the studied cases immediate complications occurred:

- ✓ Primary suturing haematoma of the contused wound– 2 cases (1-type I, 1-type II);
- ✓ Traumatic skin necrosis-4 cases(2-Type I,1-Type IIIA,1 Type IIIB);
- ✓ Infection of wound/contusion-3 cases (2-Type II,1 Type IIIB).

These complications have ben solved making use of the following methods:

- ✓ Primary suturing haematoma of the contused wound-surgical evacuation;
- ✓ Traumatic skin necrosis- necrectomy and secondary suture;
- ✓ Infection of wound/contusion- anti biotherapy according to the antibiogram until wound sterilisation.

Bacteriological examination of the isolated germs from the infected wound has shown the presence of the following types of bacteria:

- ✓ Acinetobacteria– 1 case of type IIIB fracture;
- ✓ Staphylococcus aureus – 1case of type II fracture;
- ✓ Klebsiella Oxytoca – 1 case of type II fracture.

Immediate local complications that have occurred have been successfully solved after carrying out the appropriate treatment.

Assessment of postoperative immediate and late complications was based on the post-operative hospitalisation periods, that aimed to solve a complication or just to extract the osteosynthesis material. Studied data has shown that here were no cases of malunion or late postoperative infection (osteitis).Some of the complications that have been traced in the case of post-operative hospitalisation periods are:

- ✓ intramedullary rod migration - 1 case (type IIIA);
- ✓ Infection of the external fixator rod -1 case (type IIIA);
- ✓ nonunion -3 cases (1 case-type I, 1 case-type II, 1 case-type IIIA).

These complications have been solved making use of the following methods:

- ✓ migration of intramedullary rod – reintroduction;
- ✓ infection of the external fixator-therapy based on antibiotics according to the antibiogram;
- ✓ nonunions:
  - 1 case – use of cancellous graft + plate and screws osteosynthesis;
  - 2 cases - intramedullary reaming of tibia and nailing

## V.5 Discussions and Conclusions

1. Analysing open fracture of the lower limb over the studied period, it is to be noticed the fact that the number of cases increased in 2006 and 2008, if compared with the number of cases registered in 2007. However, the number of cases of open fracture out of the total number of lower limb hospitalisations is definitively a considerable one between 2006-2008.
2. As far as sex differentiation is concerned, the number of male patients is bigger than the number of female patients. This issue can be easily explained because male subjects are frequently exposed to higher risk activities.
3. An analysis based on age group distribution indicates a bigger number of cases of open fracture of lower leg for patients up to 60 years, who live an active life.
4. Traffic accidents are the main cause of open fracture of lower leg (more than half of the cases under study). However, varied household accidents register a great number in open fracture of lower leg ethiology.
5. The leg bone is exposed to lesion due to its superficial integumentary position and lesion is frequently located along the 1/3 middle and especially the verge of 1/3 and 1/3 distal, due to the fact that this is the part of the bone shows minimal strength, its risk-prone shape, and because it is considered to be the narrowest section of the tibial diaphysis.
6. From an ethiological point of view, although traffic accidents are the major cause of open fractures of the lower leg, the type of fractures based on the Gustilo-Anderson classification, which have been frequently met are type I and II (79%), due to the action of a minor or medium intensity lesion factor.
7. Perfectly aware of the main ethiology of producing open fractures lower leg bone, one can easily associate other lesions in a plurilezional or politraumatic context. The presence of other lesions at a certain distance from the fracture site shows the violent character of the lesion factor that acted upon this segment. Moreover, this idea is reinforced by the frequent association with other fractures, such as type IIIA and IIIB open fractures.
8. Important diseases from the patient's medical history can influence therapy, prognosis, or can even force the trauma surgeon to take into consideration reconstruction or amputation of the affected limb.

9. Condition of the fracture site (simple or comminute) has played an important role in fracture site stabilisation, and, thus the AO-ASIF classification is very useful in open fracture in the lower leg.
10. Setting main objectives immediately after admission of a case of open fracture in the lower leg, even in a plurilesional or politraumatic context, is the cornerstone of correct therapeutic attitude and success of the treatment applied to the patient.
11. Nowadays initial stabilisation of the fracture site –mainly open fractures type I and II, based on Gustillo-Anderson classification-by making use of orthopaedic methods(plaster cast or trans-calcaneal conversion), denotes a cautious and expectative attitude, and also thorough observation of the future evolution of associated local lesions.
12. Definitive surgical stabilisation of the fracture site is met in majority of the studied cases(75%),and the latest trends in the treatment of open fractures of the lower leg are highlighted.
13. The most frequent case is intramedullary nailing osteosynthesis (74%),as it is the latest therapy method of treatment of open fractures of the lower leg, type I, II,and IIIA, based on Gustillo-Anderson classification.
14. One of the main objectives in therapy is to transform an open fracture to close fracture, which consists of a process that starts in the very first moment of admission, by means of primary suture of traumatic wounds or rapid spontaneous cicatrisation of punctiform points(79%).
15. Open fractures of lower leg generally ask for a longer hospitalisation period with important material and human costs. The average hospitalisation period is definitively influenced by the lesion degree of soft tissue-found in the Gustillo-Anderson classification-and it increases constantly as it is directly connected to the degree of lesions. The previous statement is also valid for the period of time between the moment of hospitalisation and definitive fracture site osteosynthesis, and for carrying out an average antibiotic prophylaxis therapy.
16. Sometimes initial stabilisation of the fracture site may become a definitive one if the appropriate clinical, biomechanical and prognosis criteria are met. Thus, in 7 of the understudy cases(26%), maintaining the internal fixator introduced in the first hospitalisation phase was the final decision, and only in one of the cases there were some complications of osteitis at the external fixator rods associated with closed non-union.
17. There have been some immediate local complications, but of reduced intensity and without any clinical-evolutionary influence on the long term. One case may be mentioned, though, of an immediate local complication (skin necrosis of the wound) and a late local complication (closed pseudoartrosis). Iatrogenic, and Klebsiella Oxytoca infection of the wound may also be mentioned in two of the cases, but these situations have been soled by applying targeted antibiotic therapy.

