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

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Abstract. The purpose of this study is to make a series of finite element analysis of the sacral bone of 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. The forces which acted on the sacral 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 a method which is 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 analyses of the sacral bone. The focus of these analyses is represented by the comparison between the normal sacral bone and sacral bone with osteoporosis indicating the fracture risk areas. In this way we can observe the areas where the sacral 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 fact 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 influence the bone density are:
- 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 the mother is suffers from osteoporosis;
- Puberty time- men with delayed puberty condition and the 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 analysis for sacral bone in different states. The analysis we made are of static type and their purpose was to indicate the areas where the breaking of bone may occur. The mechanical properties which are shown in figure 1 are getting from the literature.
We must mention the fact that all the bone structure is considered to be a homogenous one, for both types of bone [8].

![Diagram](image1)

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

In order to get the value of the force that acts on the sacral bone, we took into consideration the following assumption: a man of 1.7 [m] height and 85 [Kg] weight. The sacral bone is a part of pelvic region which is located at a height of about 1 [m] above the ground level. 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 sacral 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 sacral 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 sacral bones.

\[ F_1 = m \cdot g \cdot C_1 = 70 \cdot 10 \cdot 3 = 2100 \text{ [N]} \]  

(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 sacral bone. In figure 2 are presented the initial conditions imposed for the analysis. Colored in purple is the area where the sacral bone is fixed to the spine. Also in the figure 2 we observe the area where 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 sacral bone was divided into a number of 52,564 elements, represented by the help of 28,346 nodes.
3. **The finite element analysis. Results and interpretations**

In the figure 3 it is presented the comparison between structure of normal sacral bone and osteoporotic sacral bone when we used 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 sacral bone we can see the risk areas presented in figure 3(a) while figure 3(b) shows us the risk areas for the osteoporotic sacral bone. When we compare these two pictures, figure 3(a) and figure 3(b), we can observe the risk areas for both types of bones are localized near the coccyx bone.

From the analysis of the scale of equivalent stresses representative for the osteoporotic sacral bone we observe that the breaking limit initially assigned for the osteoporotic bone is reached starting with the light green color. Thus we can conclude that approximately the entire structure of the osteoporotic sacral bone is more affected than in the case of healthy bone.

![Figure 3](image.jpg)

**Figure 3.** The stress distribution in sacral bone structure for $F_1=2100$ [N]

(a) normal sacral bone; (b) osteoporotic sacral 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 $F_1=2100 \ [N]$ to $F_2=2800 \ [N]$. As before, the osteoporotic sacral bone was more affected than the normal one. In the case of osteoporotic sacral bone almost all the bone structure was affected.

![Figure 4](image1.png)

**Figure 4.** The stress distribution in sacral bone structure for $F_1=2800 \ [N]$
(a) normal sacral bone; (b) osteoporotic sacral bone

When we acted on the sacral bone with the force $F_3=3500 \ [N]$ we got the results from figure 5. In this case we can see that the whole bone structure was compromised for the both types of bones.

![Figure 5](image2.png)

**Figure 5.** The stress distribution in sacral bone structure for $F_1=3500 \ [N]$
(a) normal sacral bone; (b) osteoporotic sacral bone

In the finite element analysis of each type of sacral bone we used force for 0.5 [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.

With the help of figure 6 we can observe how the maximum values of equivalent stress can vary in time in the entire structure of the normal sacral bone. In this graph we have the equivalent stress variation for all three force values used in the finite element analysis.

In figure 7 is depicted how the minimum values of equivalent stress can vary in time in the entire structure of the normal sacral bone.
Figure 6. Maximum stress variation for normal sacral bone

Figure 7. Minimum stress variation for normal sacral bone

Figure 8. Maximum stress variation for osteoporotic sacral bone
Figure 9. Minimum stress variation for osteoporotic sacral bone

The figures 8 and 9 are related with the minimum and maximum variation of equivalent stress for the osteoporotic sacral 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 sacral bone and the behavior of the osteoporotic sacral 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 sacral bone is much wider than for the normal sacral bone. In all three cases the breaking limit of the bone was exceeded. This thing can be observed helped by the value scale from the pictures of the analysis.

5. References

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