Designing of Internal Dynamic Tibia Fixation 3D Model according to Mitkovic type TPL

Miodrag Manić*, Milorad Mitković**, Zoran Stamenković*, Nikola Vitković*
*University of Niš, Faculty of Mechanical Engineering/Department for Production, IT and Management, Niš, Serbia
**University of Niš, Faculty of Medicine/Department for Surgery, Niš, Serbia
miodrag.manic@masfak.ni.ac.rs
mitkovic@gmail.com
zoki2101984@gmail.com
nvitko@gmail.com

***Abstract* — This paper presents a display of originally developed method for designing a 3D model of internal dynamic tibia fixation according to Mitkovic type TPL. The internal side of the fixation, the one lying on the bone, is fully aligned with the anatomical shape of the bone surface. The method is based on the application of parameter 3D model with the marked bone fractures. This method can also be used for any other bone or tile type implant. The given model is designed for fixation production utilizing any method, and it is ideal for 3D printing.**

I. INTRODUCTION

In orthopedic surgery it is of paramount importance to apply proper methods of human skeletal system fixation in order to treat various bone fractures or other traumas. In case of internal fractures fixation treatment, it is very important to utilize internal fixation whose geometrical and topological characteristics fully correspond to the shape and size of the patient's bone, since this ensures faster and better recovery.

In order to reach this goal, the method which allows 3D modeling of internal fixation according to Mitkovic type TPL (tibia-plato-lateral) was created [1]. The suggested method is original and is based on designing fixation contour directly on patient's bone, after which extrusion is performed in order to create 3D fixation model. When this is finished, further model adjustments to the patient's bone are performed.

This approach enabled surgeons to create the fixation surface lying on the bone which fully corresponds to anatomical shape of the bone surface. The 3D model of the patient's bone which is needed for this procedure can be produced with any given method [2].

When fixation model is created in this way, it can be used for fixation production on 3D printer or CNC machines.

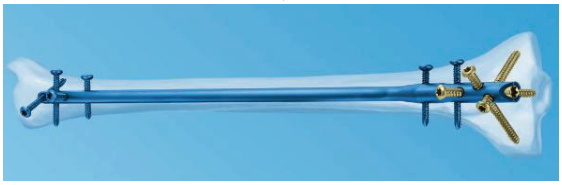
The method developed in this paper can also be used for various kinds of internal fixations that are directly attached to any bone surface.

II. SHORT DESCRIPTION OF INTERNAL FIXATION, SHAPES AND DESIGNING METHODS

Internal fixations are medical devices used as support to treat damaged or disease-infected bones brought about as a consequence of old age, disease or an accident. They are made of different kinds of biocompatible materials [3]. There are two kinds of internal fixations – intramedullary and extramedullary.

Intramedullary internal fixations are actually implant nails, as seen in Figure 1a, that are used to treat various bones (eg. tibia). They are inserted into the bone by using the bone's intramedullar canal, after which the screw bolts are inserted through the bone and previously made transverse screw holes on a nail. In this way, the binding of fractured bone fragments into a whole is created in order to treat the fracture and enable the bone to heal properly (Figure 1b) [4].

a)



b)

Figure 1. a) Intramedullary nail for tibia; b) Nail inserted into a bone [4]

Extramedullary fixations is comprised of various implants: screw bolts, tiles and dynamic fixations according to Mitkovic of different shapes and dimensions (Figure 2). These kind of implants are placed on the external surface of the fractured part of the bone [3[[1].

After this process is finished, the system of screw bolts is inserted through the previously made screw holes on a fixation. In this way, fractured bone fragments are connected into a whole, transport capacity of the joint is created and position and direction of the fragments are kept (Figure 3).

What is of paramount importance during the process of implants insertion is to create minimal direct contact between the fixation and the bone surface, while at the same time ensure that fixation follows bone contour. The pressure created when fixation rests on the bone should be avoided since it can damage the periosteum which covers the bone surface and nourishes the bone through blood vessels in it.