18. There have been rare late local complications (12%), and these have been solved by surgical methods. Late complication occurred in one case, and it was manifested by osteitis at the external fixator rods.

## CHAPTER VI

### THE INFLUENCE OF HIGH FREQUENCY ULTRASOUND THERAPY ON PSEUDOARTHROSIS AND DELAYED UNION

#### VI.1 Introduction to the research

There are several factors that may influence fracture healing, or that can even prevent it. Some of these factors are the characteristics of the fracture and patients' medical history, which can cause pseudoarthrosis.

Nowadays, there are several treatment options of pseudoarthrosis :

- ✓ surgical treatment;
- ✓ conservative treatment;
- ✓ electric stimulation;
- ✓ shockwave therapy;
- ✓ low intensity and high frequency pulsed ultrasound therapy.

Therapeutic effect of ultrasounds in treatment and consolidation of pseudoarthrosis depends on their intensity. Low intensity ultrasounds, accompanied by a high pulsed frequency, acts on fracture healing during daily irradiation. The pressure that results during this process produces vibration of mesenchymal cell walls, and causes an acceleration of cellular metabolism. Besides faster transformation of mesenchymal cells into osteoblasts and then osteocytes, it was found that sonic impulses also act on bone canaliculi opening, that help calcium ions to enter easier in bone cells. (94,118,181)

#### VI.2 Materials and methods used during the research

The study included late bone consolidation and delayed non-unions resulting from fractures treated in the Clinical Department Of Orthopaedics and Traumatology Orthopaedics, Emergency County Hospital of Sibiu between 2009-2012.

Study inclusion criteria are:

- patients with non-union regardless of bone interest or type of initial treatment of fracture;
- patients aged 18 years and more;
- at least 3 months after the fracture producing;
- absence of a stimulating bone healing treatment method at least two months before starting ultrasound therapy;
- absence of radiographic healing (minimum three cortical bridges) of the fracture that was visible on radiographs made at least two incidents.

Study exclusion criteria:

- abuse of alcohol, tobacco or drugs of the patient;
- presence of neuropathy, active malignancy or chronic metabolic diseases, that affect bone formation;
- septic non-union with active infection;
- treatment with hormones, steroids, anticoagulants or bisphosphonates.

Patients included as subjects of the study have agreed with applying cold ultrasound therapy as a method of treatment pseudoarthrosis or delayed union, diagnosed both clinically and radiologically.

Ultrasounds treatment was performed using a portable device, that is a version of the devices that stimulate new bone production, using low intensity ultrasound radiation, but high pulsed frequency.

Using the device is simple because it has been designed so that it can meet ambulatory usage and can be mounted and applied by the patient himself. Its small size and weight that makes it easy to handle.

The device should be applied to the skin, near the fracture site, without the possibility of affecting a nearby metal implant. It can also be used in plaster cast immobilized fractures, as it gives the possibility of applying the ultrasound emitter electrode through a small “window” at the bottom of the immobilized section.

The parts of cold ultrasound device(fig.no.2):

- 1) Device itself
- 2) Ultrasound electrode
- 3) Direction device for the ultrasound transmitter head
- 4) Cloth pad to protect the skin
- 5) Special gel that helps transmission of ultrasounds at the level of the skin

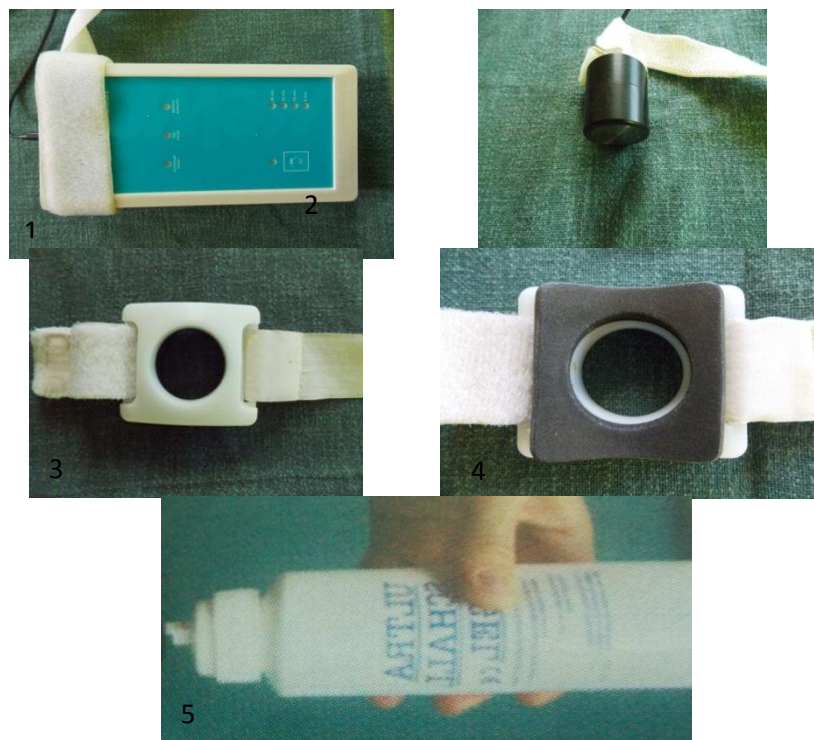


Fig. no. 2 The parts of cold ultrasound device



The technique of using device is a simple one and includes the following steps (figure no. 3):

1. marking on the skin the place where we will apply the device;
2. bracket bonding pad on the bottom of the ultrasound transmitter guiding device;
3. closely guiding device application on the skin, with fastening tape;
4. application of gel on ultrasounds transmitter;
5. placing of ultrasounds transmitter through the guide ring;
6. ensuring intimate contact skin - ultrasounds transmitter



Fig. no. 3 The technique of using the ultrasound device

Each patient in the study has used the ultrasounds device over a period of 60 days, 20 minutes daily, the time of the therapy session being indicated acoustically and visually on the screen of the device. Non-unions were considered to be healed if they met the clinical (no pain in mobilization or weight bearing, possibility of weight bearing without help, absence of functional impairment) and radiological criteria (presence of callus bridging on at least 3 of 4 cortices on the radiographs made in two incidents: anterior-posterior and lateral).

