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COMPARATIVE STUDY UPON STRESS AND STRAIN IN FEMORAL AND TIBIA BONES, FOR DIFFERENT AGE PERSONS, USING EXTENSOMETERS AND F.E.M.

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ABSTRACT
The paper presents the achievement of the stress and strain intensity in femoral and tibia bones, for different age persons, using two different modern methods. For an exactly value of strain, experimentally obtained, the author has developed an original structure having the main goal to fix the extensometer on the foot skin. It is well known that the human skin does not permit the attachment of a usual inductive extensometer upon it, due to the sliding surface. Using the Finite Element Method, it was possible to take a larger view of the stress and strain state into those two bones, not only in a particular section, as it was made using the extensometer.
Keywords: finite element method, stress and strain, strain gauge,tibia and femoral bones

1. INTRODUCTION
To perform this tests, in order to obtain the values of strain in femoral and tibia bones, loaded by traction and bending, using the experimental devices, it was compulsory to prepare the human limbs. The tests was developed upon the limbs of mature bodies, drawer from male and female corpses. 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]. 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. In order to obtain the maximal stress when the human body is walking, running, jumping and so on, the model in bipedal position, is calculated with one limb on the floor [2]. In bipedal position, the anatomical axis of the shank is coincident to the biomechanical axis of the lower member [2].

2. 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 (Figure 1), 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.

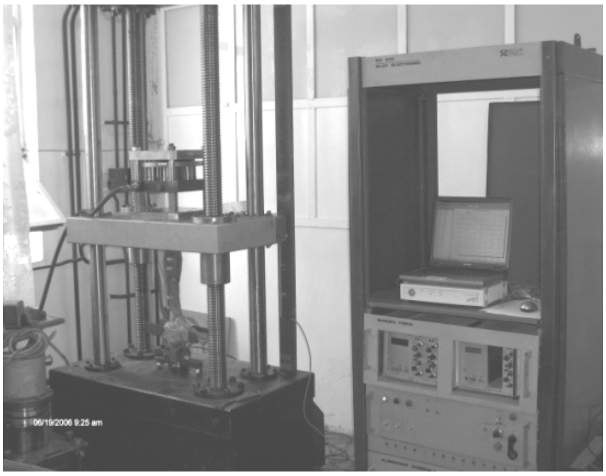

Figure 1. Universal testing machine

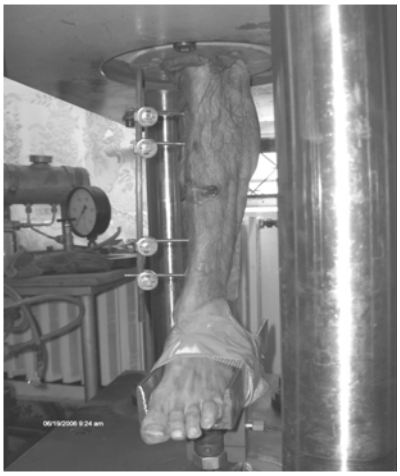

Figure 2.

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 (Figure 2). 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, while for the binding test, there was necessary a device built on the same idea, using four fixing rings.

3. 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. 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 Tables 1 … 5.

Table 1.

Bone	**Test**	**Age: between 25 – 35 years old**			
		Normal nourished			
		Male		Female	
		σ_R [MPa] (ex)	σ_R [MPa](F.E.M.)	σ_R [MPa](ex)	σ_R [MPa] (F.E.M.)
Femur	***Compresion***	1.6005	1.6806	1.587	1.6155
	Traction	4.4168	4.3995	4.4286	4.3407
	Binding	4.0218	4.1003	4.0328	4.1134
Tibia	***Compresion***	0.6506	0.6592	0.6458	0.6554
	Traction	1.4872	1.4501	1.4722	1.4437
	Binding	4.2616	4.2561	4.2732	4.3159

Table 2.

Bone	Test	Age: between 25 – 35 years old			
		Low vitamin nourished			
		Male		Female	
		σ_R [MPa] (experim)	σ_R [MPa] (F.E.M.)	σ_R [MPa] (experim)	σ_R [MPa] (F.E.M.)
Femur	***Compresion***	1.4772	1.508221	1.2655	1.275244
	Traction	4.2516	4.340884	3.9896	4.02032
	Binding	3.8792	3.960663	3.9654	3.995934
Tibia	***Compresion***	0.5529	0.564511	0.5896	0.59414
	Traction	1.1897	1.214684	1.2967	1.306685
	Binding	4.0012	4.085225	4.0589	4.090154

Table 3.

Bone	Test	Age: between 35 – 50 years old			
		Normal nourished			
		Male		Female	
		σ_R [MPa] (experim)	σ_R [MPa] (F.E.M.)	σ_R [MPa] (experim)	σ_R [MPa] (F.E.M.)
Femur	***Compresion***	1.25562	1.233396	1.075675	1.056636
	Traction	3.61386	3.549895	3.39116	3.331136
	Binding	3.29732	3.238957	3.37059	3.310931
Tibia	***Compresion***	0.469965	0.461647	0.50116	0.492289
	Traction	1.011245	0.993346	1.102195	1.082686
	Binding	3.40102	3.340822	3.450065	3.388999

Table 4.

Bone	Test	Age: between 35 –50 years old			
		Low vitamin nourished			
		Male		Female	
		σ_R [MPa] (experim)	σ_R [MPa] (F.E.M.)	σ_R [MPa] (experim)	σ_R [MPa] (F.E.M.)
Femur	***Compresion***	0.878934	0.863377	0.806756	0.804901
	Traction	2.529702	2.484926	2.54337	2.53752
	Binding	2.308124	2.26727	2.527943	2.522128
Tibia	***Compresion***	0.328976	0.323153	0.37587	0.375005
	Traction	0.707872	0.695342	0.826646	0.824745
	Binding	2.380714	2.338575	2.587549	2.581597

Table 5.

Bone	**Test**	**Age: over 50 years old**			
		Low vitamin nourished			
		Male		Female	
		σ_R [MPa] (experim)	σ_R [MPa] (F.E.M.)	σ_R [MPa] (experim)	σ_R [MPa] (F.E.M.)
Femur	***Compresion***	0.591621	0.590261	0.650783	0.649287
	Traction	1.865138	1.860848	2.051652	2.046933
	Binding	1.853825	1.849561	2.039207	2.034517
Tibia	***Compresion***	0.275638	0.275004	0.303202	0.302504
	Traction	0.606207	0.604813	0.666828	0.665294
	Binding	1.897536	1.893171	2.087289	2.082489

4. CONCLUSIONS

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.

The results of this study show that the use of elastic osteosynthesis in the femoral fracture treatment provides an optimization of the mechanical factors effect in the process of structural regeneration of the bone tissue. In this way, the process of forming of primary callus is accelerated and the healing time of patients is shortened.

5. REFERENCES

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