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BIOMECHANIC OF THE OPENING TIBIAL OSTEOTOMY

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Abstract—In the present paper we present the biomechanic of the opening osteotomy as a method to correct axial deviations which resulted from usages in the articulation. A parameterized modeling of the surgery is realized, model that allows us, by modifying the parameters, to define the situations that can occur, situations characterized by different: correction angles, positions of the hinge point or the CORA point, positions of the point in which the cutting plane is initiated, diameters of the depressuring hole, the width of the razor used for the surgery, the position of the second cutting plane at the biplane osteotomy. So as these parameters are easy to control(even by persons who are not specialized in assisted modeling) initially it was created a system of points, axes and reference planes that allow to parameterized the model, offering large possibilities of customization of the uniplane opening tibial osteotomy and biplane opening osteotomy.

Keywords—CAD modeling, CORA, gonartrosys, HTO – high tibial osteotomy, orthopedic surgery.

I. INTRODUCTION

THE 3D computerized modeling of the human anatomical structures is an important problem that must be taken in consideration for the correctitude of the simulation of the surgery procedures. The presented article is an original contribution regarding the parameterized modeling of the high tybial osteotomy("HTO") such as a method to correct axial deviations of the human lower member [1], [2].

The sources of these deviations are the gonartrosys owed to the usage of the knee's cartilages or owed to some diseases (such as the Blount disease) and the vicious consolidated fractures. In this article will be approach the first situation (gonartrosys).

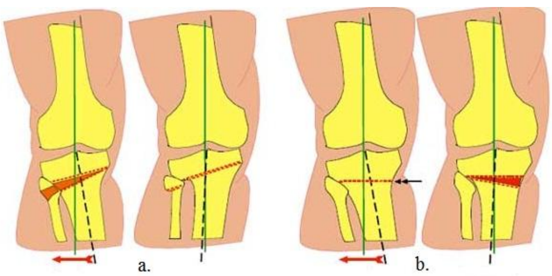

Fig. 1. High tibial osteotomy (a – closing, b – opening)

A usage of the cartilages occurs in general in the medial compartment of the knee [3]. The consequence is that the mechanical axis of the lower member does not intersect the center of the knee (the right path) deviates to the damaged area where the solicitations will be higher. In order to bring the anatomical tibia on the right path it is necessary to realize a cut and it is necessary to have a rotation movement of the tibia (with an α degree) around a point which is named the center of rotation angulation ("CORA"). CORA is established through geometrical considerations.

The afore described situations can be treated in surgery through the so named high tibial osteotomy which can be one of a closing or of an opening (Fig. 1.).

For the closing osteotomy (Fig. 1.a.) the cuts are made, the bony wedge that results being removed, and the bony fragments being realigned by closing the wedge. In the case of an opening only one cut is made, the fragments are realigned, resulting in an empty space by opening the wedge (Fig. 1.b.).

In surgical practice the opening high tibial osteothomy is most usual and from this reason I achieved the 3D CAD parameterized modeling.

II. GEOMETRICAL ELEMENTS THAT ARE NECESSARY FOR THE PLANNING OF THE INTERVENTION

For the correctitude of the modeling what we considered important is the prominence of some geometrical elements which control both the planning of the intervention and the 3D modelling. The most used geometric planning method of the intervention is well known in literature under the name of Miniaci Method.

The steps of this method are:

1) The mechanical axis of the lower member is drawn (Fig. 2.) by merging the center of the femur's top with the center of the ankle. We observe that this axis does not cross the middle of the knee and it is closer to the medial zone of the knee, aspect which needs to be corrected.

2) An axis is drawn (Fig. 2.). This axis starts from the center of the femur top and it tracks through the articulation of the knee. (Fujisawa Point).