### VI.3 Research results

Between 2009-2012, 12 patients diagnosed with non-union or late bone consolidation have been treated with cold ultrasound, and all subjects of the study met the inclusion and exclusion criteria presented in the previous section of this paper.

To establish a diagnosis three parameters were used:

1. clinical elements:

- a. pain on the fracture site;
- b. functional impotence of the affected limb;
- c. pathological mobility at the fracture site;
- d. deformity of the limb;
- e. inability to walk without aid (crutch /cane) in case of lower limb fractures.

2. radiological examinations (minimum two ortoroentgengrade incidents)

- a. no callus on radiological images (minimum 3 periosteal or endosteal cortical bridging)

3. average time between the actual accident (fracture moment )and the establishment of diagnosis:

- a. minimum of 3-6 months-delayed union;
- b. over 6 months-pseudoartosis.

Diagnosis certainty was based on association of at least two clinical elements with the radiological aspect, and the period of time between the moment of trauma and the starting day of the stimulation treatment of fracture site consolidation using ultrasounds. Thus, the study includes 6 pseudoartrosis and 6 delay of union cases.

Pain was a common symptom in all studied cases, and in establishing the diagnosis, two other aspects were considered:

- inability to walk without aid (crutch /cane)-8 cases
- functional impotence of the affected limb-4 cases

There has been no case of pathological mobility at the fracture site or deformity of the limb.

Average age of the patients under study was 43, the extreme ages were 21 and 61. In five of the cases the subjects were women and the rest of seven cases were men.

The following is a classification based on the bone affected by non-unions or by delayed union:

- tibia-6 cases;
- femur-2 cases;
- humerus-1 case;
- radius-1 cases;
- cubitus-1 case;
- scaphoid-1 case.

In 4 cases the initial fracture was an open one, three cases of tibia fracture, and one case of open radius fracture. Surgery was performed in all cases, except the scaphoid fracture.

Open reduction and osteosynthesis fracture site was performed in 4 cases, whereas in three open fractures of the tibia, intramedullary nail fixation or external fixation was performed. Thus, in the case of all the subjects (7 patients) of the present research we can identify a post-traumatic or surgically open fracture site.

Average time between trauma and initiation of therapy was 214 days, the minimum duration of was 91 days, and the maximum one 742 days. Ultrasound

therapy started 4 months (115 days) after injury for delayed union cases, and after 10 months(315 days) for pseudoarthrosis cases.

After ultrasound therapy was performed, all patients became subjects of clinical and radiological assessment. In 8 cases (75%) clinical and radiological conditions of fracture consolidation were met. The therapy proved to be successful, and the radiographs showed at least three cortical bones on the two standard incidents. Four cases in which fracture repair/healing non-union failed are mentioned below:

- radius fracture complicated by broken of plate osteosynthesis;
- femoral fracture operated upon with intramedullary locked nail;
- cubitus fracture operated upon with K intramedullary pin;
- open fracture of the tibia, previously stabilized with external fixator, and then, with intramedullary locked nail.

Three of the cases above were delayed consolidation cases, and one was diagnosed with nonunion (open fracture of tibia). Three cases of nonunion after ultrasound therapy, the fracture site was opened either surgically, or after trauma. In case of healed fractures, in two cases the fracture site was surgically opened, and in two cases it was opened post-traumatically.

Lack of healing occurred in the case of patients of different age groups (aged 24,31,60,61), two men and two women.

#### VI.4 Clinical and Radiological Aspects/Features in studied cases

One case out of all the cases that make the subject of our paper needed special attention

B.C-man, aged 52

Diagnosis: Subtrochanteric femur fracture (fig. no. 4-A )

Initial surgical intervention: open reduction and osteosynthesis with plate and screws (fig. nr. 4-B)



Fig. nr. 4 A – pre-operative radiological aspect;  
B – post-operative radiological aspect;

In evolution delayed union occurred and plate showed signs of deterioration, thus another surgical intervention was necessary and extraction of plate and screws, femoral canal reaming and intramedullary nail fixation was performed. This intervention was done 4 months after the initial one.



Unfavourable outcome, proved to be an issue in this case, as nonunion occurred thus, initiation of surgical treatment started and augmented with auto graft bone harvested from the iliac crest and changing the intramedullary rod was proceeded; 5 months after the intervention, there were major signs of fracture nonunion, and ultrasound therapy was initiated, as the following stage of protocol treatment. The outcome was eventually a favourable one, as union at the pseudoarthrosis site was shown on the radiographs.(fig. no.5).

