Healthcare Additive Manufacturing in the 21st Century

Godfrey Onwubolu, PhD, FBCS, CEng, PEng.: Centre for Rehabilitation & Health Services (CREHS) Inc.

Presented at: Spectrum Day Toronto 2019

Date: Friday, October 25, 2019; 9:30 am – 10:30 am THE TORONTO CONGRESS CENTRE, North Building, 650 Dixon Road, Etobicoke, ON M9W 1J1

Table of Content

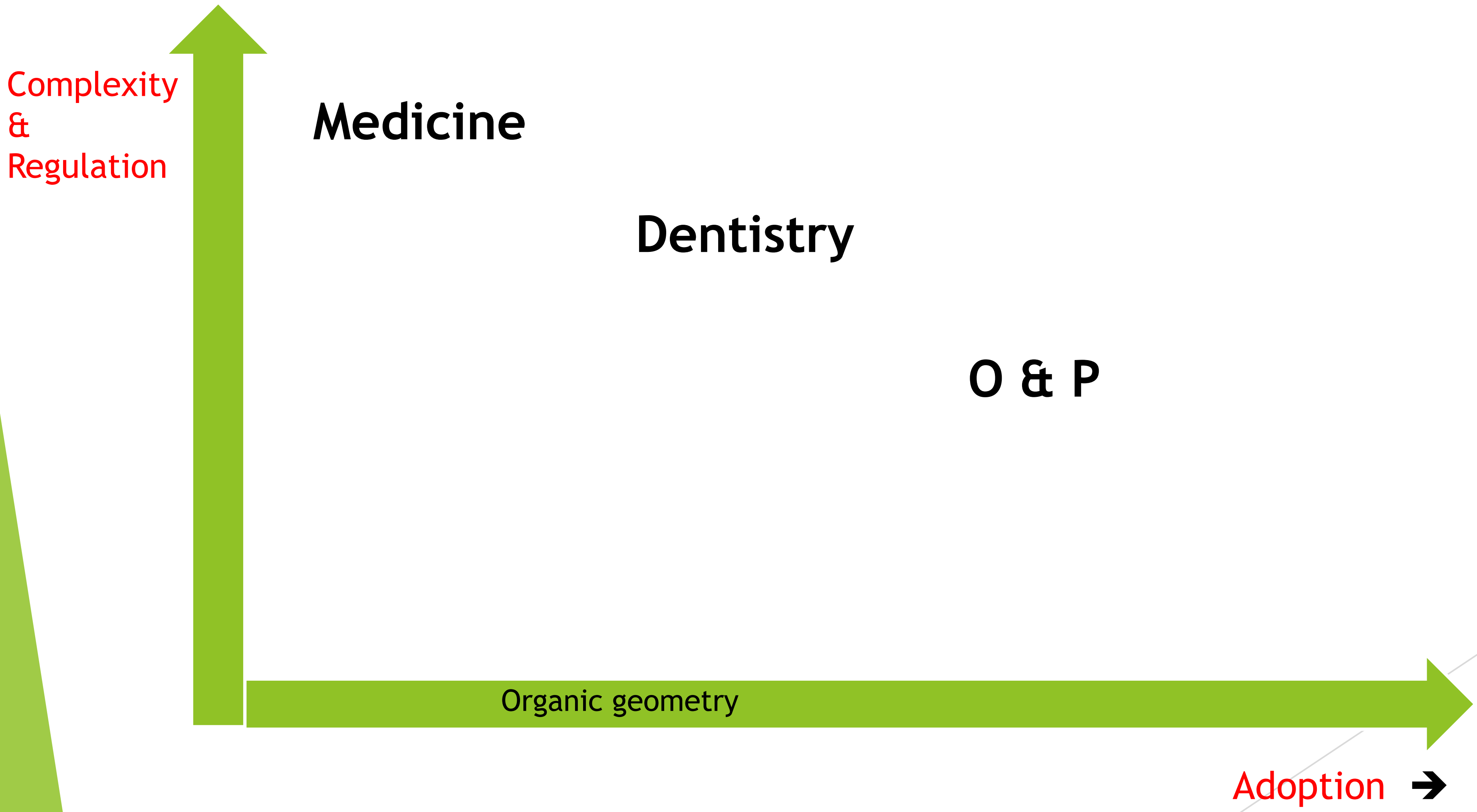
What is Digital Healthcare 3D Printing?

- From dental images, design and 3D Print dental prostheses
- From medical images (CT, MR, 3D US), use 3D Printing to make
  - reconstructed physical models of patient anatomy
  - Surgical assistance devices
  - Custom implantable devices
  - DICOM (Digital Imaging and Communications in Medicine) is the de-facto format for medical images

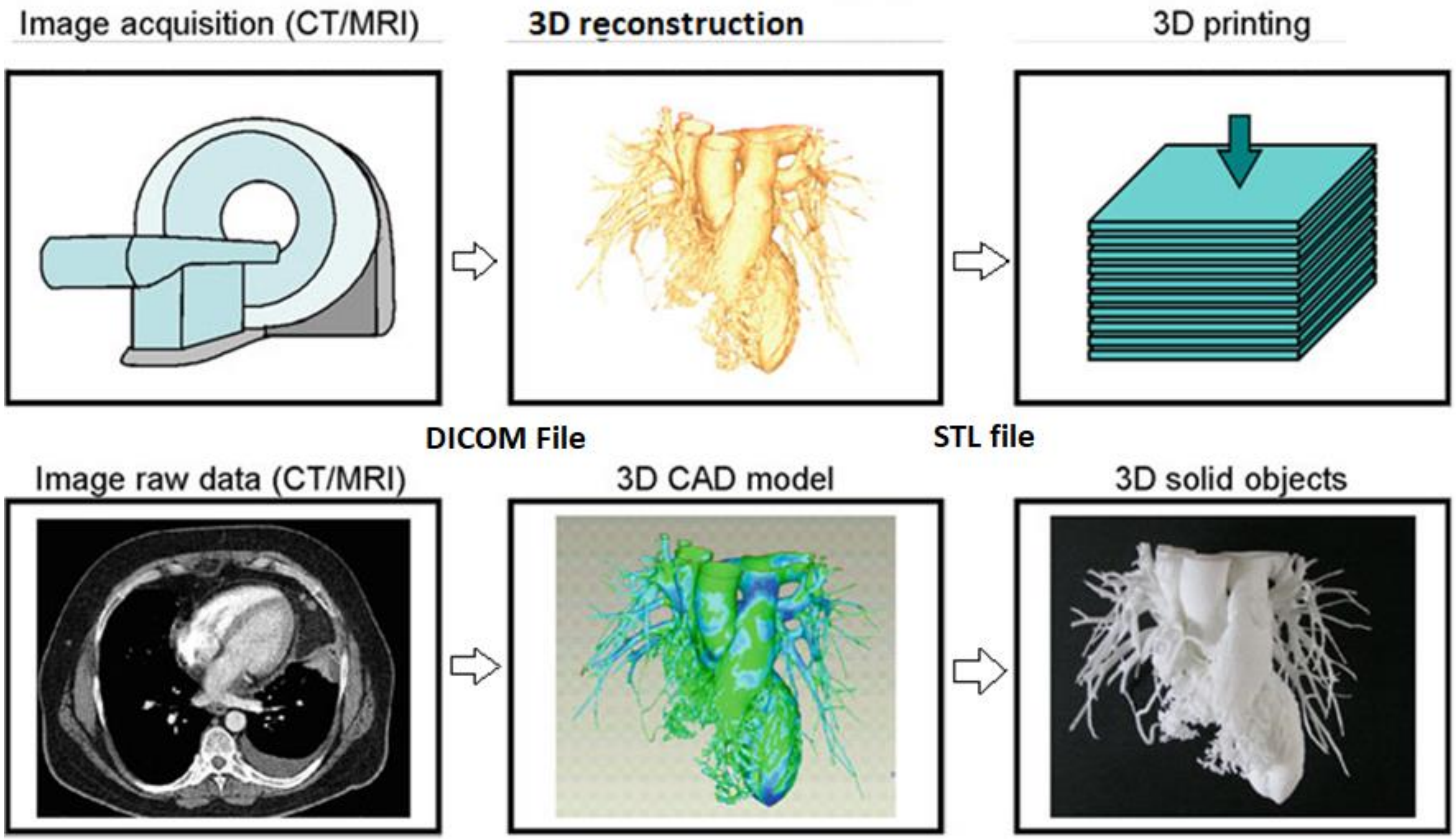
What Some Experts Say about Healthcare 3D Printing

- "*3D printing is certain to alter the daily practice of medicine (dentistry) where patients will be treated with medical products manufactured specifically for them*"—Scott Gottlieb, FDA Commissioner
- "*3D printing is a completely disruptive technology in general and in medicine (dentistry)…It will change the way that doctors do procedures. It will change the way we teach physicians*"—Dr. Frank J. Rybicki, M.D., Chair of Radiology at the University of Ottawa and Chief of Medical Imaging at The Ottawa Hospital

