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THREE-DIMENSIONAL MODEL OF A HIP PROSTHESIS

Abstract: *Serious pathological problems of the hip joint can be solved surgically, in some cases by joint prosthesis. For this reason, it is very important to be able to shape, in a first phase, the components of the prosthesis, which can then be tested virtually. For this purpose, the components of the prosthesis with fixation pins were firstly scanned three-dimensionally. This operation resulted in a model of a "cloud of points" which was subsequently transformed into virtual surfaces, then into virtual solids. These virtually solid components were assembled in a parameterized virtual environment. This prosthesis can be inserted into a biomechanical model of the hip joint and tested using the finite element method. At the end of the paper important conclusions were drawn.*

Key words: *Virtual hip, hip prosthesis, CAD methods, virtual arthoplasty, virtual bones.*

1. INTRODUCTION

Hip disorders requiring prosthesis show a change in joint morphology. Among the most common diseases in medical practice that have as final therapeutic solution as hip arthroplasty: coxarthrosis primary and secondary, followed by traumatic conditions: femoral fracture and femoral neck pseudarthrosis, aseptic femoral head necrosis stage III as well as rheumatic coxitis from rheumatoid arthritis, ankylosing spondylitis or juvenile art [1], [2], [3].

The main symptoms of these diseases that indicate arthroplasty are: pain at first it has a mechanical character after which progressively becomes disability limiting the possibility for the individual to move and at the same time restrain his circle of social activity.

Endoprosthetic arthroplasty can be defined as an intervention of reconstructive surgery with bone sacrifice and prosthetic replacement of the articular components [1], [4], [5].

It is, in the end, an operation aimed at restoring joint mobility and normal functioning of the muscles, ligaments and other periarticular structures that control joint movement [2], [5], [6].

Therefore, the prosthetic implant can be defined as "a permanent device to be used in surgical implantation technique with the aim of eliminating pain and improving hip joint functionality by restoring the geometry and support quality of the articular interface" [3], [7], [8].

Prosthetic hip surgery should always be the result of a clinical decision taken jointly by both the surgeon and the patient when there is an advanced hip dysfunction that justifies this radical technique as a therapeutic way of choice.

The purpose of endoprosthetic arthroplasty is simple: alleviating the patient's suffering through the disappearance of pain, recovering mobility and joint stability, correcting existing deformities.

The effectiveness of partial or total arthroplasty depends on [4], [9], [10]: the quality of articular and mechanical reconstruction of the artificial joint; integrity and biomechanical balance of periarticular muscles.

Two elements [5], [6], [11] are indispensable to achieve this dual purpose: a joint access path that best retains the muscles and is capable of restoring articular balance and adequate prosthesis.

For the reasons outlined above it is very important to obtain the virtual models of the components of the various hip prostheses because they can be used in various virtual simulations and analyzes.

2. HIP PROSTHESIS MODEL WITH FIXING PINS

To obtain the denture pin model (Fig. 1), three-dimensional scanning methods and direct measurement were used.

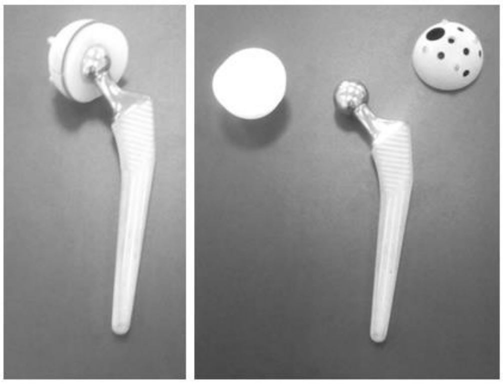

Fig. 1 Hip prosthesis with fixation pins.

This hip prosthesis model consists of the following elements:
- a metallic acetabular element with iliac bone fixation pins.
- a femoral stem that has hydroxyapatite coatings;
- a spherical metallic element;
- a high density polyethylene element.

To capture the geometric details of classic hip prostheses, a 3D Geomagic Capture scanner produced by 3D Systems (Fig. 2) having the following technical features [8] was used:

• Dimensions 287 x 49 x 81 mm;

• Data Capture Rate: 985,000 points / scan (approximately 0.3 sec scan time);
• Resolution: 0.08 mm;
• Accuracy: 0.060 mm to 300 mm; 0.118 mm to 480 mm;
• Stand-off distance: 300 mm;
• Depth of Field: 180 mm;
• Field of View: 124 x 120 mm (Approach);
• Field of View: 192 x 175 mm (distance);
• Compatible with Geomagic for SolidWorks [7], [11], [12], [13].

