Ilaria Lorena PETROVICI, Mihai Catalin TENOVICI, Razvan Cristian VADUVA, Danut Nicolae TARNITA, Georgiana VINTILA, Dragos Laurentiu POPA

ABOUT THREE-DIMENSIONAL MODELS OF OSTEOSYNTHESIS SYSTEMS

Abstract: *Implantology is based on the failure of orthopedic treatment, or cases where orthopedic treatment is incapable of reducing or maintaining, for example, fracture of the femoral neck with movement. The advantage of centromedular fixation is that it allows the bone to physically load as much as possible, minimizing the risk of implant failure. The drawbacks of conventional nails have been eliminated with the introduction of the centromedular stem locking system. The purpose of this study was to obtain several virtual biomechanical systems on which to study several types of tibial fractures and several osteosynthesis systems. Starting from the tomographic images of the tibia, a virtual model of this bone component was developed. This model was "finalized" and modified using certain Geomagic techniques and then imported into SolidWorks. The osteosynthesis element used was the rigid classical nail with orthopedic screws which was modeled using the direct observation and measurement method. It is intended that these virtual components to be used to make orthopedic virtual osteosynthesis systems that are then analyzed in Ansys with the finite element method.*

Key words: *Virtual tibia, fractures, centromedular fixation, virtual reconstruction, virtual osteosynthesis.*

1. INTRODUCTION

Diaphysis fractures of the calf are fractures of interest to one or both bones at the diaphysor level. Tibia is most commonly referred to, tibia fractures accounting for approximately 20% of all fractures; the superficial condition of the calf bone (the antero-medial surface and the anterior crest of the tibia being covered only by tegument and fatty tissue) makes them more vulnerable to direct impact trauma. They may occur isolated or in the context of politraumatisms and are still an important public health problem with important socio-economic implications due to the disabling nature of the disease, on the one hand, the severe algic syndrome, and on the other hand the immobilization or prolonged recovery period , as well as characteristic sequelae: joint abnormalities, muscular atrophy, persistent edema, osteoporosis of metatarsiae (Sudek-Leriche syndrome), algo-neuro-dystrophic syndrome, which in turn requires sustained, sometimes long-term treatment [1].

The treatment of diaphysis fractures of the calf is complex, orthopedic (gypsum immobilisation) and / or surgical (osteosynthesis with blocked, non-lockable or elastic nails, screw plates, external fixator); in the choice of therapeutic methods, the morphopathological features of the fracture (number, location, fracture type, etc.), age, general condition of the trauma, presence of shock, especially if the fracture is part of a politraumatism and last but not least the logistics of the service and the expertise of the surgical team, which directly influences the results. An important element that influences the time of consolidation, evolution, prognosis, functional recovery and re-employment of patients with diaphysis fractures of the calf is the type of osteosynthesis materials and techniques. The classic intramedullary nails used in tibia fractures have important drawbacks such as complicated orientation, manipulation and positioning and, at the same time, difficult positioning of the distal screws using the classic stem nail. Also, all these operations can lead to errors or extra cavities in the tibia, causing bone resistance to decrease and, at the same time, to increase the duration of surgery with unpredictable effects on bone repair. Extending the duration of orthopedic surgery can also result in additional irradiation of medical and patient staff.

For the reasons outlined above, it is imperative that, before producing certain elements of osteosynthesis, they are modeled in a parameterized environment and then tested virtually in different biomechanical systems [1], [2], [3].

2. THREE-DIMENSIONAL MODELLING OF THE TIBIAL BONE COMPONENT AND A OTHOPAEDIC NAIL

In order to get the correct and closest to reality model, a parameterized CAD program (Computer Aided Design) was used, initially used in engineering design and allowing the generation of very complicated geometry models. The SolidWorks program, allows to import two-dimensional contours defined with AutoCAD, has been used to effectively define virtual bone components. This program allows for parameterized three-dimensional models that can be modified and edited. Also, virtual models can be exported to kinematic simulation or FEM analysis software. SolidWorks is an industry-leading computer-aided design software that allows easy use, with no outstanding performance platforms. The program allows for constructive design, as well as product verification calculations. SolidWorks, through its modelling capabilities and the Windows intuitive interface, enables the creation of solids, assemblies and execution drawings [1], [3].

Component modelling is fully parameterized and includes multiple working possibilities. The modelling of the assemblies provides the complete design of the components in the context of an assembly and the creation of assemblies from a multitude of parts and subassemblies, ensuring the bidirectionality of the assembly and design changes. The SolidWorks interface is shown in Fig. 1.

