PVA MENISCUS DEVELOPMENT BY RAPID PROTOTYPING (RP)

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Abstract . *The recovery of the human meniscus, has been hard work for scientists since the beginning. For injuries from traffic accidents or accidents in sports, it has been most commonly performed meniscectomy for meniscal injuries of the knee. Meniscectomizeds patients have had joint degeneration as reported many clinical reports. Depending on the severity of the case, however, meniscectomy can not be avoided. Therefore, in such cases the replacement of the meniscus becomes necessary for the reconstruction of normal functions. This work aims to study to obtain artificial meniscus using polyvinyl alcohol hydrogel (PVAl), a biocompatible polymer, non-absorbable with good mechanical properties and swelling capacity, which favors its role to replace the meniscus injureds. Moreover, viscoelastic properties similar to human soft tissue can be obtained from the production process of the gel by adjusting the water content. There are many studies on the different biomechanical characteristics of human meniscus. The methodology has the following sequence: images with computed tomography was used for equipment and materials of rapid prototyping (RP) and it was made molds meniscus polyamide, which were bottling with solution PVAl after drying, we obtained the meniscus.*

Keywords*: PVA, Rapid Prototyping, Hydrogel*

1.INTRODUCTION:

Given the purpose of creating something simple and accessible to every citizen, regarding the recovery of the meniscus, this study sought to develop an artificial meniscus, through the use of a polymer, the polyvinyl alcohol (PVOH or PVAl), a polymer relatively inexpensive, which is produced in greater volume in the world for being relatively easy to obtain and a huge range of applications both in the industrial, commercial and medicine, Rosiak et al (1995) and rapid prototyping (RP), also known by names of freeform fabrication (FFF), additive manufacturing, and automated manufacturing, among others, is a set of technologies used to produce three-dimensional physical objects with highly complex geometries based on drawings of three-dimensional CAD (Computer Aided Manufacturing). Are similar to other methods that add and link layers of materials in order to obtain physical objects and highly complex geometries. PR binds and connects liquid and / or powder layers in order to form pieces; manufactures plastic objects, wood, ceramics and metals. Pham, (2001) and Chua (2003). The Fig.1 shows the sequence of the prototyping process of a skull.

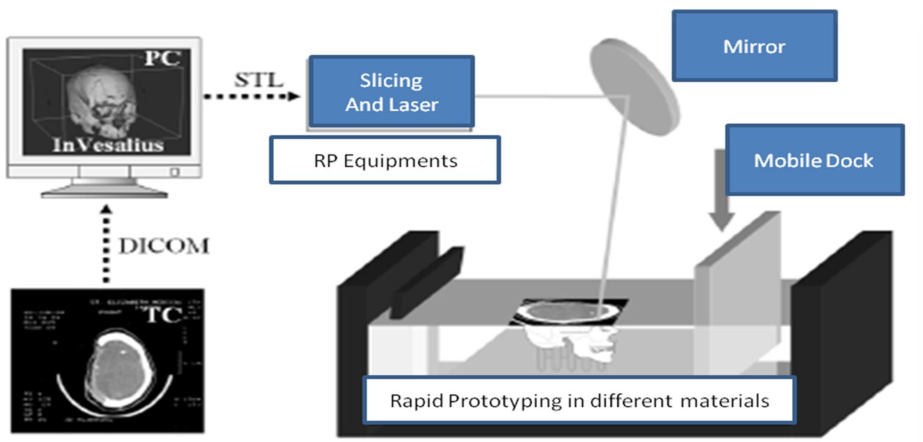

Figure 1 - Stages of the manufacturing process by biomodels layers (Meurer 2003)