3) The establishment of the hinge point B (Fig. 2.) is made relatively close to the border of the tibia so that the angular rotation is realized, but while assuring that the *bone cracks as little as possible. The minimal distance is 1,5 (cm) from the articular plan. From the bone's lateral it is recommended to leave a distance of 5-10 (mm).*

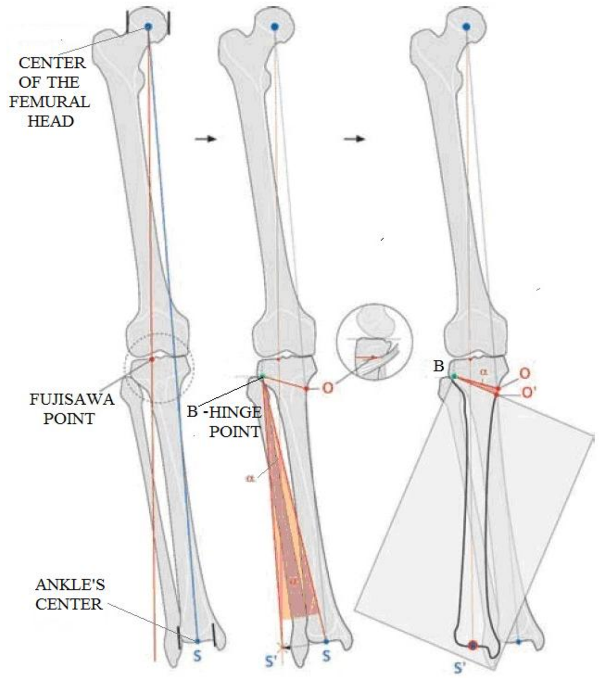

Fig. 2. Miniaci Method

4) The establishment of the second point O (Fig. 2) situated on the cortical that is opposed to the B point. The BO line determined in this manner will be the trace of the cutting plane in frontal plane. The placement of the O point is constrained by reasons of positioning the fixing plate (in particular Tomofix) which imposes a distance of minimum 30 mm from the articulation surface and from the placement of the point where the collateral tendon is inserted.

5) For the determination of the rotation angle α a line is drawn from the B point to the S point (the center of the knee's articulation). A circle's arch is drawn with the center in the B point of BS radius from the S point until it intersects the line which was drawn at the second step. By doing this, the S' point results. The α angle, between BS and BS' line is the adjustment angle and the line which affixes the center of the femoral top and the S' point is the corrected revised new mechanical axis.

6) *To effectively achieve the adjustment, a rotation of BO around the same point hinge B with the α angle until reaching OB' has to be done.*

The presentation of the algorithm mentioned above highlights a part of the geometrical parameters which are important for achieving the intervention. These are: the adjustment angle, the placement of the hinge point or CORA (B point in Fig. 2), the placement of the starting point of the cutting plane (O point in Fig.2).

Other parameters which can be studied (irrespective of the geometrical planning of the adjustment) are: the diameter of the relieving stress hole realized in B point (Fig. 2), the width of the blade that is used in the cutting process, the placement of the second cutting plane at the biplane osteotomy.

So that these parameters are easy to control (even by the laymen in aided modeling) we propose a parameterized modeling, with wide possibilities of customization, of the tibia opening osteotomy both uniplane and biplane osteotomy.

III. THE PARAMETERIZED MODELING OF THE TIBIA OPENING OSTEOTOMY

In order to achieve a parameterized modeling [4], [5] which, only by modifying the parameters on the model , creates all the situations which are about to be the focus of the research, the creation of a complex system of points and planes, according to which the parameterization will be realized, has to be done. Further, we will follow all the steps of the surgery [6], [7], starting from 3D model of the tibia which we have at our disposal.

1) The creation of the sagittal plane of the tibia. To materialize this plane, a parallel line with the sagittal plane of the human body is created. This line crosses the middle of the tibia line and through this a plane is being constructed (Plane 1). The plane forms an 90^o angle

