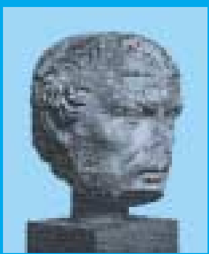
Phidias
RAPID PROTOTYPING IN MEDICINE



The Greek sculptor Phidias – fourth century BC – is known for the technical and artistic quality of his representation of the human being, full of dignity and nobility. His conserved masterpiece, the friese of the Parthenon, is still today a great symbol of European culture. The medical models resulting this project should contribute to make disabled, injured or ill persons resemblant again to the ideal human beings of Phidias.

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An abdominal aorta aneurysm/stent graft phantom

MANUFACTURED BY MEDICAL RAPID PROTOTYPING

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Introduction

At our institution the repair of abdominal aortic aneurysms may be carried out by stent grafting. The stent is made up of a dacron sheath and re-inforced with steel wire of 0.4 mm diameter. The stent is inserted into the aorta via the femoral artery and deployed in the aneurysm with the top of the stent located close to the renal artery ostia. The top of the stent is comprised of a wire mesh containing small barbs that embed in the aorta wall and hold the stent in position. The suprarenal component of the stent may interfere with blood flow to the renal arteries (1). We are currently evaluating Virtual Intravascular Endoscopy (VIE) software to visualise the position of the stent and it's suprarenal components in relation to the renal arteries by 3D helical CT scanning. Our purpose was to design and construct a suitably robust and anatomically accurate phantom to enable us to determine the CT radiological appearance of an aortic stent graft within an aortic aneurysm. Also, the phantom would enable us to assess the ability of CT to accurately image the position of a stent graft once deployed.

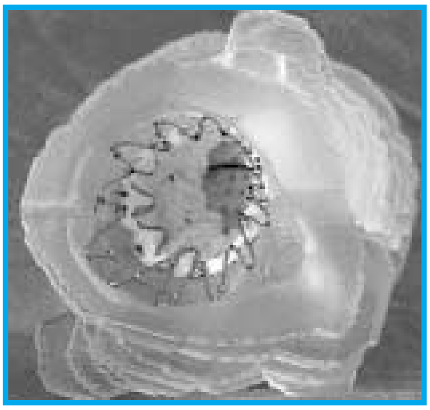

Figure 1 showing stent deployed inside stereolithography aorta model

Medical Rapid Prototyping of an aorta/stent phantom

The aorta phantom was required to be physically robust, dimensionally accurate and represent a human aorta aneurysm with a real stent inside. Medical Rapid Prototyping (MRP) has been widely exploited to build models of human anatomy from medical image data. A number of technologies are available for model building including stereolithography (1), laser sintering (2) and fused deposition modelling (3). Stereolithography was chosen as the model material is physically robust and the technology locally available.

CT scan data of a typical aorta aneurysm suitable for stent grafting was selected. The data was manipulated using image thresholding to remove the contrast media from within the aorta and was manually edited to remove surrounding tissue which cut down on model build time and cost. The CT data was then mathematically modelled using the Marching Cubes algorithm (4) and an STL data file produced. The model was built on a stereolithography system using a layer

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AORTA ANEURYSM / STENT GRAFT PHANTOM

manufactured by medical rapid prototyping

thickness of 0.354 mm and an in plane resolution of 0.8 mm. Once, cleaned a stent (Zenith, Cook Euro, Denmark) was deployed inside the model with the suprarenal wires located over the renal ostia as shown in Figure 1.

CT scanning

An iodine based contrast agent was made up to an appropriate concentration (CT number = 450) to simulate typical contrast enhancement relative to the aorta model wall (CT number = 180). Figure 2(a) shows a VIE image of inside the model without stent (slice = 5 mm and a 5 mm reconstruction). Note the strong presence of stair step artefact. Figure 2(b) shows the appearance of the suprarenal wires covering the renal artery ostium with 1 mm reconstruction interval. The aorta/stent phantom will be used to assess image quality at a wide range of CT scanning parameters to determine the most appropriate imaging protocol for the follow up assessment of aorta stent grafting.

Figure 2(a)

Figure 2(b)

Figure 2(a) showing high degree of stair step artefact at 5 mm reconstruction

Figure 2(b) showing good resolution of stent wires at 1 mm reconstruction

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Modeling and design

of a custom made cranium implant for large skull reconstruction before a tumor removal

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Introduction

Custom made implants for large cranium defect have already been described by many authors [1,4]. Most authors describe the design and the manufacturing of the implant using stereolithographic models of cranial structures [2,3]. The concerned implants are designed to cover a known defect after a trauma or an undefined defect before the tumor removal.