The production of a prototype can be classified as: subtractive (objects are formed by subtraction of material), additive (objects are formed by joining particles or layers from the raw material in the raw state) and compressive (objects are obtained by compressing material semi-solid or liquid to a desired shape, which is induced to solidify or harden). RP in medicine has been of great advantage because, in general, the materials used for this purpose have low specific heat, requiring no warm high. Once in PR, most techniques require heating the material, it is advantageous when the material does not need to be heated. The materials used in PR are not biocompatible, however, tissue engineering has developed in recent years. For cell growth in general is need of support matrices, also called scaffolds. Today we use the Policaprolactama (PCL), a bioreabsorbable polymer that has been the target of much interest for this purpose, Jacob (2000). Speed, accuracy, training of specialists and the cost has been some of the problems encountered in the molds for the RP. Some solutions are being developed in order to provide the best product possible. Despite the name no technique is rapid and can lead to hours of taking days to create a single prototype complex but become faster as compared to conventional machining processes, forming, casting and more. For this laser could be used more and more appropriate materials for the manufacture of prototypes. The accuracy of the objects obtained via PR is not, in some cases, as important, but in other cases it may be a critical issue. The methods still need improvement to reach a level of tolerance lower. Grenda (2003). In order to expedite the exchange of medical images and information between hospitals, clinics and other users with radiology equipment and software, developed in the DICOM (Digital Imaging Communications in Medicine) file format since the 80s has been improved and now uses to DICOM 3.0. (Meurer, 2002). In the 1980, was developed by the industry's image, represented by the National Electrical Manufacturers Association (NEMA) (Standards, 2004) and the American College of Radiologists (ACR) (Castiglia, 2001) et al, the DICOM protocol. Plates were unique forms radiology examinations provided by the CTs, the Protocol regulates saidade data format, which all manufacturers of CT (Computed Tomography) should follow. This provided the medical image acquisition for the construction of virtual models and even physical, Sta.Barbara (2005). The InVesalius, In (in), Vesalius (Homage to the doctor Andreas Vesalius, "father of modern anatomy, born in Brussels on December 31, 1514) is a software for public health which aims to aid diagnosis and planning surgery. From images in two dimensions (2D) obtained from computed tomography or magnetic resonance imaging, the program lets you create virtual models in three dimensions (3D) corresponding to anatomical structures of patients under care. The software has demonstrated great versatility and has contributed to several areas among them medicine, dentistry, veterinary medicine, archeology and engineering. The program was developed by former CenPRA current CTI (Centre for Information Technology Renato Archer), a unit of the Ministry of Science and Technology (MCT), through the Python and C + +. Currently operates in GNU / Linux (Ubuntu, Fedora and OpenSuse have been tested) and Windows (XP and Vista), and is licensed under CC-GNU GPL (General Public License) version 2 (in Portuguese). Developed since July 2001 in the context of PROMED (Rapid Prototyping in Medicine), the program has been widely used by surgeons and hospitals in Brazil since 2004 (Smith, 2004). The main applications in the medical field for surgery maxillo-facial, are: a) program for image analysis, data preprocessing, normalization and filtering. b) programs for viewing images in computer graphics in 2D and 3D virtual modeling and visualization. c) Viewing files in Dicom. d) volume and surface interpolation and filtering contour. e) Export data in STL format, so that the 3D images, can be seen in CAD software and then be prototyped and generate models. The Rhinoceros is a CAD (Computer Aided Manufacturing) for three-dimensional design widely used for complex geometries. The Rhinoceros is certainly a program that presents the greatest diversity of features and commands. For this reason has been the choice of micro and small enterprises from various branches of activity, such as manufacturers of consumer products, footwear, architectural offices, headquarters, jewelry (in this case, more specifically, the Rhino Gold), shoes, among others. Nonetheless, their presence can also be seen in large corporations. Among its users are, for example: adidas-Group, Nike, Bombardier, Tiffany & Co, Boeing, Lego, Motorola, Pininfarina, Philips Design, Volkswagen, Porsche, Whirlpool Corp. and Yamaha Motors. In addition, a number of educational institutions worldwide have licenses to educational Rhino in their courses. The STL (Structured Triangular Language) is the default file being used as interface between the processes of rapid prototyping (Smith, 2004). It's technology that produces plastic parts that most resemble those produced by other processes. STL files - for the rapid prototyping industry. Being open and straightforward, STL won the preference of the other rapid prototyping systems that emerged after the stereolithography. The representation of "cellular" and another way of expressing a solid model. It originates from the analysis code which requires the description, so to speak, on the surface of the solid cells typically triangular, square or polygonal. The triangulation and the format used by most machines stereolithography, formatted files called STL. Interfaces CAD / CAM - Currently there are several CAD and CAM (Computer Aided Manufacturing). Some integrated and not others. Basically can be mentioned three types of CAD systems that dominate the sector mechanisms: 1) systems for solid modeling, 2) systems for modeling surfaces, and 3) hybrid systems (solid and surface). Modelers are more stable and solid geometries generated are valid physically. The modelers can generate free-form surfaces and complex. The CAM system for a rapid prototyping equipment is simpler than urn CAM system from other machines. The simplicity is because the tool has a unique geometry and hardly undergoes changes that need adjustment. Munhoz (1998). Poly (vinilalcool) - PVAl, fig. 2 - is a synthetic resin, water soluble, which is produced in greater volume in the world. Through the hydrolysis of poly (vinyl acetate), which is the way of obtaining commercial use to date, was obtained in 1924 by Herman and Haehnel the first time. The polymerization of vinyl acetate can generate three different structures PVAl estereoregulares: isotactic, atactic and Syndiotactic. The PVAl commercial shows a high degree of hydrolysis (up 98.5%) being formed by mixing different types estereoregulares shaped, predominantly, atactic. Their physical and chemical properties relate to their estereoregularidade which is a function of its method of production. The concentration of acetate groups present, or even of its degree of hydrolysis modify their chemical properties, solubility and crystallinity. (Pepper, 1987). The basic properties of polyvinyl alcohol also depend on the degree of polymerization and degree of hydrolysis. Due to its excellent properties, PVAl has been used in large number of industrial applications. It has good resistance to solvents, oils and greases, and its resistance to the passage of oxygen is higher than any known polymer, Marten (1985). Due to its excellent physical and chemical properties, the PVAl, is used in many medical applications, such as intraocular implants. The hydrogel PVAl was the first to be widely used for implants, and was the subject of intensive investigations .Used in chest implants, repairs of defects in the skull, nose, chin, cleft palate repair and how to film in the eardrum, Rosiak et al (1995).