Fig. 2 3D Geomagic Capture scanner.

To obtain the geometry of the prosthesis components, the 3D scanner and its scanning program have a user interface in the SolidWorks CAD software (Fig. 3).

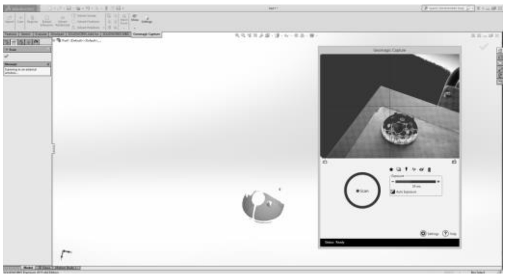

Fig. 3 Geomagic for SolidWorks Scanning Interface.

Obtaining the final geometry of the metal cup with fixing pins requires several successive scans that overlap and align automatically [14], [15], [16], [17]. A first scan composed of a "point cloud" is shown in Fig. 4.

Fig. 4 The first scan of the metal cup.

The scan operation was repeated with the cup rotated successively about 5 degrees. Some of these repetitive scans, superimposed by automatic alignment, are shown in Fig. 5.

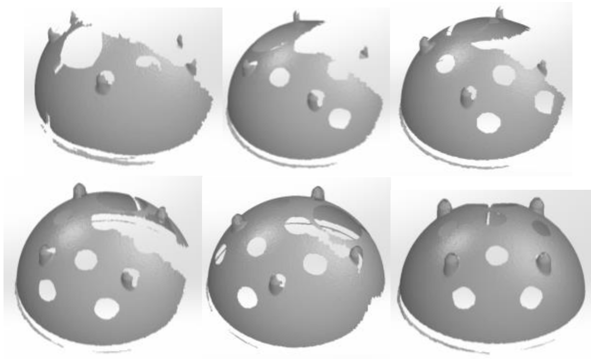

Fig. 5 Successive scans automatically aligned.

For the correct delimitation of the primary geometry, the basic plane of the acetabular component was identified and modelled (Fig. 6).

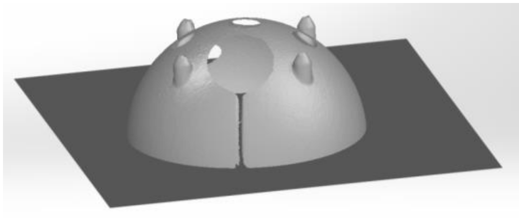

Fig. 6 Identify the base plan.

Using similar techniques, the fixing pins were identified modelled (Fig. 7).

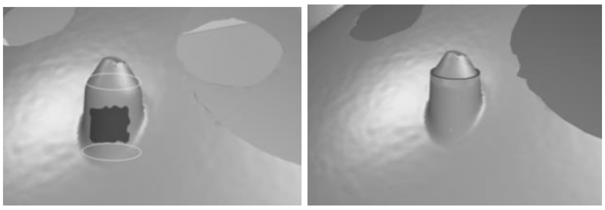

Fig. 7 Identification of the base cylinders of the fixing pins.

Similarly, the cones of the fixing pins were identified, but also their starting and ending planes (Fig. 8).

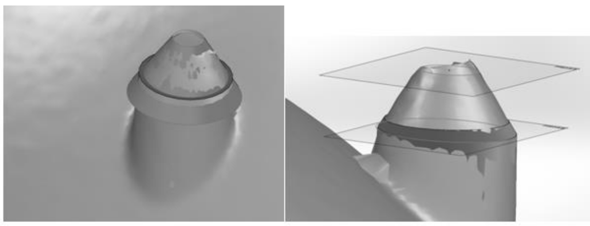

Fig. 8 Identification of the fixing pins.

Using the software techniques, the other geometric elements of the cup with fixing pins were determined, also using the internal scanning (Fig. 9).

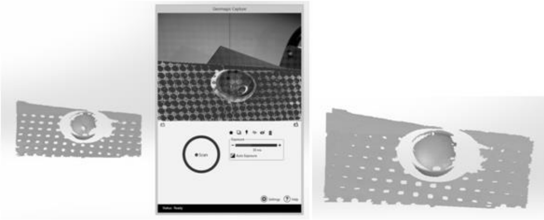

Fig. 9 Inside scan of cup with fixing pins.