Figure 2. a) Standard and locking tiles and screw bolts.; b)Tibia fixations according to Mitkovic

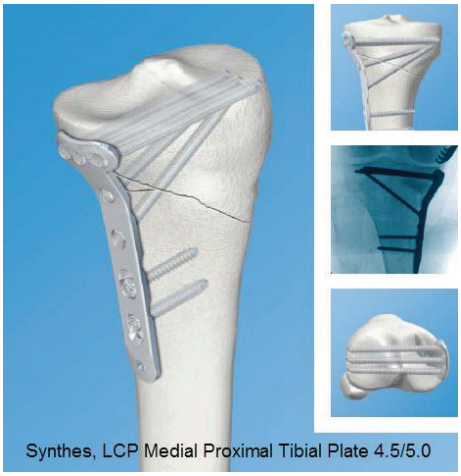


Figure 3. Insertion of a tile for the upper part of tibia [4]

III. 3D Modeling of Internal Implants

There can be found only few described examples of the methods for creating a 3D model of anatomically adjusted internal implants which correspond to the bone contour in the literature.

Usual methods that are applied include the using of CAD software to plan and design internal implants and these methods are based upon the ideas of orthopedic surgeons and engineers. These people constantly seek for new methods and techniques for designing and production of the internal fixations that could heal any bone fracture.

The basis for creating a 3D geometrical model of an internal fixation is a scheme of its contour defined in a suitable position in relation to the bone surface. Using the scheme, retraction or rotation of the model volume is performed, depending on the type of the internal fixation that is being used. Furthermore, modeling of the contact surface of the fixation, the surface lying on the bone, is performed In the end, new screw holes for the corresponding screw bolt type are made on the surface of the fixation model.

In [5] it can be seen an example of designing a fixation in the shape of a tile (Figure 4), as well as the dynamic screw bolt of a hip [6] (Figure 5).

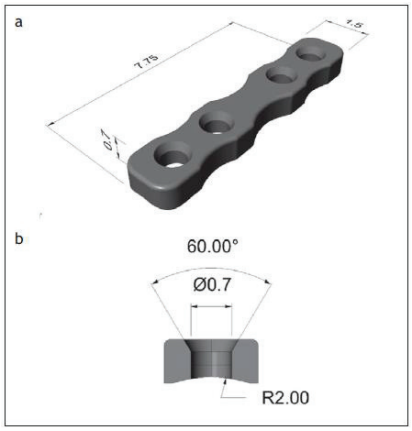


Figure 4. a) Tile modeling; b) Creation of the screw holes [5]

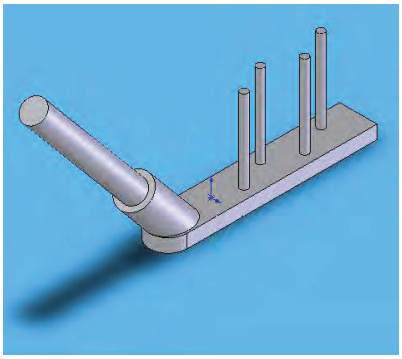


Figure 5. Designing of a dynamic screw bolt of a hip [6]

In [7] the description of a way and procedure of designing an internal fixation in the shape of a tile type "medially locking plate" (MLP) is described, which is used for treating femur fracture from its lateral side.

For designing process a 3D femur model is used. The positioning of a tile according to femur is defined by creating a datum plane. The datum planes were positioned in such a way that the sagittal plane was parallel to a planar approximation of the medial epicondylar surface and approximately tangent to the diaphyseal surface. The coronal plane was then position 90° to the sagittal plane rotated about a linear approximation of the diaphyseal axis (Figure 6).

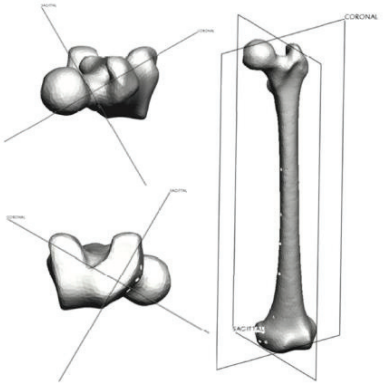


Figure 6. Creating a plane for drawing on a bone [7]

Next, a medial sketch of the MLP was created on the sagittal plane such that diaphyseal a d condylar shape matched that of the average femur (Figure 7).

