

"GEORGE EMIL PALADE" UNIVERSITY OF MEDICINE, PHARMACY, SCIENCE, AND
TECHNOLOGY OF TÂRGU MUREŞ

SCHOOL OF DOCTORAL STUDIES

DOCTORAL THESIS
ABSTRACT

Reconstruction of tibial plateau fractures using customised surgical instruments designed with the support of three-dimensional technologies

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Tibial plateau fractures are joint injuries that threaten short- and long-term knee function. Tibial plateau fractures represent 1% of all fractures in adults. These may be associated with high-energy trauma or, in the elderly with osteoporosis, with mild traumatic injuries.

New three-dimensional (3D) digital technologies mainly cover 3D imaging, 3D design, numerical simulation, and 3D printing. They have a high potential for use in clinical practice and allow the efficiency of various medical investigations.

The overall objective of this thesis is to improve surgical techniques for the reconstruction of tibial plateau fractures by using customized surgical instruments, designed and manufactured with the support of 3D technologies.

In order to achieve the objectives of the thesis, I have conducted five research studies. The protocols of these research studies were performed in accordance with the ethical principles of the Helsinki Declaration and were approved by the Medical Ethics Commission for the Clinical Study of Medicines within the Târgu Mureș County Emergency Clinical Hospital (protocol code 2Ad.6108 / 02.03.2021). Informed consent was obtained from all subjects involved in the study.

In the first study, entitled "Integration of three-dimensional technologies in orthopedics: tools for preoperative planning of tibial plateau fractures" by exploring the applications of 3D technologies in orthopedic surgery, described by the scientific literature, allowed the creation of the appropriate framework for their integration into a clinical workflow, which supported the following exploratory studies in this thesis.

Another research methodology used in this study is the modeling and simulation of tibial plateau fractures with the support of 3D technologies.

In the second study, entitled "Alignment algorithm integrated in 3D technologies - a tool for personalized surgical treatment of tibial plateau fractures" it was used as research methodology the development of innovative algorithms for alignment of comminutive fracture surfaces whose clinical application is supported by the structured integration of new 3D technologies, as well as the validation of algorithms in orthopedic biomechanical laboratory conditions.

The research methodology used in the third study entitled "Study of heat generation in the process of surgical bone drilling" is experimental and involved the development of a new method for measuring the temperature of the bone sample in which holes are made, by using an experimental stand.

The fourth study, entitled "Control of tightening moments of cortical screws" has used as research methodology the experimental study on an orthopedic biomechanical laboratory stand in order to make more efficient the screw fixation of tibial fractures fragments.

Study five, entitled "Guide for screw fixation of tibial fracture fragments" has as research methodology the design and development of innovative surgical guidelines which ensure the reduction of fracture fragments as established in the preoperative planning stage, by employment of the comminutive fractures fragments alignment algorithm, as well as validation of the reconstruction method of the tibial plateau fractures in an orthopedic biomechanical laboratory.

The validation of the developed models was performed on five cases of tibial plateau fractures type I, II, IV, V, respectively VI according to Schatzker classification, which were collected in the interval 2020-2021 from the U.P.U.-S.M.U.R.D. Mures.

The originality of the thesis results from the interdisciplinary character of the performed studies, with numerous scientific contributions of **clinical, biomedical and technological** importance, among which it is highlighted:

- I have developed the clinical workflow integrating 3D technologies for patient-specific applications in orthopedics, which is an integrative and innovative concept;
- I have tested the software products Democratiz3D and Invesalius, for application to segmentation and 3D reconstruction of the tibial plateau, then I have validated them for five cases of investigated tibial plateau fractures and I have formulated conclusions and recommendations on the performance of preoperative planning according to the severity of the analyzed fractures;
- I have created tools that allow the fractures exploration from any direction, allow a better understanding of the fracture nature, identify difficult reductions of bone fragments, careful reconstruction of the joint line, and also reduce the risk of post-traumatic osteoarthritis;
- I have developed an original innovative algorithm for alignment of the bone fracture fragments that allows to obtain a precise restoration of the bone from its fragments, so that it becomes similar to the original unfractured bone;
- Original experimental contributions of orthopedic biomechanics completed with important guidelines for orthopedic surgeons, on the conditions for conduction holes execution which avoid bone necrosis and increase the capacity of the bone to retain the cortical screw;
- Another original experimental contribution to the biomechanical stability of orthopedic surgery is the development of a new method for determining the significant moments of tightening the cortical screw in the bone sample;
- In the research it is developed an innovative personalized surgical tool, the guide for fixing comminutive tibial fracture fragments with screws, which allows the precise execution of the cortical screws conduction holes, as well as the mounting and fixing by tightening of cortical fixing screws, with reduced effort of the orthopedic surgeon.