Future Healthcare: The Impact of 3D Printing

Godfrey Onwubolu, PhD, FBCS, CEng, PEng.: Delta Additive Manufacturing (DAM) Inc.

Presented at: Keenan Research Centre for Biomedical Sciences

St Michael's Hospital, 30 Bond St, Toronto, ON M5B 1W8

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- What Some Experts Say about Healthcare 3D Printing
- Healthcare 3D Printing Applications
- Some basic facts about Healthcare 3D printing:
  - typical workflow from image to 3D models, materials available etc.
- Medical models that can be used for surgical planning, simulations, trainings and educations
- 3D printing technologies for personalized implants:
  - Case Study 1—Ventricular Septal defect (VSD)
  - Case Study 2—Soft Tissue Sarcoma
  - Case Study 3—Bilateral Transhumeral Amputation Project
- Display some physical models at the seminar

What is Healthcare 3D Printing?

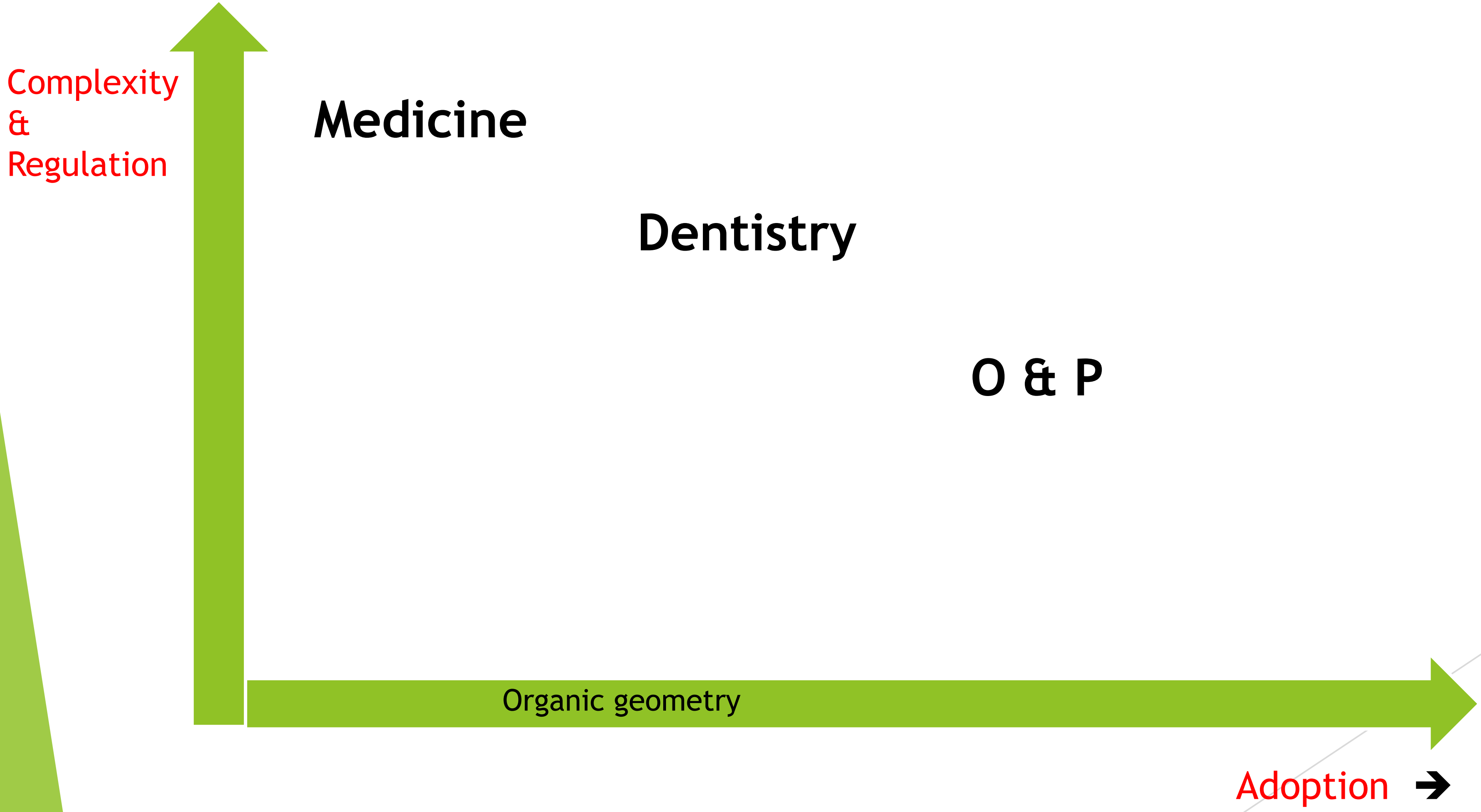
- From medical images (CT, MR, 3D US), use 3D Printing to make
  - reconstructed physical models of patient anatomy
  - Surgical assistance devices
  - Custom implantable devices

  - DICOM (Digital Imaging and Communications in Medicine) is the de-facto format for medical images

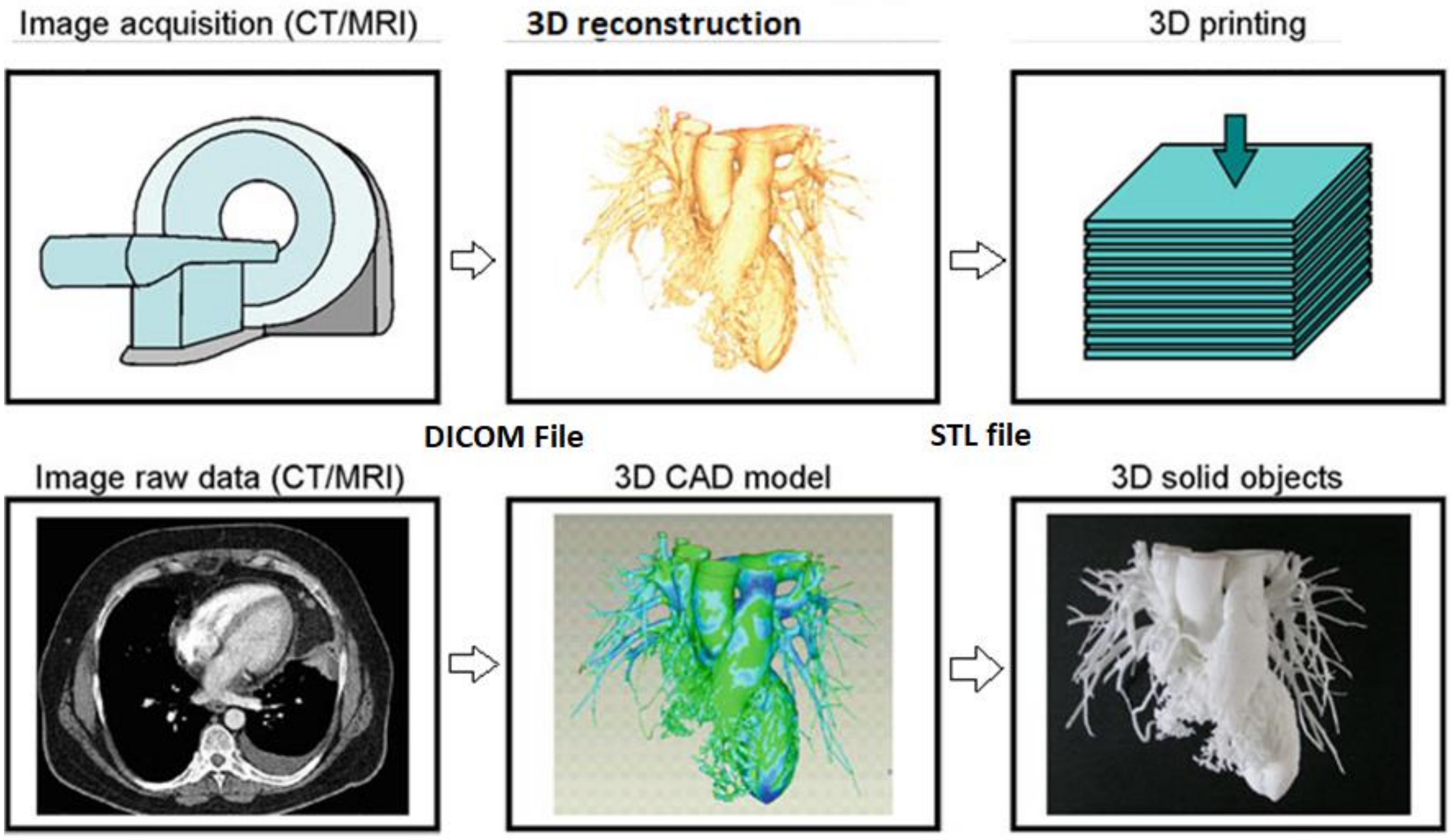
What Some Experts Say about Healthcare 3D Printing

- "*3D printing is certain to alter the daily practice of medicine 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…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