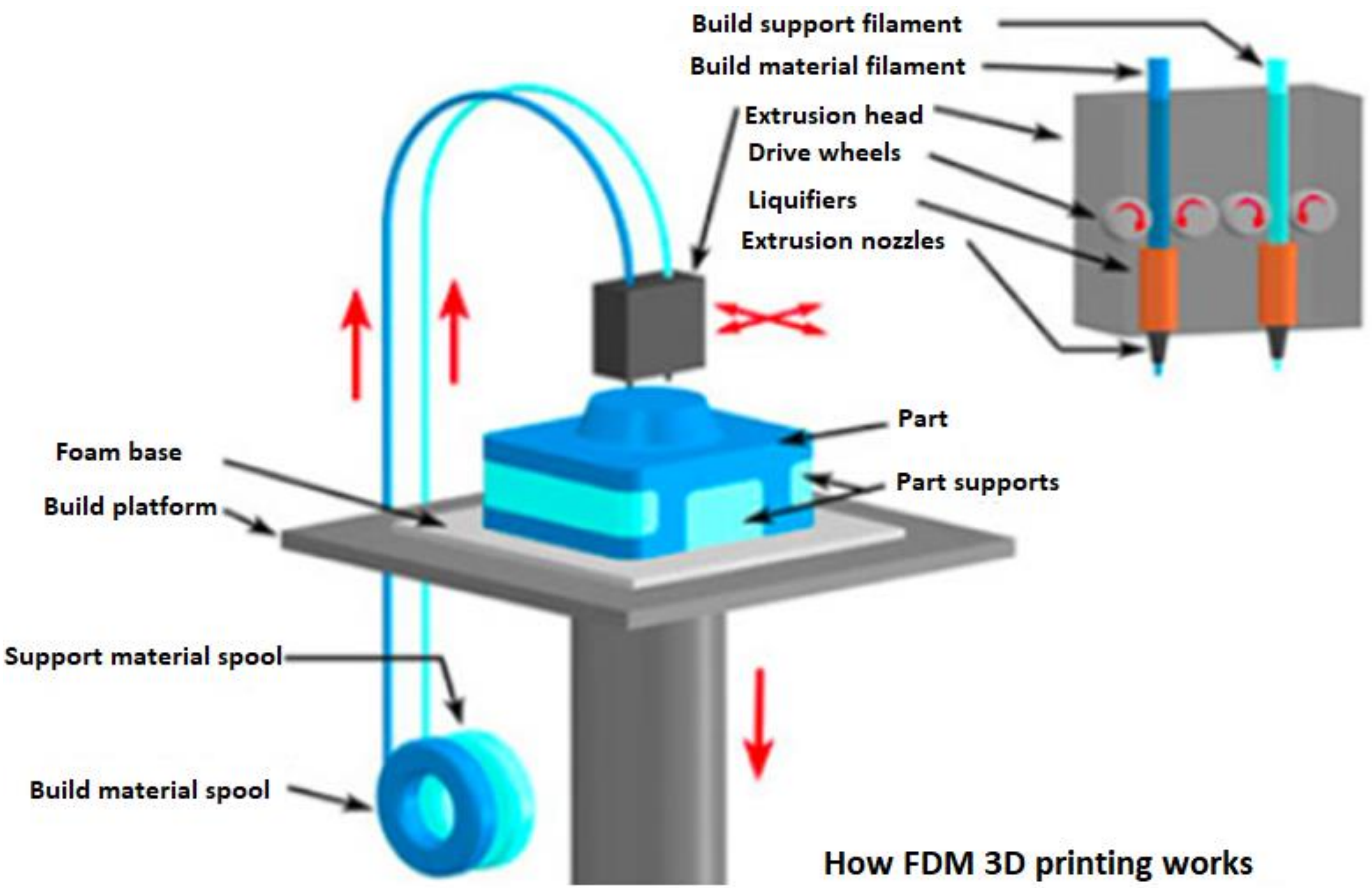
Healthcare 3D Printing Applications



Some basic facts about Healthcare 3D printing

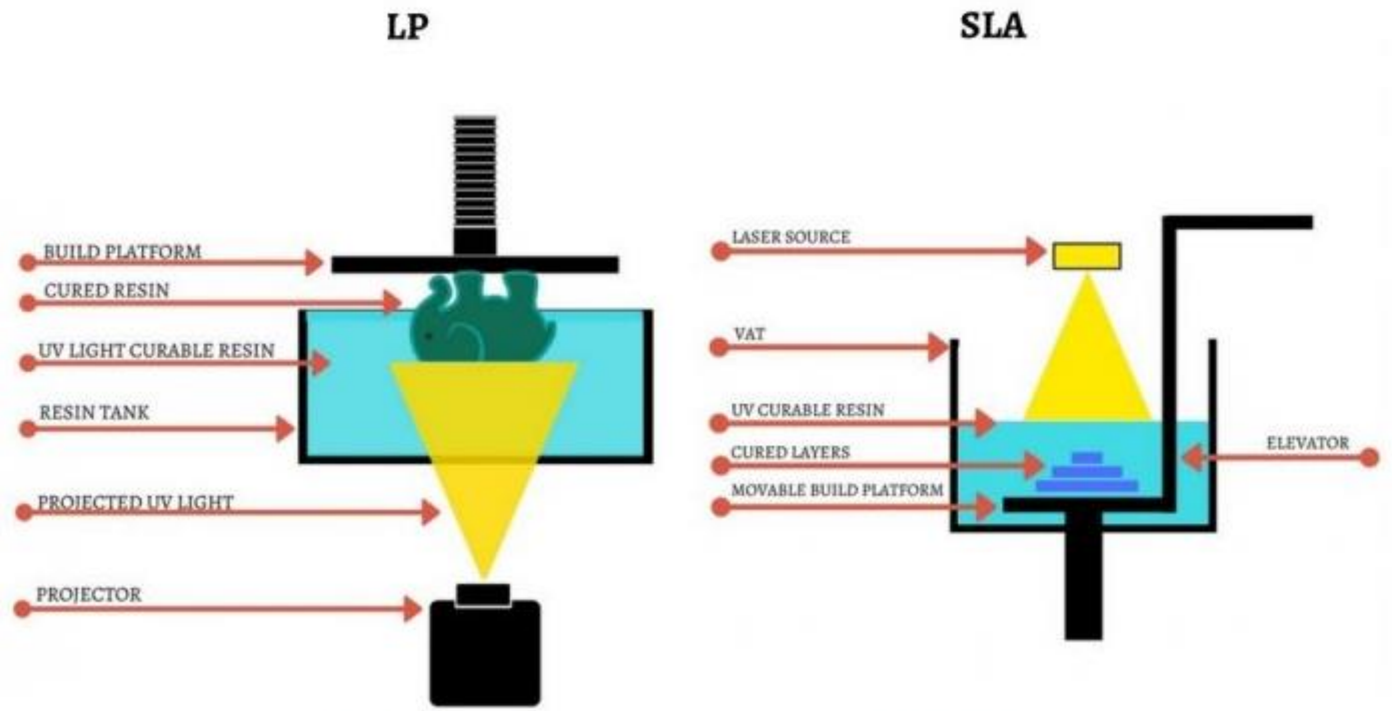


Fused Deposition Modeling (FDM)
3D printing Works for Medical Applications



How FDM 3D printing works

Continuous Digital Light Manufacturing (CDLM) 3D printing for Dental Applications



The DLP and SLA printing processes. [Image credit: Manufactur3D]

envisionTec; FormLab; MoonRay; Carbon 3D-printer follow DLP technology

Continuous Digital Light Manufacturing (CDLM) 3D printing for Dental Applications

- **Materials Available for the Vida cDLM Printer:**
- E-Dent 400 MFH
- E-Denture 3D+
- E-Model
- E-Guard

Biocompatible Materials Available

- The human body contains highly corrosive environment. Some scaffolds are made for implants that are designed to be mechanic and to stand loads but others are supposed to be biodegradable leaving a new regenerated tissues behind. Materials suitable, in vivo, for 3D printing in medicine are ceramics, metals and polymers:
- Alumina Al_2O_3 is a very strong material used for example in a hip replacement [1]
- Cobalt-chrome is an ideal material for medical devices
- Zirconia ZrO_2 is a very hard material that hardens with time that can lead to fractures, thus it is very good to mix it with Alumina [1]

Biocompatible Materials Available

- Hydroxyapatite HA is used to produce bone or to stimulate bone growth. Stereolithography (SLA) and Selective Laser Sintering (SLS) can produce insert-able objects from this material [2]
- Stainless steel is used in pins, plates and screws [2]
- Titanium implants are made by SLA and more techniques for individual patients to repair mandible and maxilla defects. Titanium and its alloys are able to integrate into bone, it usually does not bond with bone but by subjecting it with NaOH and use heat treatments it bonds with the surrounding bone [3]
- The above materials are the most commonly used but there are many more materials available

Medical Models for Trainings, Education, Surgical Planning and Simulations

- Aorta Workbench
- Kidneys
- Virtual Surgical Planning

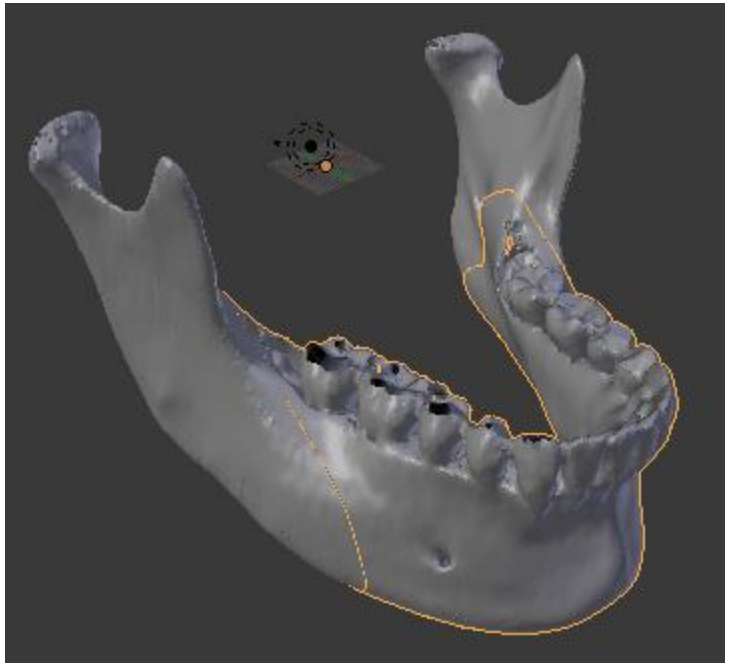
Aorta Workbench

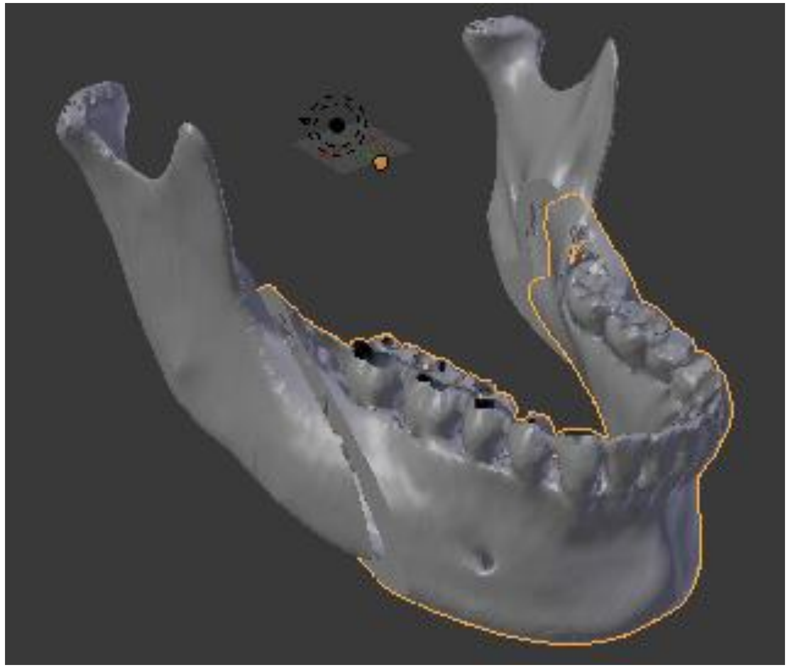
3D printed Kidneys

Orthognathic Surgery (Virtual Surgical Planning—VSP)

