The Study of Massive Trochanterion Fractures

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Abstract— **This paper studies the massive trochanterion fractures using two methods of fixation, namely DHS (Dynamic Hip Screw) and Gamma rod. The analysis is carried out both experimentally (photoelasticimetry and tests on human femur) and numerically (finite element method).**

Keywords— **femoral bone, massive trochanterion, fracture, photoelasticimetry, finite element.**

I. Introduction

The massive trochanterion fractures are among the most common fractures seen in elderly subjects and can be generated even after minor trauma [1]. This type of fracture requires an emergency surgery, minimally aggressive to speed up mobilization and reduce the subjects immobilization period in the supine position so that the recovery can be initiated early.

Kyle's classification of the trochanteric fractures divides them in four categories (Figure 1) [4]: 1 – stable intertrochanterion fractures without displacement and tearing; 2 – stable intertrochanterion fracture with displacement and minimum tearing; 3 – unstable intertrochanterion fracture with displacement and posterior-medial breakage; 4 – unstable intertrochanterion fracture with posterior displacement, posterior-medial breakage and undertrochnaterion component.

The stability is provided by the bone tissue or by the particular soft parts. This study examines the biomechanics of the osteosynthesis using two methods (Figure 2):

1. DHS (Dynamic Hip Screw) – in which case the force arm unloads the body's weight on a larger length, positioned between the femoral head and the plate fixed to the external cortex;
2. Gamma rod – in which case the rod is inserted in the centre of the shaft, without opening the focus area of the fracture.

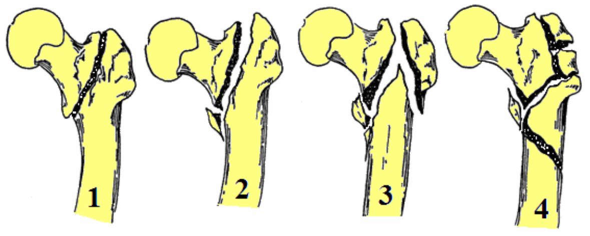

Fig. 1 Trochanterion fractures – Kyle's classification [4]

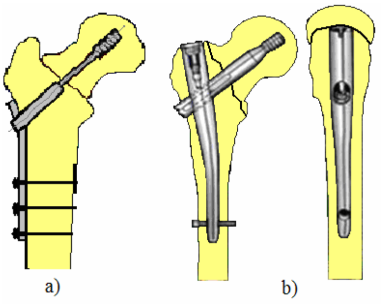

Fig. 2 a) The fixation of the massive trochanterion – DHS method; b) The fixation of the massive trochanterion – Gamma rod [4]

II. Experimental analysis

The study is carried out on two femoral bones that represent the massive trochanterion fracture. For osteosynthesis are used a DHS system (Figure 3) and the Gamma rod (Figure 4).

The experimental setup is composed of the following elements: 1 –U2B10kN (HBM) force transducer that establish the value of the load; 2 –WA20mm (HBM) displacement transducer that show the movement of the femoral head on the vertical direction; 3 - Catman Easy (HBM) data acquisition interface; 4 – Spider8 (HBM) data acquisition system.

When using the DHS system the femur is loaded with the maximum mass of 134.6 kg, the recorded displacement of the femoral head being 14.48 mm. The higher values of the loaded weight produce pronounced crushing and the contact areas cannot support the load.

When using the Gamma rod the maximum weight that loads the femoral bone is 161 kg and the displacement recorded in the vertical plane is 7.61 mm. In this case as well, the crushing problem in the contact area becomes extremely important.

To highlight the state of stresses in the contact area between the metal elements and the bone matter we appeal on an optical investigation method, namely the photoelasticimetry. Based on experimental optical principles and mathematical theory of elasticity, photoelasticity was noted from the very beginning to be a simple experimental technique with broad possibilities of application in the state of stresses and strain analysis. Unlike other tensometers methods (mechanical, optical or strain gauges method) which

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provide information in discrete points, photoelasticimetry provides a complete full field of stresses, thereby enabling the determination of stresses (in magnitude and direction) at any point on the tested model [2], [3].