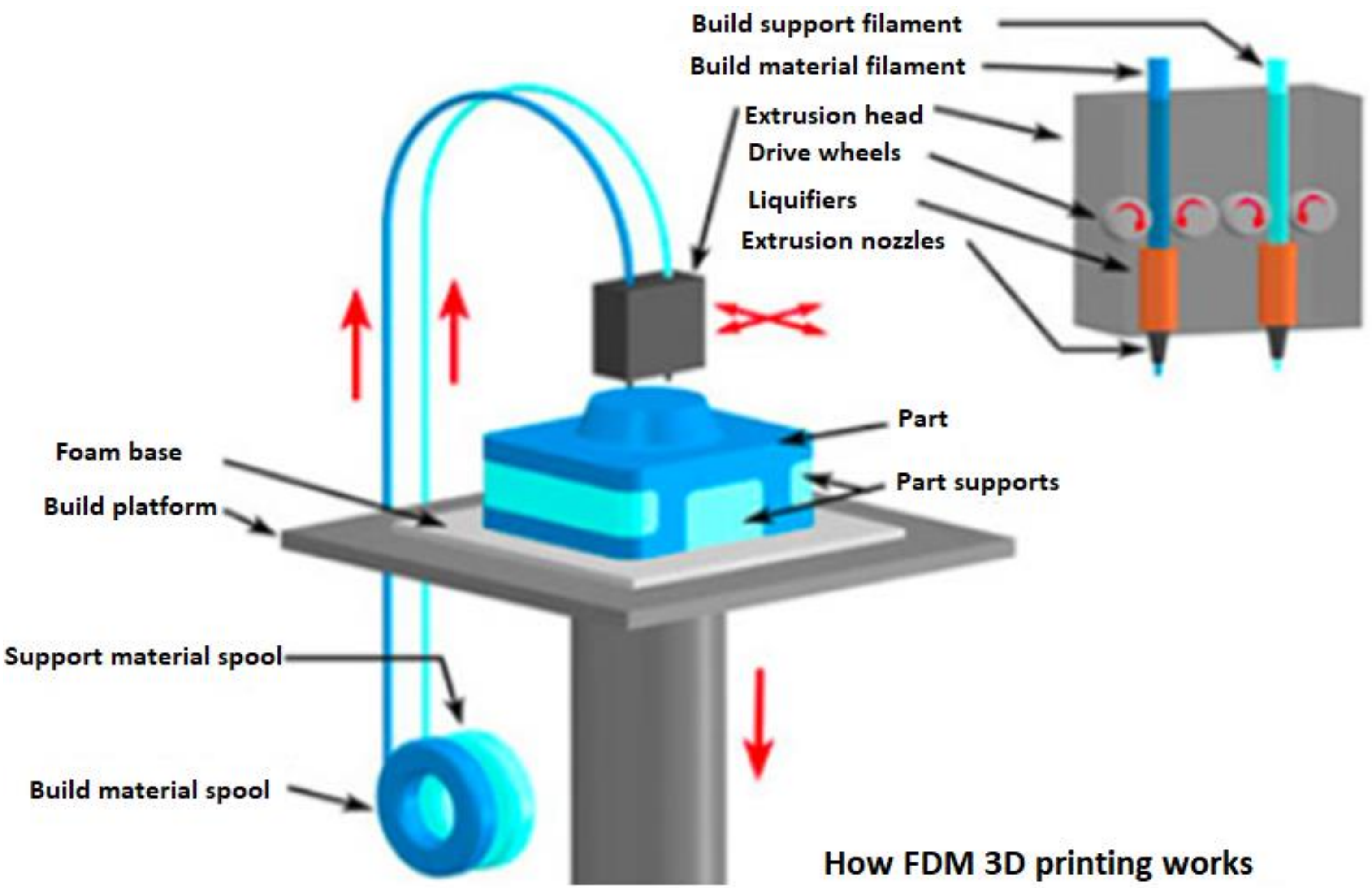
Healthcare 3D Printing Applications



Some basic facts about Healthcare 3D printing



How Fused Deposition Modeling (FDM) 3D printing Works



How FDM 3D printing works

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]
- 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

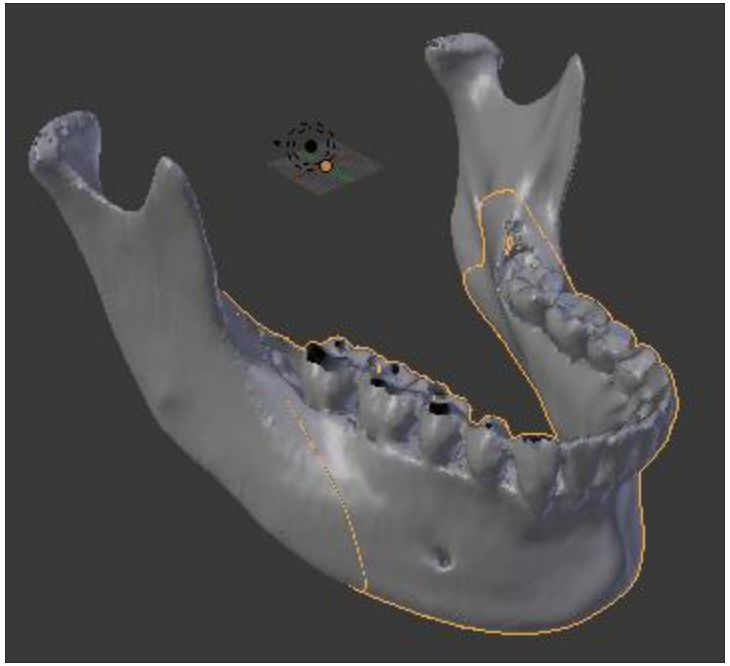
Aorta Workbench

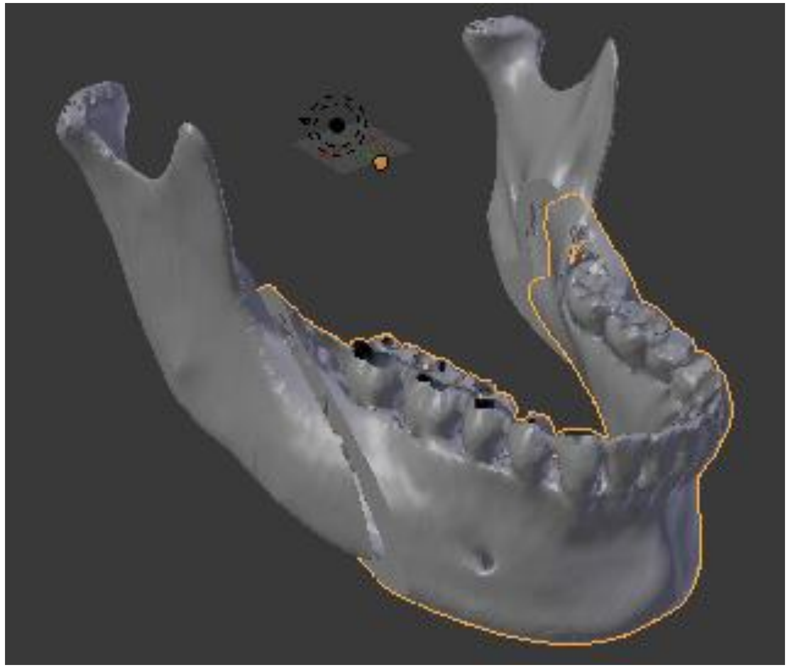
3D printed Kidneys

Orthognathic Surgery (Virtual Surgical Planning—VSP)

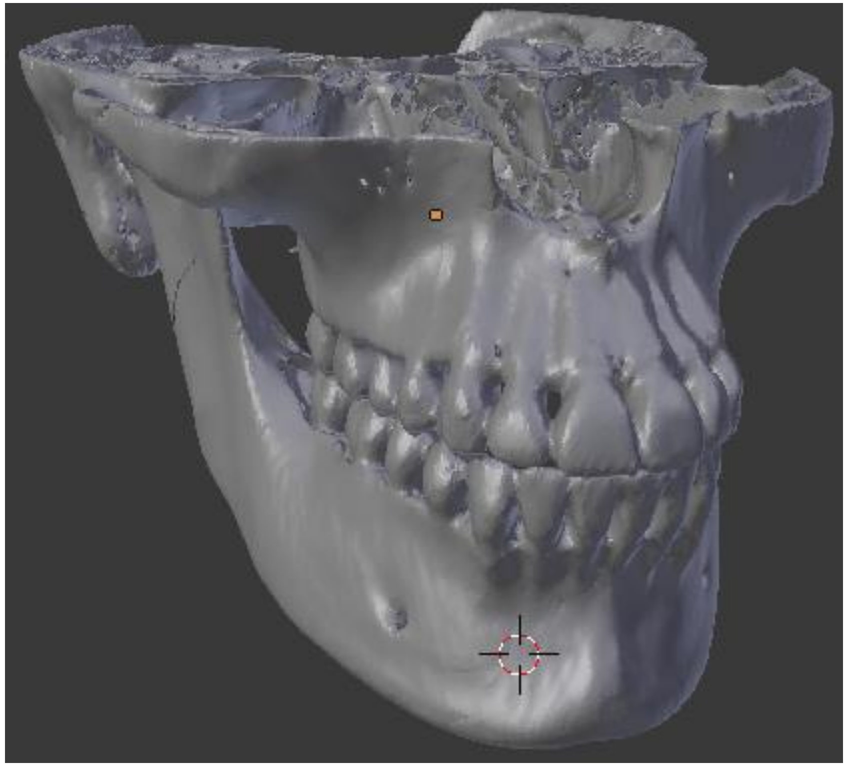
- Orthognathic Surgery: means to straighten a jaw
- Osteotomy: means a surgical operation in which a bone is cut to shorten/lengthen it or to change its alignment
- Common Osteotomies:
- BSSO-Bilateral Sagittal Split Osteotomy
- Bilateral C-Ramus Osteotomy
- Bilateral Inverted-L Osteotomy
- Bilateral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