In our case we test several possibilities to design the best shape to bridge a large skull defect before the tumor removal in a historic méningioma case [Photo 1]. We use both CAD design on virtual 3D

Photo 1) The external aspect of the megingioma.

reconstruction of the skull as well as stereolithographic models to enhance the planning. This case is a collaboration between the plastic and the neuro-surgery department

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From the (new) Project manager's desk

Phidias Network Administration
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The Phidias Network is in its last year now and so is this newsletter. We've accomplished a lot already in promoting the medical Rapid Prototyping by this newsletter and by several local or specific topic workshops, presentations, articles, and so on.

Being the last year of the project I would like to stress once again our evaluation study for the assessment of the usefulness of using RP models in surgery. We need as many questionnaires as possible to be able to show that in certain circumstances, the use of RP models increases the quality of life for the patient, improves the surgical result and reduces overall costs. The current results are already promising but the more questionnaires we get in the study the more accurate the results, so please help the medical Rapid Prototyping forward and send on your questionnaires to MDK, the German National Health Insurance.

As you might have already noticed this article has not been written by Kris Wouters but by myself. Kris Wouters is redrawing himself from the European project to soon face new challenges in the Materialise office in the United States. The advances in the different applications of medical Rapid Protoyping in Europe will now be shown and promoted extra in this vast country. We can only wish him good luck on this quest. For the Phidias Network Administration nothing will change except for me being the new Project Manager, so please contact me for any questions regarding the administration.

Colour Rapid Prototyping

– an extra dimension for visualising the human anatomy

By Kris Wouters
Materialise

1. Introduction

Currently, a few RP techniques exist to produce 3D parts in colour. These techniques allow the selective colouring of certain structures in the three dimensional solid model.

The tangible 3D information of a solid model combined with the extra information from the selective colouring of certain anatomical structures provides an interesting diagnostic and preoperative planning tool.

Some techniques, like Fused Deposition Modelling offered by Stratasys, can build colour models by building part of the model in a support material with a different colour. This method has recently been facilitated by Boolean operations in good image processing software allowing easy elimination of overlap in between colour zone and non-colour zone. This treatment is necessary, because material overlap will compromise correct layer building.

Very recently, the manufacturer of 3D printing machines, Z Corporation, announced the possibility to produce multi-colour models by working with multiple material jets, each with their own coloured liquid binder. So far, we have not seen any medical multi-colour parts but judging the quality of the multi-colour technical parts, this technique has a lot to offer.

Since several years, colour stereolithography is available. So far, it has been the most important colour RP technique for medical applications thanks to a special medical grade colour resin. Because of the long track record, this method will be described in more detail below.

2. Colour stereolithography

Stereolithography is a rapid prototyping technique that builds three dimensional structures by solidifying layer by layer, a photo-curable resin, using a UV laser.

The selective colouring is produced by providing a higher dose of laser light, to a special colourable resin, at the spots that need to be coloured. When moving the laserbeam slower in a certain region, the laser will light that region for a longer time and the resulting radiation dose will be higher. In that particular region, the resin will not only solidify, but also shift colour from light transparent to deep red.

Every stereolithography machine can be turned into a colour machine simply by using the only colour resin currently available: Stereocol. This resin was developed in the Phidias project, an EC-sponsored project that was the predecessor of the Phidias Network, sponsoring this magazine.

Stereocol was designed to be a medical resin. Apart from its selective colourability, it is highly non-toxic (FDA USP Class VI) and can be sterilised.

Since its introduction to the market in 1997, several service bureaux in Europe, USA and Asia have invested in the technology and are currently offering colour models. Over 2000 models in colour resin have been produced so far.

3. Use of colour stereolithography

It is mostly the 3D visualisation aspect that is improved by using colour models. Every structure that produces a good contrast in the scanner images with its neighbouring structures, can be highlighted in colour.

Some applications are:

- The visualisation of tumours and their extension relative to the neighbouring anatomy. Also a tumour inside bone can be seen "through the bone" by the colouring technique (fig. 1).

- Visualisation of teeth and teeth roots within the upper and lower jaw. In the preparation of complex jaw surgery the surgeon will be in a better position to take into account the dental situation. (fig. 2).