For some shapes, the direct measurement technique was also used [14], [17]. Finally, using the CAD techniques, the parameterized virtual model of the pin with the fixing pins shown in Fig. 10 was obtained.

Fig. 10 The three-dimensional parameterized model of the cup with fixing pins.

In principle, the same scanning techniques used previously were used. Fig. 11 shows some steps and phases of this process, including identifying a freeform.

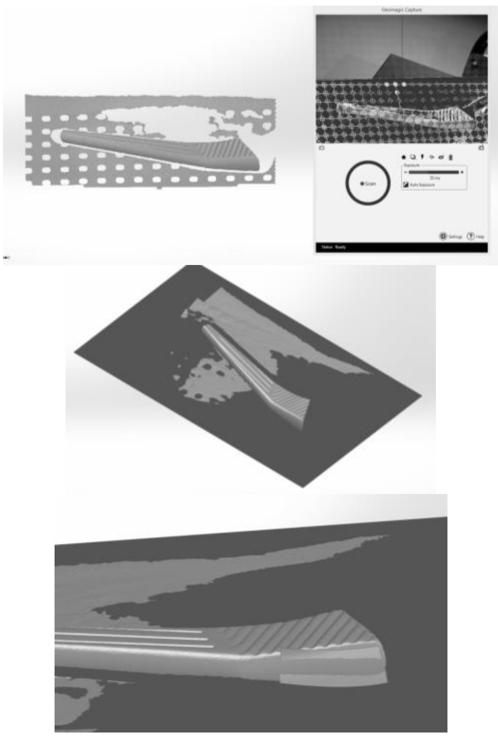

Fig. 11 Different stages of the scanning and identification process.

For some forms the direct measurement method was used. Finally, following the application of specific CAD procedures, the three-dimensional parameterized model of the stem shown in Fig. 12 was obtained.

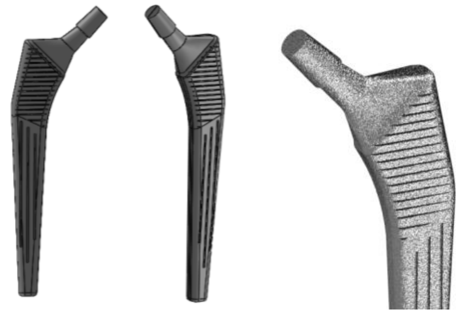

Fig. 12 The final stem model (two views and one detail).

Using the same CAD and scanning techniques and methods, the polyethylene cup model shown in Fig. 13 was obtained.

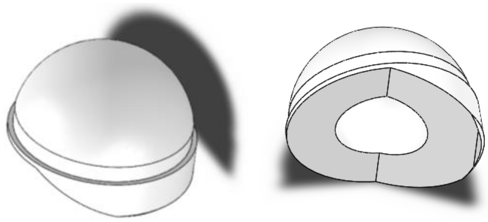

Fig. 13 The final model of the polyethylene cup (two views).

The spherical metallic element could not be scanned, being a very finished and glossy object, completely reflecting the laser ray of the scanner. For this component, the Direct Measurement Method was used and CAD-specific commands and techniques were applied [16], [17], [18]. The final model of this spherical metallic element is shown in Fig. 14.

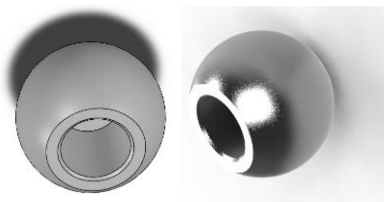

Fig. 14 The final model of the spherical metal element (different views and rendering).

Finally, after loading these models into the SolidWorks Assembly Module and applying the appropriate motion constraints, the final model of the fixation pin prosthesis shown in Fig. 15 was obtained.

Fig. 15 The final model of the prosthesis with fixing pins (different views, details and rendering).

3. CONCLUSIONS

Analyzing the methods, techniques and models obtained the following conclusions were drawn:

- The prosthesis components are parameterized, so they can be adapted to different anatomical dimensions;
- These models can be used in various tests and virtual experiments;
- By applying this prosthesis model to some bone virtual components, "in vitro" analyzes can be obtained.

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