The finite element analysis of pelvic assembly resulted from a pedestrian’s traffic accident. The analysis of the iliac bone

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Abstract. The purpose of this study is to make a series of finite element analyses of the iliac bone of a pedestrian involved in a car crash. The analyses are of a static type. The conditions for the analyses were chosen as to reflect the reality of the situation. The forces which acted on the iliac bone have been experimentally determined. In this study, the authors want to highlight the benefit of the finite element analysis in the road accidentology field.

1. Introduction
The finite element analysis is an investigation method which is very often used in a lot of areas. Thus, we can discuss about the finite element analysis in medical area such as orthopedic area, biomedical area, stomatology area et cetera [4]. Using the ANSYS program we made some finite element analysis of the iliac bone. The focus of these analyses is represented by the comparison between the normal iliac bone and the iliac bone with osteoporosis indicating the fracture risk areas. In this way we can observe the areas where the iliac bone may be fractured as a result of a car accident.

The osteoporosis is a disease that causes the bones to become weaker and easily broken. This medical condition influences the density and quality of the human bones. As a cause of this disease the essential minerals for human body, like calcium, are not properly assimilated by the bones [2], [5], [6]. This facts leads to a decreased bone density and increased bone porosity and after that to a low resistance to fractures of the bones.

The main factors which are influencing the bone density:
- gender – men have higher bone density than women;
- race-black people have higher bone density than the rest of the people;
- genetic factors – the bone density is lower in the case of the girls if their mother suffers from osteoporosis;
- puberty time – men with delayed puberty condition and women with delayed menarche have a higher risk for developing osteoporosis;
- intake of calcium – the moderate increase in calcium during the prepubescent period amplifies the bone growth [1].

2. The theoretical basis of the study
In this study we made a series of finite element analyses of the iliac bone in different states. The analyses we made are of a static type and their purpose was to indicate the areas where the breaking of the bone may occur. The mechanical properties of the iliac bone which are shown in figure 1 we got
from the literature [6]. We must mention the fact the all the bone structure is considered to be a homogeneous one, for both types of bones [8].

![Diagram showing Young's Modulus, Poisson Ratio, Mass Density, and Breaking Limit for Osteoporotic and Normal bones.](image)

**Figure 1.** The mechanical properties of iliac bone

In order to get the value of the force that acts on the iliac bone, we took into consideration the following assumption: a man of 1.7 [m] height and 85 [Kg] weight. The iliac bone is a part of pelvic region which is located at a height of about 1 [m] above the ground level [3]. The weight that acts on the whole pelvic region is represented by the weight of the body form the middle upwards, that of the upper limbs, neck and head. For this simulation we considered a weight of 70 [Kg].

\[ F = m \cdot g \] (1)

With the help of relation 1 it was possible to measure the value of the force used for acting on the iliac bone. Knowing the position of the sacral bone from the ground when the person becomes unbalanced and falls on the back, the value of the force which acted on the iliac bone is multiplied by these coefficients: \( C_1=3, C_2=4, C_3=5 \). In this way we obtained the value of the three forces used for acting on the both types of the iliac bone.

\[ F_1 = m \cdot g \cdot C_1 = 70 \cdot 10 \cdot 3 = 2100 \text{ [N]} \] (2)
\[ F_2 = m \cdot g \cdot C_2 = 70 \cdot 10 \cdot 4 = 2800 \text{ [N]} \] (3)
\[ F_3 = m \cdot g \cdot C_3 = 70 \cdot 10 \cdot 5 = 3500 \text{ [N]} \] (4)

In order to make the finite element analysis we used a 3D scanned image of a iliac bone [7]. In figure 2 are presented the initial conditions imposed for the analysis. Colored in purple is the area where the iliac bone is fixed to the sacral bone. Also in the figure 2 we observe the area the F force is going to act. Actually, this represents the first area which hits the ground when a person falls on the back. In order to get accurate results, the iliac bone was divided into a number of 27,116 elements, represented by the help of 49,282 nodes.
3. The finite element analysis. Results and interpretations
In the figure 3 it is presented the comparison between structures of normal iliac bone and osteoporotic iliac bone when we use a force of $F_1=2100 \ [N]$. We notice that in both situations the specific breaking limit for each type of bone was reached and even exceeded. The areas marked with red circles highlight the zones where the breaking limit was exceeded. For the normal iliac bone we can see the risk areas presented in figure 3(a), while the figure 3(b) show us the risk areas for the osteoporotic iliac bone. When we compare these two pictures (figure 3(a) and figure 3(b)) we can observe that the risk areas for the osteoporotic iliac bone are more and wider.

![Figure 2. The initial conditions for the analysis](image)

![Figure 3. The stress distribution in iliac bone structure for $F_1=2100 \ [N]$](image)

(a) normal iliac bone; (b) osteoporotic iliac bone
We can observe in figure 4 that the risk areas became wider when the force we had acted with on both types of sacral bones was increased from $F_1=2100 \text{ [N]}$ to $F_2=2800 \text{ [N]}$. As before, the osteoporotic iliac bone was more affected than the normal one. In this case the osteoporotic iliac bone was more affected.

When we acted on the iliac bone with the force $F_3=3500 \text{ [N]}$ we got the results from figure 5. The risk areas are wider in comparison with the first case when we had acted with force $F_1=2100 \text{ [N]}$. We notice the osteoporotic iliac bone is affected almost entirely in the lower part.

**Figure 4.** The stress distribution in iliac bone structure for $F_2=2800 \text{ [N]}$
(a) normal iliac bone; (b) osteoporotic iliac bone

**Figure 5.** The stress distribution in iliac bone structure for $F_3=3500 \text{ [N]}$
(a) normal iliac bone; (b) osteoporotic iliac bone

In finite element analysis for each type of iliac bone we used force for $1 \text{ [s]}$. From the ANSYS program we took the maximum and minimum values for equivalent stress distribution. We introduced
these values in EXCEL program and we got the next graphs which are depicted with the help of figures 6,7,8 and 9.

![Graph showing maximum stress variation for normal iliac bone](image1)

**Figure 6.** Maximum stress variation for normal iliac bone

The figure 6 shows how the maximum values of equivalent stress can vary in time in the entire structure of the iliac bone. This graph contains the variation of equivalent stress for all three force values used in the finite element analysis.

![Graph showing minimum stress variation for normal iliac bone](image2)

**Figure 7.** Minimum stress variation for normal iliac bone

The figure 7 shows how the minimum values of equivalent stress can vary in time in the entire structure of the iliac bone. Also, and this graph contains the variation of equivalent stress for all three force values used in the finite element analysis.

The figures 8 and 9 are related with the minimum and maximum variation of equivalent stress for the osteoporotic iliac bone. In these two graphics we can observe how the equivalent stress vary in time in the entire osteoporotic bone structure.
4. Conclusions
Using the finite element analysis, we compared the behavior of the normal iliac bone and the behavior of the osteoporotic iliac bone when the force is variable in its value. Also, with the finite element analysis we highlighted the fact that the area of fracture risk propagation for the osteoporotic iliac bone is higher than for the normal iliac bone. In all three cases the breaking limit of the bone was exceeded. This thing can be observed by helped of value scale from the pictures of the analysis.

5. References
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