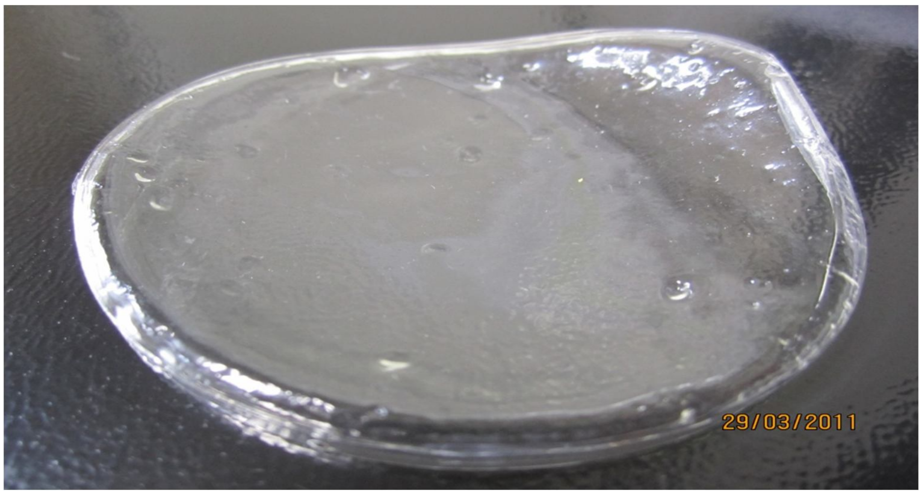

Figure 2 - Hydrogel of PVAl after being irradiated by γ radiation.

2. METHODOLOGY

The methodology for this paper is divided into five steps outlined below and Fig. 3 shows the sequence of tasks of this methodology.