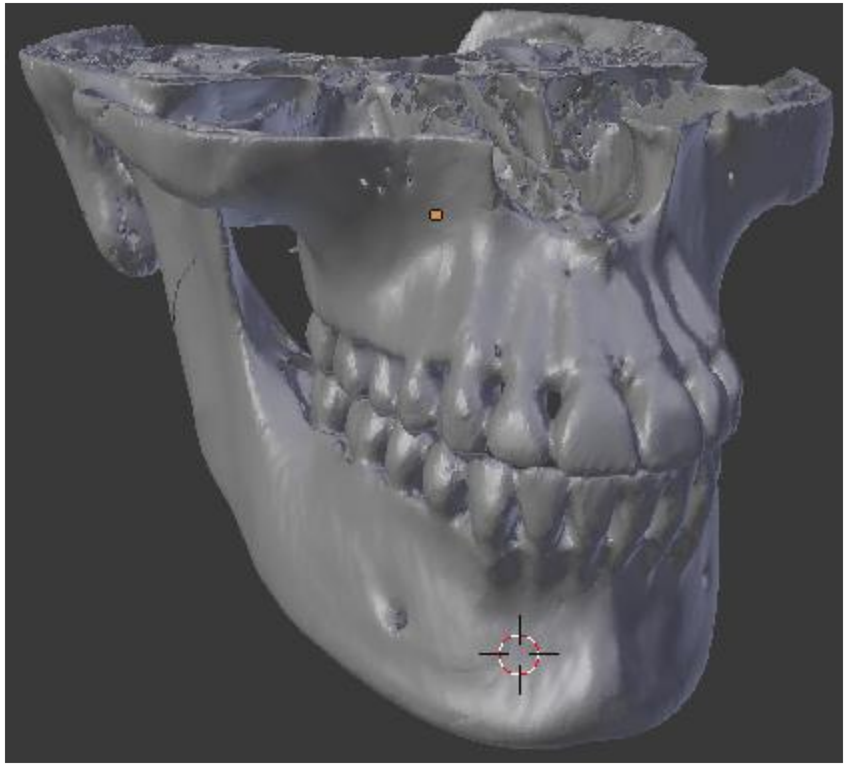
- Orthognathic Surgery: means to straighten a jaw
- Osteotomy: means a surgical operation in which a bone is cut to shorten/lengthen it or to change its alignment
- Common Osteotomies:
- BSSO-Bilateral Sagittal Split Osteotomy
- Bilateral C-Ramus Osteotomy
- Bilateral Inverted-L Osteotomy
- Bilateral Vertical-Ramus Osteotomy
- Genioplasty Osteotomy
- Lefort-I Osteotomy

