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# COMPARATIVE STUDY UPON FRACTURE RESISTANCE AT FEMORAL AND TIBIA BONES, FOR DIFFERENT AGE PERSONS

**Valentin Zichil**
**University of Bacau**
**Calea Marasesti 157, 600115 - Bacau**
**Romania**

**Carmen Savin**
**University of Bacau**
**Calea Marasesti 157, 600115 - Bacau**
**Romania**

**Aurelian Albut**
**University of Bacau**
**Calea Marasesti 157, 600115 - Bacau**
**Romania**

**Adrian Judele**
**University of Bacau**
**Calea Marasesti 157, 600115 - Bacau**
**Romania**

## ABSTRACT
*The paper presents the results achieved after tests on tibia and femoral bones, obtained from corps, upon fracture resistance at different age persons, from different social levels, using two different modern methods. For an exactly value of strain, experimentally obtained, it was used extensometers placed upon the skin. Using the Finite Element Method, it was possible to take a larger view of the stress and strain state before the bones was broken, in addition to the development of the fracture.*
**Keywords:** finite element method, stress and strain, strain gauge, fracture, tibia and femoral bones

## 1. INTRODUCTION
The goal of the tests was to compare the mechanical proprieties of the bones between female and male, between dead bodies of a 25 years old and 60 – 70 years old dead people. It has to be said that the corpses used for tests belongs to some very poor dead people, that's why the mineral concentration in bones was very low. In some other studies, it was possible to achieve the density of the bones, based on computing tomography [1].

In bipedal position, the anatomical axis of the shank is coincident to the biomechanical axis of the lower member. Thus, the tibia is loaded in compression. When the lower limb is in flexion, with the toes fixed on the ground (during walking, running, jumping, etc.), both the weight of the body G and the equilibrium force of the deltoid and biceps muscles $F_m$ act upon the tibia in a frontal plane, while the weight G and the motor force of the extensor muscles, act in a sagital plane. Thus, a composed loading of bending and compression appears. The maximum stresses appear in the cross sections between the medium and distal third, this phenomenon being confirmed by the high frequency of the fractures in this area [2].

The values of the bones density are 0.31±0.03 kg/cm3 (p=0.01) for the extreme limits of the bones and 0.175±0.01 kg/cm3 (p=0.03) for the middle section. As it can be observed, the density at the end of the bones is much smaller as in the middle section. The difference is about 16.67%, the smaller value match the limits of the bones.

## 2. PHYSIOPATHOLOGY OF THE SHANK
Shank fractures are often produced by the action of external factors during accidents. Tibial fractures may be open (when the fractured bone goes outside through the skin) or closed. The line of the

fracture is determined by the intensity of the aggressive factors involved in the fracture mechanisms: it can be spiral (for lower energy fractures) or slanting and comminutive (for high energy fractures).

In the treatment of the diaphysis shank fractures, one uses both conservative methods and surgical osteosynthesis techniques as: Kuntscher technique, Ender technique using elastic nails, external fasteners, plate and screws fastening technique, etc. Each of these methods and techniques has advantages and disadvantages. One cannot apply a universal technique, valid for all types of fractures.

It is well known that the local stress values due to compression loading at the level of the inter-cellular substance are an important stimulus in the recovery of the bone-forming cells. Thus, when choosing the treatment technique for a certain type of fracture one should start from a good knowledge of the biomechanical behaviour of the fractured bone and take into account that the chosen osteosynthesis system ensure the most favourable level of the compressive stresses in the focus of the fracture.

The case studies revealed in the scientific literature show that the Kuntscher intra-medullar nail techniques are more efficient in the treatment of the tibial fractures, compared with other methods. This is because these techniques diminish the healing time of the patient and ensure an adequate level of the compressive stresses in the focus of the fracture.

## 3. MODEL AND TESTS

Using the fundamental theorems of the dynamics, into the study of the movement lows of the human limb, may be difficult due to the differential equations which contains the muscular forces. Those forces are variable in time and may be only approximated after some simplifying hypothesis [1] with a direct influence upon the torque developed in the bones joint. More than that, modeling the shape of the constituent of the limb inserts errors even if we use primitives or a modeling a part of the elementary shape. Between those two possibilities, the last was preferred.
The mechanical tests was made on a universal machine for mechanical testing, assisted by a computer in order to achieve the signals from the acquisition device, using a load rate of 0.001 s-1, as in a classical static loading. The breaking forces and the sectional areas was calculated in order to achieve the breaking stress in bones.