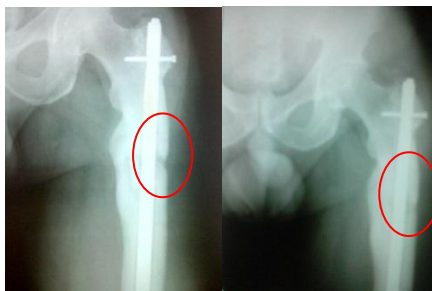


Fig. no. 5 A – pre-ultrasound therapy radiological aspect; B – post-ultrasound therapy radiological aspect;

## VI.5 Conclusions

1. Although, from a clinical-radiological point of view, there are no differences between delayed union and pseudoarthrosis, time is the only factor that can make a difference in this situation, because it triggers a different therapeutical attitude.
2. Radiological examination is a must, and it has to be performed and interpreted in connection with the appropriate clinical context, in order to establish a delayed union or a pseudoarthrosis diagnosis.
3. Establishing a delayed union or pseudoarthrosis diagnosis is a very difficult task, as clinical symptoms, that signal pseudoarthrosis (pathological mobility at the fracture site, bone crepitation, interruption of bone continuity, no movement at the fracture site) do not always occur in the case of fractures where osteosynthesis was performed.
4. Age and sex markers were not considered negative prognosis factors in the evolution of fracture towards delayed union or pseudoarthrosis, not before or after ultrasound therapy.
5. Tibia is considered to be the bone that is highly prone to delayed union or pseudoarthrosis, based on its anatomic-structural characteristics, and on the fact that it is the bone that is commonly involved in open fractures. Ultrasound therapy was not influenced by initial localisation of the fracture.
6. The factors that influence the evolution of a fracture towards delayed non-union or pseudoarthrosis are: traumatically or surgically opened fracture (a situation in which deterioration and devascularisation of the bone are associated), anatomical and vascular characteristics of the bone, insufficient or inadequate osteosynthesis, infection at the fracture site.
7. Equal proportion of union/nonunion of the fractures in which the fracture site was opened (surgically or traumatically), after performing ultrasound therapy, clearly indicates that evolution of the fracture site after ultrasound therapy is

not influenced by initial clinical condition of the fracture or the type of osteosynthesis decided upon.

8. Surgical treatment of pseudoarthrosis is „the golden standard” even if healing stimulation at the fracture site by means of ultrasound therapy fails.
9. Ultrasound therapy has proved to be successful even for failure of surgical treatment of femoral pseudoarthrosis.

## CHAPTER VII

### THE INFLUENCE OF ULTRASOUND THERAPY IN THE EVOLUTION OF OPEN TIBIAL SHAFT FRACTURES

#### VII.1 Introduction to the research

Over the time, low frequency pulsed ultrasounds have been successfully used in the treatment of delayed union, or even pseudoarthrosis. Mechanism that makes these ultrasounds stimulate the process of bone healing, still remains a mystery, although there are some theories that highlight the idea that ultrasounds trigger a micro-mechanical stress that accelerate cellular metabolism.

#### VII.2 The purpose of the research

Perfectly aware of the pathophysiology of open fractures, and of the fact that one of the most important stage for a favourable evolution-fracture hematoma stage-is missing, the purpose of the present paper is to determine whether low frequency pulsed ultrasounds may have a positive influence or even shorten the healing period in open tibial shaft fractures..

#### VII.3 Materials and methods used during the research

The present study focuses on open tibia shaft fractures operated in the Clinical Department Of Orthopaedics and Traumatology ,Emergency County Hospital of Sibiu between 2010-2012.The study does not include all patients who presented open tibia shaft fractures, because a selection based on inclusion-exclusion criteria was used, in order to get a solid study group, with similar characteristics ,as far as fracture and influential factors in the normal course in fracture evolution are concerned.

Study inclusion criteria was:

- open tibia shaft fractures;
- open tibia shaft fractures(type I,II,IIA-Gustilo-Anderson classification);
- fractures treated with locked reamed intramedullary nail osteosynthesis;
- aged over 18,or emphasizing closure of a growth plate epiphysis.

Study exclusion criteria was:

- Open tibia fracture type IIIB,IIIC(Gustilo-Anderson classification)
- Fracture location/extension in the epiphyseal part (5 cm proximal /distal) of the tibia;
- Bifocal fractures of the tibia;

- A period of time of over 10 days from the moment when the fracture occurred and definitive stabilization;
- Fracture with bone defects needing bone grafting;
- Occuring of an infection at the site of fracture;
- Politraumas;
- Known abuse of alcohol, tobacco or drugs;
- presence of neuropathy, active malignancy or chronic metabolic diseases affecting bone formation;
- treatment with hormones, steroids, anticoagulants or bisphosphonates;

Based on the previously mentioned criteria, a number of 22 patients were included in the research. However, 5 patients were excluded from the study, as 2 of them presented infection at the fracture site, and 3 gave up therapy that included performance of all stages in the observation of evolution, based on objective or personal reasons.

All the other patients in the study group went through all stages of the therapy. Subjects were divided into two groups:

- ✓ group A-patients treated with high frequency pulsed ultrasounds;
- ✓ group B-patients for whom high frequency ultrasound therapy was not applied.

Patients from group A, that were included in the research have agreed with application of cold ultrasound treatment in the case of open tibia fracture, that was clinically and radiologically diagnosed.

Cold ultrasound therapy was performed by means of a portable device, an alternative of the devices that stimulate new bone production, using low intensity ultrasound radiation, but high pulsed frequency.

All patients in group A were given this kind of specialized therapy, in which each patient used the ultrasound device over a period of 60 days, 20 minutes daily, as time was previously pre-set. The time of the therapy session was indicated acoustically and visually. Therapy was initiated 3 days after fracture definitive stabilization, and it took place within the premises of the patient's home, after prior training on the way the device worked.

Continuous assessment of the fracture was performed by strictly set medical checks, that included clinical-radiological evaluation of fracture at 1,2,3,4,5,6 months (within a margin of +/- 5 days), and at 9 and 12 months (within a margin of +/- 14 days). 3,6,9 and 12 months after operation focused on a global assessment of healing at the fracture site, and the 9 and 12 months medical checks radiographs were analysed to see whether the fracture line disappeared.

The criteria upon which evaluation of fracture consolidation were based upon, were divided in two categories, and registered in a chart, at every meeting with the subjects of the present research:

1. clinical criteria:
  - absence of pain at rest or in motion, at the fracture site;
  - absence of mobility at the fracture site;
  - possibility to walk without aid (crutch /cane);
  - no other intervention that might favour callus formation at the fracture site;
2. radiological criteria:

- presence of callus bridging on at least 3 of 4 cortices on the radiographs made in two ortoroentgengrade planes(anterior-posterior and lateral)

In the case when all the previous criteria were met, the fracture was considered to be healed.