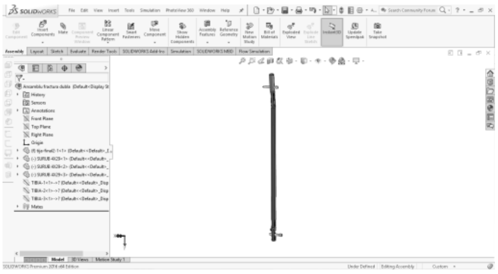

Fig. 1 The SolidWorks interface.

To obtain tomographic images of the bone components, a bone component, namely, the tibia was used in a first phase [4], [5], [6].

The experiment was performed using a CT scanner installed at a private clinic in Craiova.

For the subsequent definition of a fixed reference point against which the two virtual bone models could be generated, a plastic pipe having dimensions were used. Also, this marker was later used to scale up CT images and bring them to their natural size.

The CT scanner allows us to obtain images in DicomWorks format, a specialized software for medical imaging.

Three folders were created with a total of 113 images grouped on surfaces CT scanned.

Fig. 2 shows six important tibia images. These tomographic images were also used in [5], [6], [7].

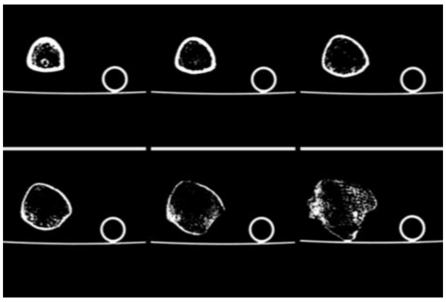

Fig. 2 CT images of tibia.

In each cross section the fixed pipe appears (Fig. 3).

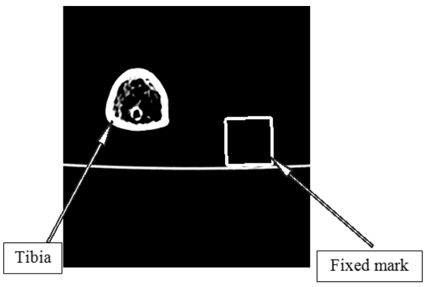

Fig. 3 Tibia and the fixed mark in a transverse tomographic image.

To produce the CT images, a scanning method as shown in Fig. 4 was used based on parallel planes spaced at 1 mm for the ends of the bones and 3 mm for the medial areas.

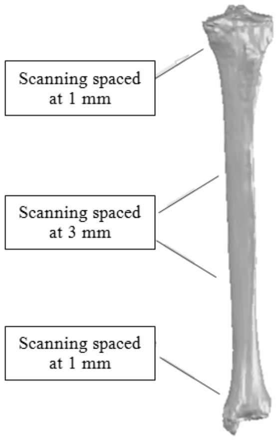

Fig. 4 The tomography pattern used for the tibia.

The images made by the CT scanner in DicomWorks format were turn into Windows Bitmap, and the resulting files were organized into separate folders taking into account the zones highlighted in the scan pattern.

These images were loaded one by one into AutoCAD. This computer-aided design program allows definition of non-parametrized two-dimensional models.

First, the files were loaded into AutoCAD to determine the scale of the CT images. Because each CT image also contains the fixed reference (a plastic pipe having a round section of 20 mm in diameter), by comparing the dimensions on real-life pictures with the actual plastic bar, the scale at which these images were imported into CAD software so images appeared on natural scale.

To begin with, the inner (green) and outer contour (blue) of the bone and a 20 mm diameter circle (red) corresponding to the section of the bar used as a fixed mark (Fig. 5) were drawn above the image loaded in AutoCAD [7], [8], [9].

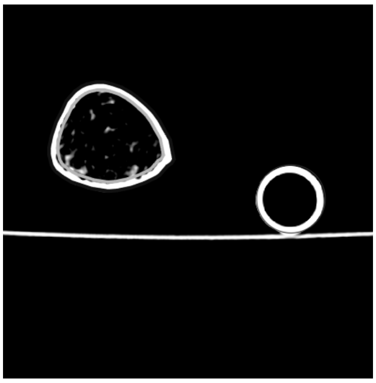

Fig. 5 The inner (green), outer (blue) and the fixed mark (red) drawn in AutoCAD.

In SolidWorks software, were defined parallel planes with the Insert / Reference Geometry / Plane command located similar to the scanning distances (Fig. 6) were defined [8], [9], [10].

