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RP Medical Model Preparation And Its Applications

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ABSTRACT

The most interesting and challenging applications of rapid prototyping technologies are in the field of medicine. RP medical models have found application for planning treatment for complex surgery procedures, training, surgical simulation, diagnosis, design and manufacturing of implants as well as medical tools. This paper explores and presents the procedure for making medical models using RP, medical rapid prototyping technologies application in different fields of medicine and the future trends in this area. The Computer Aided Engineering (CAE) is almost used in every industry. Presently the aid of computer in the field of Bio-Medical and Surgery planning is predominantly growing. The study is intended to know about the latest trends in rapid prototyping, customized according to the patients need for better accuracy and efficiency. The rapid prototyping is a used to build an object formed layer by layer. The input to the RP system is given from the digitizer. The digitizer captures the three dimensional surface data of the object. The captured data is then manipulated by a CAD/CAM system, where modification and enhancement of the image can be performed. The enhanced geometric model of the object is then converted into physical product, accurately and quickly by rapid prototyping process for bio medical application.

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I. INTRODUCTION

The impact of the CAE technology, the advancement in Design and Manufacturing plays a vital role in particular, advanced manufacturing techniques like rapid prototyping (RP) technology, where the 3D medical images obtained by Computer Tomography [CT] or Magnetic Resonance Imaging [MRI] scanned images are analyzed by medical image analysis software, where the possibility of transforming 3D facial image to surgery implant by means of a RP technique. Today the growth of Engineering in the field of Medical applications is enormous, from the custom fabricated broken skull implants to dental implant surgical procedures are being facilitated by means of CAD/CAM technology. As it is well known, the term "rapid prototyping" refers to a number of different but related technologies that can be used for building very complex physical models and prototype parts directly from 3D CAD model. Among these technologies are stereolithography (SLA), selective laser sintering (SLS), fused deposition modeling (FDM), laminated object manufacturing (LOM), inkjet-based systems and three dimensional printing (3DP). RP technologies can use wide range of materials (from paper, plastic to metal and nowadays biomaterials) which gives possibility for their application in different fields. RP (including Rapid Tooling) has primary been developed for manufacturing industry in order to speed up the development of new products. They have showed a great impact in this area (prototypes, concept models, form, fit, and function testing, tooling patterns, final products - direct parts). Preliminary research results show significant potential in application of RP technologies in many different fields including medicine. This paper covers possibilities of using RP technologies as a multi- discipline area in the field of medicine. Using RP in medicine is a quite complex task which implies a multidisciplinary approach and very good knowledge of engineering as well as medicine; it also demands many human resources and tight collaboration between doctors and engineers.

After years of development rapid prototyping technologies are now being applied in medicine for manufacturing dimensionally accurate human anatomy models from high resolution medical image data. The procedure for making medical models using RP technologies is also presented in this paper.

II. RP MEDICAL MODEL PREPARATION

The procedure for making 3D medical models using RP technologies implies few steps:

- 3D digital image
- Data transfer, processing and segmentation
- Evaluation of design
- RP medical model production
- RP medical model validation.

A. 3D digital image

3D digital image can be obtained by using computer tomography - CT scanner or MRI data (see Fig. 1). These imaging technologies are used for modeling internal structures of human's body. Medical models made from this data must be very accurate and because of this they require a spiral scanning technique which allows to do full volume scanning. This makes possible to generate a high number of slices (recommended thickness 1-2 mm) and what is very important, the pixel dimension in each slice could be reduced depending on each case. Most CT and MRI units have the ability of exporting data in common medical file format - DICOM – digital imaging and communication in medicine.

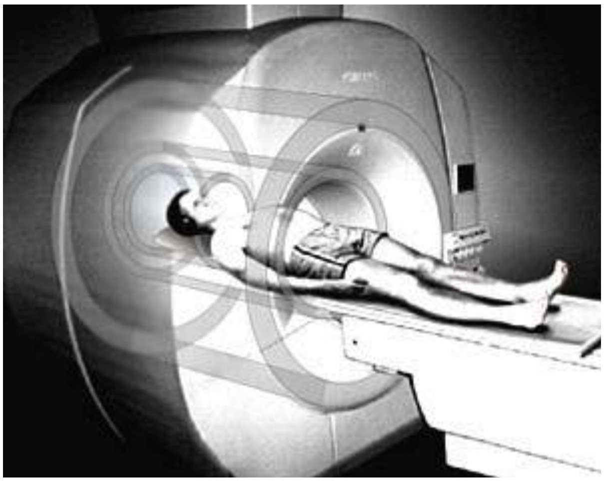

Fig. 2.1. MRI Unit

B. Data Transfer, Processing and Segmentation

After saving CT or MRI image data, they should be transferred to RP or RE laboratory. The next step is processing these data, which is a very complex and important step, that the quality of the final medical model depends on.