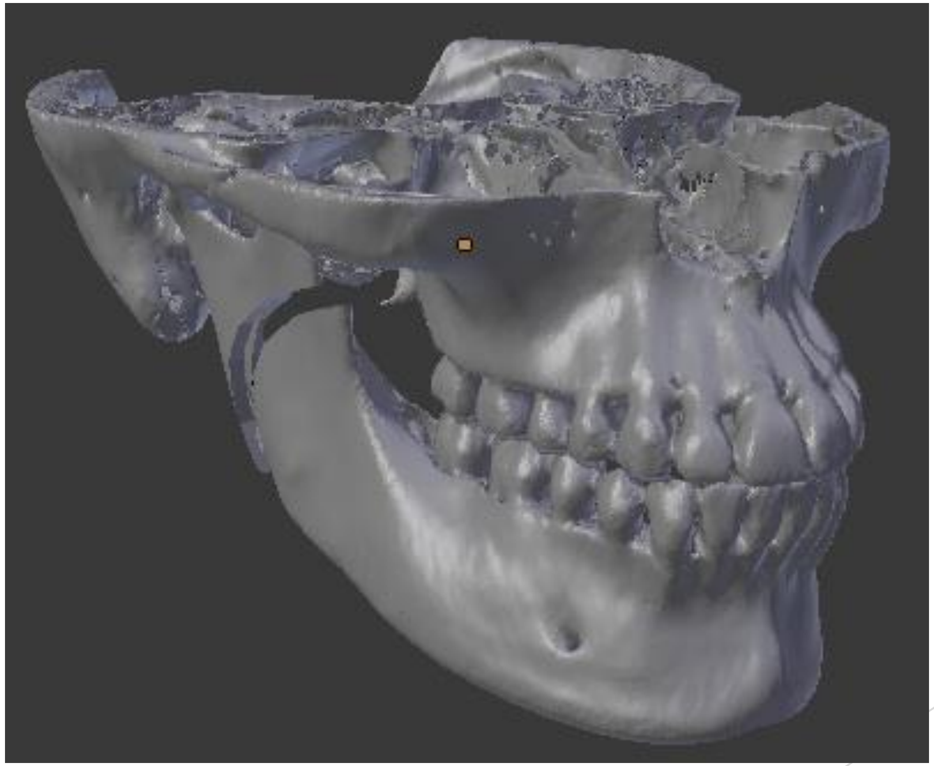
BSSO-Bilateral Sagittal Split Osteotomy



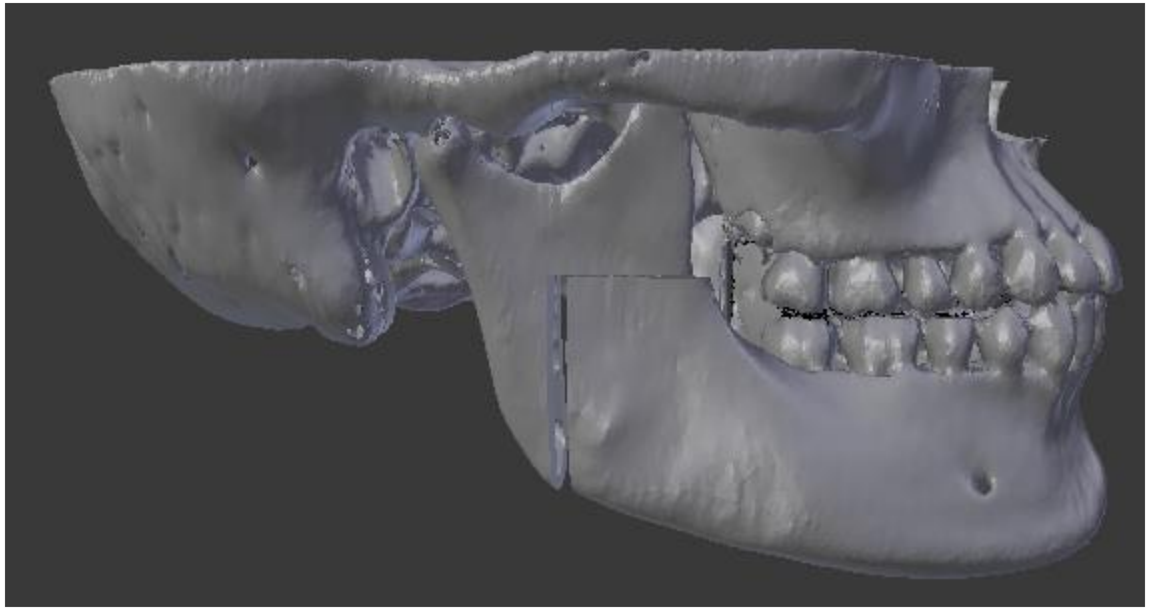


Bilateral C-Ramus Osteotomy

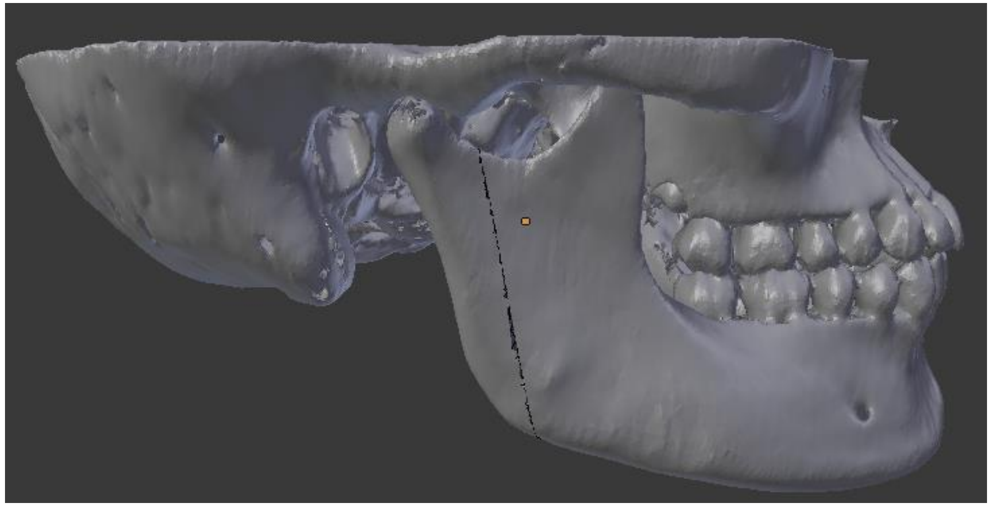


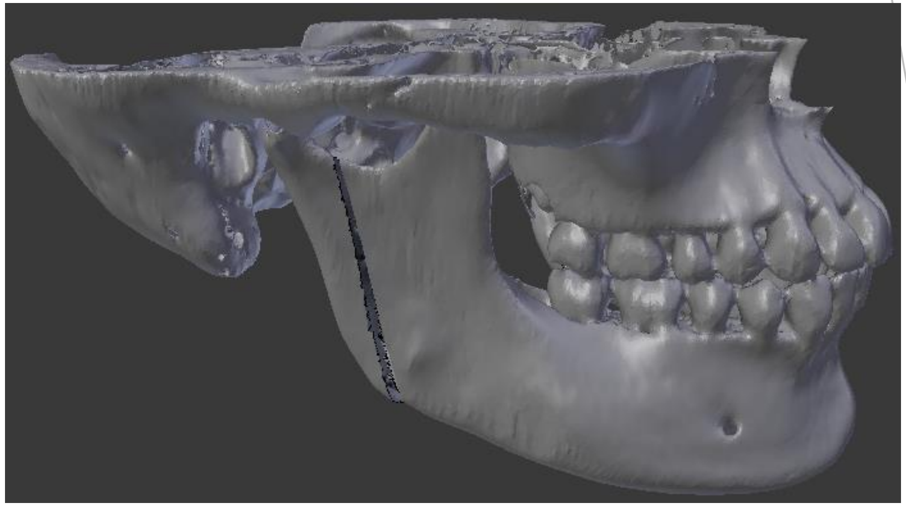


Bilateral Inverted-L Osteotomy

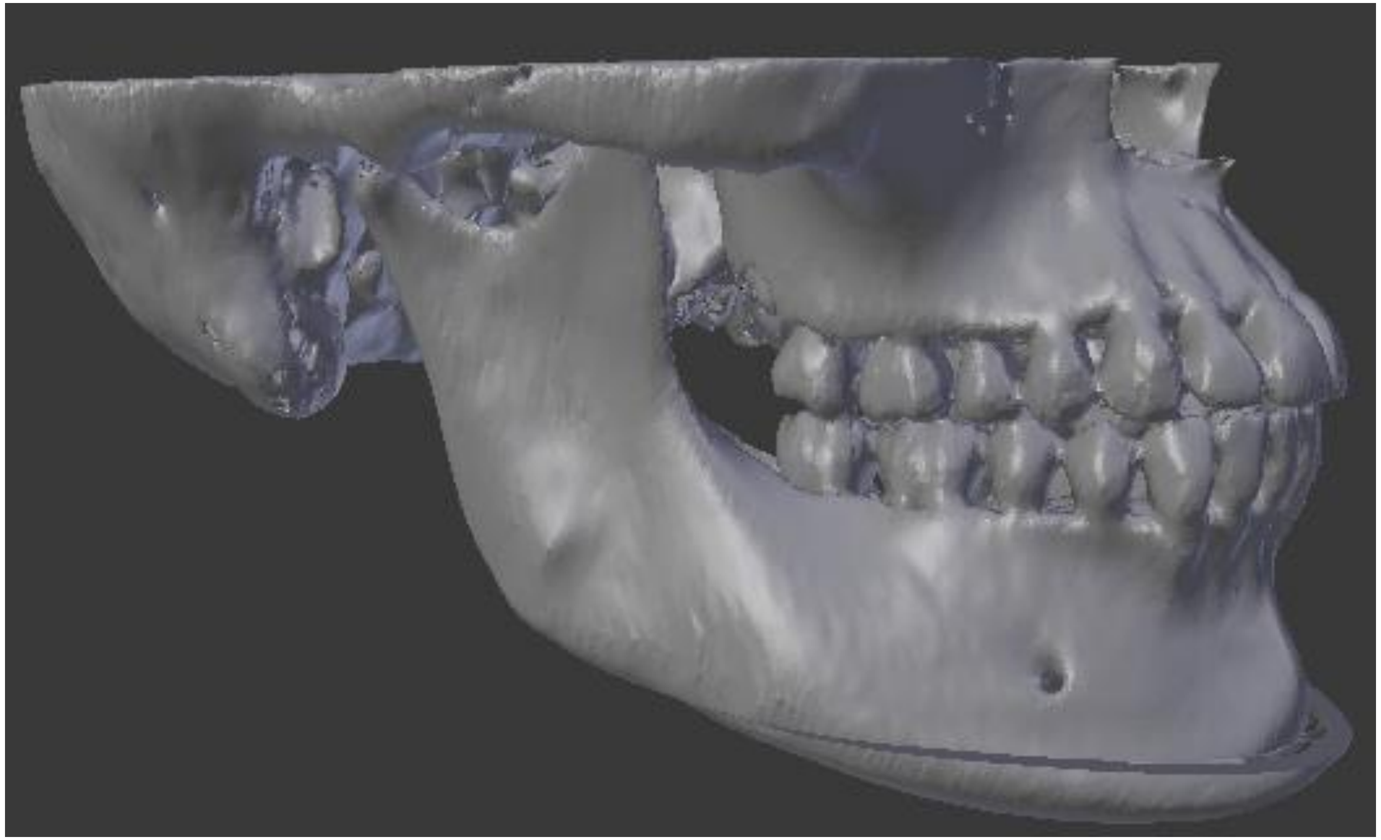


Bilateral Vertical-Ramus Osteotomy