- Visualisation of nerve tissue (fig 3), metal plates and screws, special structures that need attention, ...

- Labelling is another application. When models are used more often, it becomes important to label patient name and other relevant information on the model.

Figure 1

Figure 2

Figure 3

Conclusion

Medical RP models, and especially models with selectively coloured areas, are an ultimate tool for all the steps in the process of treating patients with complex pathologies: visualisation of the problem, communication in a team, diagnosis, implant design, planning of the surgery and rehearsal of the surgery.

Medical RP modelling, and colour stereolithography in particular, is still very young but promising. Colour models have a lot of potential, but only few of the applications have been discovered so far. Therefore, it is very important that the medical world gives feed back to a forum like the Phidias Network, aiming at promoting medical RP modelling.

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Modeling and design

of a custom made cranium implant for large skull reconstruction before a tumor removal

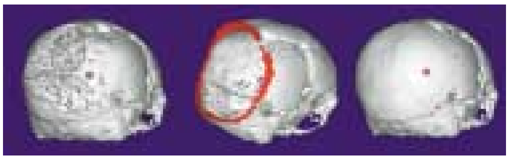

Image 1) The bone reconstruction before the tumore removal
Image 2) Virtual removal of the tumor
Image 3) Reconstruction using another skull patient as template

of the Cliniques Universitaires Saint Luc of Brussels the maxillo-facial surgery Dpt of Amiens and Materialise N.V.

The clinical case

Because of the situation and the size of the brain tumor it was necessary to perform the tumor resection and the skull reconstruction in one stage. A forty year's female was seen in the University clinic of brussels with an important meningioma of the posterior brain remaining to a large part of the posterior cranium (occipital and parietal bones) and the scalp.

A CT scanner was performed in Brussels (Clingnique Universitaire St Luc), the data conversion was made by Materialise in Leuven. Data were then transferred by ftp to the maxillo-facial department of Amiens hospital. We evaluate several approaches to achieve our goals and discuss them with the multidisciplinary surgery team.

Models from a CT scan of other skull patients

The first procedure uses STL files obtained from other skull patients from our personal CT scan database (Maxillo-facial surgery dpt of Amiens). These files were used as template to find the best curvature and geometry to fit with the woman skull. These STL models were also shaped and deformed in Rhinoceros © (Mc Neel and Associates.) and controled in Magics RP © (Images 1,2,3) giving a good idea about the needed reconstruction.

Complete design of the implant using NURBS

The second approach was based on NURBS Surfaces designed on a Network curves according to the exact shape of the supposed tumor area. The Surface was then built in Rhinoceros using the B-splines curves obtained from the CT scan images in Mimics/MedCAD ®. Image 4

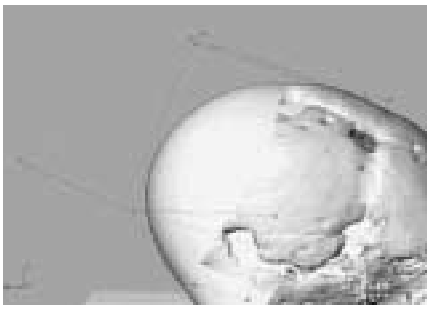

Image 4) Design of the implant using NURBS surface

The retained solution

Both solutions were materialised using stereolithography allowing the surgeons to discuss around a hard copy of the needed models. The discussion concern not only the "shape" or the "form" of the possible reconstruction but also the optimal material which could be used. For the best procedure it's certainly a combination between the CAD design (no matter how the master implant is made: NURBS or 3D template from other skull patients) and the direct fitting on the stereolithographic model before the surgery which give more predictable results

We eliminate the Titanium [5] and ceramic materials because the impossibility of adding or removing material during the surgery. The selected solution was to manufacture the implant using PMMA wich allow the surgeon to add or remove material according to the unforeseen or in case of unexpected situation during the surgery.

Image 5) The PMMA Implant.

Surgical procedure

Finally the implant was sterilized in the allowed manner for the operating time.

Firstly the tumor including bone and skin was removed, then the different brain structures were covered by a fascia lata aponeurosis graft (Photo 2). The implant was insetted on the skull with some coaptation with the border of the remained vault thanks to a remodelling of the implant for the best possible cranial shape (Photo 3).