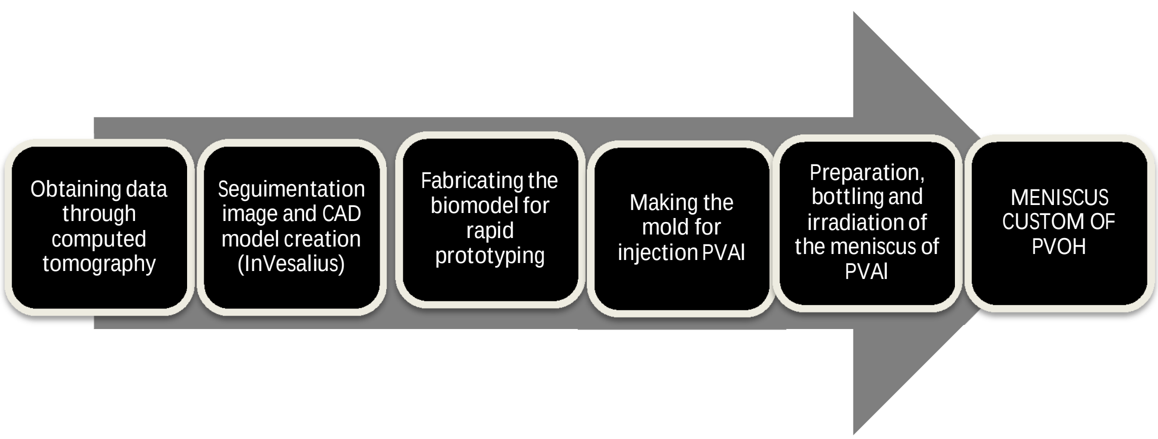

Figure 3 - Sequence of tasks, working methodology

2.1. Acquisition of computed tomography images

The CT images were obtained at the Clinics Hospital of Unicamp, the achievements of the department of informatics. The images are especially of the knees of patients, Fig.4. These images, in DICOM format files on it, we will transform the 3D format, using the program InVesalius.

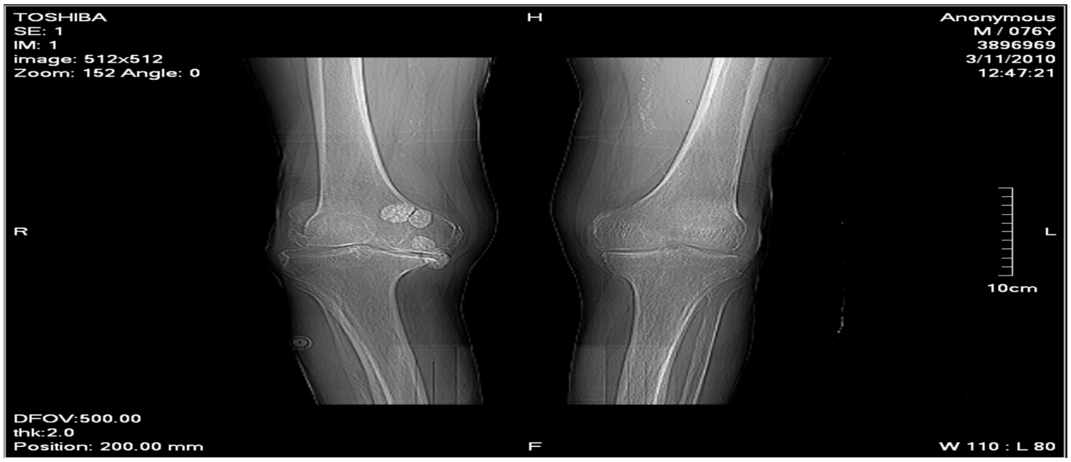

Figure 4 - image of the knee of a patient obtained via computed tomography, assigned by the UNICAMP Clinics Hospital.

2. 2. Segmentation of the images that led to the virtual models in 3D

The Fig.5 contains the sequence of the process which led to the virtual prototyping of the meniscus, we used the software Rhinoceros 4.0 to correct the imperfections commonly found on surfaces of the bone tissues of the 3D images, obtained by InVesalius (a). Lines are traced on the surface damaged to preserve the anatomic landmarks at the time of image reconstruction (b). New lines were drawn in order to create smoother surfaces than the first file (c). Mounted with the surfaces, we used the same procedures above to create a "the box" "box" (d). With models fermur and tibia, became the Boolean subtraction, leaving the surface exactly equals the bones. Done that created lines are in the box to make a contour closest to the meniscus, extracting the parts that were left of the box (e). The solid is formed which subsequently give rise to the meniscus (e). The image of the solid was again converted to STL format in order to be prototyped.