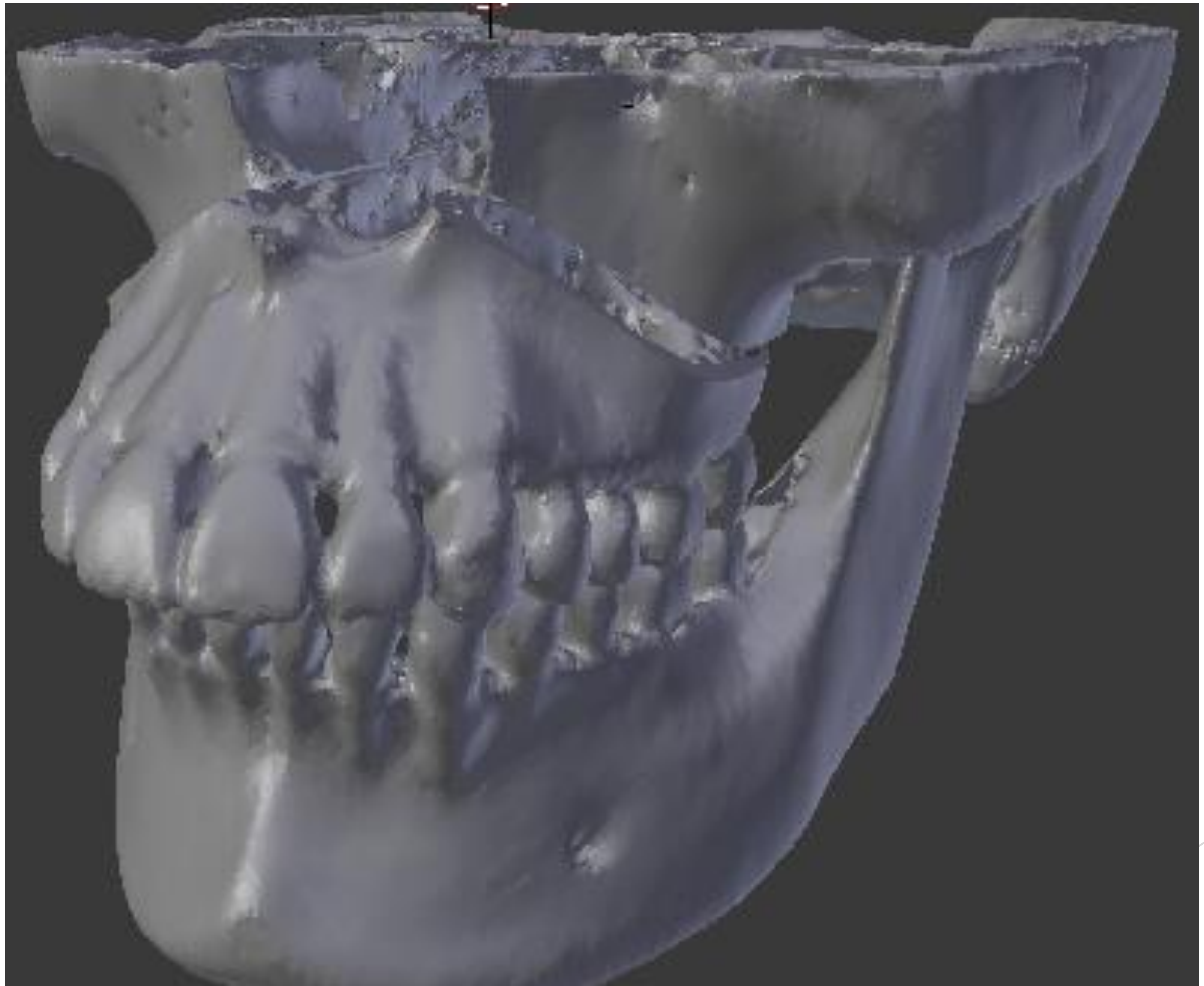




Genioplasty Osteotomy



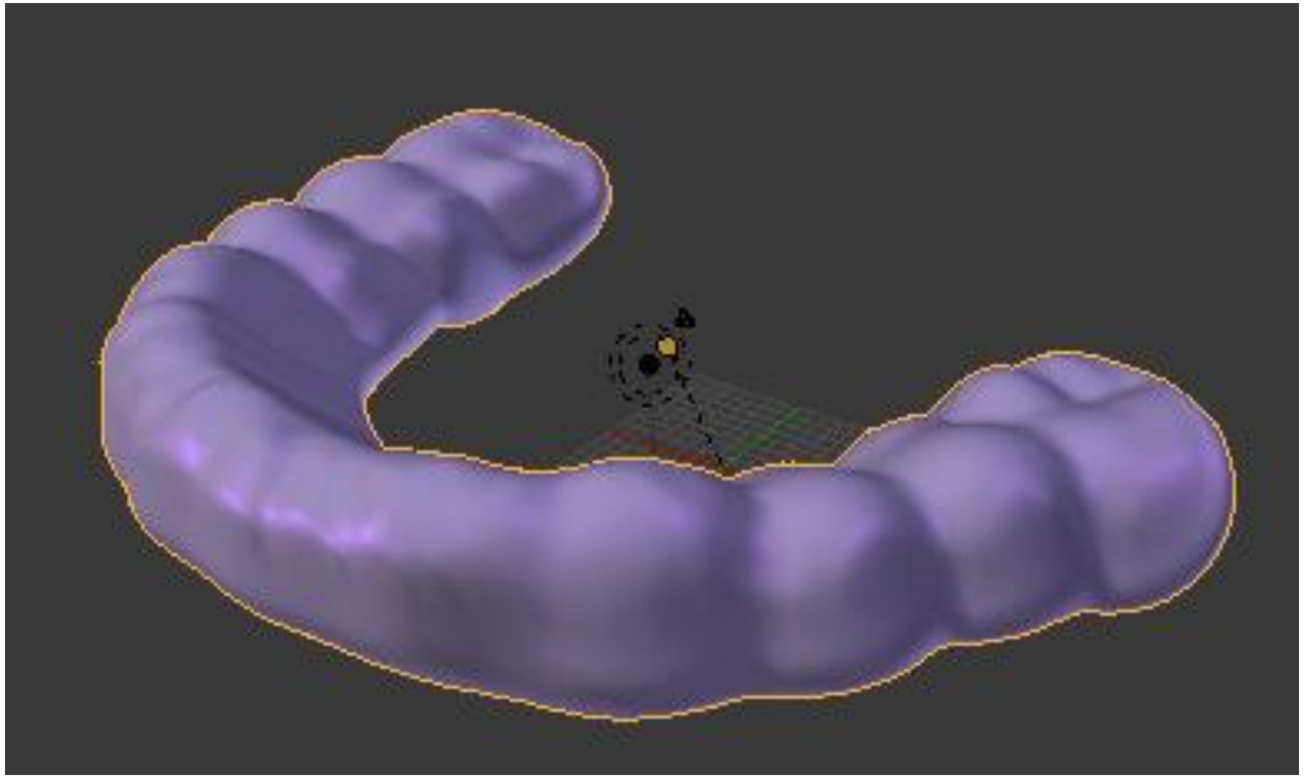
Lefort-I Osteotomy



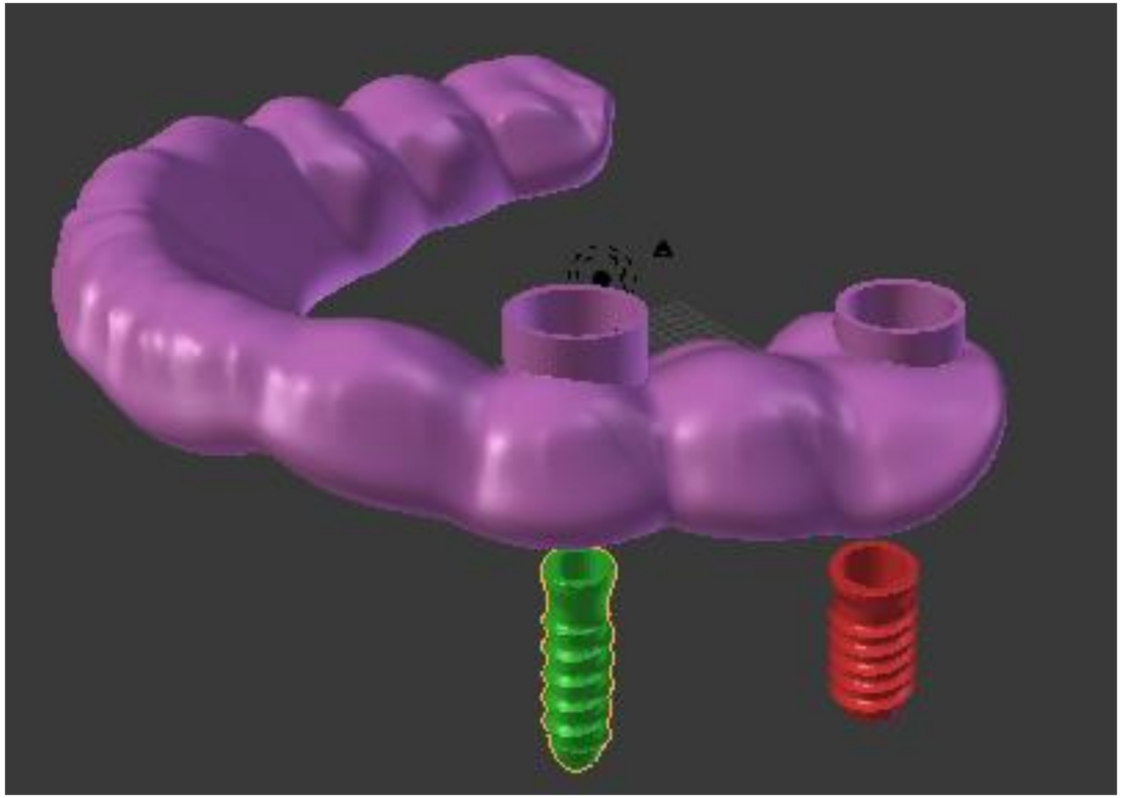
Digital Dentistry

- CREHS focuses in this area:
- Splints/Night Guard
- Surgical Guides
- Teeth Bridge Restoration
- Partial Framework
- Full Denture