For this step engineers need software package (Mimics, 3D Doctor) in which they can make segmentation of this anatomy image, achieve high resolution 3D rendering in different colors, make 3D virtual model and finally make possible to convert CT or MRI scanned image data from DICOM to .STL (Stereolithography) file format, which is universally accepted RP file format (see Fig. 2). These software packages allow making segmentation by threshold technique, considering the tissue density. In this way, at the end of image segmentation, there are only pixels with a value equal or higher than the threshold value. The virtual model of internal structures of human's body, which is needed for final production of 3D physical model, requests very good segmentation with a good resolution and small dimensions of pixels. This demands good knowledge in this field which should help engineers to exclude all structures which are not the subject of interest in the scanned image and choose the right region of interest ROI (separate bone from tissue, include just part of a bone, exclude anomalous structures, noise or other problems which can be faced). Depending on complexity of the problem this step usually demands collaboration of RE engineers with radiologists and surgeons who will help to achieve good segmentation, resolution and a finally accurate 3D virtual model.

C. Evaluation of Design

This step depends on a case-to-case basis. Sometimes the created model is directly used as an input for RP machine (biomodels). For making surgical tools, incorporating other objects (fixation devices, implants), bone replacements, producing patterns for making fixtures or templates or other complex problems in different fields of medicine, this virtual model in IGES or STL format is processed using some CAD package (Pro Engineer, Catia). This is necessary for evaluation of design, quality of the made model, checking possible errors or other important steps which depends on the concrete case.

D. RP Medical Model Production

This step implies choosing the right RP technology according to the purpose of model itself as well as demanding accuracy, surface finish, visual appearance of internal structures, number of desired colors in the model, strength, material, mechanical properties, etc. Finally 3D virtual model in STL format should be inputted into the RP commercial software for production of 3D physical model.

Fig.2.2. RP System

E. RP Medical Model Validation

When the RP medical model is manufactured it should be validated by surgeons. If there are no errors the model is ready for application.

III.THE USE OF AM TO SUPPORT MEDICAL APPLICATIONS

AM models have been used for medical applications almost from the very start, when this technology was first commercialized. AM could not have existed before 3D CAD since the technology is digitally driven

AM-based fabrication contributes significantly to one or more of the following different categories of medical applications:

- Surgical and diagnostic aids
- Prosthetics development
- Manufacturing of medically related products
- Tissue Engineering

A. Surgical and Diagnostic Aids

The use of AM for diagnostic purpose was probably the first medical application of AM. Surgeons are often considered to be as much artists as they are technically proficient. Since many of their tasks involve working inside human bodies, much of their operating procedure is carried out using the sense of touch almost as much as by vision. As such, models that they can both see from any angle and feel with their hands are very useful to them. Surgeons work in teams with support from doctors and nurses during operations and from medical technicians prior to those operations.

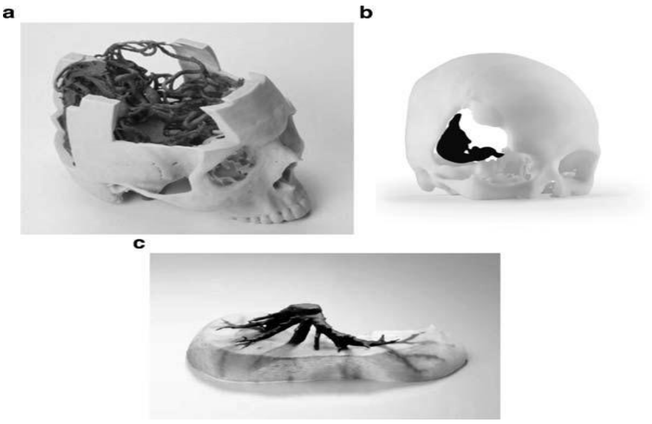

Fig.3.1. Images of medical parts made using different colored AM systems. (a) 3DP used tomake a skull with vascular tracks in a darker color. (b) A bone tumor highlighted using ABS.(c) Objet Connex process showing vascularity inside a human organ.

B. Prosthetics Development

Initially, CT generated 3D models combined with the low resolution of earlier AM technology to create models that may have looked anatomically correct, but that were perhaps not very accurate when compared with the actual patient. As the technology improved in both areas, models have become more precise and it is now possible to use them in combination for fabrication of close-fitting prosthetic devices. Wang states that CT-based measurement can be as close as 0.2 mm from the actual value. While this is subjective, it is clear that resulting models, when built properly, can be sufficiently precise to suit many applications. Support from CAD software can add to the process of model development by including fixtures for orientation, tooling guidance, and for screwing into bones. For example, it is quite common for surgeons to use flexible titanium mesh as a bone replacement in cancer cases or as a method for joining pieces of broken bone together, prior to osteo integration. While described as flexible, this material still requires tools in order to bend the material. Models can be used as templates for these meshes, allowing the surgeon's technical staff to precisely bend the mesh to shape so that minimal rework is required during surgery