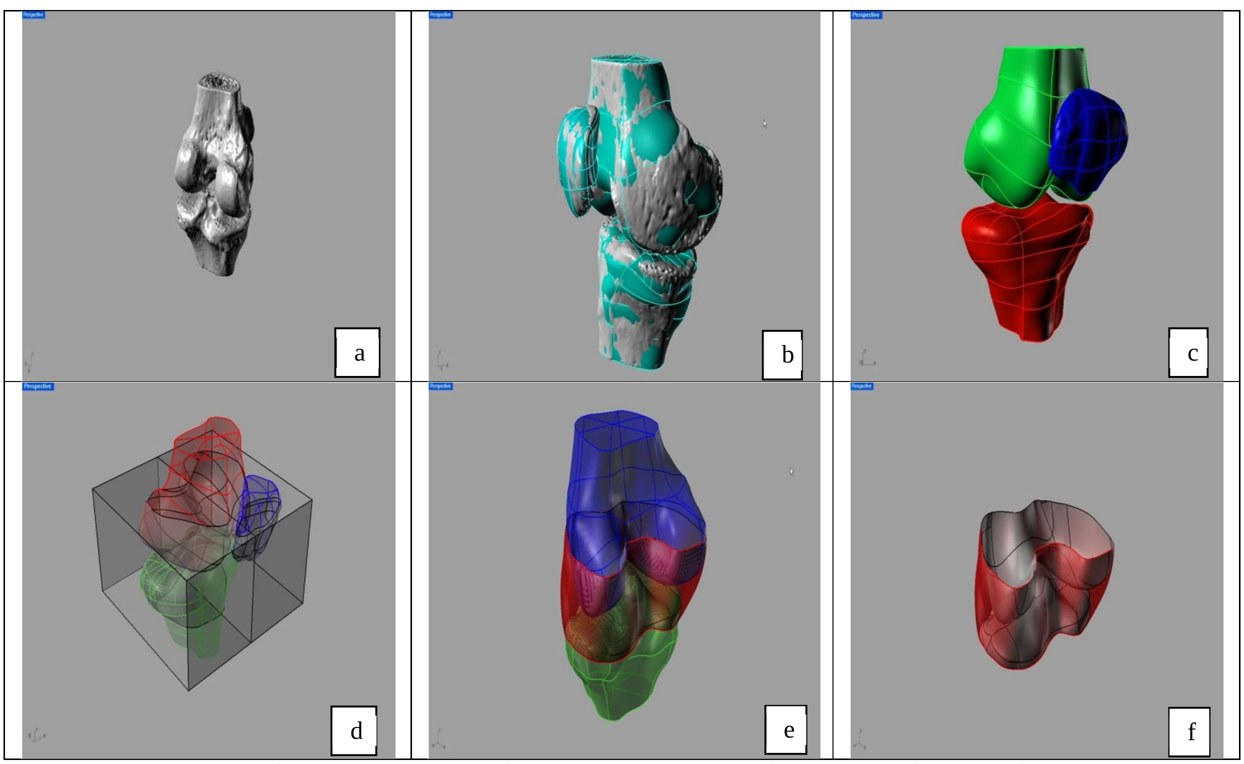

Figure 5: - CT imaging of the knee; b - image of the knee in the process of repairing surface imperfections made by the software Rhinoceros c - image prepared with the software Rhinoceros, d - box delimiting area of the meniscus (Rhinoceros) and - detail of the outline done in the area of the meniscus; f - virtual object ready for rapid prototyping.

2. 3. Making the mold for injection PVAl

The three-dimensional model of the meniscus, Fig.6c, used to operationalize the development of the mold was obtained by laser scanner manual self-positioning EXAscan, Fig.6b Creaform and produced by the system of prostheses Search Evolution Fig.6a. This equipment enables the playback of high resolution 3D models, because it works with a precision of 0.04 mm. The model in STL format generated from the scanning, had its triangle mesh edited to obtain a uniform surface and refined using the software Magics 15.0 Fig.6d developed by Matrialise, Belgium. The software also enabled the generation of molds for forming the material through a specific module developed by the manufacturer.

