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THE CAD MODELLING OF THE HUMAN TIBIA AFFECTED BY FORM DEVIATONS

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Abstract**—**The studies concerning the correction surgery of the lower member which is affected by axial deviations present more and more interest. The sources that lead to the appearance of axial deviations of the lower members are the usages that appear in the knee's articulation and the modifications of the tibia's geometric form as a result of a congenital disease or a malformation. Starting from the CAD (Computer Aided Design) tridimensional model of the human tibia, which we have realized in a previous research, a CAD modeling was made, a modeling which was parameterized by taking into consideration the main parameters that define this type of deviation: the CORA (center of rotation angulation) position and the deformation amplitude. By modifying the parameters we can obtain tibia models with different degrees of deformation. By reassembling the affected tibia in the foot model, we can obtain the model of the affected foot, model which can be used in order to simulate correction surgery techniques.

Keywords**—**CAD modeling, CORA, deformed tibia model, orthopedic surgery.

I. Introduction

THE engineering researches regarding the orthopedics surgery of a knee presents a very good approach given the interferences between the two fields (orthopedics surgery and engineering) and given the possibility of improving the surgery procedures using methods which are specifics to mechanical research.

The articulation of the tibia and femur of a normal knee joint is characterized by a mechanical axis which passes from the head of femur through center of the knee to the center of the ankle joint. There are two principals sources for alteration of the normal mechanical axis of the leg. The first source is due of the wear of the bones in the joint zone. The wear is characterized by cartilage destruction–gonartrosys. The second source is due of the bones shape. The bones can to modify their shape as a consequences of the diseases (like Blount's disease) or a fracture healed wrong.

The principal goal of the article is to study and design using 3D modeling principles the second sources of axial deviation due of the bone shapes.

The aims of the researches are to establish:

1. *The parameters which characterized the axial deviation;*
2. *The 3D modeling of the human tibia affected of the shape modification;*
3. *Parameterized CAD (Computer Aided Design) modeling using Catia V5 with the possibilities to modify principals parameters*
4. *Assembly of the deformed tibia in the inferior member ensemble.*

II. Parameterized Modeling of the Deformed Tibia

A. Parameters of the deformation

For a geometrical analysis of the axes and of the axial deviations of the knee, it's important to refer to the leg axis from a healthy patient.

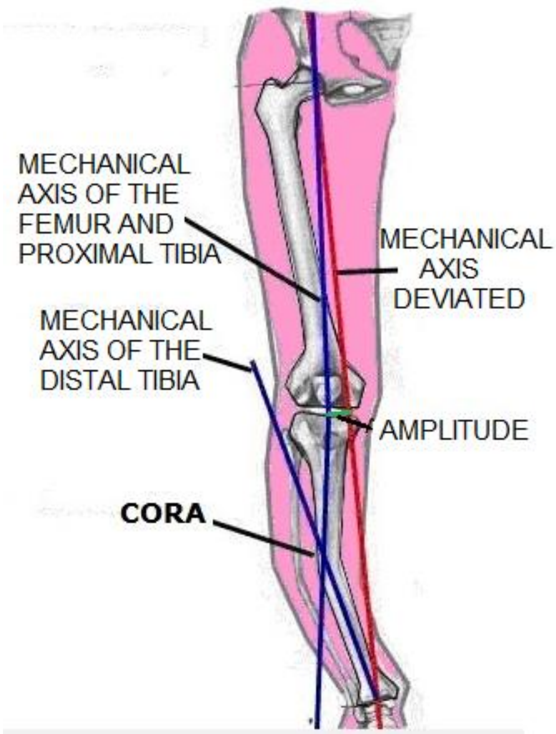

Fig. 1. Deviations owed to the shape of the bones[1]

At a lower member in the bipedal anatomical position, we can distinguish three axes [1]. The first axis – mechanical axis aligns the centers of the hip, knee and ankle. It is the mechanical axis of the lower member. It is considered that a deviation of the knee's axis any deviation of the mechanical axis from the position that was described above.

In this article we study, the situation of axial deviations of the mechanical axis is owed to the form of the bones. It results in the case of a consolidated vicious fracture or in the cases of a disease like The Blount's disease. In this case, the mechanical axis (red) of the foot, drawn from the center of the femoral head to the center of the wrist articulation center does not intersect the center of the knee's articulation, (Fig. 1.).

This aspect has consequences on the stress state of the articulation. In consequence, the CAD modeling of the deformed tibia and the future CAE (Computer Aided Engineering) analyses that can be made on the model represent interesting research subjects.

In order to increase the applicability area of the modeling we will approach a parameterized modeling through which on a general model we can give values to the parameters in order to obtain particular models.