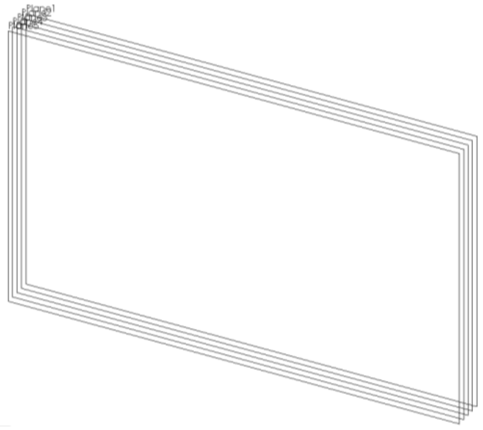

Fig. 6 The Reference planes defined at pre-established distances.

In each of these planes, were downloaded from AutoCAD using the Windows Copy / Paste tandem sections. Fig. 7 shows an AutoCAD section downloaded into a SolidWorks drafting plan .

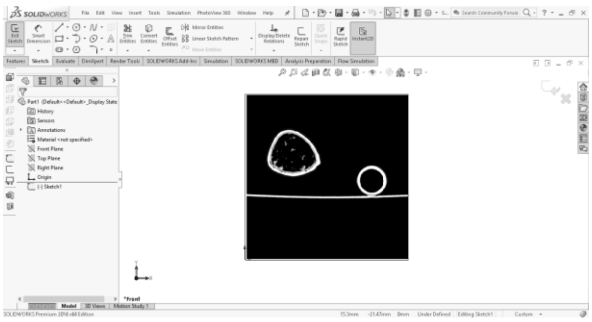

Fig. 7 Section imported into SolidWorks.

The circle representing the fixed mark is used to align the sections of a virtual bone component. The sections are defined in succession in AutoCAD and downloaded in parallel to SolidWorks in parallel planes. The operations presented are repeated for each individual tomography. The sections obtained for the femur and two details of the lower and upper areas are shown in Fig. 8 [5], [6], [7], [8].

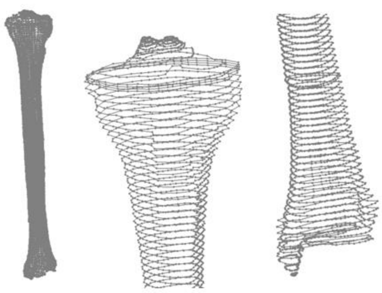

Fig. 8 Sections that define the shape of the tibia in SolidWorks.

The SolidWorks program allows you to get a virtual solid by "joining" transverse sections drawn at parallel planes. The shape that "solidifies" these sections was made by Loft command and defines the virtual solid from these sections and a guide curve. Fig. 9 shows the Loft tibia definition scheme [5], [6], [8], [11].

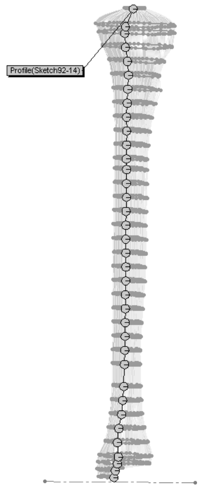

Fig. 9 Scheme for defining virtual tibia.

In Fig. 10 were presented three images of the virtual tibia.

Fig. 10 Three views of the tibial virtual model.

But this model is complicated, so it has been subject to techniques and methods of "smoothing" using the Geomagic program for adding surfaces, decreasing the number of triangles, etc.. The final model is shown in Fig. 11.

Fig. 11 The final model of tibia (three views).

Using specific modelling commands, as well as the direct measurement method, the model of an orthopedic nail for the tibia and the necessary screws was obtained. At this time, it was intended to analyze the behaviour of orthopedic systems for different types of fractures, and these results to be compared to the situation of an integral tibia loaded for normal walking. Fig. 12 shows different views of the orthopedic nail with the corresponding screws [1], [3].

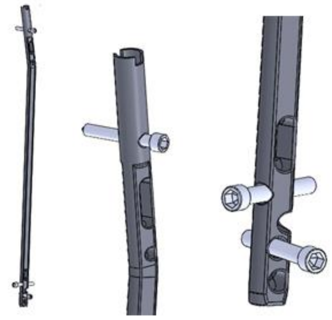

Fig. 12 Different views and details of tibia nail.

3. CONCLUSIONS

Starting from the previous research, we have analyzed the orthopedic implants used in the long bones as a whole and found some inconsistencies between the osteosynthesis material and the bone tissue.

The purpose of this paper is to improve both the osteosynthesis materials and to prevent accidents and incidents between the implanted material and the bone structure following implantation. In order to achieve this, the bone component of the tibia and a rigid centromedullary rod have been modeled.