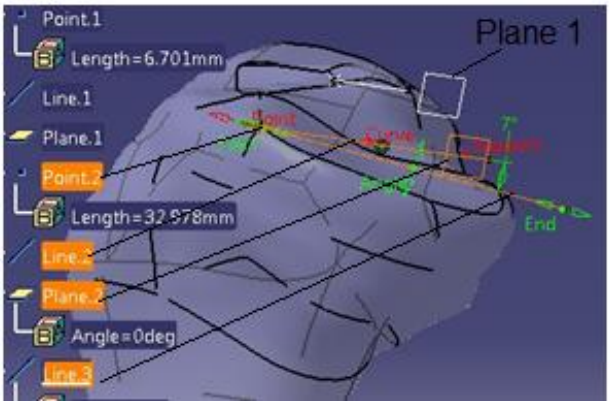

Fig. 3. Tibial plateau inclination

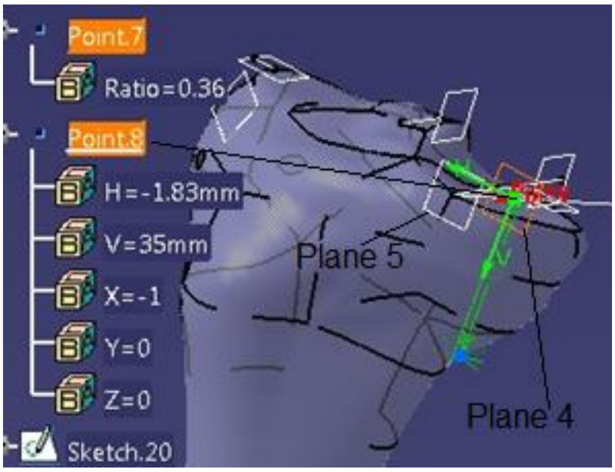

Fig. 4 . Cuting entry point

with the horizontal plane(Fig. 3)

2) The prominence of the posterior tilt of the tibia planes. In order to highlight the posterior tilt with a 7^o angle of

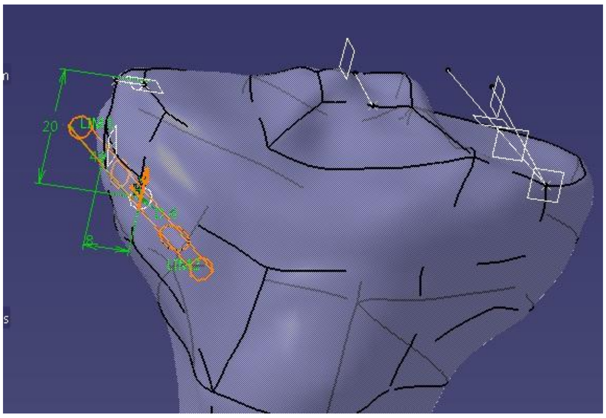

Fig. 5 . Relieving stress hole

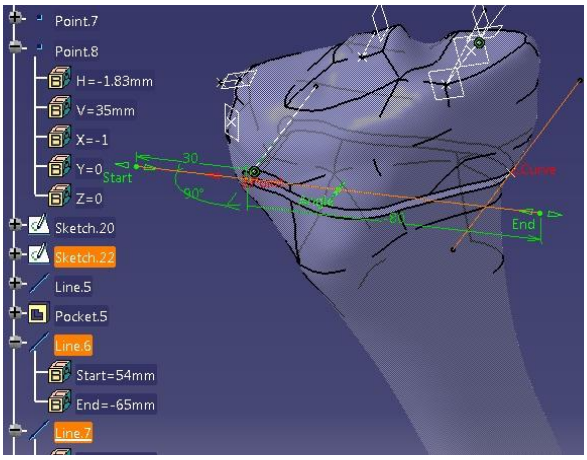

Fig. 6 The cutting for the uniplanar ostheotomy

the tibial planes, Point 2 has to be defined on the tibial plane, in the center and boundary to the intersection with the anterior surface of the tibia (Fig. 3.). Through this point Line2 will be defined as parallel to the one defined at the previous step. Through this line a Plane 2, rotated with 0^o (parallel) towards Plane 1, and in his plane Line 3 at 7^o towards Line 2 (Fig. 3.).