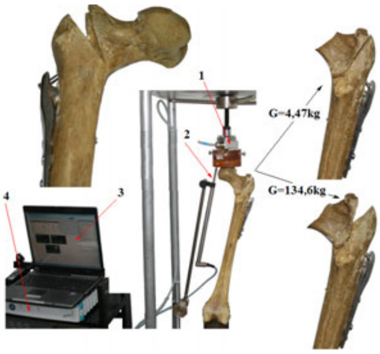


Fig. 3 Experimental setup for testing the model with the DHS system

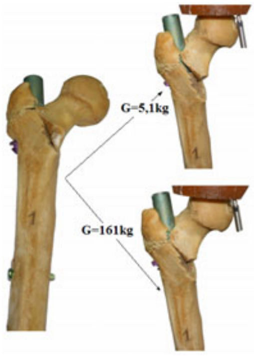


Fig. 4 The loading and straining manner using Gamma rod

Thus, in Figure 5 is shown the three dimensional model obtained by casting epoxy resin, in which a DHS system is introduced.

In terms of quality, analysing the distribution of the isocromates (Figure 5b and 5c), the maximum load areas are in the points O_1 and O_2 as well as O_3 and O_4.

In Figure 6 is presented the three dimensional model made from epoxy resin in which a Gamma rod is inserted.

Qualitatively speaking, analysing the distribution of the isocromates (figure 6b and 6c), we can see that the maximum loaded areas are in the points O_5, O_6 and O_7, O_8.

The results lead to important qualitative indications on the most loaded areas, representing the basis for a numerical analysis (finite element method) or giving information that deserves to be taken into account in choosing the optimum process in regard to the fixation of fractures of the massive trochanterion.

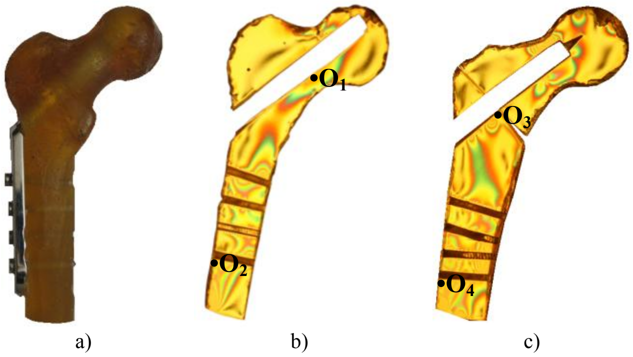


Fig. 5 Model obtained from epoxy resin – DHS system: a) model before loading; b) plane section through model without fracture; c) plane section through the model with fracture

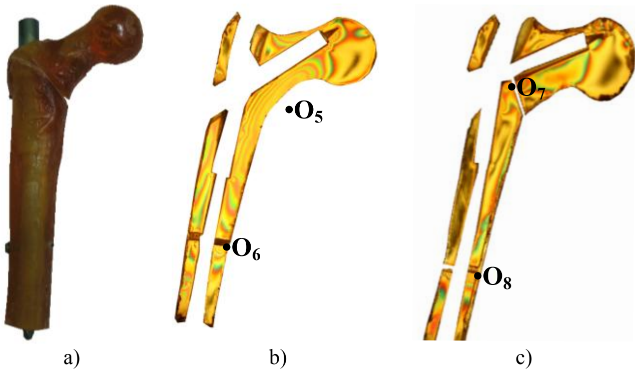


Fig. 6 Model obtained from epoxy resin – Gamma system: a) model before loading; b) plane section through model without fracture; c) plane section through the model with fracture

III. NUMERICAL ANALYSIS

For numerical modelling using finite element method the specific features of the osteoarticular system's biomechanics should be considered. Finite element calls as input the actual numerical values of the elastic constants and of the loads. Great difficulties arise from trying to determine them.

The bone is highly anisotropic and inhomogeneous and it is desirable that the idealized structure to be developed as such. If in which regards the development of the structure no unsolved problems remain, the most difficult problems come from determining the variable elastic characteristics of the bone tissue [1].