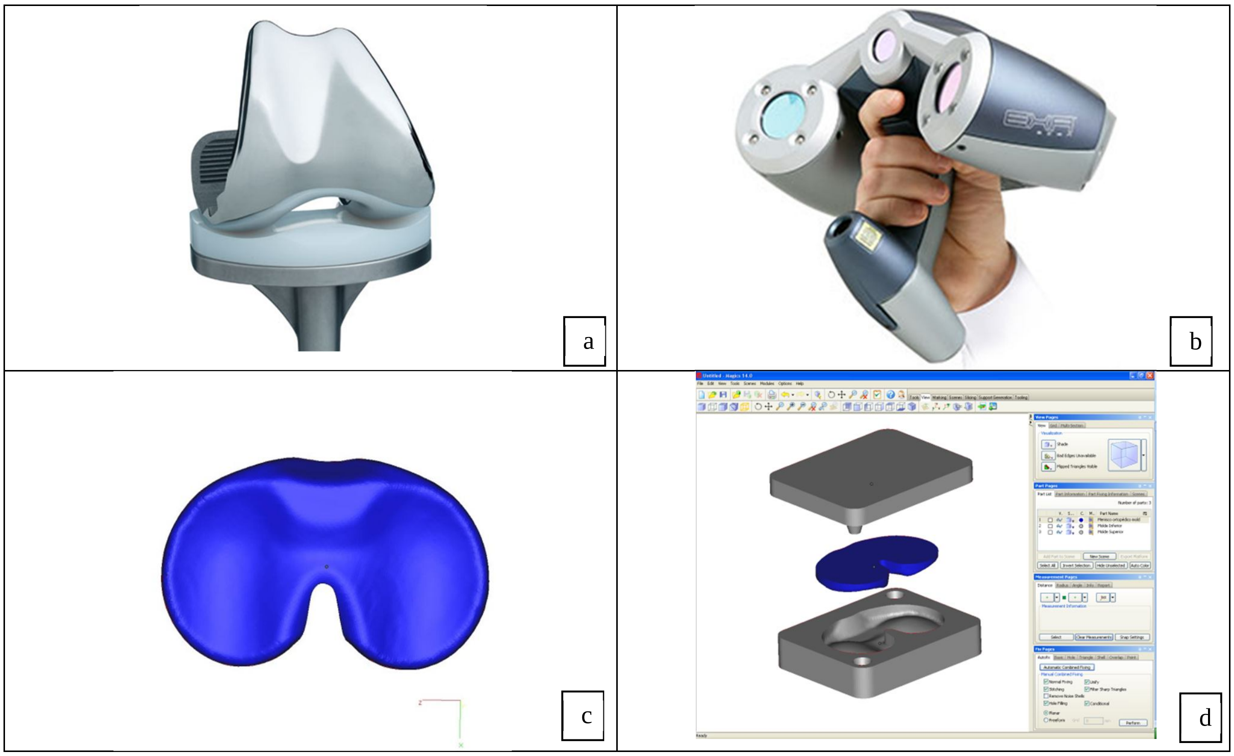

Figure 6: System - Search Evolution prostheses b – Portable scanner EXAscan c - top view of menisco3D d - Interface Magics 15.0 and molds.

2. 4. Fabricating the biomodel by rapid prototyping

For the fabrication of prototypes of the molds were used two additive manufacturing technologies and processes that work with different materials, seeking models with different porosities. The first technology used was a 3D Printer (Printer Tridimentional) model Spectrum 510 from Zcorp, Fig.7, which produces plaster models of high performance with accuracy of 0.4mm. The second technology was used (SLS Laser selectivity Sinterization) HiQ model of 3D Systems, Fig.8, which produces models through the sintering of polyamide with an accuracy of 0.2 mm.