Approximation of the moment when cortical bridges might occur, and of fracture healing was calculated in terms of the number of days that passed after surgery.

Data collected in all of the 8 meeting with the patients was introduced in a chart, that included information on local pain evaluation, soft tissue lesions, radiological aspect at the fracture site, and that also measured evolution from one meeting to the other. Gathered data was analysed in order to evaluate outcome.

**VII.4 Research findings/results and discussions**

Between 2010-2012 in the Clinical Department Of Orthopaedics and Traumatology, Emergency County Hospital of Sibiu 5432 patients have been hospitalized, and a number of 256 patients were diagnosed with fracture of lower leg. Out of this number, 216 patients had closed fractures, and 40 patients had open fractures. However, only 17 patients (8-group A; 9-group B), who presented open fracture of the lower leg, succeeded in meeting the inclusion criteria of the present research.

Average age of the study group was 40 years and 6 months(36 years-group A; 43 years-group B), and the extreme ages 18 and 70 years. The study group included 15 men and 2 women.

Ethiology of open fractures of the lower leg covered a wide range. Crushing accidents were caused by the fall of a wall(1 case), of a log (2 cases), or a metal panel(2 cases). Household accidents were caused by a fall at the same level(3 cases), or a slip on ice(1 case). Traffic accidents included pedestrians(4 cases), and the occupant of a vehicle(1 case).

Assessment of the lesion degree of soft tissue associated with fracture of the lower leg bones, allowed systematisation of fractures based upon Gustilo-Anderson classification(fig.no.6). If distribution of cases for open fractures type I and II maintained an equilibrium in the two groups under study, one can notice that those two open fractures IIIA belonged to group B.

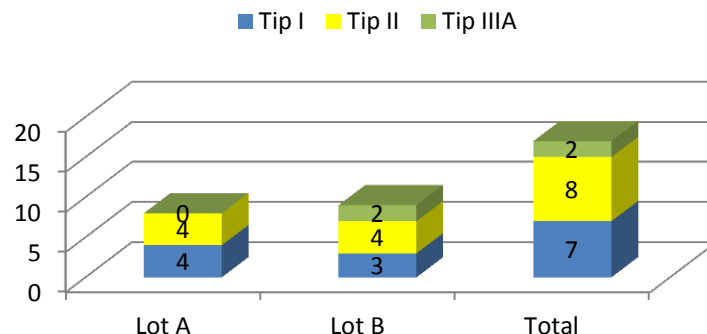


Fig. no. 6 Systematisation of fractures based upon Gustilo-Anderson classification

A systematisation of the cases under study was done based on the complexity of the fracture site, by means of the radiographs performed in the moment of hospitalisation. (fig.7)

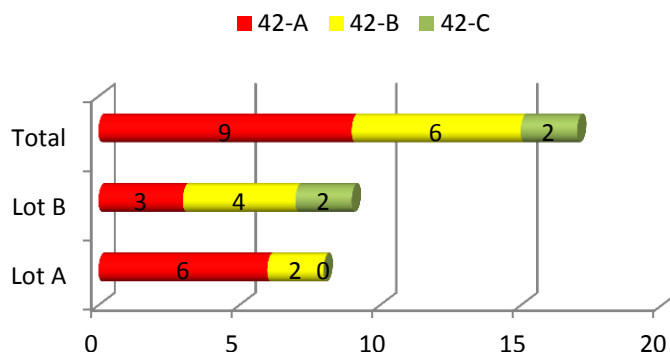


Fig. no. 7 Systematisation of the cases under study based on the complexity of the fracture site.(classification AO\_ASIF)

Average number of hospitalisation days was 13,5(7 days minimum,34 days maximum),and the average number of days from the moment of hospitalisation until definitive osteosynthesis was 6 days.(2 days minimum,10 days maximum). Longer periods between moment of hospitalisation and definitive osteosynthesis was due to presence of posttraumatic circulatory disorders, that occurred at the fracture site, sometimes in association with fracture blisters.(fig.8)

Definitive stabilisation of fractures was performed by reamed locked static intramedullary nailing. During the surgery one incident occurred: the drill broke in the attempt to proximally lock the tibia, using the guidelines included in the medical kit.



Fig. no. 8 Posttraumatic circulatory disorders (fracture blisters) in open fractures of the lower leg bones

Comparative analysis of the groups under study has shown the following:

- ✓ patients in group A met the clinical criteria of fracture healing earlier with an average of 22 days;
- ✓ healing radiological criteria were met earlier with an average of 60 days in group A;
- ✓ comparative analysis of the studied groups, that was meant to highlight clinical bone healing criteria, has shown that in the situation of the two study groups in 2/3 of the cases the moment in which the criteria were met almost matches;
- ✓ comparative analysis of the studied groups, that was meant to highlight radiological bone healing criteria, has shown that in all cases from group B, they were met with a certain delay.

An important issue in the present research was evolution of the fracture union, based on the lesion degree of soft tissues, that was associated with the open fracture (Gustilo-Anderson classification). This aspect was analysed by measuring union data collected at the fracture site 3,6,9 and 12 months after surgery, for each study group.

All fractures type II healed within 3 months, in both situations of group A and B. A fracture that was considered type I healed within 3 and 6 months, whereas the others healed in the first 3 months. In the case of the fractures type IIIA, one healed after 3 months and the other after 9 months.