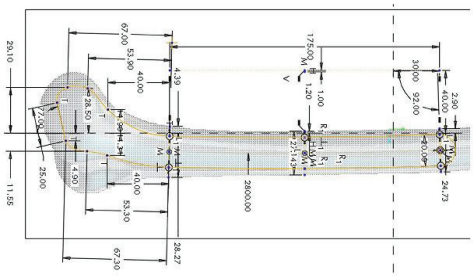


Figure 7. Creating the contour of an internal fixation [7]

The medial sketch was then extruded in both normal directions so that the extrusion intersected the femur at all points within the cross section and extended at least 1 cm beyond the most medial point on the medial epicondylar surface (Figure 8).

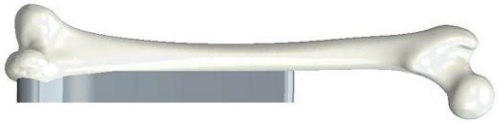


Figure 8. Extruding the contour of an internal fixation [7]

A sketch of the anterior profile – with an initial plate thickness of 5.0 mm – was then created on the coronal plane having a contour that matched the average femur. The sketch was then infinitely extruded in both directions, removing material where it intersected the initial medial/lateral extrusion (Figure 9).

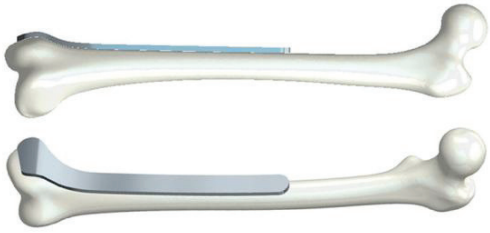


Figure 9. Extrusion cutting of the anterior profile [7]

Finally, the initial locations of the threaded interlocking screw holes were sketched and extruded - removing material when intersecting the concept model – from the sagittal plane (Figure 10). The final model of a tile optimized for structure integration is shown in Figure 11.

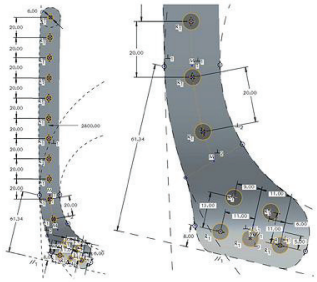


Figure 10. Creating the screw holes for the fixation screw bolts [7]

Figure 11. Final model of MLP internal fixation [7]

In [8] and [9] the method which is used for designing an internal fixation according to Mitkovic type TPL (tibia-plato-lateral) is shown. The suggested method is based on the application of MAF - Method of Anatomical Features and newly developed techniques for designing fixation supporting surfaces. The result of the application of this method is the parametrical fixation model whose shape and geometry could be changed with a change of parameters. With this approach it was allowed to change the shape of a fixation in order to adjust it to the patient's bone shape, in this case tibia, based on parameters values (dimensions) read from a suitable X-ray (for instance, a CT - Computer Tomography – scan) (Figure 12).

Figure 12. Fixation according to Mitkovic, type TPL created using the method described in [9]

IV. Designing Technique of an Anatomically Adjusted Dynamic Internal Fixation of Tibia According to Mitkovic Type TPL

The principle of anatomical adaptability implies that the internal fixation with its contact surface fully corresponds to the surface of the part of a bone where the fracture is located. In this paper, we present the process of designing

an anatomically adjusted dynamic internal fixation of tibia according to Mitkovic type TPL, by using CATIA V5 software package.

Designing procedure is the following:

The parametrical 3D geometrical model (of tibia) made on the basis of patient's CT scan is used [10]. After that, a vertical plane not far from the lateral surface of tibia is created, which is placed opposite the contour of the fracture (Figure 13). Inside it, the contour of the proximal part of the fixation is drawn (Figure 14).