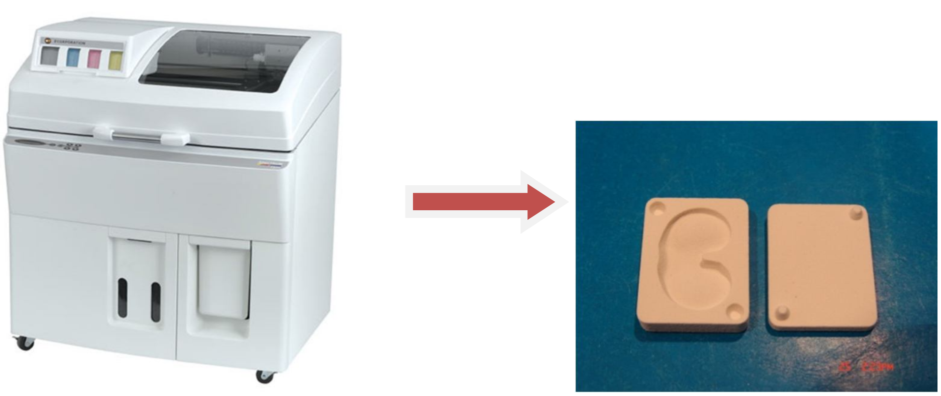

Figure 7 - Plaster mold powder produced 3D Printer Spectrum

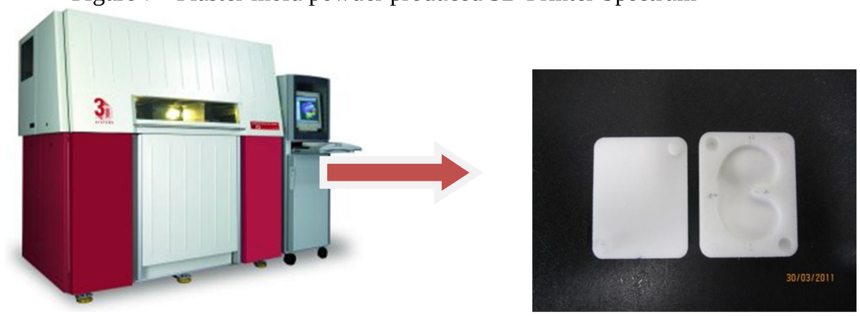

Figure 8 - Molde polyamide produced by SLS HiQ

2. 5.Preparation, bottling and irradiation for PVAl

To obtain the polymer devices as substitutes for meniscus was used PVAl (Aldrich Mw 89000 to 98000 g / mol, 99% hydrolyzed), the structural formula above, Fig.9, in the polymer concentration in solution of 20% (w / w). In a volumetric flask were added to the polymer previously weighed and distilled water in sufficient quantity to obtain the desired concentration. Solution was heated to 95ºC until the total homogenization. PVAl The solution was put in plaster cast and polyamide, already in the shape of the meniscus and left to dry for 24 hours under ventilation for evaporation of the solvent, as shown in Fig. 10.

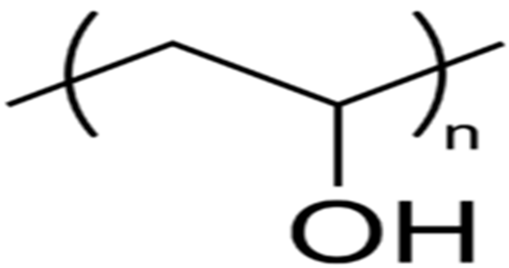

Figure 9 - structural formula of PVAl

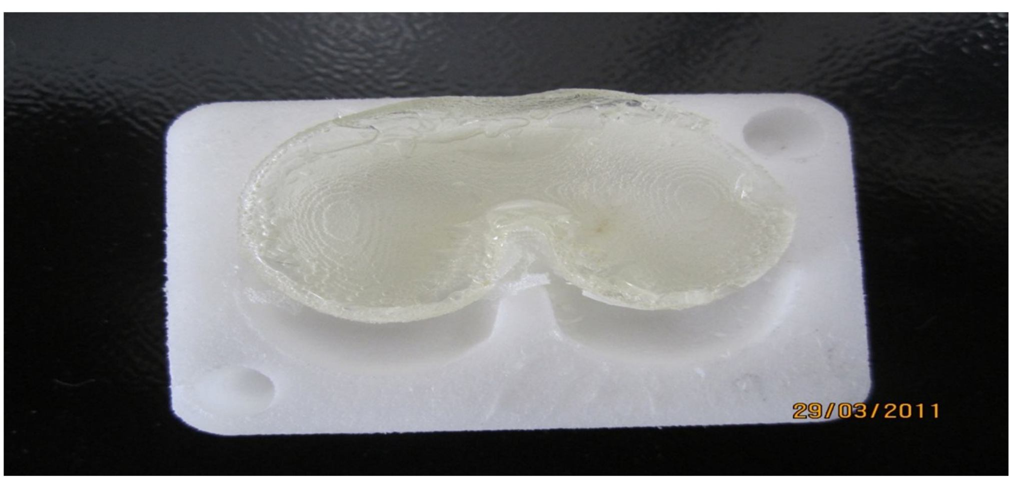

Figure 10 - PVAl placed in mold meniscus polyamide, after passing through the drying process.