3) Defining the cutting entry point. This point is extremely important because it defines the place from where the osteotomy cutting is initiated from medial to the lateral side. This point will be an important parameter in my research. Consequently, it has to be modeled so that it will be easily controlled.For the modeling 2 planes, perpendicular on the inclination line of the tibia plane, are constructed: Plane 5 through Point 2 and Plane 4 through a point situated on Line 3 at half the previous posterior distance of the tibia (Fig. 4). In this plane (Plane 4) it is defined the starting point of the cutting (Point 8) which is situated on the medial cortical of the tibia and at a controllable distance (35 mm in the figure) towards the tibia plane (Fig. 4.).

4) The execution of the relieving stress hole in the hinge (CORA). The next step consists in the making of a hole which has a double role: eliminating the stress concentrators from the bottom of the osteotomy wedge and limiting the lateral cutting plan. For this 2 planes had been constructed (Fig. 5.): one-vertically tangent to the lateral surface of the tibia and one –tangent to the tibia plane. Towards these 2 planes a sketch necessary for the making of the hole was realized. The two scales related to the planes above define the position of the hole. It is worth mentioning that the hole is not horizontal but parallel to the tibia planes. This method of modeling, apparently more complicated, was also created with the purpose of offering the model a high degree of generality [1].

5) The execution of the cutting-the main plane. For the modeling of the cutting it has been considered (as for the depressuring hole) Plane 4 as scketcher plane. In this sketch (Fig. 6.) a line which connects Point 8 with the center of the relieving stress hole is drawn (as a helpful construction). This line is a theoretical trace of the cutting plane on the frontal plane. Because of the sectioning, which is made with a thickness defined blade, the modeling allows the parameterization of the blade's thickness. Subsequently, the Pocket is realized on a covering distance (Fig. 6.). At this moment, the tibia is cut and prepared for the uniplane osteotomy. The modeling will also continue for the execution of the second cutting plan used at biplane osteotomies.

6) Defining the reference elements for the biplane osteotomy. The following reference elements were defined: the point situated at the intersection of the relieving stress hole axes with the anterior surface of the tibia, a line parallel with the axis of the CORA hole that goes through the entry point of the first cut (Point 8), a line (line 6) perpendicular on the two lines that go through the point which was constructed at the extremity of the relieving stress hole (Fig. 6.).

7) Execution of the cutting on the main osteotomy plane in the biplane osteotomy. The pocket for the main osteotomy plane in this case won't be made from one side to the other, but it will be modeled in accordance to the sketch in Fig. 7. In order to make the sketch, initially,

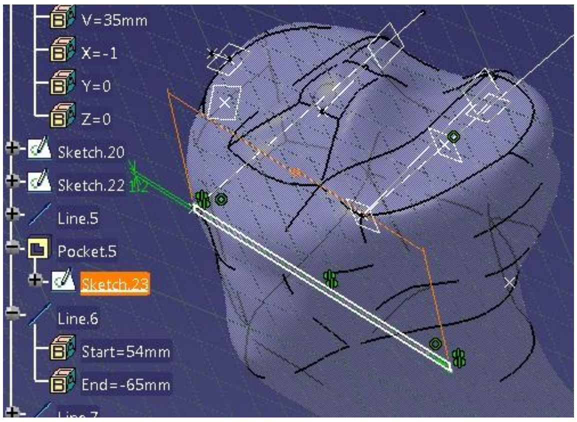

Fig. 7 The sketch of the cutting on the main osteotomy plane in the biplane osteotomy