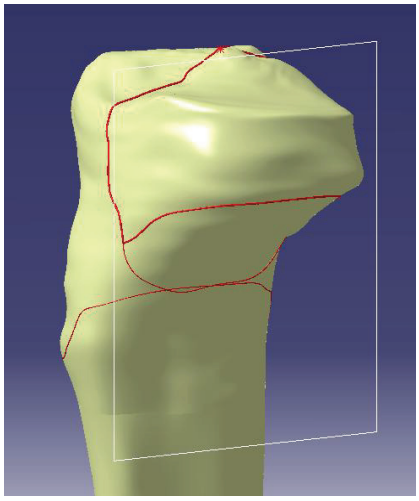


Figure 13. Creating the plane for contour drawing

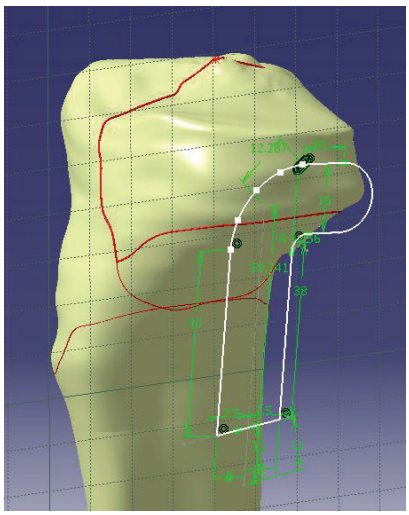


Figure 14. Creating the contour of the proximal part of the fixation

Following that, contour extrusion in the direction of the lateral tibia side is performed so as to ensure that extruded contour surface penetrates the bone surface (Figure 15).

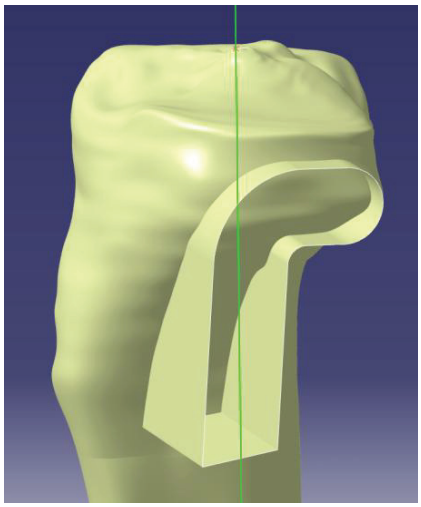


Figure 15. Extrusion of the contour and its penetration through the bone

The intersected closed contour of the fixation's internal side is created in this way (Figure 16). Inside of that contour, curve drawing of the 3D splines that follow the bone contour is performed (Figure 17).

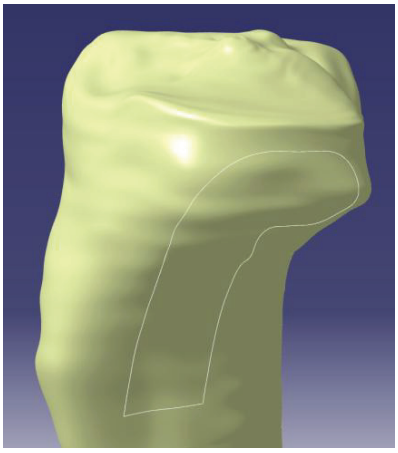


Figure 16. Creating the intersecting contour curve

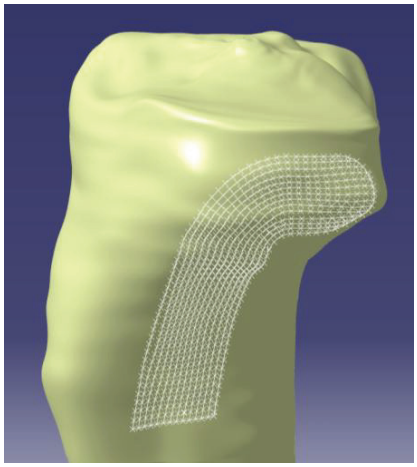


Figure 17. Creating 3D splines inside of the contour

After this step, the moment comes when all the surfaces are removed and the only surface left is the one

that actually presents the internal side of the fixation that is put directly on the bone (Figure 18a). Now this surface is extruded to transform it into a full model. With this process completed, we get a full 3D model of a proximal fixation part that is completely anatomically adjusted to the surface of the proximal part of tibia (Figure 18b).

