JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Building a Workflow for Cooperatively Controlled Robotic Mandibular Surgery

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Clinical Motivation

- Mandibular Surgery [1]
  - Used to correct overextended jaw or receding chin
- Surgery involves cutting through the mandible
- The alveolar nerve in the mandible can be damaged during surgery [3]
- Nerve damage can lead to:
  - Numbness of the chin, lower lip, and lower teeth

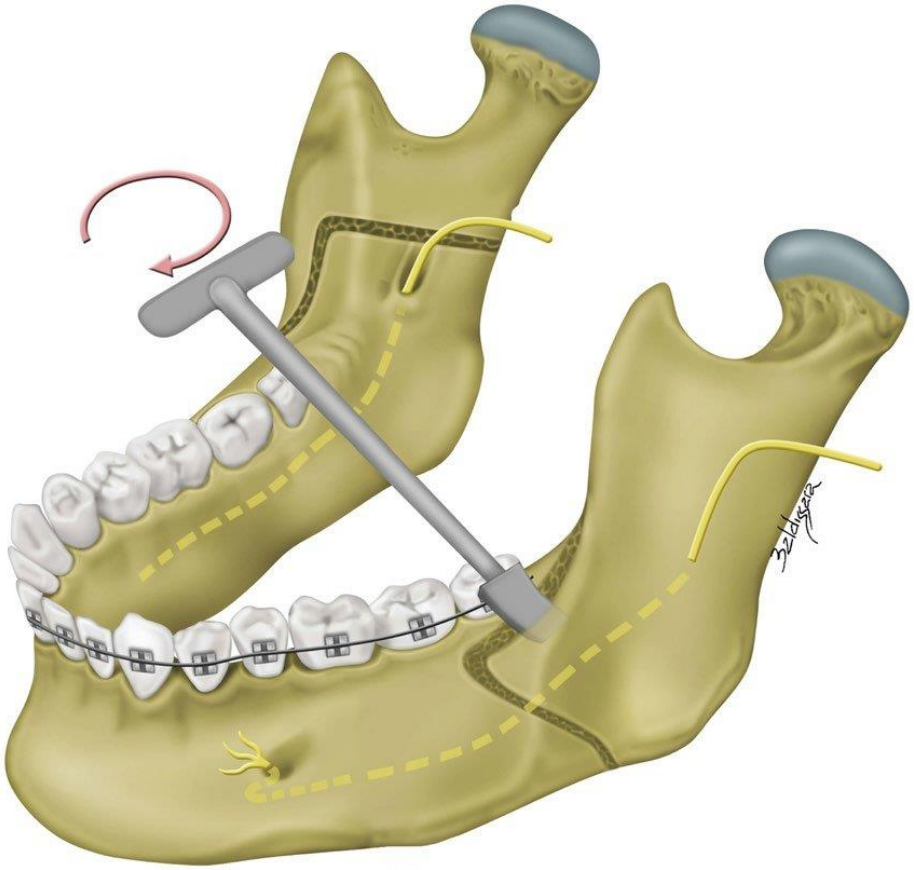


Image: [2]

Goals and Significance

- Goals:
  - Establish a workflow for robot-assisted mandibular osteotomy with virtual barriers
- If successful:
  - This will be the first semi-autonomous robot-assisted mandibular osteotomy workflow
  - Improves procedure safety
  - Helps to pave the way for future cooperative robot procedures

Image: [4]

Key Deliverables

	Deliverable
Minimum	• 3D printed phantoms that are drillable and similar in feel to bone • Documented approval of phantoms by physician
Expected	• Demonstrable cooperative control robot-assisted mandibular osteotomy • Documented approval of system function by physician
Maximum	• Demonstrated registration between the phantom, CT model, and robot
Summer	• Demonstration of virtual fixtures for robot-assisted mandibular osteotomy • Documentation of virtual fixtures function via CT data • Documented approval of system function by physician