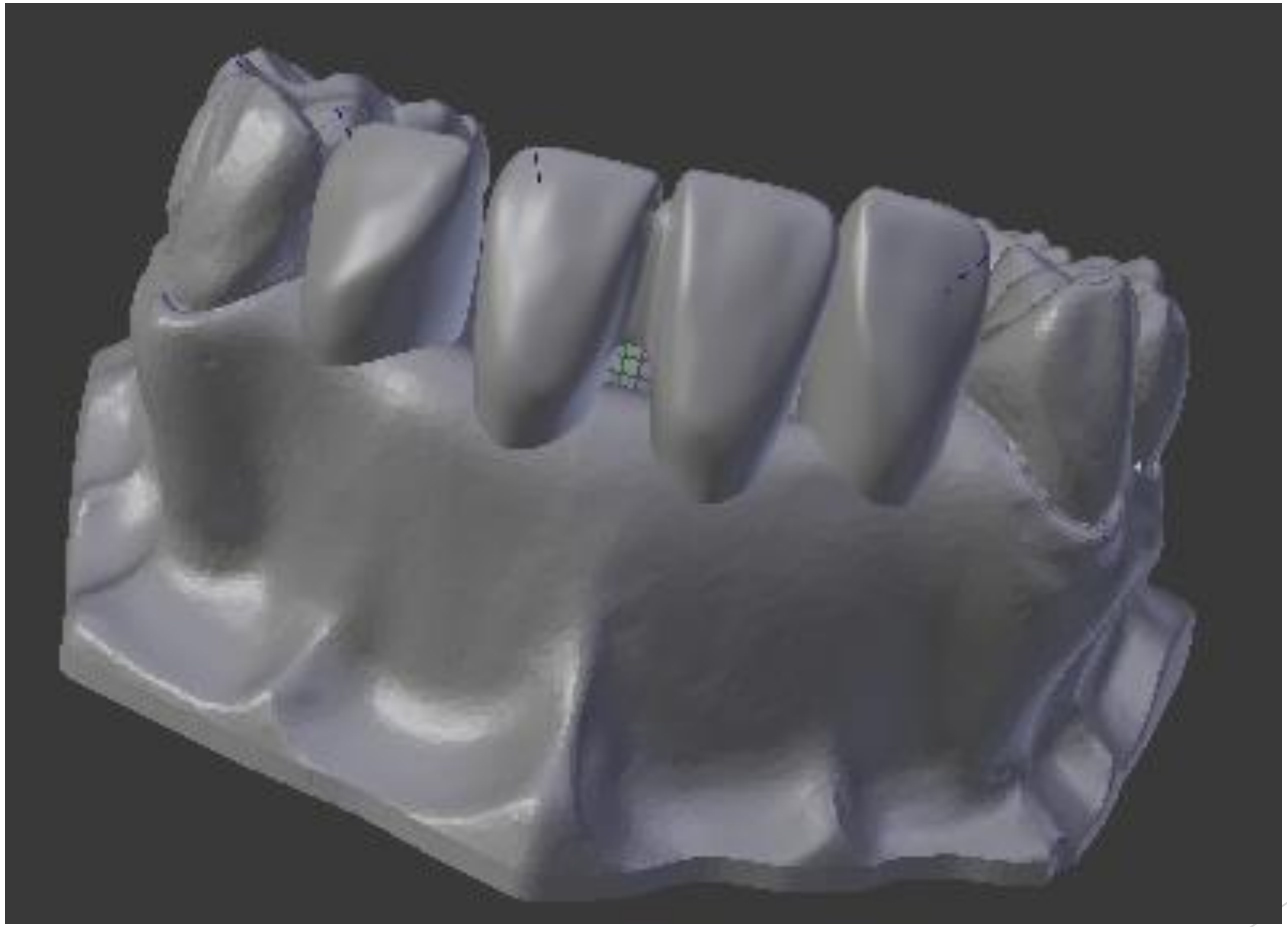
Splints/Night Guards



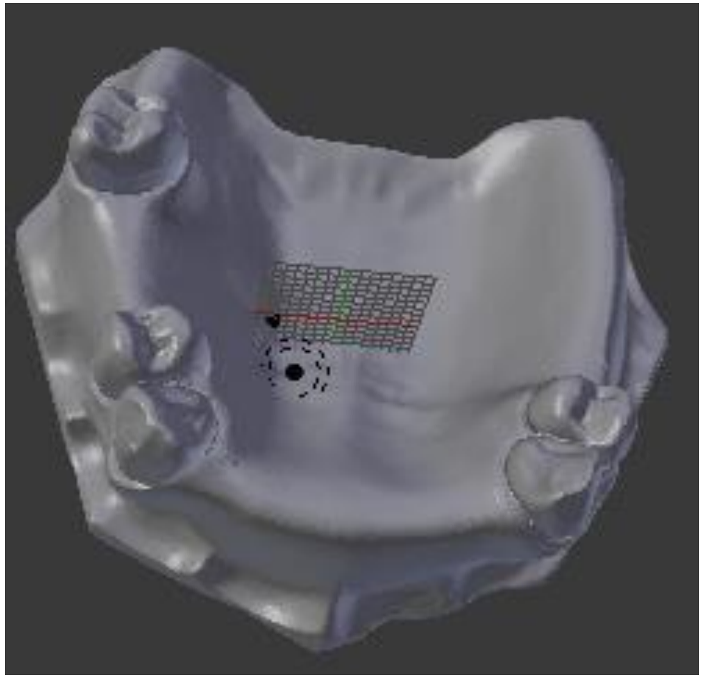
Surgical Guides

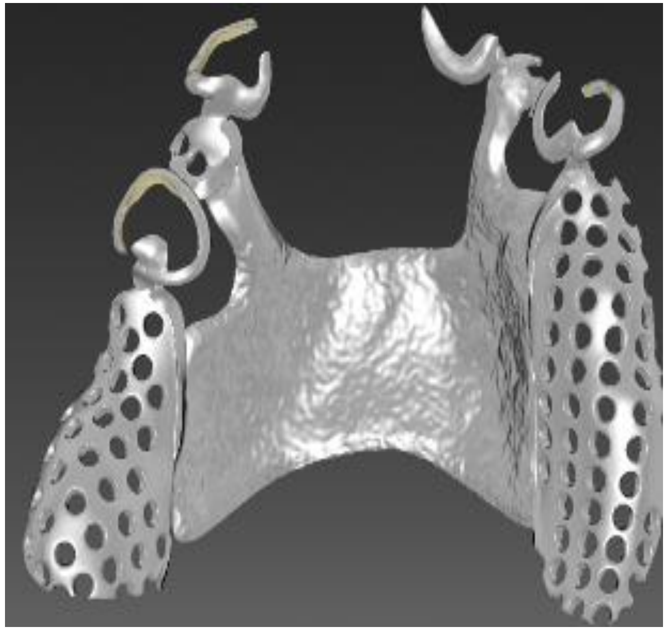


Teeth Bridge Restoration

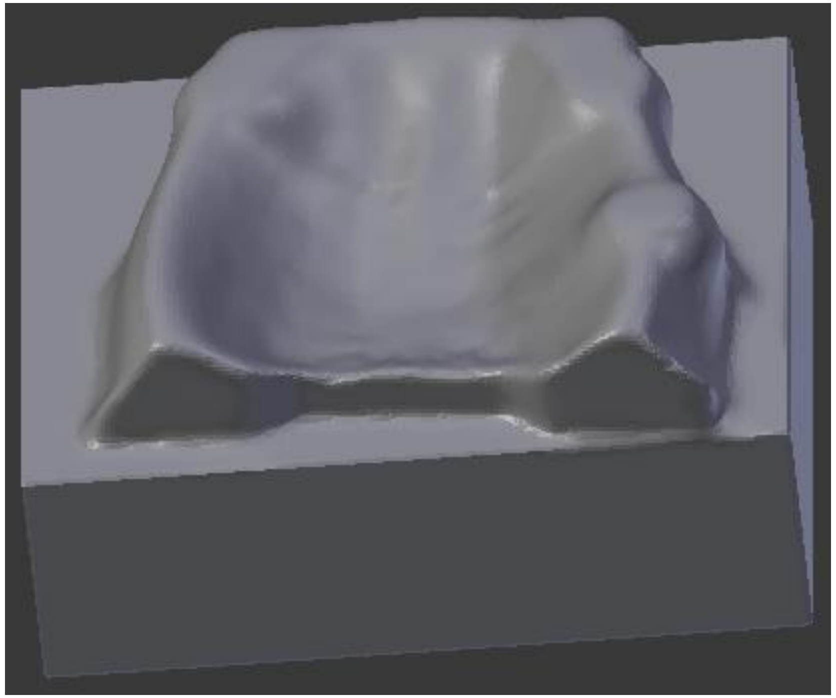


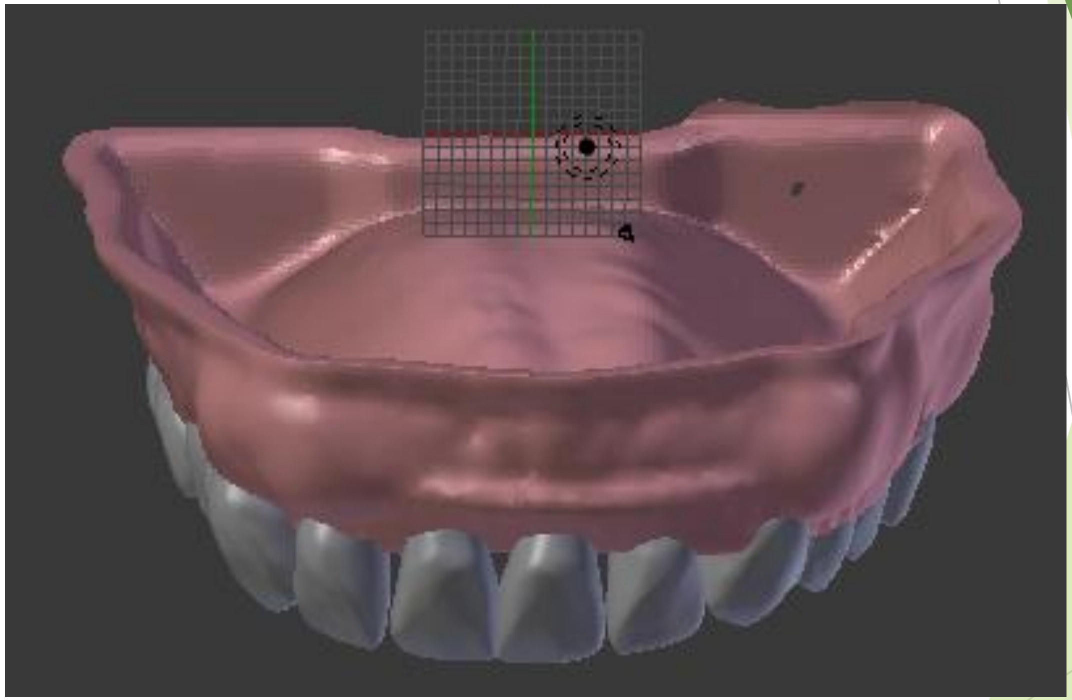
Partial Denture



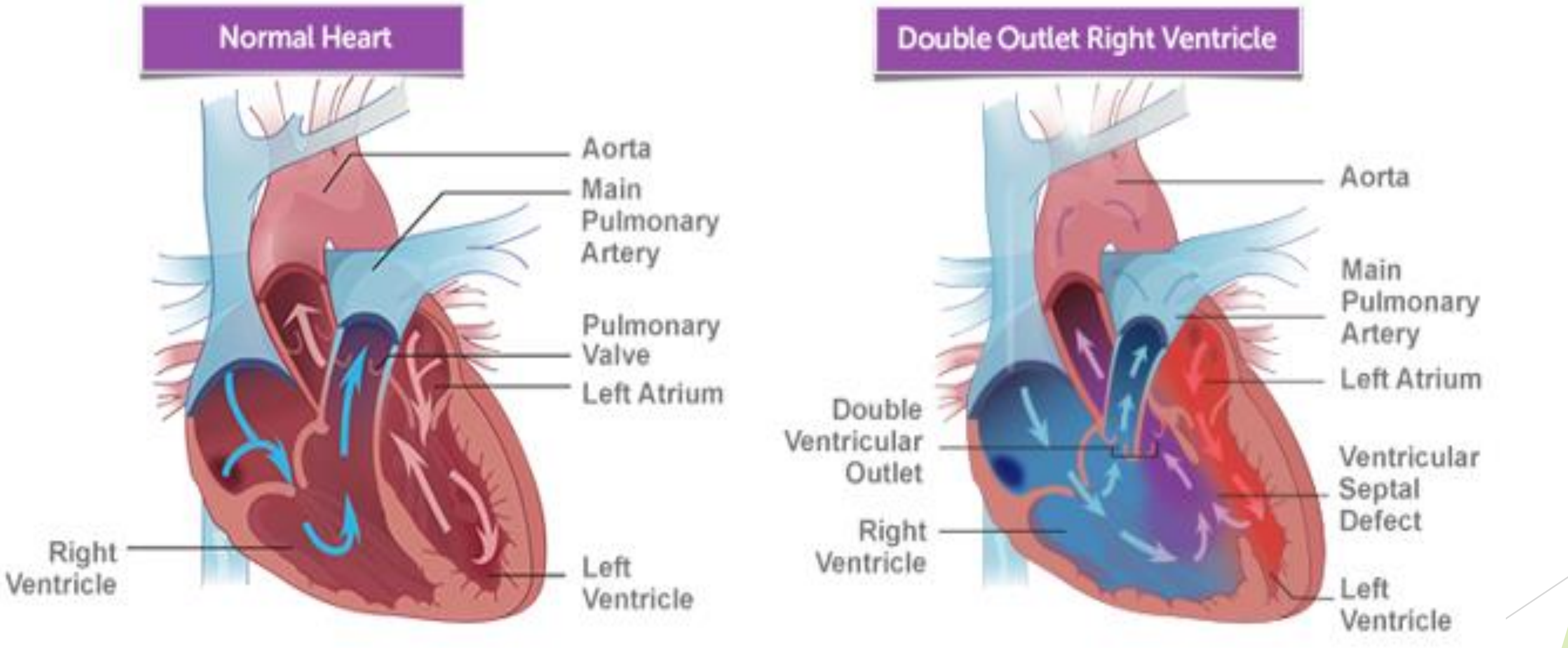


Full Denture





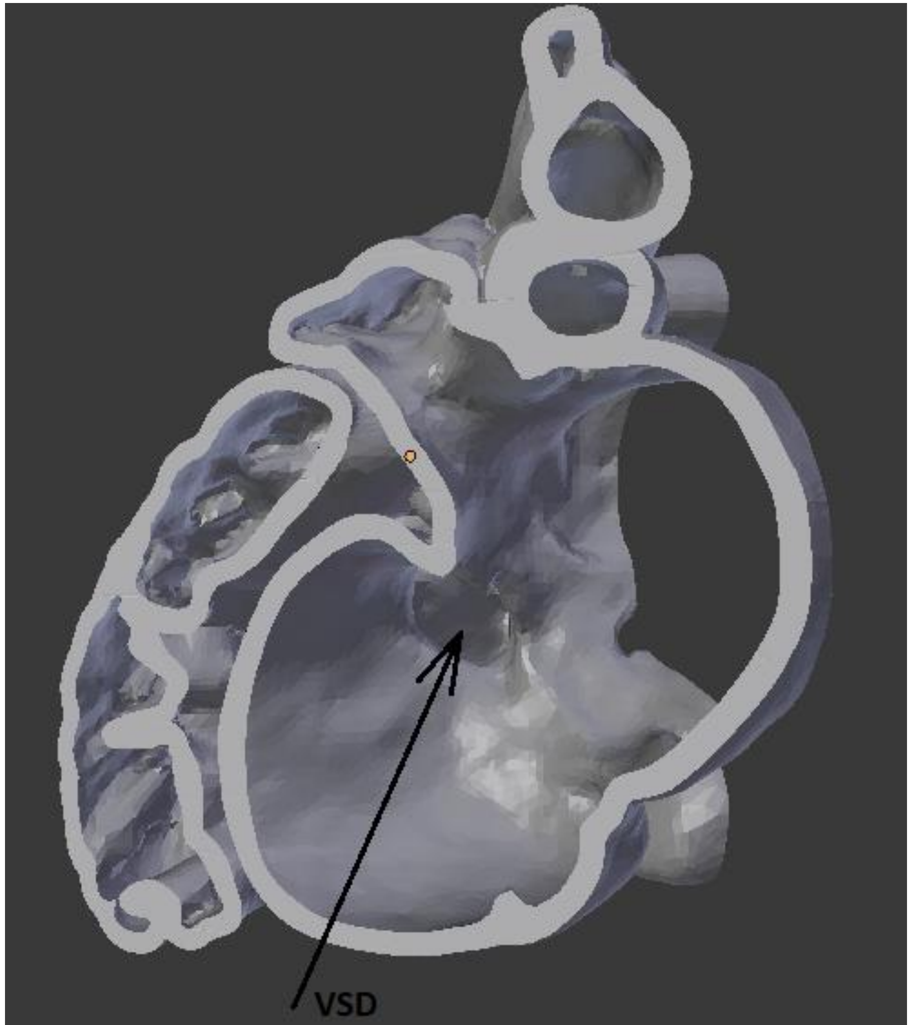
Case Study 1—Ventricular Septal defect (VSD)



Describing the Case

- The patient was born with double outlet right ventricle syndrome (DORV), accompanied by a ventricular septal defect (VSD).
- DORV: both great vessels (aorta and pulmonary artery) arise entirely from the right ventricle