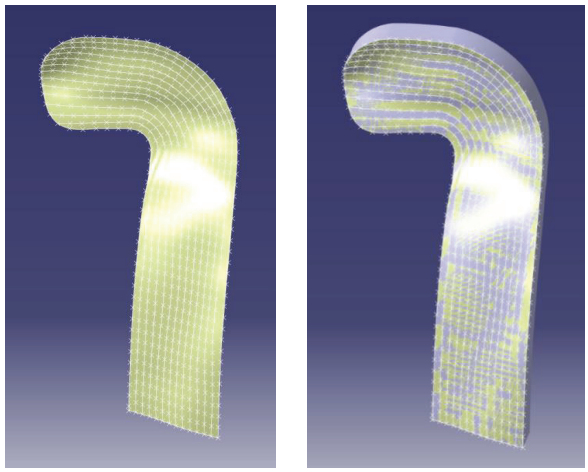


Figure 18. a) Creating a 3D surface; b) Creating a full model of proximal fixation part

The remaining parts of the internal dynamic fixation according to Mitkovic are made with the use of standard technical elements. What is characteristic for this part is a distal part of the fixation with two grooves used for the process of dynamization (Figure 19). In fact, the process of dynamization can be performed because of the lower groove with screw bolts, i.e. when the screw bolt from the upper groove, which enables previous deactivation of the whole process, is removed. In this way, a direct interaction between fractured bone fragments is created, in order to create new bone tissue and enable the bone to heal.

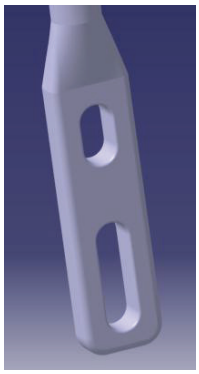


Figure 19. Distal fixation part with the grooves for dynamization

After the internal fixation has been shaped, the creation of the screw holes on the proximal fixation part is performed. According to the orthopedist request, an additional scheme of concentric circles with points for screw holes production is created (Figure 20). The process of screw holes creation is based on projection points and created tangent planes and is performed on the part of the proximal fixation surface (Figure 21).

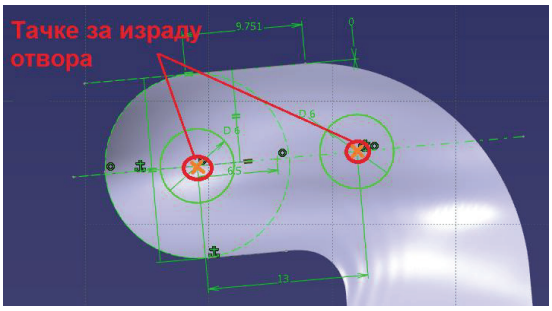


Figure 20. Creating an additional scheme with points for screw holes

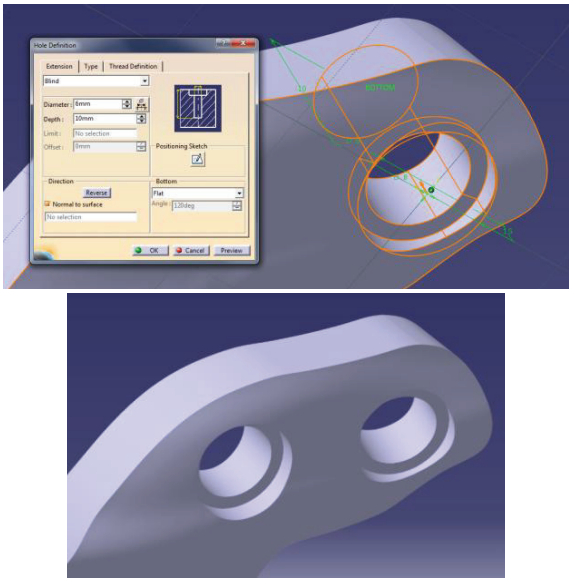


Figure 21. Creating screw holes

The final model of the internal dynamic fixation for tibia according to Mitkovic is shown in Figure 22.