The period of time that is needed for fracture healing (measured in terms of days), has shown the fact that, statistically speaking, there are no major differences, and the period of time necessary for fractures type IIIA, doubled-if compared with the other types of fractures that make the purpose of the present study. Although, from a statistical point of view, there were no significant differences of time, as far as healing period is concerned, in the situation of type I and II, earlier union occurred for patients in group A (an average time of 33 days for fractures type I, and an average period of 31 days for type II)

An analysis of the fracture site evolution, based upon the complexity of the fracture(AO classification) has reached the following results:

- ✓ one of the simple site fractures(42A) healed between 3-6 months from surgery, and another one between 6-9 months;
- ✓ fractures type 42B healed in the very first 6 months, the majority (5) healed in the first three months;
- ✓ fractures type 42C needed a longer period to heal;
- ✓ there was a difference of 46 days between group A and group B for fractures 42A, as far as healing period is concerned, and a difference of only 9 days for fractures 42B;
- ✓ a comparison of the difference between the period of time needed for fractures type A and B to heal, and the total time of fracture healing, one can reach the conclusion that it was 5 days shorter, respectively 18 days longer for group A, and 19 days, respectively 33 days shorter for group B-due to an average longer period of time (228,5 days) needed for healing type C fractures, situation that definitively influences the average global time for fracture healing.

In an statistical analysis of fracture healing, as far as its occurrence at the tibial diaphysis level is concerned, the present research has taken into consideration only fractures located in the 1/3 medium and distal of the tibial diaphysis, because there was only one case of a fracture 1/3 proximally located. The results of this analysis are:

- ✓ all fractures in group A healed in the first 3 months after surgery;
- ✓ in one case from group B the fracture, that was 1/3 medium located healed between 6 and 9 months after operation;
- ✓ in two cases from group B, located 1/3 distal of the tibial diaphysis, the fractures healed between 3 and 6 months after surgery;
- ✓ average difference of time in healing fractures from group A was of 15 days, in favour of those 1/3 medium located;
- ✓ average difference of time in healing fractures from group B was of 4 days, in favour of those 1/3 distally located;
- ✓ a comparison of the difference between the period of time needed for fractures to heal based on their anatomical location, and the global healing/consolidation time of fractures, it was 5 days shorter in the case of



fractures located 1/3 medium, respectively, 10 days longer for fractures located 1/3 distal, in group A, and 10 days, respectively, 14 days shorter for group B.

## VII.6 Conclusions

1. Anatomical, etiological and pathophysiological characteristics of the lower leg impose in the case of open fractures, differentiated lesion characteristics, multiple clinical aspects, therapeutical issues and doubtful prognosis.
2. Open fractures of the diaphysis of tibia occur in any category of age, but usually, they are considered an ordinary issue for those who live an active life.
3. The most common site for fracture was the distal and medium third (1/3) of the tibia, a situation that can be easily explained by tibia architectural structure, and anatomical features of lower limb area, where tibia is superficially located at the skin surface, and receives less protection, due to the soft tissue from this level.
4. Increased number of open fractures of the lower limb is due to road traffic and workplace accidents.
5. In the case of road traffic, pedestrians are more prone to suffer from open fractures of the lower leg.
6. Open fractures of lower limb caused by car accidents, crush injuries, falls from height are characteristic for the active period of one's life, whereas, open fractures of lower limb caused by household accidents are characteristic for the category of age over 50. This highlights the fact that open fractures mostly occur in active lives, whereas, for people of over 50, opening of the fracture site was caused by „in-out mechanism”, a favourable element, as far as prognostic terms are concerned.
7. Lesion degree of soft part tissues and bone structures is proportional to the traumatic mechanism type and kinetic energy level produced by this, a fact that definitively influences further development of fracture healing. However, the utmost outcome, in the treatment of open fractures, that is satisfactory functional recovery, is not an easy target to achieve.
8. Complexity of the fracture site is an important element as far as intensity traumatic approach is concerned. Comminuted fractures, usually involve complex lesions in surrounding soft tissue, and both of them may have a negative influence upon natural evolution of fracture healing.
9. Treatment of open fractures of lower limb, is a process that involves several stages, and follows a well-defined therapeutic algorithm, as far as soft part tissues and osteosynthesis of the fracture site is concerned.
10. Long average hospitalisation period is due to the fact that definitive osteosynthesis of the fracture site was initiated after remission or improvement of local post traumatic disorders. Thus, hospitalisation costs, in the case of open fractures, are above the average.
11. Absence of local pain, in most of the cases under study, involves movement at the fracture site, and impossibility to walk without aid (crutch /cane), in most of the cases, were consequences of the type of osteosynthesis applied -reamed locked intramedullary nailing. Number of cortical bridges, that are in favour of patients in group A, the group that was subjected to cold ultrasound treatment of the fracture site, highlight the positive aspect of this type of treatment.

12. Favourable difference of patients, with an advantage of group A, after two months from the surgery revealed first healing signs on radiographs, besides improvement of clinical consolidation criteria.
13. Clinical-radiological healing can be noticed in the case of all patients in group A (the radiographs showed the presence of four cortical bridges, in some of the cases), whereas in group B some of the patients showed no signs of cortical bridges at the fracture site.
14. Patients in group A showed no complications at the fracture site, union occurred early in all cases, with an average period of time of 22 days faster than in group B in which one of the patients delayed union at the fracture site was revealed.
15. All consolidation criteria were met earlier, in both groups A and B, due to the type of osteosynthesis performed.
16. Clinical consolidation criteria occurred earlier in group A, if compared to group B, although in 2/3 of the cases the moment of clinical union of the fracture was very close from one another.
17. Radiological criteria of union at the fracture site occurred later than the clinical criteria, in the situation of both groups, with a slight difference, in favour of group A.
18. Radiological criteria that showed union at the fracture site, needed a longer time, twice as long, in group B, after all clinical criteria were met.
19. As clinical criteria were met earlier, due to the strict osteosynthesis of the fracture site that was performed and to the appropriate therapy of soft tissues, a fact that the idea that evolution of the fracture showed on the radiographs is the major signal of fracture consolidation.
20. There are no significant differences between union time in the case of fractures type I and II (Gustilo-Anderson classification), although significant differences between the two groups show that fracture union occurred earlier in group A.
21. Healing period, that is almost twice in terms of length for open fractures type IIIA, if compared to type I and II, highlight the prognostic importance of application of Gustilo-Anderson classification, that is mostly used in this situation.
22. As far as open fractures are concerned, complexity of the fracture site cannot be used as an appropriate indicator of prognosis in the evolution of fracture consolidation; thus, Gustilo-Anderson classification is used in this situation.
23. Early union of fractures in group A, localised in the medium third(1/3)of the tibia, an area that is very well vascularized, supports its role in the pathophysiology of fracture healing and accelerates cell metabolism theory, by means of pulsed high frequency ultrasounds, used at the fracture site.
24. Adjunctive pulsed high frequency ultrasound therapy involves no contraindications, and did not determine any local, or general complications.
25. Final results holds a reference position in adjunctive therapy of open fractures, situations in which late complications, such as delayed union or pseudoarthrosis may frequently occur.