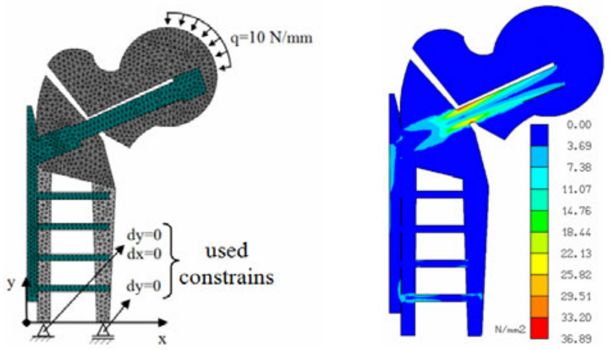
Difficulties also result in determining the values of the loads and their points of application. In general, the forces are transmitted to a bone through the joint surfaces, which are three dimensional, with a rather complicated geometric configuration. In these circumstances, the consideration of concentrated loads is a rough shaping of the reality, and the consideration of a distribute load requires knowledge of its distribution law.

The method has proved effective in objectively and effectively analysing complex structures, such as those of osteoarticular system.

In this case a plane model is provided that corresponds with the two cases studied. The mechanical characteristics of the epoxy resin suitable to the experimental model are taken into account.

Figure 7a shows the meshing design of the experimental model for the first studied case using triangular finite elements. The material used for the numerical simulation is epoxy resin. The loading is performed with a uniformly distributed load (q = 10 N/mm). Also, in figure 7a are defined the used constrains. Contact elements are not defined in this application. Instead, the material characteristics for the fracture's fixation system of the model are (epoxy resin and steel).

The Tresca equivalent stresses distribution that are calculated based on the maximum tangential stresses distribution and the third resistance theory are shown in Figure 7b.



a) b)

Fig. 7 a) Meshing design for the DHS model
b) The variation of the Tresca equivalent stresses – DHS model

In Figures 8 and 9 we can see the distribution of the Tresca equivalent stresses, both in the fractured section D-D' and in the area where the metal plate is inserted E-E'. The highest stresses are in the section area (D-D'). For the area where the metal plate is inserted, the maximum values of the stresses appear in the fourth screw.

The same analysis regarding the meshing model (Figure 10a) and Tresca equivalent stresses variation (Figure 10b) are done for the Gamma fixation system.

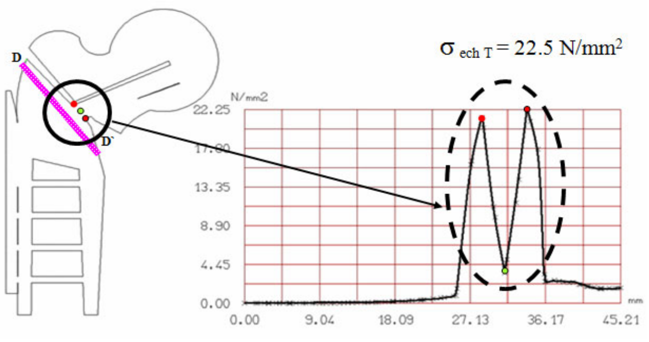


Fig. 8 The variation of the Tresca equivalent stresses in the D-D' section – DHS model

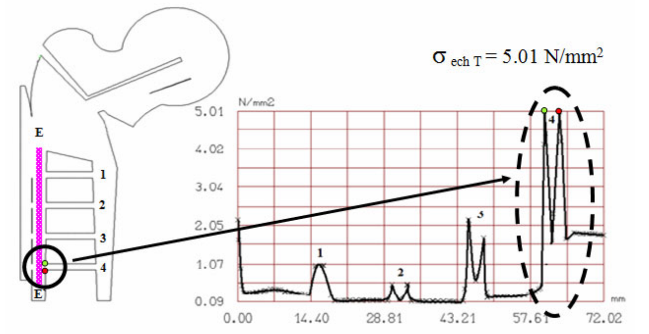
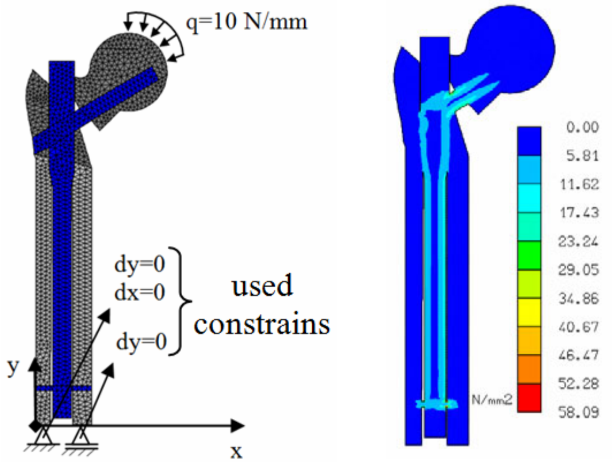