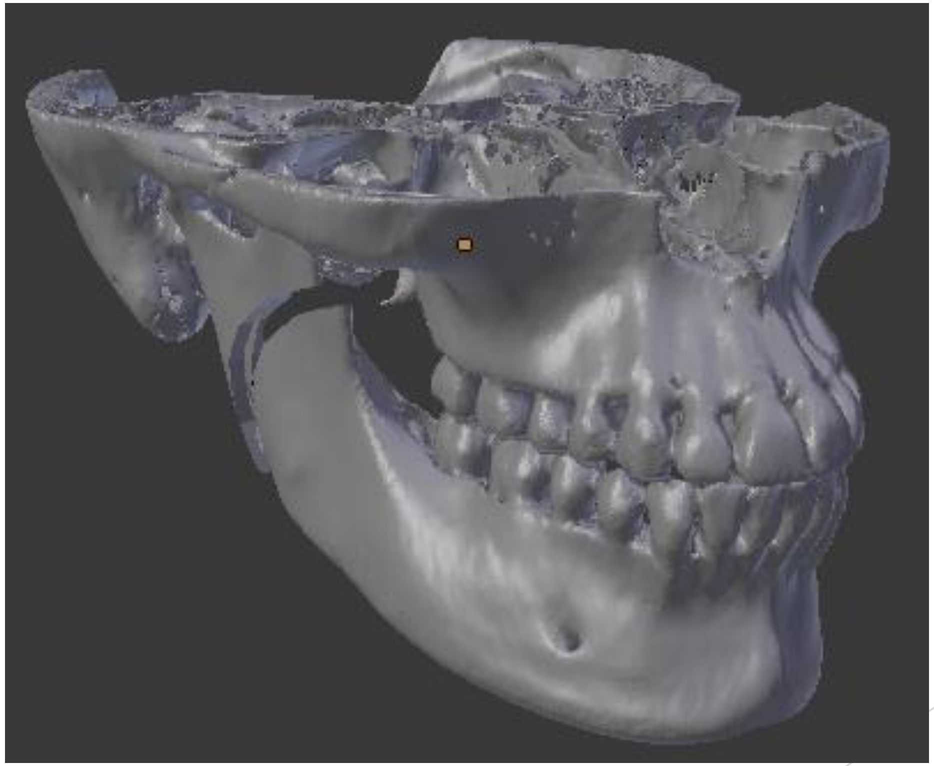
BSSO-Bilateral Sagittal Split Osteotomy



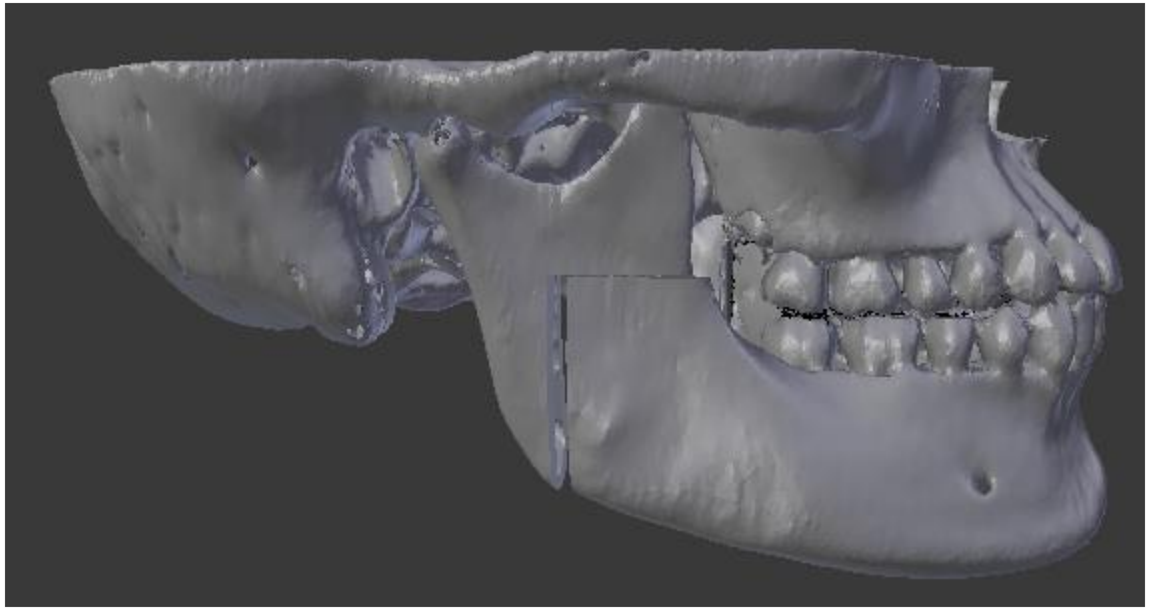


Bilateral C-Ramus Osteotomy

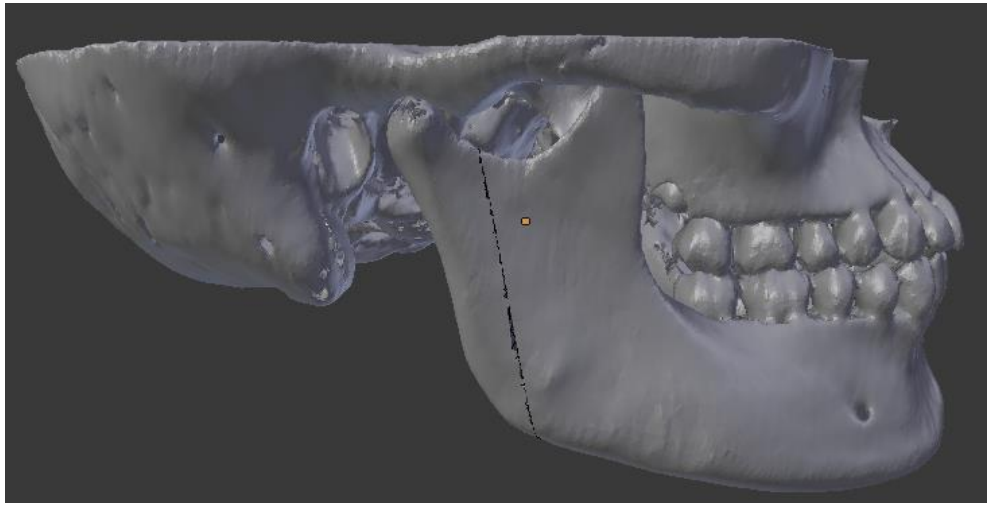


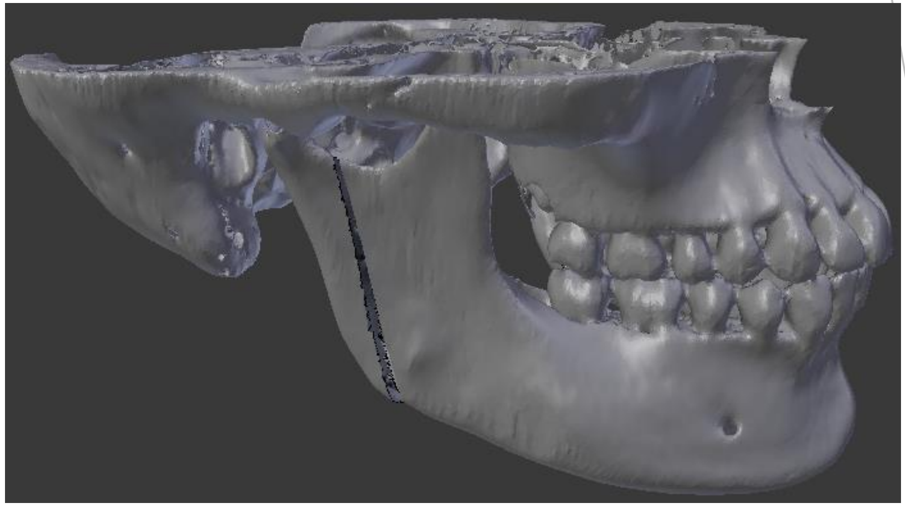


Bilateral Inverted-L Osteotomy

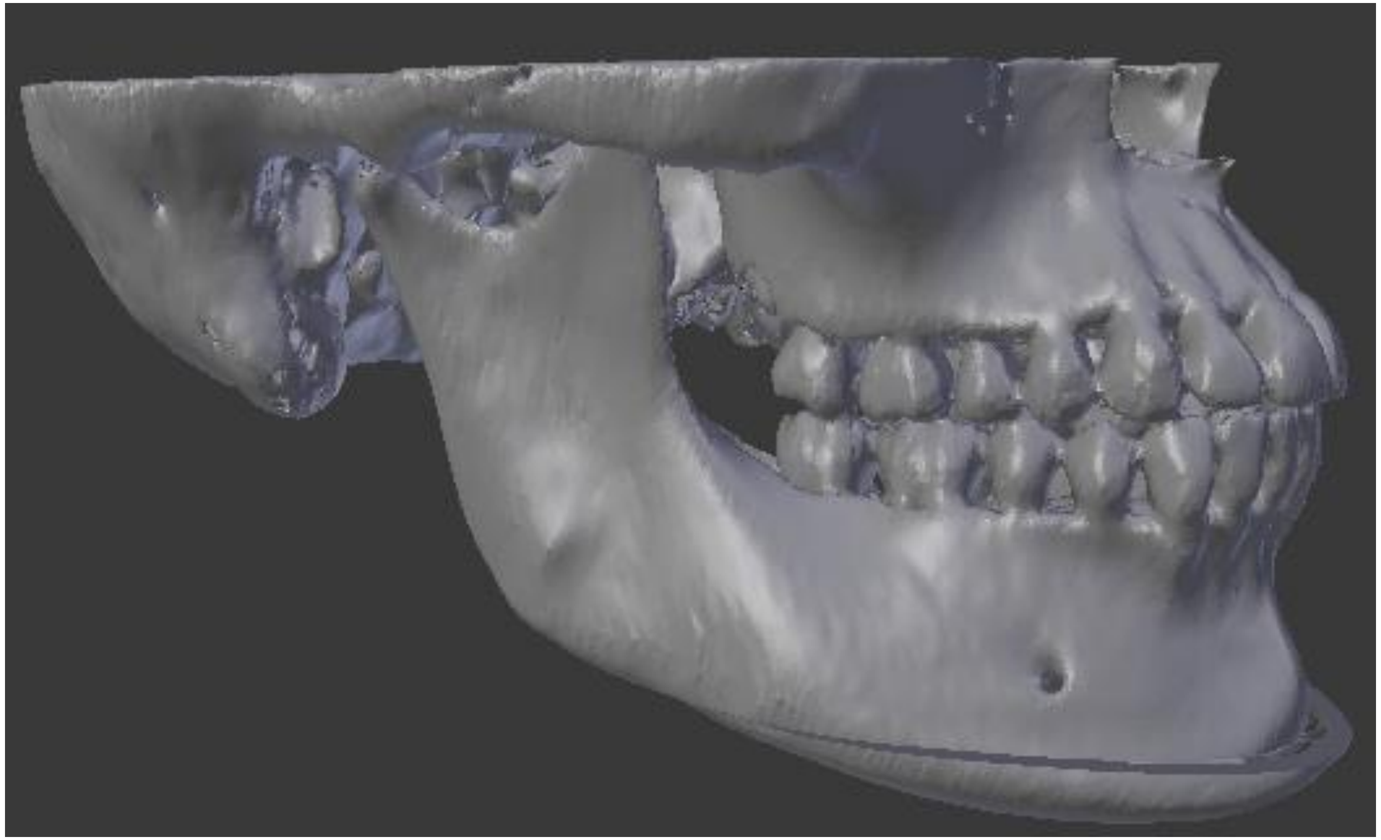


Bilateral Vertical-Ramus Osteotomy