The distribution of these stresses in different sections changes along the bone [2]. In the case of femoral diaphysis, the load transmitted through the femoral head is applied eccentrically and produces traction or compression stresses in different cross-sections. At the proximal part, the traction stresses is situated in the outer part of the section, while the compression stresses are on the inner side. At the distal part, the traction stresses develop at the inner part of cross-section and the compression ones – at the exterior. Thus, along the femoral shaft, the neutral axis follows a helicoidal line, dividing the cross-sections in unequal zones loaded in traction or compression. The biomechanical comparative study undertaken by FEM was done for the bone-implant ensemble, in the case of a femur whit a closed diaphysis fracture.

The simulations were performed for the case of one leg standing (monopodal) position. The femur was considered free at the upper part and constrained in the condyl zone. A load P = 500 N was applied in the centre of the femoral head, inclined at an angle of 16º with respect to a vertical line. The bone tissue was considered isotropic, having a Young's modulus E = 1,65·104 MPa, and a Poisson's ratio ν = 0,24. For the implants (manufactured from steel), the following values were adopted: E = 2,1·105 MPa and ν = 0,3.

The Kuntscher nail was introduced on the medullar canal of the two bone fragments resulted from the fracture and was fixed in the upper part on the tibial plateau and in the lower part on the malleolar zone. The presence of the primary callus in the focus of the fracture was simulated in the case of fractured tibia, by placing a thin layer of soft rubber in this area. The tibia was loaded in compression with different loads progressively applied (P1 = 181N, P2 = 2P1, P3 = 3P1), through a loading device with levers and weights. The loads were applied on the ends of the tibia through some wood parts processed as to model the shape of the bone in the two tibial-fibular joints (upper and lower). The cartilaginous tissue of these joints was simulated using a thin layer of rubber.

The stresses were determined along the tibial diaphysis, both in frontal and sagital planes for the normal and fractured bone, for the third loading case (P3 = 543 N). This case corresponds to the load acting on a tibia when running, in the sequence when the leg is fixed on the ground.

## 4. EXPERIMENTAL DEVICE

The major difficulty in attaching an extensometer upon a part of the human limb is to fix the device as well as to keep in contact the parts of the extensometer with the skin during the compression, traction and binding tests. That is the reason that the author had developed an mechanical device made for traction. The device is based on metallic detachable rings, that may be fixed with three thread plugs through some thread holes, through the skin. Using the device, it is possible to measure with high accuracy the distance where the two parts of the inductive extensometer will be placed.

For the compression and traction tests, a device using only three rings fixed one on the upper part and the others two at the lower part of the middle cross section, has proven to be enough (Figure 1), while for the binding test, there was necessary a device built on the same idea, using four fixing rings (Figure 2).