## CHAPTER VIII

### C-T SCANNING UTILITY IN FOLLOWING AND ASSESSMENT OF OPEN FRACTURES OF THE TIBIAL DIAPHYSIS

#### VIII.1 Introduction

Standard observation of the evolution of a fracture is based on local clinical features and radiological images in at least two views. The other imaging technologies, such as magnetic resonance imaging, computed tomography, bone scintigraphy are not considered a routine in exploration of the fracture site, because they prove to be useful especially in soft part tissues disorders (magnetic resonance), tumoral pathology (computed tomography and bone scintigraphy). CT and MRI examinations have proved to be especially useful in traumatology of the spine, pelvis and articular fractures of long bones. In the situations mentioned above, imaging technologies are used to establish a clear diagnosis, a realistic prognosis, and appropriate therapy planning. Seldom, CT examination is used in those situations in which radiological examination of the fracture cannot give sufficient data to achieve the utmost result, that is union.

#### VIII.2 Purpose of the Research

Perfectly aware of the slow process of evolution of diaphyseal open fractures of lower limb, the purpose of the present research is to evaluate the importance and the possible advantages of the observation of the fracture site healing process, by means of CT scanning. Obtained data are interpreted and compared to data gathered from observation of radiological examination of the fracture site.

#### VIII.3 Materials and Methods used During the Research

The present research has focused on cases of open fractures of the tibia between 2010-2012 in the Clinical Department Of Orthopaedics and Traumatology ,Emergency County Hospital of Sibiu. The study does not include all patients with tibia open fractures, because the research is based on a series of inclusion and exclusion criteria, in order to get a compact study group, with similar characteristics, as far as fracture and influential factors in a normal evolution are concerned.

Study inclusion criteria, the present research is based upon:

- open tibia shaft fractures;
- open tibia shaft fractures (type I,II,IIIA - Gustilo-Anderson classification);
- fractures treated with locked reamed intramedullary nail fixation;
- patients aged over 18, or emphasizing closure of a growth plate epiphysis;

Study exclusion criteria, the present research is based upon:

- Open tibia fracture type IIIB,IIIC(Gustilo-Anderson classification)
- Fracture location / extension in the epiphyseal part (5 cm proximal / distal) of the tibia;
- Bifocal fractures of the tibia;

- Fracture with bone defects needing bone grafting;
- Politraumas;
- presence of neuropathy, active malignancy or chronic metabolic diseases affecting bone formation.

Selection based upon the previously mentioned criteria, included a number of 6 patients.

Intervention was performed by a single orthopaedic surgeon, and the same osteosynthesis method was used: reamed locked intramedullary nailing.

Clinical, radiological, and CT examination was performed in the case of every patient 1,3,6, and 12 months after surgery.

Clinical evaluation of the fracture site focused on identifying elements that stand for evaluation of clinical union of the fracture site ,too:

- ✓ local pain;
- ✓ motion at the fracture site;
- ✓ possibility to walk , without aid(crutch /cane),and weight-bearing ability on the operated foot/ limb;

Radiological criteria that highlighted union at the fracture site was:

- ✓ presence of 3 cortical bridges (endosteal and periosteal aspects) in two views.

Fracture was considered to be healed, from a clinical-radiological aspect, when it met all clinical and radiological criteria mentioned above.

CT examinations provided images in axial plane (fig.no.9),and 2D reconstructions were performed in in coronal and sagittal planes. For the coronal reconstruction (fig.no. 10), the "slices" are located parallel to a tangent line to the rear edge of the tibial condyles. In the sagittal reconstruction, the "slices" are located perpendicular to a line tangent to the tibial plateau. Images collected show the entire fracture site and 2 extra cm below and above it.

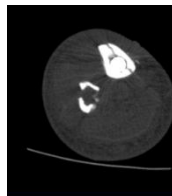


Fig. nr. 9 CT image in axial plane

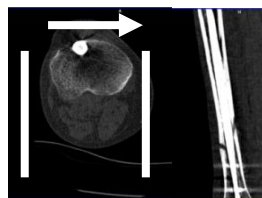


Fig. nr.10 CT reconstruction in sagittal plane

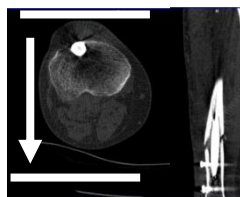


Fig. nr.11 CT reconstruction in coronal plane

Clinical, radiological, and computed-tomography data collected during every medical meeting, that was carefully planned in the case of every patient, were registered, by means of a fill in form.

### VIII.4 Results and Discussions

Average age of the study group was 45 years, the extreme ages were 19, and 65. According to Gustilo-Anderson classification, the research includes two open fractures for each type I, II and IIIA. Using radiographs performed in the moment of admission (anterior-posterior and profile view), another classification of the cases was realised, based on the complexity of the fracture site (AO classification). Thus, there were two type A, two type B and two type C fractures. Injury mechanism was a direct one (crush fracture), in 4 cases, and an indirect one, in two of the cases (falling from height - 1 case; fall from the same level - 1 case).