we created a perpendicular plane on the relieving stress

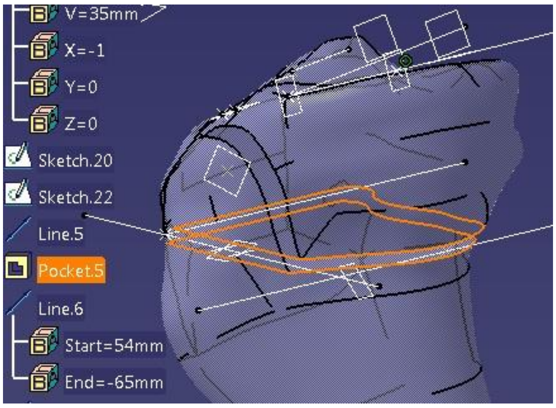

Fig. 8 The cutting for the biplanar osteotomy

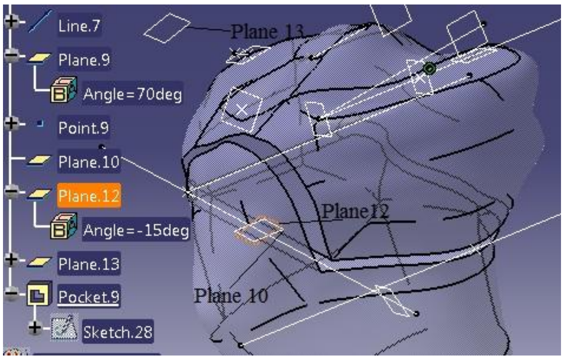

Fig. 9. Control planes for the second cutting

hole axis, which we placed at its extremity. The pocket was generated in this plane from the posterior of the tibia (Fig. 8.).

8) Execution of the cutting for the second osteotomy plane in the biplane osteotomy. The second plane of the biplane osteotomy will also go through Line 6, line which we have previously defined, and the cutting will start to ascend from this line. For the parameterized control of this cutting we build the following planes: Plane 10 - the plane of the first cutting (the main one), plane 12-which goes through line 6 and forms with Plane 10 a 15 degrees angle, an important parameter for our research and Plane 13-a plane offset with Plane 12, at a covering distance (Fig. 9.). In this last plane the sketch will be

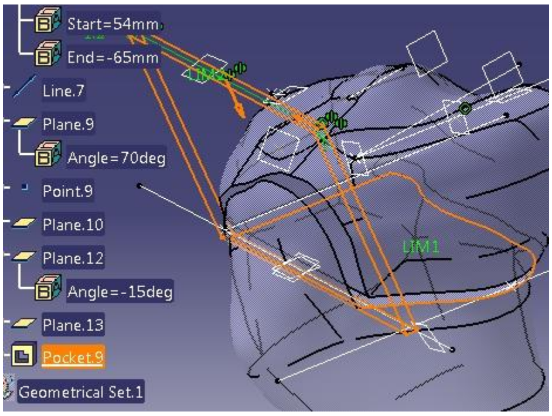

Fig. 10. The cuttings for the biplanar osteotomy

realized, in the form of a rectangle with a parameterized width. The pocket (Fig. 10.) will be generated from this plane and towards to the surface of the other cutting.

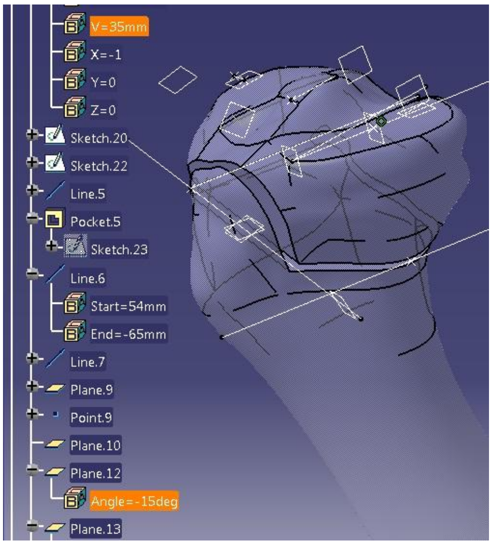

Fig. 11 Customize the model. The values of the parameters: V1 – 30 mm, V2 – 105^o

The 3D generalized model allows us to obtain a multitude of cutting possibilities only by modifying the presented parameters in the tree structure of the model. In the example from Fig. 11. are presented the following parameters(parameters which are highlighted and can be modified):V1-entry point of the cutting on the medial cortical and V2-angular position of the second cutting plane towards the first.

In this way we can realize any configuration and we can easily prepare the geometric structures in order to undergo the analyses through the finite element method.

IV. CONCLUSION

The created model was designed so as it will present a high degree of flexibility and so as to ensure that, only by modifying parameters, a large variety of particularized models will result.

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