3. RESULTS AND DISCUSSIONS

The PVAl solution obtained had small holes in its structure due to irradiation, but that did not harm the final result. Getting the mold and model for the production of the meniscus was possible through the PR equipment. It was found difficulty in Moldel through plaster casts, Fig.a, as small gipc particles were impregnated in PVAl, as shown in Fig.b already in the mold of polyamide, Fig. c, PVAl stayed with a well defined, however, showed air bubbles because they are the cover Fig.d. The problem was solved without drying up the cover to see Fig.10.

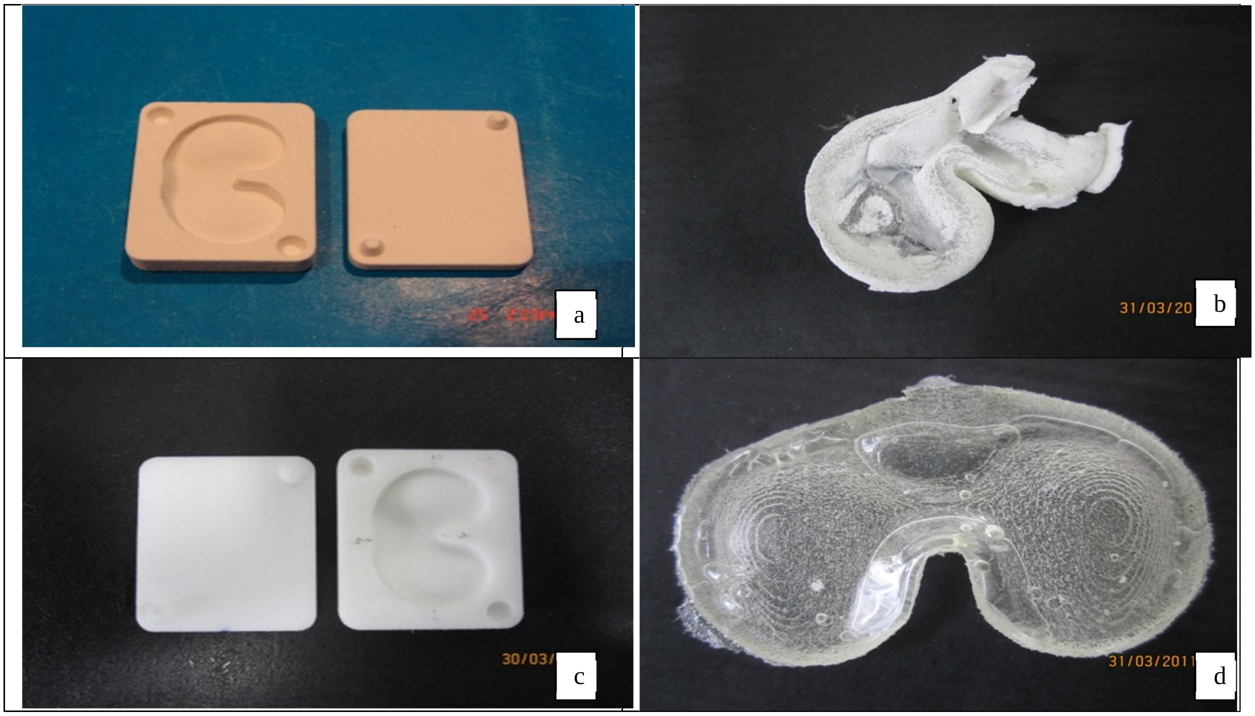

Figure 11 – a- plaster cast; b - PVAl meniscus impregnated with gypsum particles; c - Polyamide Cast; d - PVAl meniscus

4. CONCLUSIONS

The model for obtaining the reproductive pattern showed, some changes should be made PVAl yet seen the difficulties to fill the mold, as shown in Fig. 3, there is bubbling over materials.This main objective was achieved, since achieved through rapid prototyping, making a prosthetic meniscus, build a mold and then produce a meniscus, although the level of the laboratory, however, with highly favorable properties playback on a large scale, that really will appeal to both institutions medical and industrial.

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