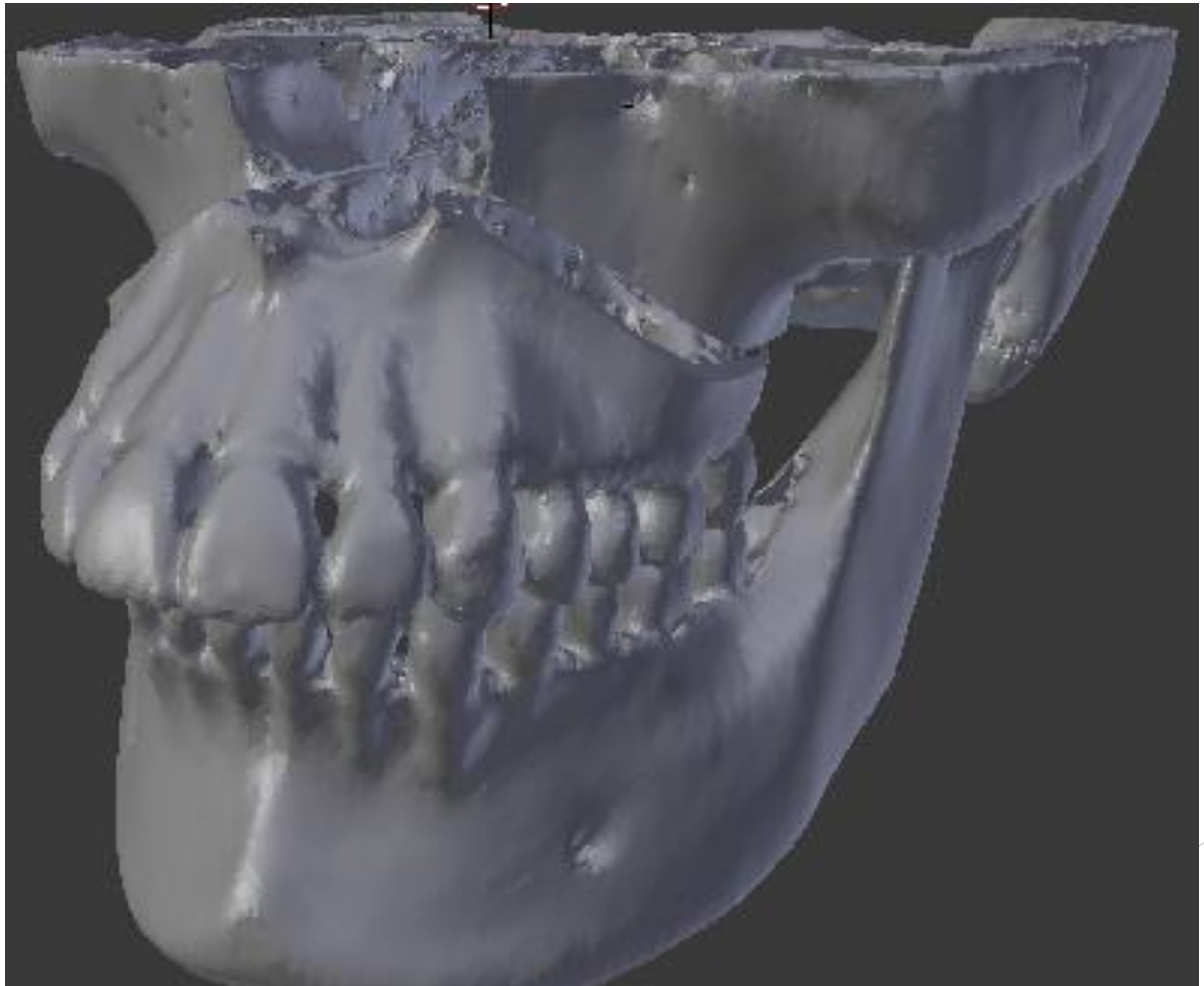




Genioplasty Osteotomy



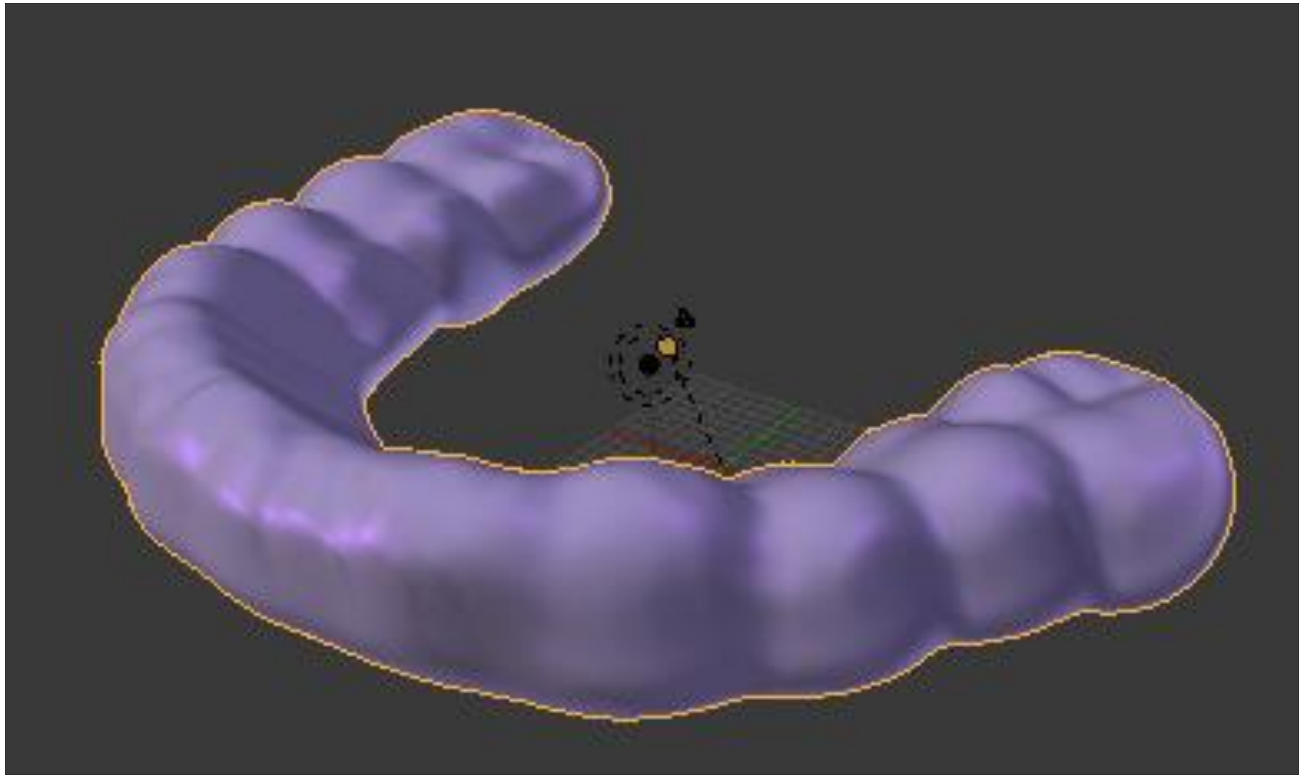
Lefort-I Osteotomy



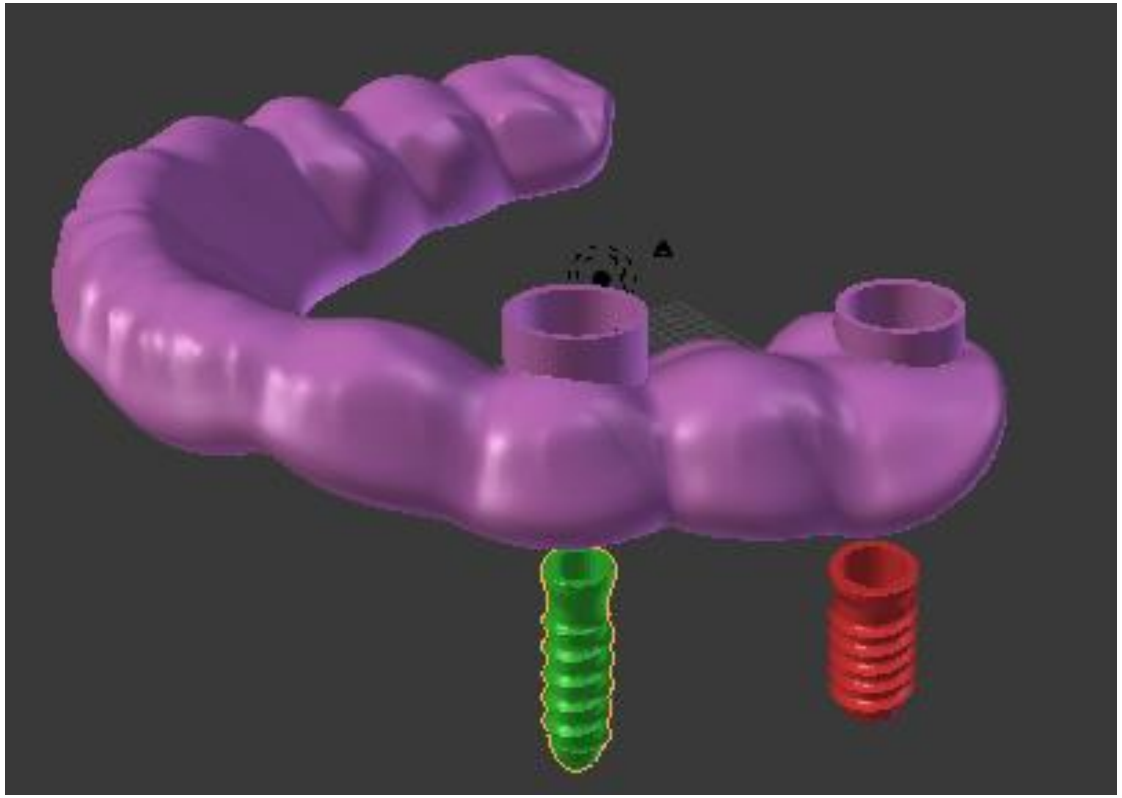
Digital Dentistry

- Delta AM has done a lot of work in this area:
- Splints/Night Guard
- Surgical Guides
- Teeth Bridge Restoration
- Partial Denture
- Full Denture