There was some dead space under the perforated implant which was fixed with three titanium miniplates and screws. After that the covering was ensured by a latissimus dorsi muscular free flap

Photo 2) After the tumor removal

with a thin meshed skin graft on it. The final shape of the skull was rather good and the first follow-up was not so bad with a good cicatri-

Photo 3) Peroperative view of the PMMA implant.

sation of the muscle but there was also some serious pulmonary infection during her stay in intensive care department

Conclusion

The planning of the reconstruction of complex cranial defects could be enhanced by merging different procedures: CAD techniques with a direct control on stereolithographic models.

This procedure increases the quality of the planning allowing to test numerous solutions on virtual models including surgery procedures before the stereolithographic testing and the realisation of the final implant.

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Come to Nürnberg in October

CAS 2001 WORKSHOP

Computer Assisted Surgery (CAS) and Rapid Prototyping Techniques (RPT) in Medicine were the topics of previous workshops in Erlangen. The 6th workshop will be dedicated to new developments and clinical results in both fields and shall provide an interdisciplinary forum for discussions. It is our intention again to cover a broad spectrum and involve both basic scientists and clinical users.

RPT has been the focus of the European Union sponsored PHIDIAS network. It will come to its conclusion in early 2002 and will hold its final workshop jointly with CAS 2001. This will provide the opportunity for a full review of technical developments and clinical applications.

CAS demands interdisciplinary work and collaboration. This involves different technical fields such as imaging, visualization, simulation, training, navigation, robotics and telesurgery. They all will be covered with a particular focus on neurosurgery, new concepts in 3D imaging and orthopedic surgery.

In addition to scientific sessions and poster and technical exhibits, we will offer a number of review lectures by internationally renowned experts in the field.

We would be happy to welcome you in Nürnberg !

Willi A. Kalender

The workshop is sponsored by the International Socciety for Computer Aided Surgery (ISCAS) and the International Society for Computer Assisted Orthopedic Surgery (ISCAOS). The workshop is eligible for CME credits.

WORKSHOP TOPICS

All topics relevant to CAS & RPT will be covered in papers, in poster presentations and in the technical exhibit.

Technical Aspects

- ***Rapid prototyping technologies***
- ***Advanced medical imaging***
- ***Image processing & Virtual reality***
- ***Implants***
- ***Navigation, Robotics & Mechatronics***
- ***Quality assurance & Risk management***

** Bavarian Center of Excellence for Medical Imaging and Image Processing (www.imp.uni-erlangen.de/forbild/)*

Clinical Studies

- ***Surgical planning & simulation***
- ***Preparation of implants***
- ***Intraoperative imaging & navigation***
- ***Image-guided surgery***
- ***Implant surgery***
- ***Robot-assisted surgery***
- ***New surgical applications***

Additional Activities

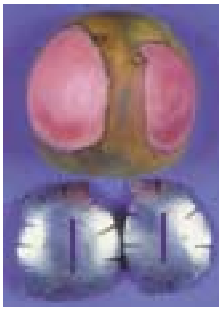
- ***Basic Course on CT Principles, Applications and Dose Considerations October 10, 2001***
- ***PHIDIAS - Annual Meeting October 11, 2001***
- ***FORBILD* - Final Meeting October 12, 2001***

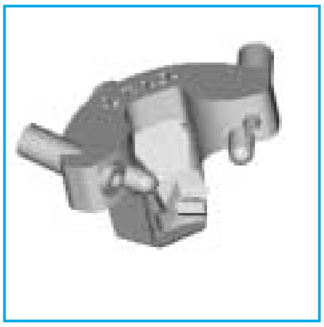
Phidias Workshop

Belfast 2001

Friday 14 September 2001

Europa Hotel, Belfast, UK





Full programme: *www.phidias.org*

or
Dr E Berry
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Mr J Winder
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Attendance at the workshop is free of charge, but places are limited! Please register by 24 August.

The Phidias workshop is taking place alongside the European Congress of Medical Physics and Clinical Engineering, which runs from 11-15 September, 2001. More information on the Congress, including details about travel and accommodation, is available at ***www.n-i.nhs.uk/Belfast2001***

Are you looking for

Phidias -partners, -publications, or -events?

Find them in ***www.phidias.org***

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The aim of the Phidias Newsletter is to inform the vast majority of medical practitioners throughout Europe on the significant influence of Rapid Prototyping on the effectiveness of medical practice. This target will be reached via descriptions of selected cases where Rapid Prototyping has been taken into use.

The newsletter is published two times per year and is circulated to 3000 medical practitioners throughout Europe.

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