Fractures under study were located in the middle 1/3 (3 cases), and in the distal 1/3 (3 cases) of the tibial diaphysis, in association to fibula fracture, at different levels. In all cases, debridement, sterilisation, and primary suture of the wound was performed at the fracture site.

Average hospitalisation period was 16,5 days, with a minimum of 12 days, and a maximum of 34 days (a fracture complicated by skin necrosis). Hospitalisation period was double in the case of open fractures type IIIA (27 days), if compared to open fractures type I (15 days). Average time between hospitalisation period and definitive stabilisation of the fracture site was of 8 days, with a minimum of 4 days, and a maximum of 13 days. This situation doubled its sizes, as it was approximately 2,5 bigger (11 days) in the case of open fractures type IIIA, than in the case of open fractures type I (4,5 days).

One month after surgery (table no.5), most of the patients showed no signs of pain at the fracture site, 5 were able to walk without a cane, and 3 patients showed the presence of cortical bridges on the radiographs. An analysis of the CT images showed the presence of two cortical bridges in the case of 3 patients. None of the fractures met the clinical-radiological criteria, in this evolution stage.

Table no. 5 Evaluation of healing process at the fracture site one month after surgery

Pain		Yes	No		
	At rest	2	4		
	During mobilisation	1	5		
Motion at the fracture site		4	2		
Possibility to walk without cane/crutch		1	5		
Cortical bridges visible on the radiographs	0	1	2	3	4
	3	3	0	0	0
Cortical bridges visible on CT	0	1	2	3	4
	2	1	3	0	0

Three months after surgical intervention, all patients –subjects of the present research, met the clinical healing criteria at the fracture site, and two of them met the radiological healing criteria (table no. 6). The same situation stands at one months ,

after surgical intervention, when CT examination of the fracture site showed evidence of more cortical bridges than the ones showed on the radiographs. According to the CT examination, in the case of 3 patients at least 3 cortical bridges between the fractured bone fragments. To conclude, three months after surgical intervention, only two cases met the clinical-radiological healing criteria.

Table no.6 Evaluation of healing process at the fracture site three months after surgery

Pain		Yes	No		
	At rest	0	0		
	During mobilisation	0	0		
Motion at the fracture site		0	0		
Possibility to walk without cane/crutch		6	0		
Cortical bridges visible on the radiographs	0	1	2	3	4
	1	2	1	1	1
Cortical bridges visible on CT	0	1	2	3	4
	1	1	1	2	1

Six months after the surgical intervention, the clinical-radiological analysis showed that clinical healing criteria at the fracture site were met by all patients, and 5 of them met the radiological criteria. It is important to mention that both radiologically and at on CT examination the same number of cortical bridges between the fractured fragments were evident.(table no.7) In the case of the patient that did not meet the radiological consolidation criteria, a new diagnosis was established-delayed union.

Table no.7 Evaluation of healing process at the fracture site six months after surgery

Pain		Yes	No		
	At rest	0	0		
	During mobilisation	0	0		
Motion at the fracture site			0		
Possibility to walk without cane/crutch			0		
Cortical bridges visible on the radiographs	0	1	2	3	4
	1	2	1	1	1
Cortical bridges visible on CT	0	1	2	3	4
	1	1	1	2	1

Twelve months after surgical intervention, all patients met the clinical-radiological criteria of healing of the tibial fracture site. In addition, radiological and CT examination showed evidence of the same number of cortical bridges between the fractured tibial bone fragments (table no. 8)

Table no. 8 Evaluation of healing process at the fracture site twelve months after surgery

Pain	Yes		No		
	At rest	0	0	0	0
	During mobilisation	0	0	0	0
Motion at the fracture site	0		0		
Possibility to walk without cane/crutch	6		0		
Cortical bridges visible on the radiographs	0	1	2	3	4
	0	0	0	2	4
Cortical bridges visible on CT	0	1	2	3	4
	0	0	0	2	4

### VIII.5 Conclusions

1. Open fractures of diaphyseal tibia may be met in any category of age , but are specific to an active lifestyle.
2. Lesion complexity and of the fracture site is closely connected with the kinetic energy developed by the traumatic agent that causes the fracture.
3. Localisation of open fracture at the middle and distal third of the tibia may be easily explained by the architectural structure, and the anatomical features of the lower limb area, where tibia is superficially located at the skin surface, and receives less protection, due to the soft tissue from this level.
4. Treatment of open fractures of lower limb, is a process that involves several stages, and follows a well-defined therapeutic algorithm, as far as soft part tissues and osteosynthesis of the fracture site is concerned.
5. Long average hospitalisation period is due to the fact that definitive osteosynthesis of the fracture site was initiated after remission or improvement of local post traumatic disorders. Thus, hospitalisation costs, in the case of open fractures, are above the average.
6. Clinical healing criteria of the fracture site are met earlier than radiological criteria, due to the strong osteosynthesis performed at the lower limb level.
7. Conservative therapeutic approach is an useful option in delayed union situations, that met all clinical criteria.
8. CT examination frequently showed less cortical bridges between the fractured bone fragments, in the very first months after surgical intervention, but later on, the radiological and CT results were identical. Thus, a conclusion can be drawn in the case of CT examination, that is a valuable „tool”,with a predictive value in the evolution of the fracture site, or in borderline cases of consolidation of the fracture site.
9. Results of the present research in conjunction with high costs and high irradiation, highlight the fact that CT examination is an inappropriate investigation in the routine observation of the evolution of healing of the fracture site in cases of open fractures of lower limbs.

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# MODERN THEORIES OF STIMULATING CONSOLIDATION OF DIAPHYSEAL FRACTURES OF THE LOWER LIMB

SUMMARY OF THE PhD THESIS

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