These axial deviations are controlled through the following parameters [1]-[3]:

1. *Amplitude;*
2. *CORA (center of rotation angulation);*
3. *Deformation Plane;*
4. *Direction of deformation.*

Amplitude is the distance from the center of the knee and the deviated mechanical axes. CORA is the center of rotation angulation. The plane according to which the deformation occurs is a frontal one, sagital or most of the times oblique, and the deformation direction is considered towards a neutral axis (Fig. 1.).

These parameters will be used for 3D CAD parameterized modeling of the deformed tibia.

B. CAD modeling of the deformed tibia step by step

For a parameterized modeling of the tibia affected of the form deviation the next steps will be followed

1. Building of the mechanical axis and the articular planes. As a starting point the CAD model of a regular tibia will be loaded, model which was realized in previous researches.

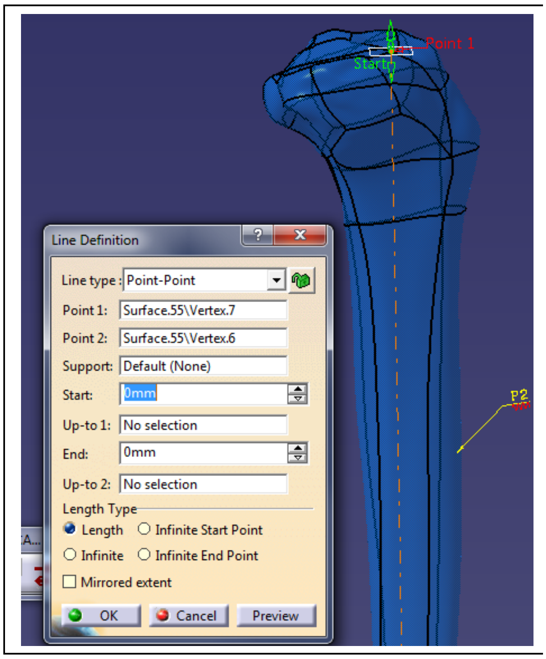

Fig. 2. Insertion of the mechanical axis of the tibia

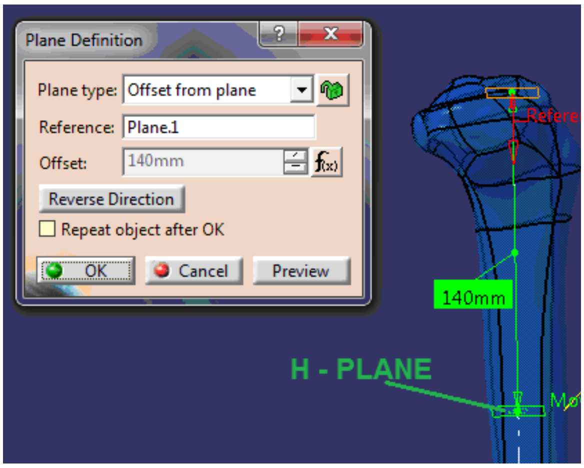

Fig. 3. Insertion of the CORA plane

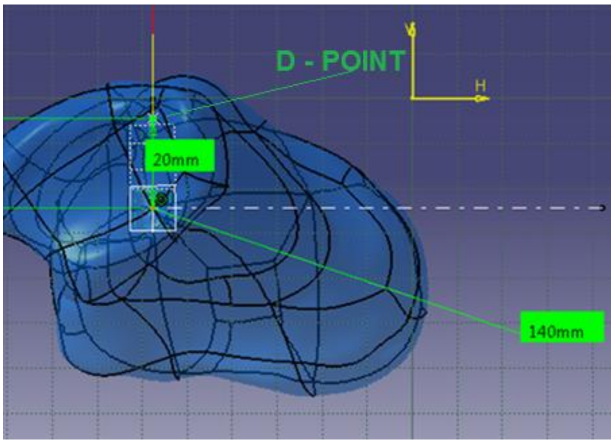

Fig. 4. CORA determination

The mechanical axis of the tibia will be modeled by uniting the symmetry center of the contact area between the tibia and the foot's feet with the symmetry center of the tibial spine. Afterwards, we will create two planes which are perpendicular on the mechanical axis of the tibia and tangent to the articular surfaces of the knee's and ankle's articulation (Fig. 2.).

2. Insertion of the plane used for the vertical positioning of the CORA [4]. The next step is dedicated to the creation of an offset plane (Fig. 3.) towards the superior plane. The position of this plane represents actually the positioning of CORA in vertical plane.

The plane was named H because it expresses a height and because the fact that in the effective modeling it was put at 140 mm towards the plane in the superior part of the tibia (Fig. 3.).