Fig.3.2.Titanium mesh formed around a maxillofacial model

C. Manufacturing

There are now examples where customized prosthetics have found their way into mainstream product manufacture. The two examples that are most well known in the industry are in-the-ear hearing aids from companies like Siemens and Phonak and the Invisalign range of orthodontic aligners as developed by Align Technologies.Both of these applications involve taking precise data from an individual and applying this to the basic generic design of a product. The patient data is generated by a medical specialist who is familiar with the procedure and who is able to determine whether the treatment will be beneficial

Fig.3.3.Siemens hearing aid and shell

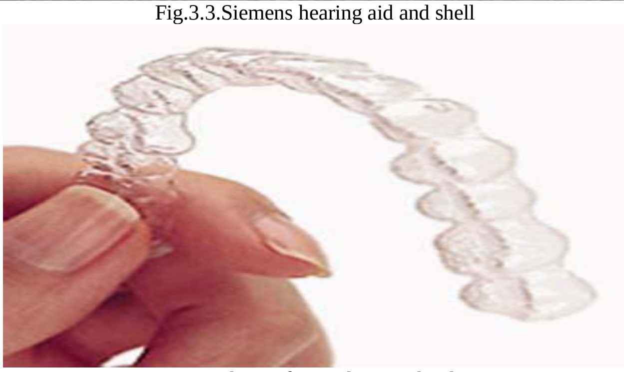

Fig.3.4. Aligner from Align Technology

D.Tissue Engineering And Organ Printing

The ultimate in fabrication of medical implants would be the direct fabrication of replacement body parts. This can feasibly be done using AM technology, where the materials being deposited are living cells, proteins and other materials that assist in the generation of integrated tissue structures. However, although there is a great deal of active research in this area, practical applications are still quite a long way noff. The most likely approach would be to use printing and extrusion-based technology to undertake this deposition process. This is because droplet-based printing technology has the ability to precisely locate very small amounts of liquid material and extrusion-based techniques are well-suited to build soft-tissue scaffolding.

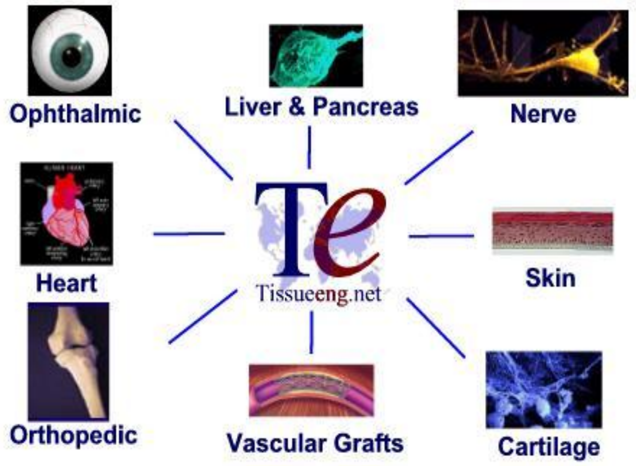

Fig.3.5. Implants for various types of tissues

IV. LIMITATIONS OF AM FOR MEDICAL APPLICATIONS

i) Speed : AM models can often take a day or even longer to fabricate. Since medical data needs to be segmented and processed according to anatomical features, the data preparation can in fact take much longer than the AM building time. Furthermore, this process of segmentation requires considerable skill and understanding of anatomy.

ii) Cost : Using AM models to solve manufacturing problems can help save millions of dollars for high-volume production, even if only a few cents are saved per unit. For the medical product (mass customization) manufacturing applications mentioned earlier, machine cost is not as important as perhaps some other factors.

iii) Accuracy : Many AM processes are being improved to create more accurate components. However, many medical applications currently do not require higher accuracy because the data from the 3D imaging systems are considerably less accurate than the AM machines they feed into. However, this does not mean that users in the medical field should be complacent.

iv) Materials : Only a few AM polymer materials are classified as safe for transport into the operating theater and fewer still are capable of being placed inside the body. Those machines that provide the most suitable material properties are generally the most expensive machines.

V. CONCLUSION

It is difficult to say whether a particular AM technology is more or less suited to medical applications. This is because there are numerous ways in which these machines may be applied in this field. One can envisage that different technologies may find their way into different medical departments due the specific benefits they provide. However, the most common commercial machines certainly seem to be well suited to being used as communication aids between surgeons, technical staff and patients. Models can also be suitable for diagnostic aids and can assist in planning, the development of surgical procedures and for creating surgical tools and even the prosthetics themselves. Direct fabrication of implants and prosthetics is however limited to the direct metal AM technologies that can produce parts using FDA (The US Food and Drug Administration) certified materials plus the small number of technologies that are capable of non load-bearing polymer scaffolds.

VI. FUTURE SCOPE

Looking ahead, the future for Rapid Manufacturing appears to be bright. The potential that these technologies offer to manufacturing industry should not be underestimated and the vast majority of new applications that will be achieved with Rapid Manufacturing have not even been conceived yet. There is a vision of the future whereby the equivalent of today’s 3D printers will be in place in people’s homes, next to a PC. For new consumer purchases, the design data will be downloaded from the internet, with any personal modifications, and the product manufactured in-situ. The aim truly being ‘mass individualisation’.

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