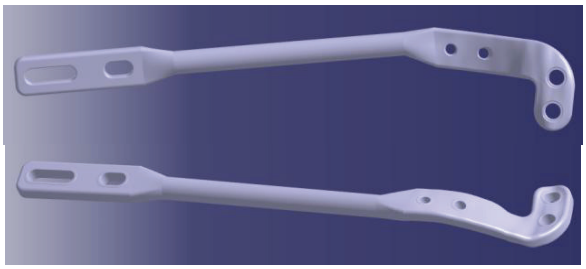


Figure 22. Final model of dynamic fixation according to Mitkovic

V. CONCLUSION

The method described in this paper presents the designing process of a 3D internal dynamic fixation model according to Mitkovic type TPL, whose internal surface lying on the bone is fully aligned with the bone surface. In this way, it ideally lies on the bone. With this model it is possible, based on a 3D model of bone and fracture, to

create a fixation for any fracture location. 3D fixation model is ideal for 3D printing or production using a CNC machine.

The method developed and described in this paper is applicable to many other implants of tile type and for any human bone. The requirement that must be fulfilled is a 3D bone model with imprinted fracture.

This method has significantly improved the technique for production of anatomically adjusted internal fixations.

ACKNOWLEDGMENT

This paper is a result of the project III41017, supported by the Ministry of Science and Technological Development of the Republic of Serbia.

REFERENCES

[1] Mitkovic Milorad, Milenkovic S., Micic I., Mladenovic D., Mirkovic Milan, Results of the femur fractures treated with the new selfdynamisable internal fixator (SIF).. Eur J Trauma Emerg Surg. 2012 Apr;38(2):191-200

[2] Vitković, N., Milovanović, J., Korunović, N., Trajanović, M., Stojković, M., Mišić, D., Arsić, S. Software system for creation of human femur customized polygonal models, Computer Science and Information Systems, Vol. 10, No. 3, pp. 1473-1497, 2013

[3] D. Djenadić, M. Manić, D. Tanikić, S. Randjelović, P. Djekić, Analiza i prikaz vrsta fiksatora u medicini kao i metoda obrade materijala za izradu fiksatora, Vojnotehnički glasnik, Vol. 61, No. 2, pp. 123 - 139, 2013.

[4] http://www.synthes.com/MediaBin/International%20DATA/036.000.380.pdf. Accssed on 9 Jan 2015.

[5] Matthys R, Perren SM. Internal fixator for use in the mouse. Injury, Int. J. Care Injured (2009) 40S4, S103– S109

[6] Nooshin Sadeghi Taheri, Modelling and analysis of a dynamic hip screw: biomechanical analysis of a dynamic hip screw under different load conditions, Master thesis, Swinburne University of Technology Faculty of Engineering and Industrial Sciences, (2011), pp 57-58.

[7] Arnone Joshua. A comprehensive simulation-based methodology for the design and optimization of orthopaedic internal fixation implants, Ph. D., The Faculty of the Graduate School, University of Missouri-Columbia, 2011.

[8] Vitković, N., Veselinović, M., Mišić, D., Manić, M., Trajanović, M., Mitković, M., Geometrical models of human bones and implants, and their usage in application for preoperative planning in orthopedics, 11th International Scientific Conference MMA 2012 - Advanced Production Technologies, Novi Sad, 2012, pp 539-542

[9] Dalibor M. Stevanović, Nikola M. Vitković, Marko M. Veselinović, Miroslav D. Trajanović, Miodrag T. Manić, Milorad B. Mitković, Parametrization of internal fixator by Mitkovic, International Working Conference ''Total Quality Management – Advanced and Intelligent Approaches'', 4th – 7th June, 2013., Belgrade, Serbia, pp 541-544

[10] Vidosav Majstorovic, Miroslav Trajanovic, Nikola Vitkovic, Milos Stojkovic, Reverse engineering of human bones by using method of anatomical features, CIRP Annals - Manufacturing Technology 62 (2013) 167–170 (M21, IF 2,251)