Our intention is to analyze a series of well-known fractures in the literature to use several types of centromedular rods. These biomechanical systems made up of different components will be imported into Ansys and analyzed with finite element method.

The methods presented in the paper prove that it is possible to model geometrically complicated methods and the contacts between different materials, as are these complex biomechanical systems.

REFERENCES

[1] Buciu, G., Popa, D.L., Grecu, D., Niculescu, D., Nemes, R., (2012). *Virtual comparative study on the use of nails at the fixation of tibial fractures using finite element method*, Proceedings of The 4th International Conference Advanced Composite Materials Engineering COMAT 2012, Lux Libris Publishing House, ISBN 978-973-131-162-3, pp.381-386, Brasov, Romania.

[2] Ciunel, S., Duta, A., Popa D.L., Popa-Mitroi, G., Dumitru, V.C., (2014). *The Behaviour of the Virtual Human Head-Neck System during the Main Movements*, Applied Mechanics & Materials, no.657, pp. 780-784.

[3] Popa A.D., Mogosanu A.M., Popa D.L., Duta A., Teodorescu A., (2017). *Virtual and rapid prototyping methods applied in civil engineering: Snow, wind and earthquake simulations on a five storey building*, FME Transactions, vol. 45, no. 2, pp. 276-282.

[4] Popa, D.L., Buciu, G., Grecu, D., Niculescu, D., Chiutu, L., Stoica, M., (2013). *Studies about virtual behaviour of tibia fractures and nails during the fixation process*, JIDEG, no.8, pp. 5-10.

[5] Popa, D., Duta, A., Pitru, A., Tutunea, D., Gherghina, G., (2013). *About the Simulation Environment for Dental Implant Studies*, Scientific Bulletin of the "POLITEHNICA" University of Timisoara HIDROTEHNICA Series, vol. 58, pp. 137-141.

[6] Popa, D., Tarnita, D., Iordachita I., (2005). *Study method for human knee applicable to humanoid robots*, Proceedings of The 14th International Workshop on Robotics in Alpe-Adria-Danube Region, RAAD, vol.5, pp.26-28.

[7] Popa, D., Tarnita, D.N., Tarnita, D., Grecu, D., (2005). *The generation of the three-dimensional model of the human knee joint,* Romanian Journal of Morphology and Embryology, vol.46, no.4, pp. 3-6.

[8] Tarnita D., Tarnita D.N., Bizdoaca N., Popa D., (2009). *Contributions on the dynamic simulation of the virtual model of the human knee joint*, Materialwissenschaft und Werkstofftechnik: Entwicklung, Fertigung, Prüfung, Eigenschaften und Anwendungen technischer Werkstoffe, vol. 40, no. 1-2, pp. 73-81.

[9] Tarnita D., Tarnita D.N, Bolcu, D., (2011). *Orthopedic implants based on shape memory alloys,* chapter in Biomedical Engineering – From Theory to Applications, in InTech Publishing House, pp.431-468, ISBN: 978-953-307-283-8, Viena.

[10] Vatu, M., Craițoiu, M.M., Vintila, D., Mercuț, V., Popescu, M.S., Scrieciu, M., Popa, D..L., (2018). *Determination of resistance forces from mandibular movements through dynamic simulation using kinematic analysis and finite elements method*, Romanian Journal of Oral Rehabilitation, Vol. 10, Issue 1, pp. 20-28.

[11] Vatu, M., Vintila, D., Popa, D.L., (2018). *3D Skull Virtual Model Based on CT or MRI Images Used for Dentistry Simulations*, Applied Mechanics and Materials, Vol. 880, pp. 101-110.

Authors:

Ilaria Lorena PETROVICI, PhD student, University of Medicine and Pharmacy of Craiova, E-mail: ilaria.petrovici@yahoo.com.

Mihai Catalin TENOVICI, PhD student, University of Medicine and Pharmacy of Craiova, E-mail: mihai.tenovici@yahoo.com.

Razvan Cristian VADUVA, PhD student, University of Medicine and Pharmacy of Craiova, E-mail: vaduvarazvan1@yahoo.com.

Danut Nicolae TARNITA, Professor, University of Medicine and Pharmacy of Craiova, E-mail: dan_tarnita@yahoo.com.

Georgiana VINTILA, student, University of Medicine and Pharmacy of Craiova, E-mail: vintila_georgiana9@yahoo.com.

Dragos Laurentiu POPA, Associate Professor, University of Craiova, Faculty of Mechanics, E-mail: popadragoslaurentiu@yahoo.com.