Fig. 9 The variation of the Tresca equivalent stresses in the E-E' section – DHS model

The variation of the Tresca equivalent stresses are presented for the fracture section F-F' (Figure 11) and for the area where the safety screw is inserted H-H' (Figure 12).



a) b)

Fig. 10 a) Meshing design for the Gamma model; b) The variation of the Tresca equivalent stresses – Gamma model

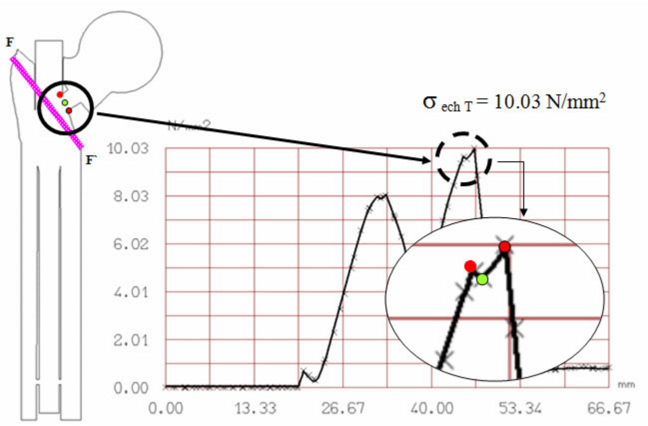


Fig. 11 The variation of the Tresca equivalent stresses in the F-F' section – Gamma model

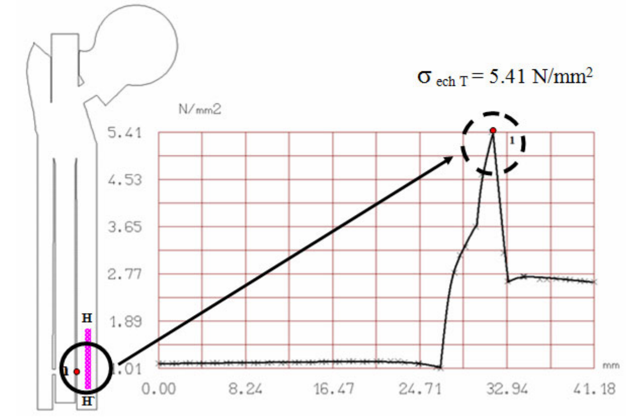


Fig. 12 The variation of the Tresca equivalent stresses in the H-H' section – Gamma model

IV. CONCLUSIONS

From the study conducted we can conclude the following:

- the numerical and experimental analysis identifies the area where the load is maximum, which is the surface area between the greater trochanter and the lesser trochanter.
- by using photoelasticimetry it could be underlined the stresses distribution in the fractured area of the femoral bone.
- from Figures 7b and 10b results that the equivalent stresses Tresca have maximum values in the inferior fibres of the rods (DHS and Gamma system), noticing that for the Gamma system they have maximum value ($\sigma_{ech\ T}$ = 58.09 N/mm^2) in comparison with the DHS system ($\sigma_{ech\ T}$ = 36.89 N/mm^2).
- as well, in the contact area between the rod (or screws) and the model (bone tissue or epoxy resin) the loads level could be quantified.
- thus, according with Figures 8 and 11, the DHS system has the maximum stresses ($\sigma_{ech\ T}$ = 22.5 N/mm^2), in comparison with the Gamma system ($\sigma_{ech\ T}$ = 10.03 N/mm^2).
- Figures 9 and 12 show the equivalent stresses Tresca distribution in the areas where the two systems are fixated, the femoral bone shaft. It can be noticed that, in this area, in the case of the DHS fixation system the equivalent stresses Tresca are 5.01 N/mm^2, while for the Gamma system their value is 5.42 N/mm^2.
- the comparative study between the two systems used in the fixation of a trochanteric fracture shows that the Gamma system is the better choice; the disadvantage is that is also the expensive one.

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