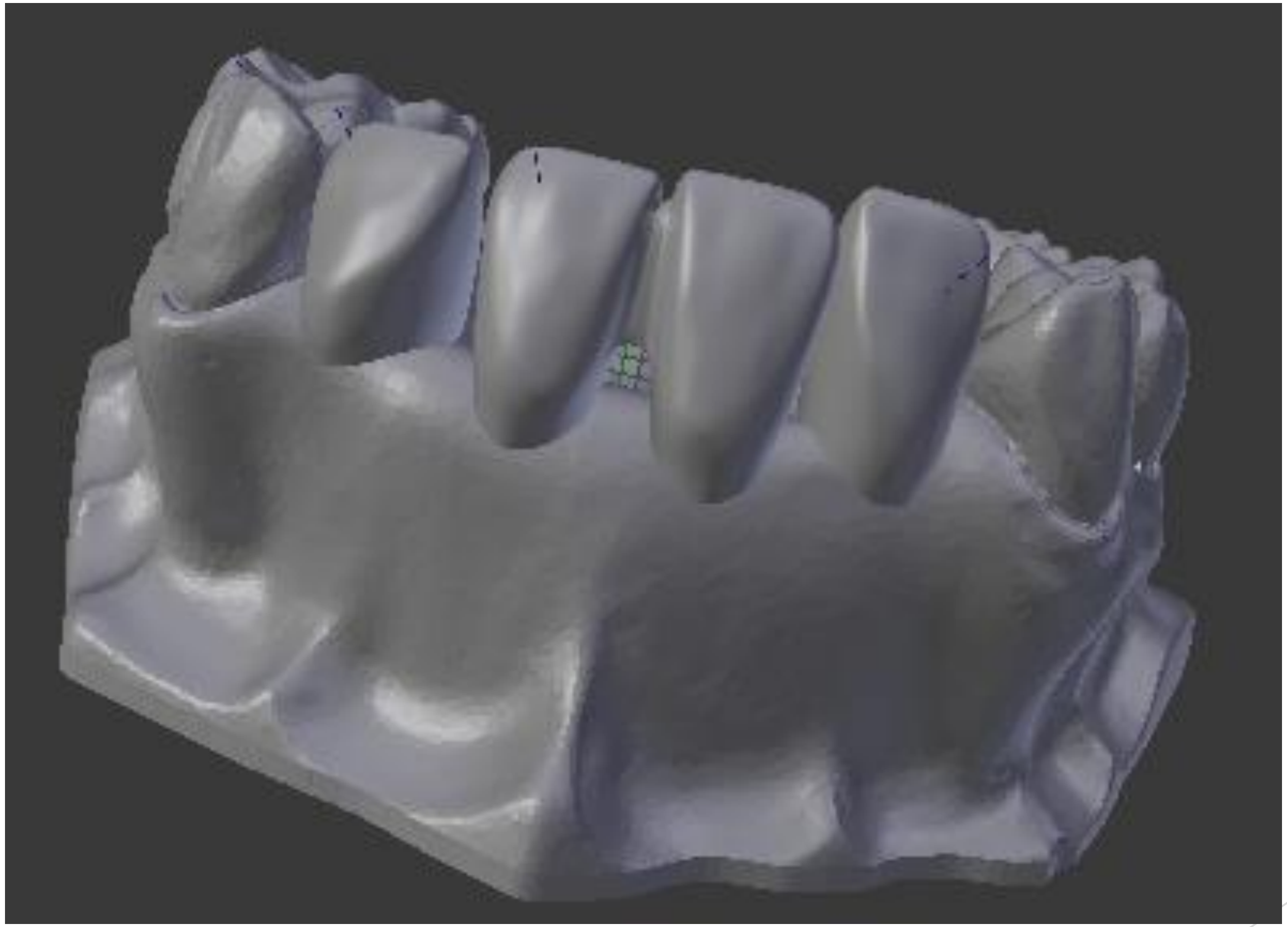
Splints/Night Guards



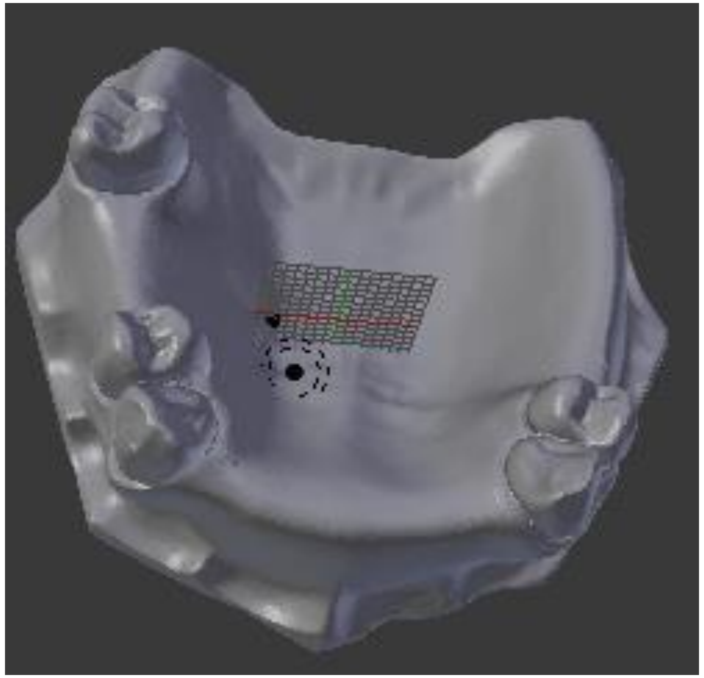
Surgical Guides

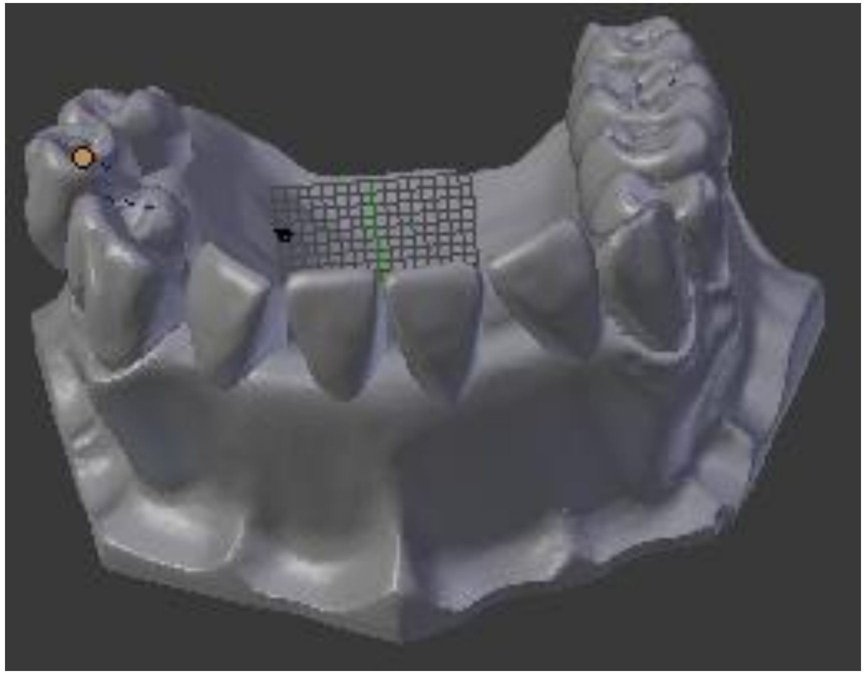


Teeth Bridge Restoration

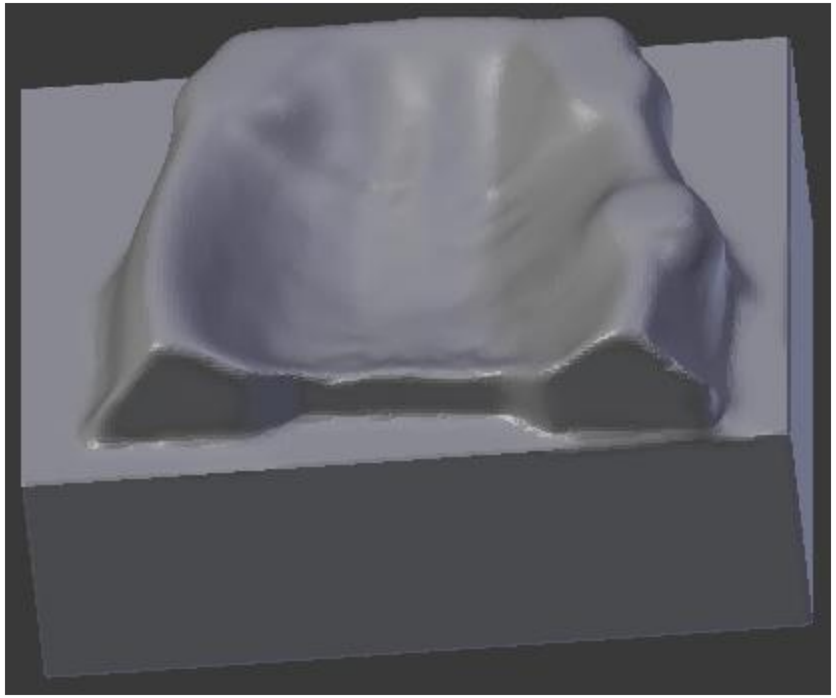