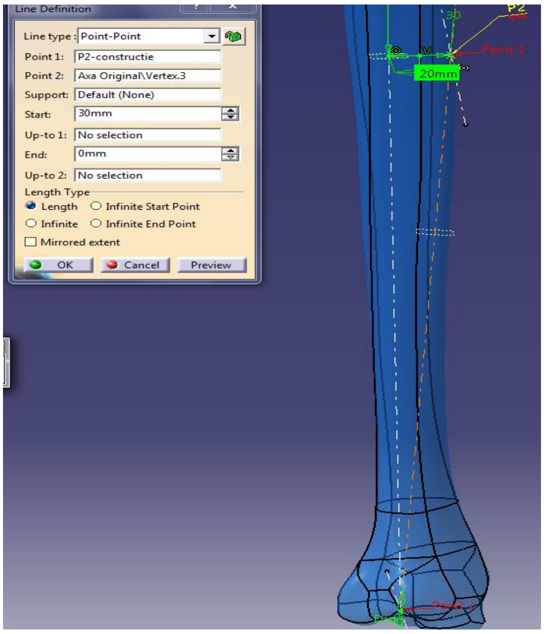

Fig. 5. Definition of the axis support - down

3. Positioning of the CORA in horizontal plane. The plane that we defined at the previous point will become a sketching planed used to determine CORA. As we can observe (Fig. 4.) CORA point can be inserted on the V

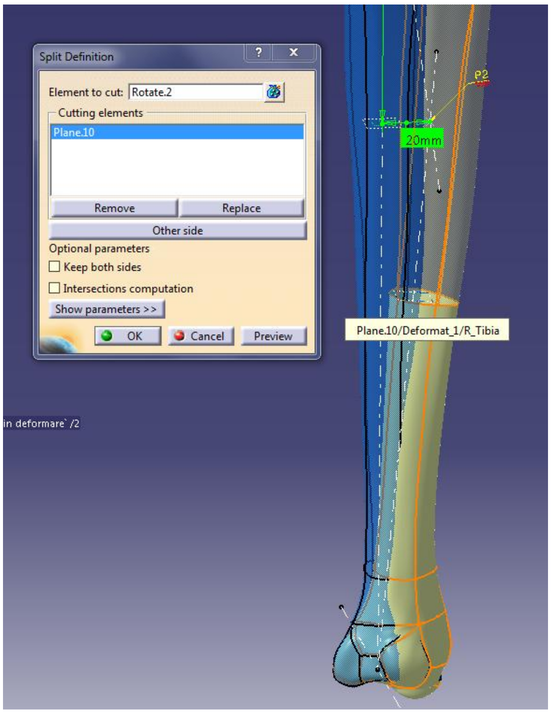

Fig. 6. Rotation of the distal surfaces

direction and afterwards we will have a deformation in sagittal plan or on the H direction resulting in a deformation on the frontal plane, or anywhere reported to the H and V axes, in this case resulting an oblique deformation. In this last case, the position of the CORA point reported to the origin of the axes system VH defines the position of the deformation plane(which will