- The pulmonary artery receives oxygenated blood from the left ventricle and into the pulmonary circulation whereas non-oxygenated blood from the RV is streamed to the aorta and thus to the systemic circulation.
- Treatment: VSD closure requires an intra-ventricular patch sutured into place, closing the ventricular septal defect and redirecting left ventricular outflow to the aorta.

Medical 3D Reconstructed VSD Model



3D printed VSD haptic Model

Case Study 2—Soft Tissue Sarcoma

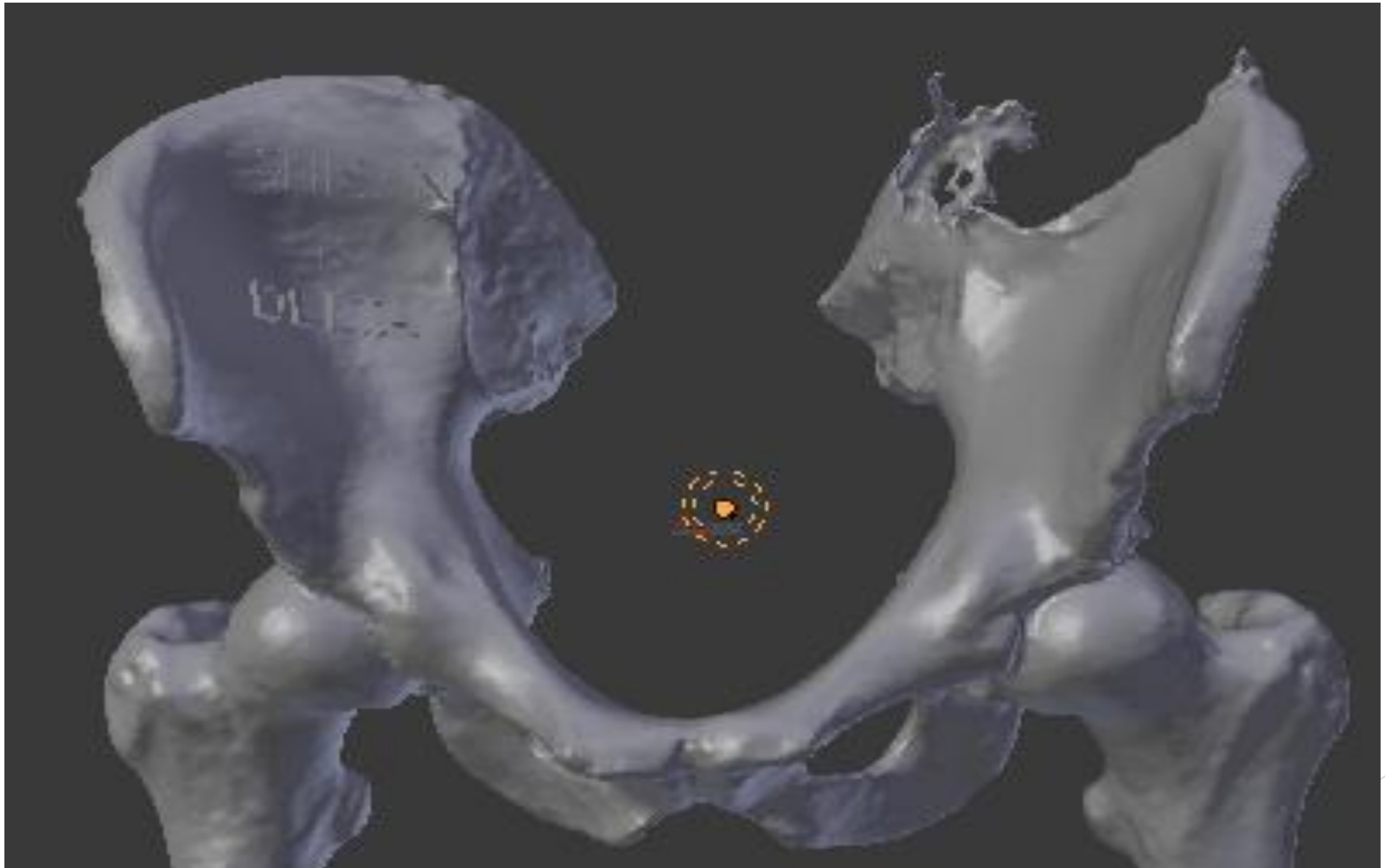
- The patient has extensive soft tissue sarcoma invading into the osseous structures of the left pelvis
- Treatment: Clinician identifies the extent of the neoplasm; resects with wide margin. The skeletal defect is then filled using a *patient-specific prosthetic implant*.