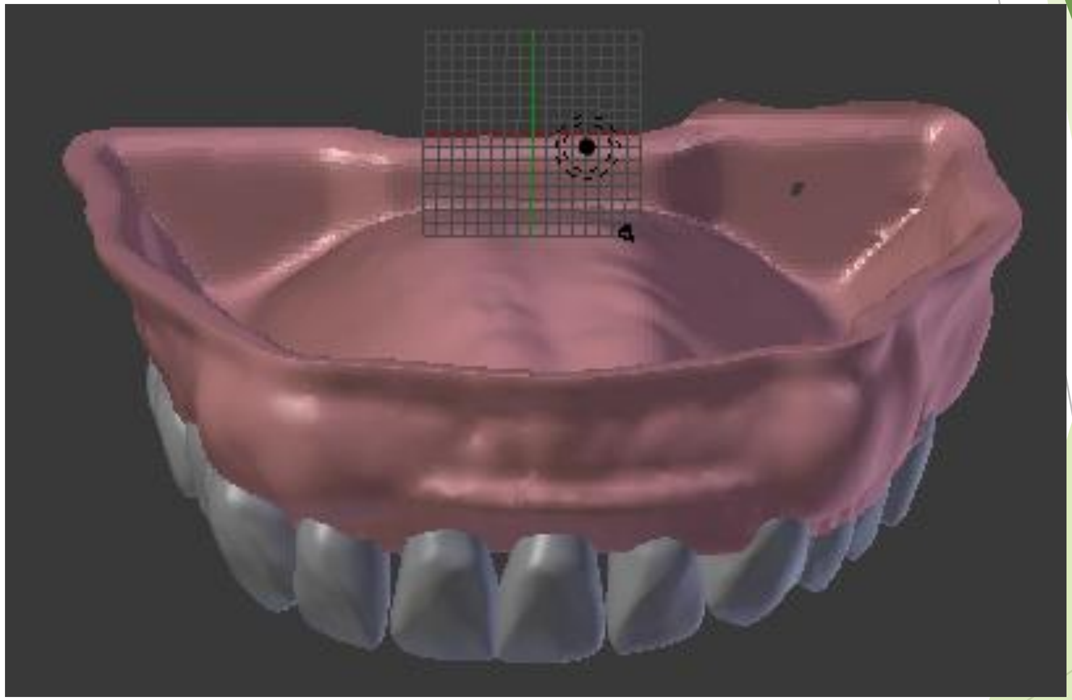
Partial Denture



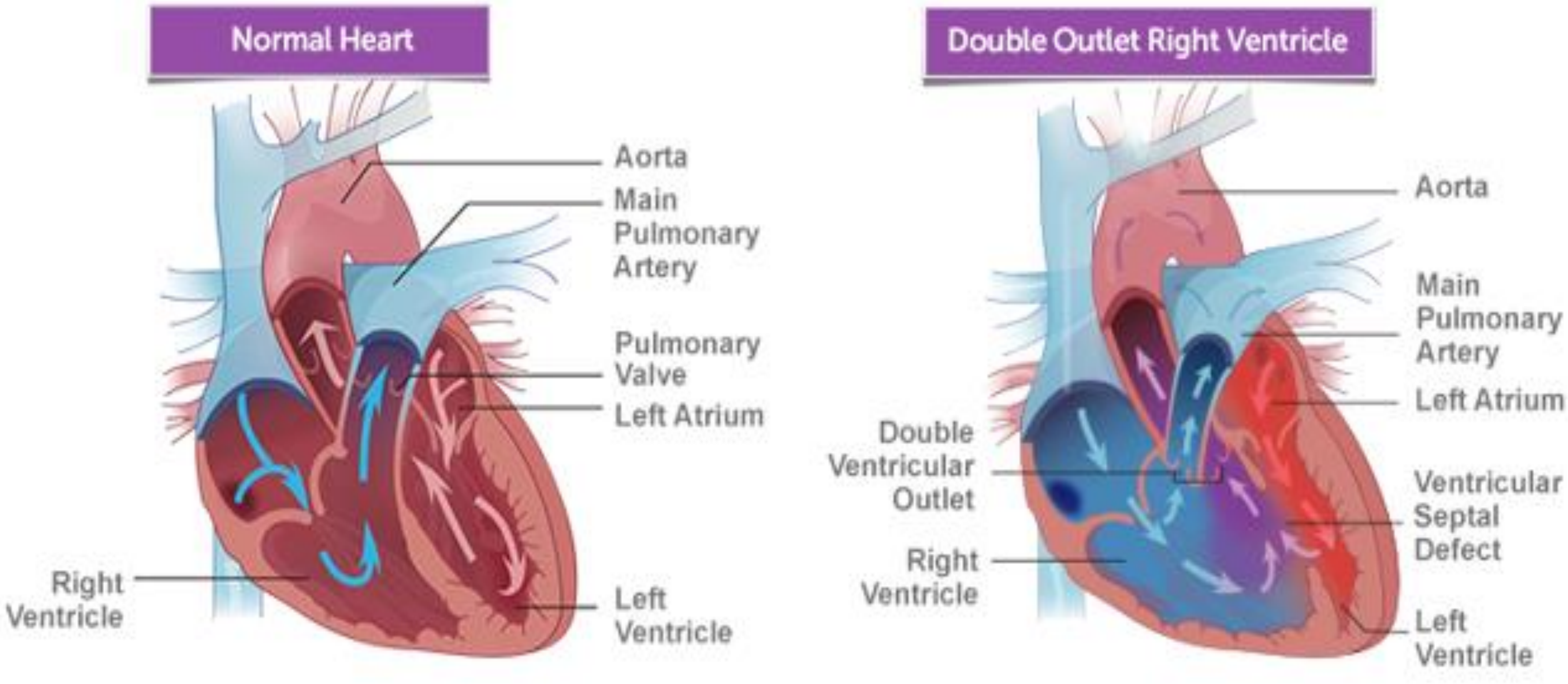


Full Denture





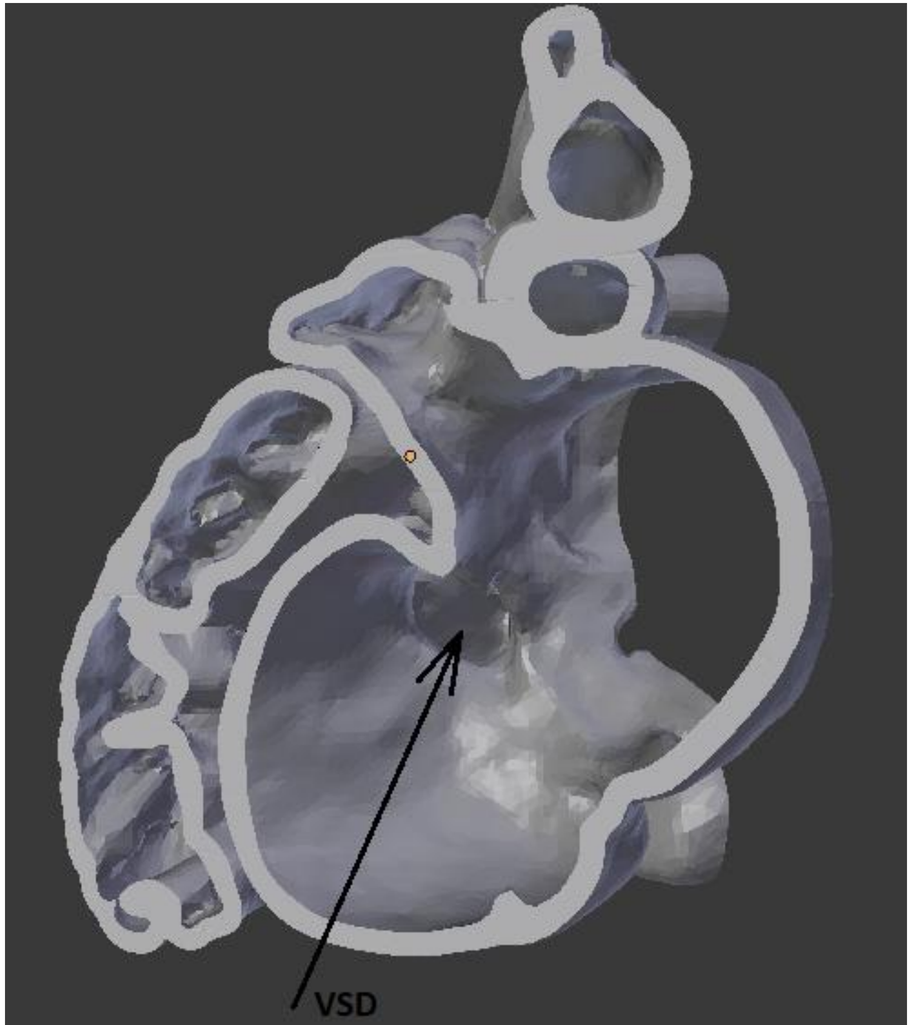
Case Study 1—Ventricular Septal defect (VSD)



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