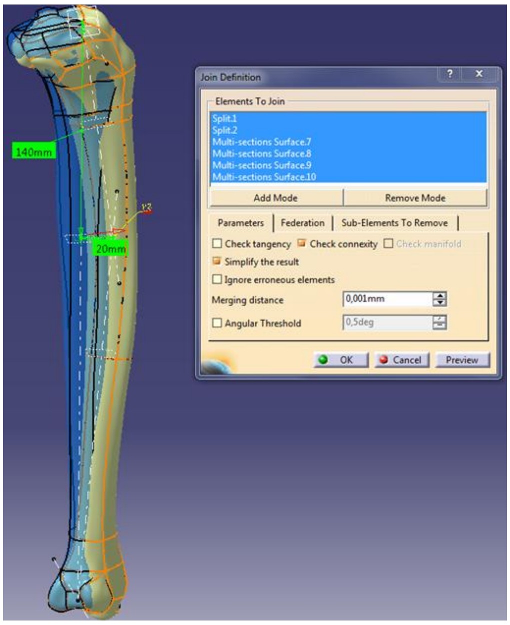

Fig. 7. Join of the surfaces – deformated tibia

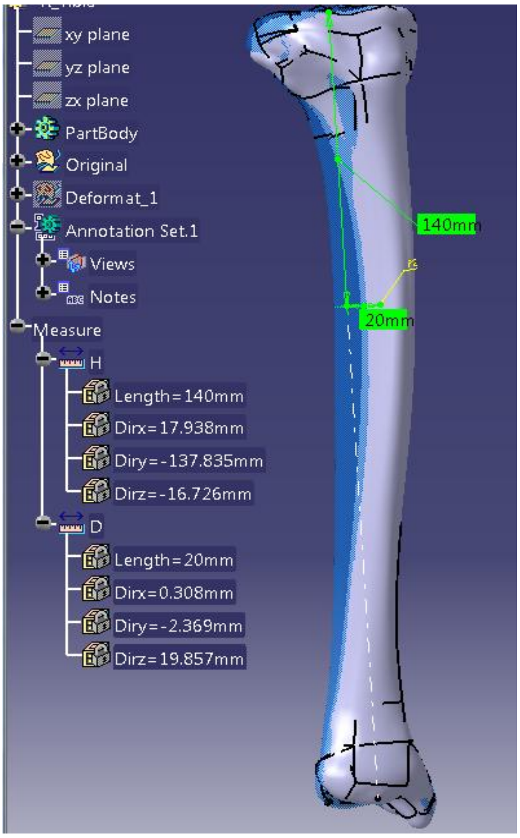

Fig. 8. Automatic modeling of the deformation in the sagital plan

be an oblique one) and the deformation direction(from origin towards the CORA point), parameters used for the characterization of these deformations [5]. In the proposed modeling it was chosen a point situated at 20mm towards the V directions. The amplitude of the deformation will result on the assembled model of the lower member, being a parameter defined in report to the center of the knee's articulation and perpendicular of the mechanical axis (Fig. 1.). In this moment were defined

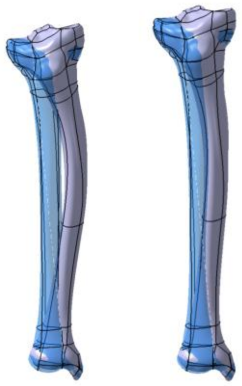

Fig. 9. Examples of the different deformations of the tibia

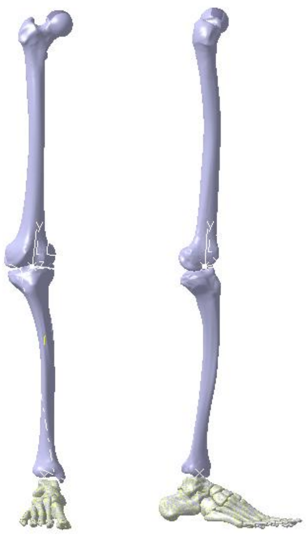

Fig. 10. Ensemble – deformated tibia and healthy femur

all the parameters that define the deformation and we can move on to the effective modelation.

4. Building of the broken tibial axis [6], [7] for the deformed tibia. In order to model the broken axis, we will create two axis that will have as starting point the points situated on the mechanical axis and in the articular horizontal planes (previously defined) and as end point, the CORA point previously defined. These two axes will be the support elements for the deformed tibia. Also, two lines perpendicular on the aforementioned axis, lines which will be the "rotation axis" for the movement of the surfaces from the right tibia to the deformed tibia (Fig. 5.). In figure it is presented the procedure used to define the support axis from the lower part of the tibia.

5. Creating the solid of the deformed tibia. For this, the surfaces on the initial axis will be rotated on the axes that were created at step number 4. The rotation will be made using the Rotate command in CATIA V5R20. The procedure will be executed both for the proximal and for the distal tibia (Fig. 6.). In figure it is presented the ration of the surfaces corresponding the distal tibia, and afterwards for the removal of the surfaces that cross the intersection area between surfaces the cutting of the tibia will be realised by using the Split command. The final connection (Fig. 7.) of the surfaces will be made by using the Join command.

In order to ensure that the presented application has a high degree of generality, we have also realized a parameterization of the model. This allowed us to create connections between the databases that contain parameters and also allowed us to connect the parameters through mathematic formulas. The parameters that were defined are: H plan, (Fig. 3.) which, as we have previously observed in the modeling phase practically defines the vertical position (on height) in which the deformation will be realized and the D point, (Fig. 4.) which determines the CORA's final position. This were defined in the specialized CATIA tab, which can be accessed the f(x) function and the parameters that were defined in this manner can be loaded in Excel or other databases and can be connected using mathematic relations. Different particularized models of the deformed tibias can be realized using different values for the parameters. In order to exemplify we have modeled a deformation in sagital plane at a distance of 140 mm from the knee's articulation (Fig. 8.). Also, we modeled two tibias in which the deformation occurs in a frontal plan (Fig. 9.).

The tibias modeled according to the aforementioned methodology can also be assembled on a healthy femur, (Fig. 10.).

III. Conclusion

We consider that the originality of the article stems from the modeling technique and from the possibility to customize, through parameterization, in accordance to the parameters that are characteristic to this type of deviation. The possibility of a virtual simulation of the correction surgery on the modeled sick tibia is also of great importance.

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