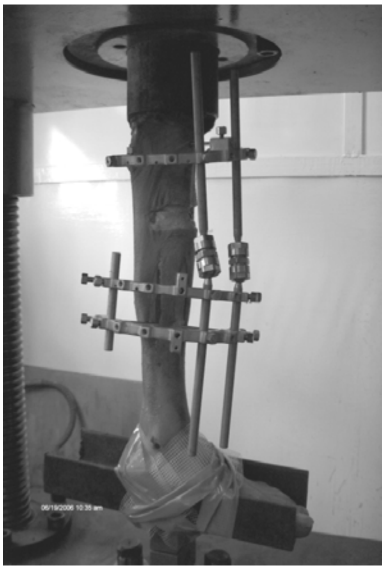

*Figure 1.*

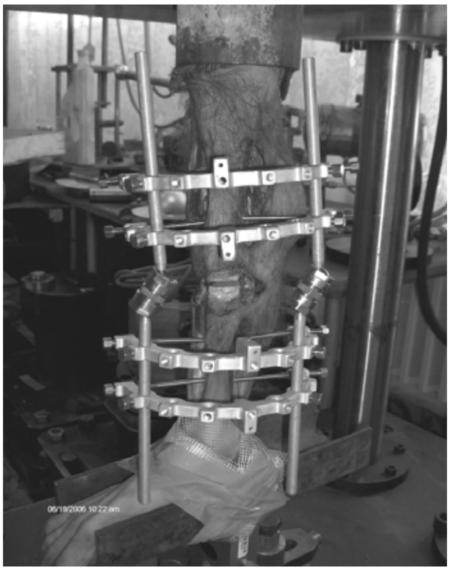

*Figure 2.*

## 5. RESULTS

As it is known, the osteosynthesis techniques used in fracture treatment must provide stability to the bone fragments from the fracture focus, as much as possible. That is why the implants must constrain the relative displacements of the bone fragments, avoiding thus the appearance of pseudoarthroses. In the same time, the implants must provide a certain level of compression stresses in the fracture focus, suitable for forming the primary callus. Therefore, in order to compare the biomechanical performances of the studied osteosynthesis systems, the stresses and displacements in the focus of the fracture were firstly analysed. For this, the fields of equivalent von Mises stresses and resultant displacements were obtained by processing the results. These results, according to the force - displacement diagram, correspond to each of the considered assemblages.

Due to the Finite Element Method (F.E.M.) it was possible to obtain a larger view of the stress and strain state into the tibia bone. For the beginning, the model and the results achieved using F.E.M. had to be verified and validated. A comparison was made at the half height of the tibia bone in a cross section. The results are shown in Tables1 and 2.

*Table 1.*

| **Bone** | **Test** | **Age: between 35 – 50 years old** | | | |
|---|---|---|---|---|---|
| | | ***Normal nourished*** | | ***Low vitamin nourished*** | |
| | | Male | Female | Male | Female |
| | | $\sigma_R$ [MPa] | $\sigma_R$ [MPa] | $\sigma_R$ [MPa] | $\sigma_R$ [MPa] |
| **Femur** | ***Compresion*** | 1.25562 | 1.075675 | 0.878934 | 0.806756 |
| | ***Traction*** | 3.61386 | 3.39116 | 2.529702 | 2.54337 |
| | ***Binding*** | 3.29732 | 3.37059 | 2.308124 | 2.527943 |
| **Tibia** | ***Compresion*** | 0.469965 | 0.50116 | 0.328976 | 0.37587 |
| | ***Traction*** | 1.011245 | 1.102195 | 0.707872 | 0.826646 |
| | ***Binding*** | 3.40102 | 3.450065 | 2.380714 | 2.587549 |

*Table 2.*

| **Bone** | **Test** | **Age: over 50 years old** | | | |
|---|---|---|---|---|---|
| | | ***Normal nourished*** | | ***Low vitamin nourished*** | |
| | | Male | Female | Male | Female |
| | | $\sigma_R$ [MPa] | $\sigma_R$ [MPa] | $\sigma_R$ [MPa] | $\sigma_R$ [MPa] |
| **Femur** | ***Compresion*** | 0.62781 | 0.57633 | 0.591621 | 0.650783 |
| | ***Traction*** | 1.80693 | 1.658762 | 1.865138 | 2.051652 |
| | ***Binding*** | 1.64866 | 1.51347 | 1.853825 | 2.039207 |
| **Tibia** | ***Compresion*** | 0.234983 | 0.215714 | 0.275638 | 0.303202 |
| | ***Traction*** | 0.505623 | 0.464161 | 0.606207 | 0.666828 |
| | ***Binding*** | 1.70051 | 1.561068 | 1.897536 | 2.087289 |

## 6. CONCLUSIONS

The results of finite element simulations for the four types of osteosynthesis put in evidence superiority of the elastic osteosynthesis. These assemblages take a part of the loads transmitted from the femoral head, providing an optimum level of compression stresses in the fracture focus. During walking, when the leg is up, the load vanishes, the deformed nail revolves at its initial undeformed position, pushing through their ends in the bone tissue where they are fixed. In this way, the collagen fibres which form in the fracture focus are subjected to traction. So, one can say that during walking, the collagen fibres formed in the fracture focus are subjected to cycles of variable loading of compression-traction which provide the necessary environment to stimulate the process of bone regeneration.

These cycles of traction-compression act on the osteogenic cells, producing in the bone structure, by piezoelectric effect, bio-currents, that change periodically their polarity. Under the action of these currents, the mineral salts deposit on the collagen fibres along the principal directions of stresses.
The biomechanical stimulating effect produced by the elastic osteosynthesis techniques is determined by the correct embedding of nails and, in the same time, by the capacity of the tissue to take the local stresses developed in the contact zones.

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