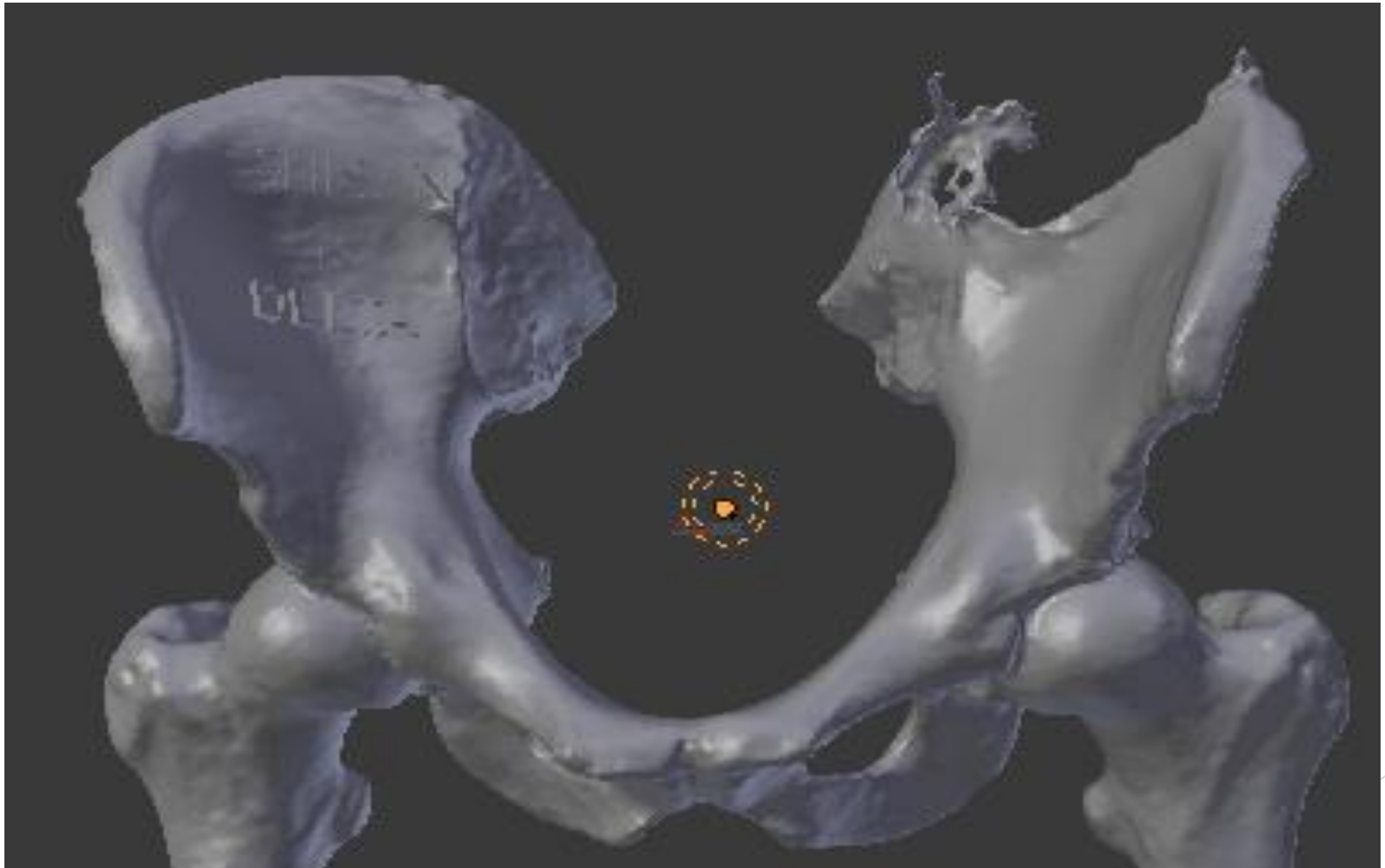
- Treatment: Clinician identifies the extent of the neoplasm; resects with wide margin. The skeletal defect is then filled using a *patient-specific prosthetic implant*.