Pleomorphic (Soft Tissue) Sarcoma

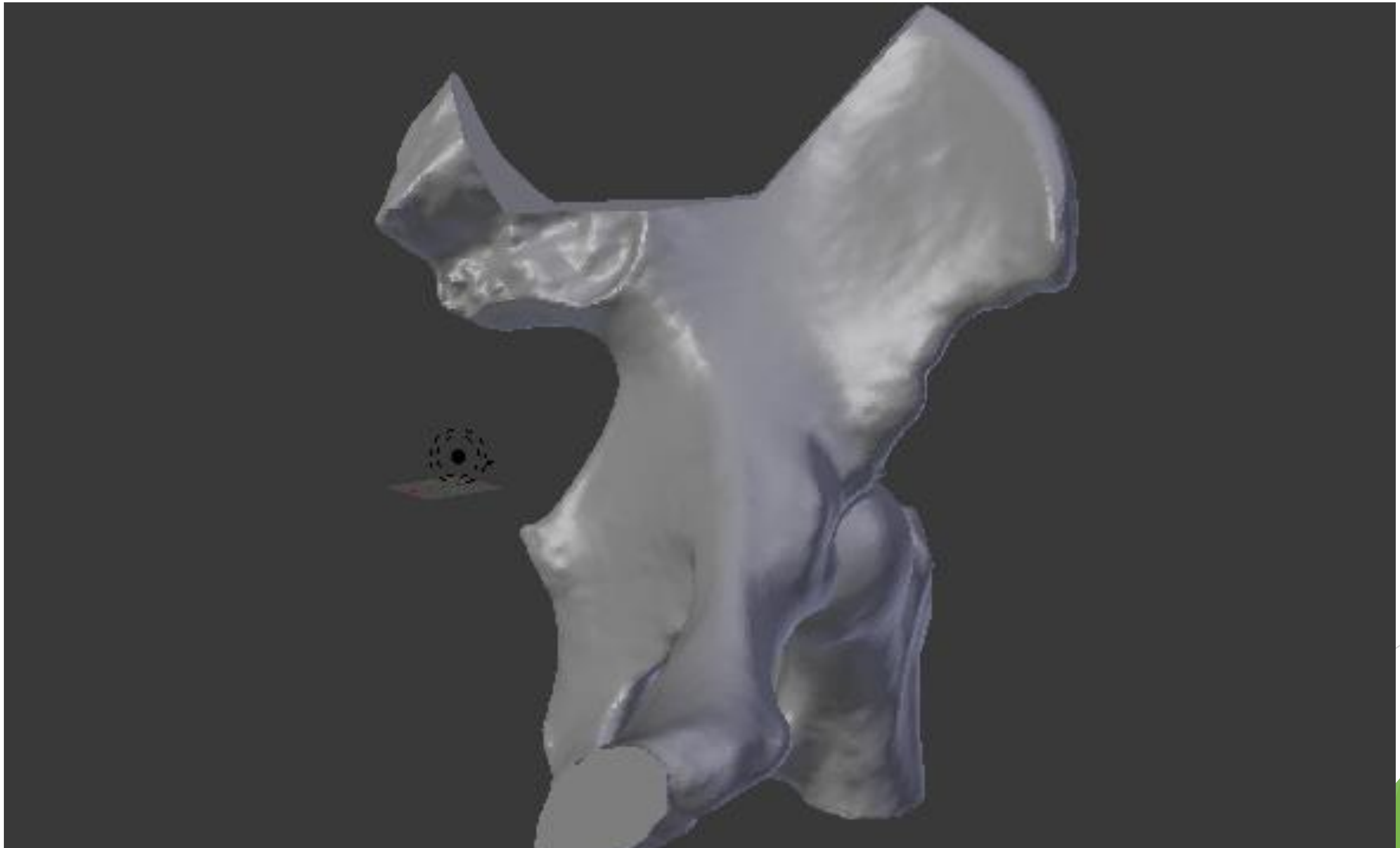
Planning/Simulating the Treatment

- Reconstruct pelvis (note: missing left iliac crest due to bone segmentation);
- Design hemi-pelvis
- Use cutting guides to guide the excision of the neoplasm
- Reconstruct the excised bone fragment using a customized implant
- Provide surgical guide
- 3D print the customized implant

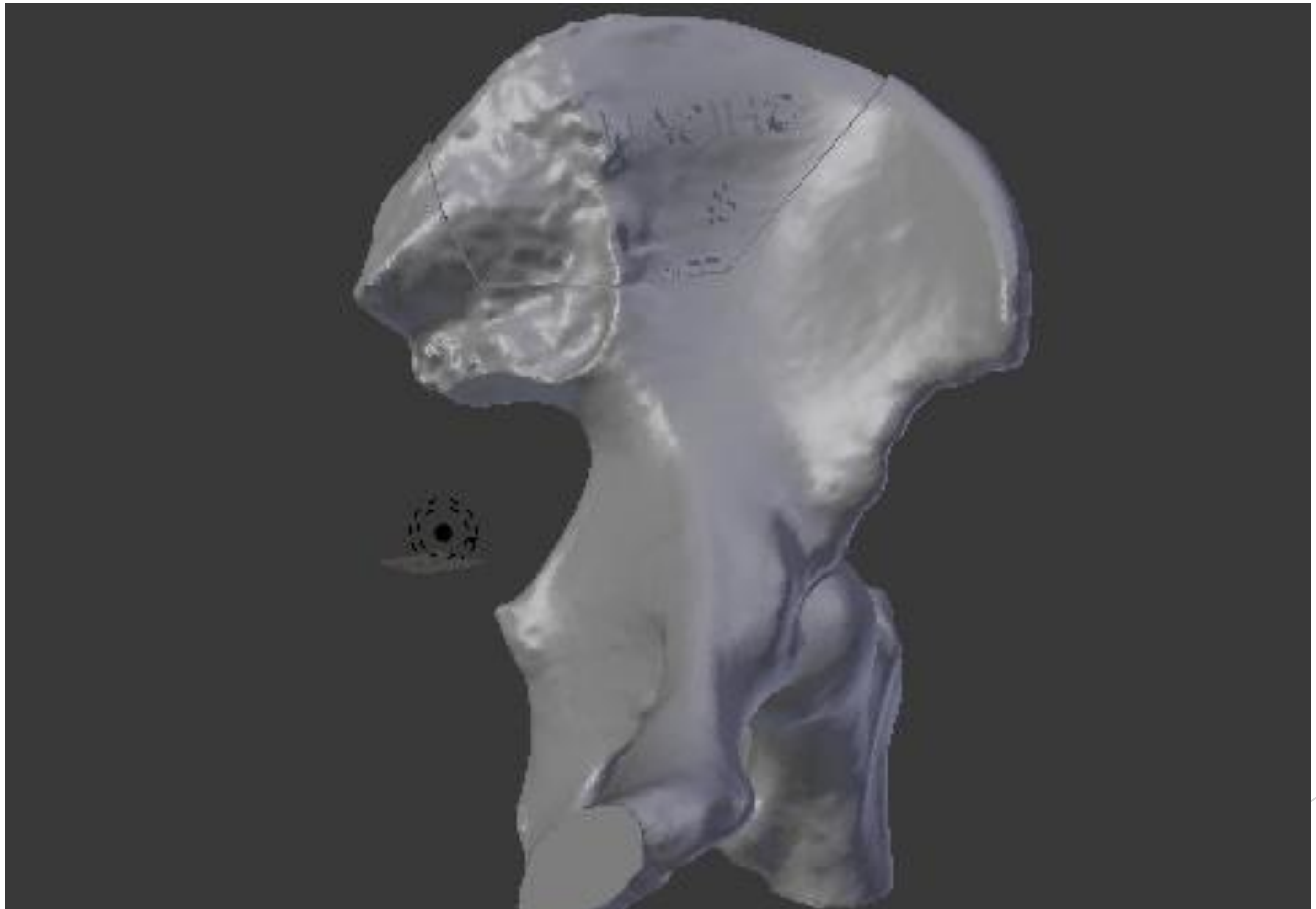
3D Reconstructed Pelvis Model



Excision of the Neoplasm



Reconstruct the excised bone fragment using a customized implant



3D-printed medical customized implant

- 

Case Study 3—Bilateral Transhumeral Amputation Project

- <u>Case Description</u>
- A 19-year-old man who accidentally lost his two arms on December 16, 2015, due to contact with overhead wire. He caught on fire, his right hand was detached and his left arm was broken. One of the most challenging life situations is when someone experiences the loss of both arms above the elbow joint, known as bilateral transhumeral amputation. This was the case of this young man.
- His case was taken up by Medical Makers, Canada as a project, to offer solutions. Delta AM was involved in the project of providing artificial arm. Scans of the hands were taken, and Delta AM used the scan data to design and 3D print the left-hand socket.

The Patient

Prosthetic device for Patient

- The completed left prosthesis: Delta AM provided digital O&P solution to the socket

Carbon and Dentsply Sirona introduce new 3D printed denture workflow and material system

- Carbon’s Digital Light Synthesis (DLS) 3D-printers PLUS
- Dentsply Sirona’s Lucitone Digital Print Denture materials
- Will lead to accuracy, consistency and throughput in denture manufacture

Carbon’s Digital Light Synthesis (DLS) 3D-printers for denture manufacture

Source: https://www.3dprintingmedia.network/carbon-dentsply-sirona-3d-printed-denture-workflow/

Why Dentists and Dental Labs Should take Digitalization Seriously

- We hear that about 75% are still into analog while about 25% are into digital. This is dangerous!
- It is the Dentistry of today and tomorrow
- It is eco-friendly
- It will continue to satisfy customer requirements
- It is ‘time-cost-speed’, ‘one-stop’ healthcare solution
- Dental clinics and laboratories that stick to analog will loose out to digital clinics and labs in the next few years!

Main Challenges Affecting Adopting Medical & Dental 3D Printing in North America

Three that clearly stand out:

- Reimbursement
- Point of Care (POC) manufacturing
- Regulatory huddles with FDA and Health Canada

Future Medical & Dental 3D Printing

- The future is happening today
- 3D Printing Lab in hospital and bedside
- New custom implantable medical/dental devices
- More FDA & Health Canada clearances
- Evidence-based publications will ease reimbursement
- Tissue printing

Digital Dentistry at Centre for Rehabilitation & Health Services (CREHS)

Digital Dentistry at Centre for Rehabilitation & Health Services (CREHS)

What Next?

- Let’s promote digital dentistry in Canada
- Many organizations in USA are promoting digital healthcare way ahead of what is happening up North! (Confirmed from reports of SME in Medical AM/3D Printing Workgroup)
- Collaboration amongst clinics and laboratories is the key
- Research, Education, and Training (RET) cannot be compromised.

Contact:

Dr. Godfrey Onwubolu,
Centre for Rehabilitation & Health Services (CREHS) Inc.
2 County Court Blvd, Suite 202,
Brampton, ON Canada, L6W 3X7

Email: godfrey.onwubolu@crehsinc.com
Website: www. crehsinc.com
Tel: 905-451-5979; 416-886-8132

Thank You for Listening

- Questions & Answers!

- I would like to thank Mr. **Ettore Palmeri** for inviting me to this occasion; I would like to thank Deepak Naik & Lisa Rogers of George Brown College; Dr. Femi Adegun and Dr. Leroy Clarke who are my colleagues at Centre for Rehabilitation and Health Services. Patterson and Dentsply-Sirona are appreciated for their support.
- Presented By: Dr Godfrey Onwubolu Ph.D, FBS, C.Eng, P.Eng

References

- [1] Navarro, M., Michiardi, A., Castano, O., andPlanell, J., "Biomaterials in orthopaedics", Journal of the Royal Society Interface, vol. 5, no. 27, pp. 1137-1158, Oct. 2008
- [2] Singare, S., Ping, W., andGuaghui, "The Application of Rapid Prototyping and Manufacturing for Anatomical Modelling in Medicine", Journal of Biomimetics, Biomaterials, and Tissue Engineering, vol. 6, pp. 57-65, Sep. 2010
- [3] Pattanayak, D. K., Fukuda, A., Matsushita, T., Takemoto, M., Fujibayashi, S., Sasaki, K., Nishida, N., Nakamura, T., Kokubo, T., "Bioactive Ti metal analogous to human cancellous bone: Fabrication by selective laser melting and chemical treatments", Acta Biomateriala, vol. 7, no. 3, pp. 1398-1406, Mar. 2011