Pleomorphic (Soft Tissue) Sarcoma

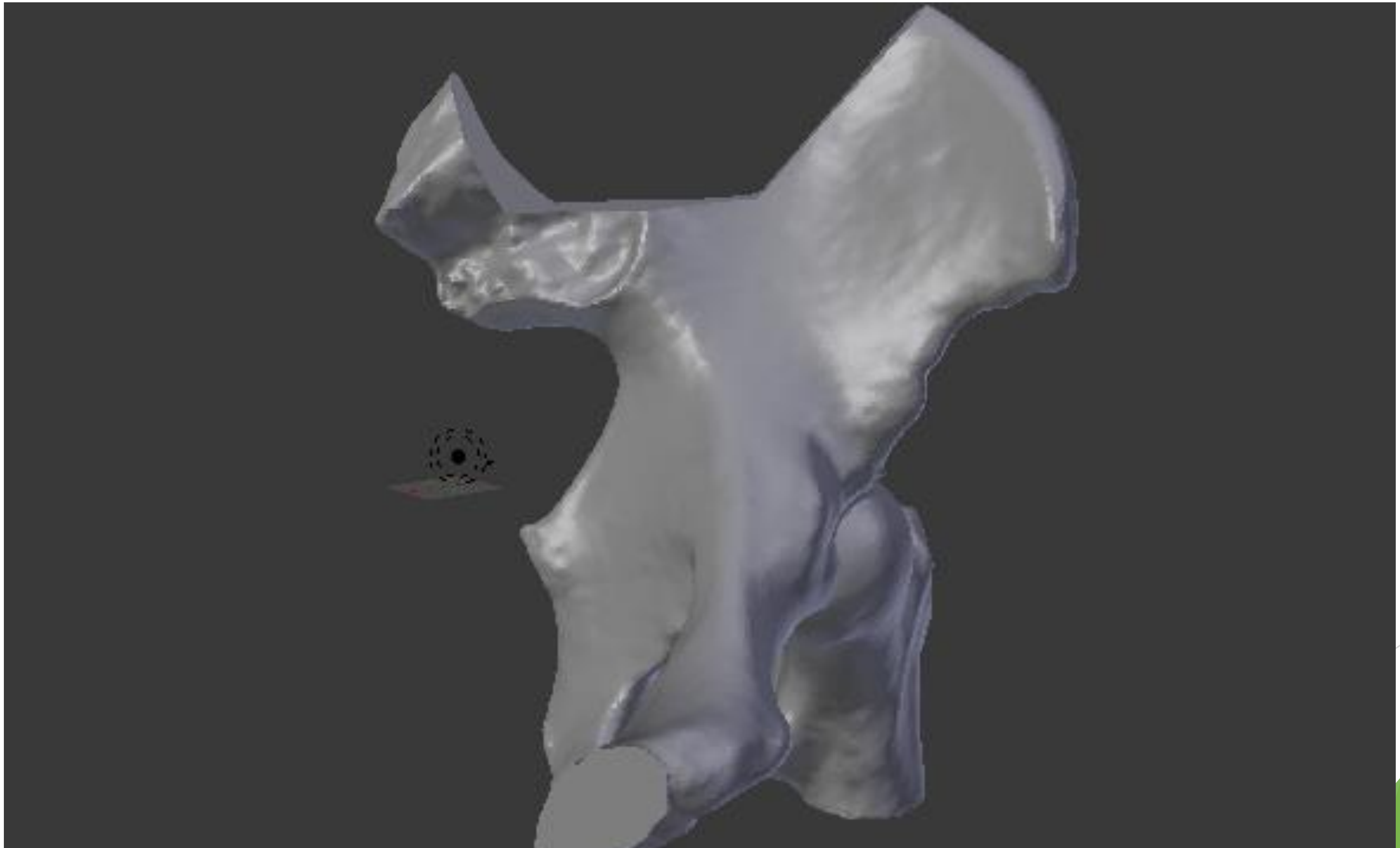
Planning/Simulating the Treatment

- 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

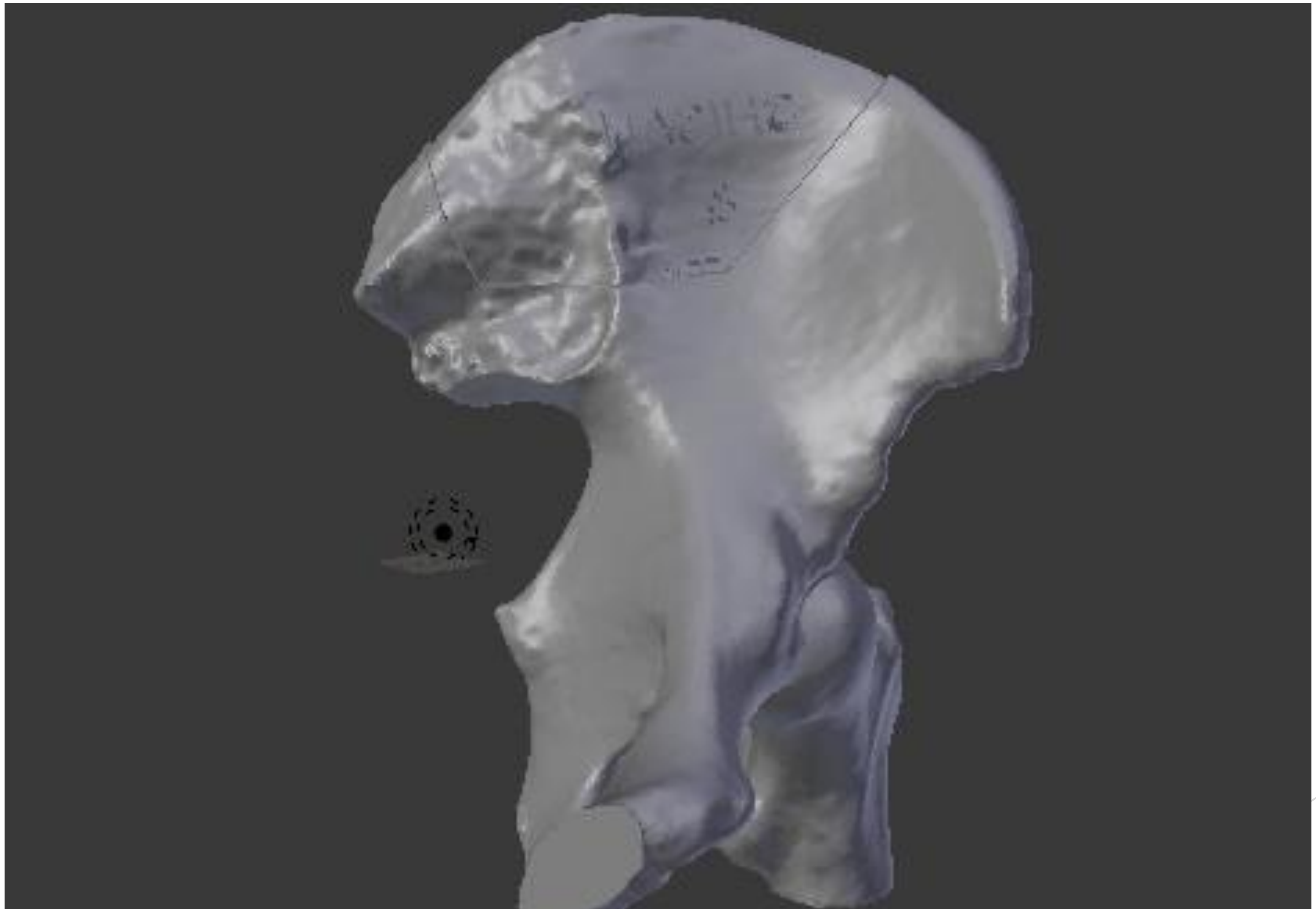
3D Reconstructed Pelvis Model



Excision of the Neoplasm



Reconstruct the excised bone fragment using a customized implant



3D-printed medical customized implant

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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

Main Challenges Affecting Adopting Medical 3D Printing in North America Hospitals

Two that clearly stand out:

- Reimbursement
- Regulatory huddles with FDA and Health Canada

Future Medical 3D Printing

- The future is happening today
- 3D Printing Lab in hospital (bedside)
- New custom implantable medical devices
- More FDA clearances
- Evidence publications will ease reimbursement
- Tissue printing

Thank You for Listening

- Questions & Answers!

- I would like to thank, **Dr. Ori Rotstein,** Director of the Keenan Research Centre for Biomedical Science for inviting me;

  Dr. Dario Bogojevic for organizing the details;

  and all of you for attending.

- 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
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