Timeline/Milestones

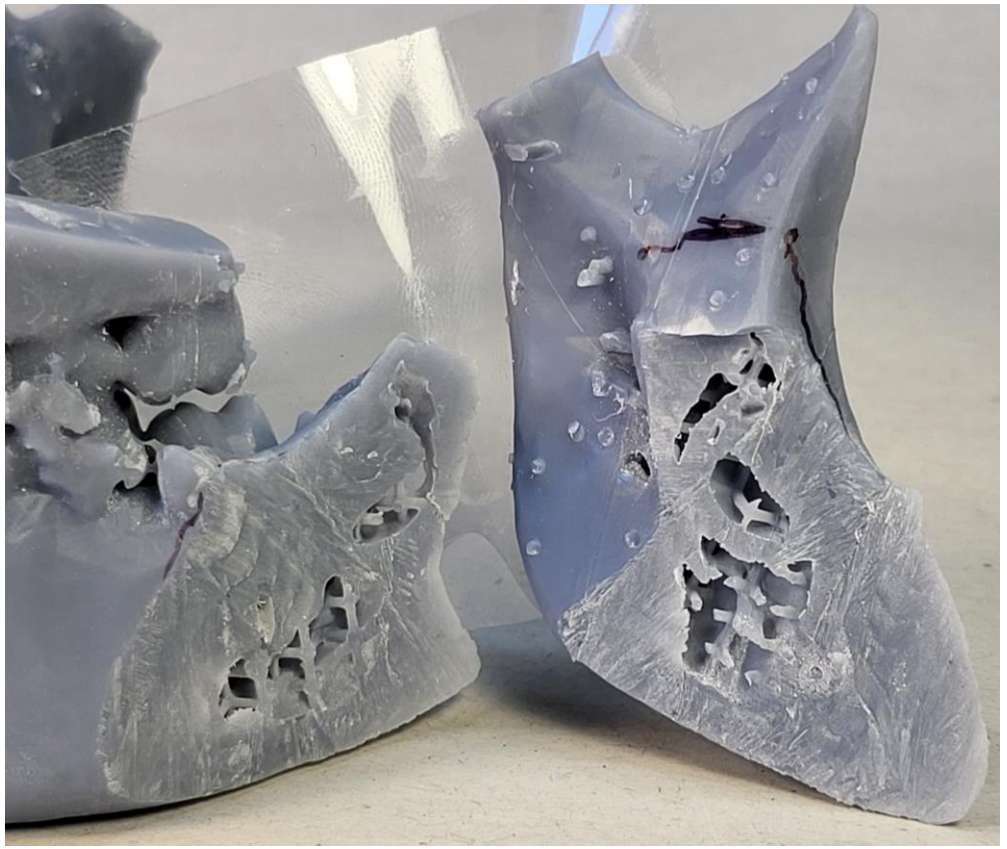
Milestones	Start	End	Delayed End
Mandible Phantoms	02/18	03/18	03/25
Galen configured for mandibular osteotomy	02/18	04/08	04/15
Registration with Galen	04/08	04/22	04/29
Virtual Fixtures Algorithm	05/13	06/03	06/10
Workflow Documentation	06/03	07/10	07/17

Dependencies

Dependency	Status	Fallback/Prevention	Need by	Effect
3D Printing Availability	Obtained / Phantom Created	Personal 3D printers	Feb 28th	Delay in phantom creation
Mentor Feedback	Schedule dependent	Weekly meetings and early communication to avoid conflict	Mar 14th	Delay in phantom and Galen configuration
Drill and Drill Bits	Obtained	N/A	Feb 28th	Delay in Galen configuration
Galen accessibility	Schedule dependent	SharePoint calendar to schedule use	Throughout	Delay in all milestones
3D Segmentations suited for printing	Obtained	Edit segmentations and use fewer models	Feb 21st	Delay in phantom creation
Optical Tracking Markers	Delivered Next Week	Order additional markers	April 11th	Delay in Registration

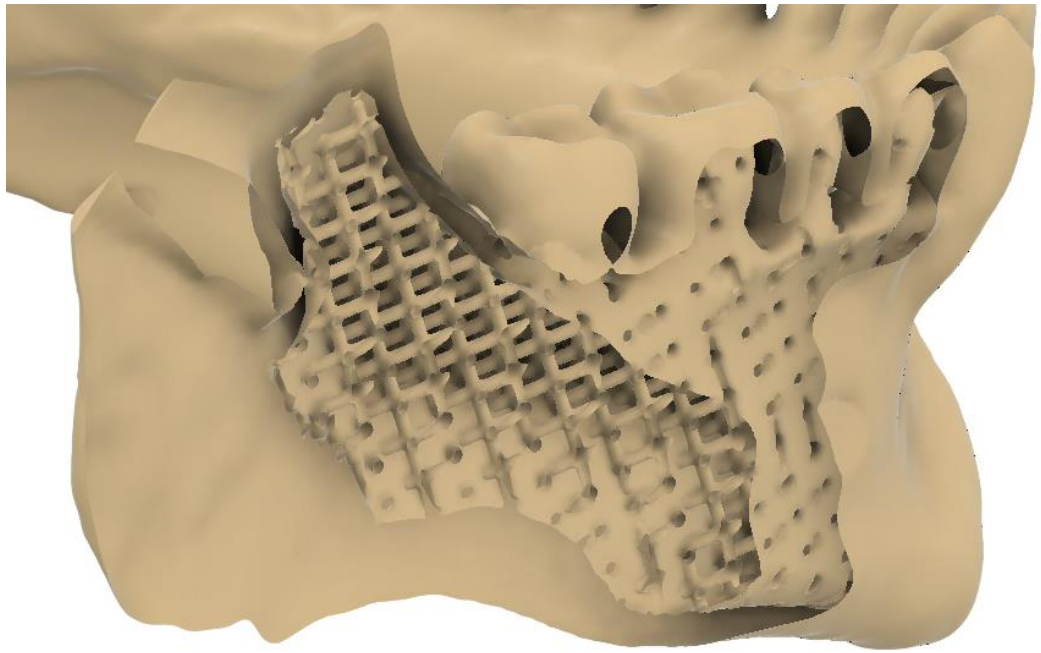
Printed Phantoms

- **Printed mandibles with lattice structure**



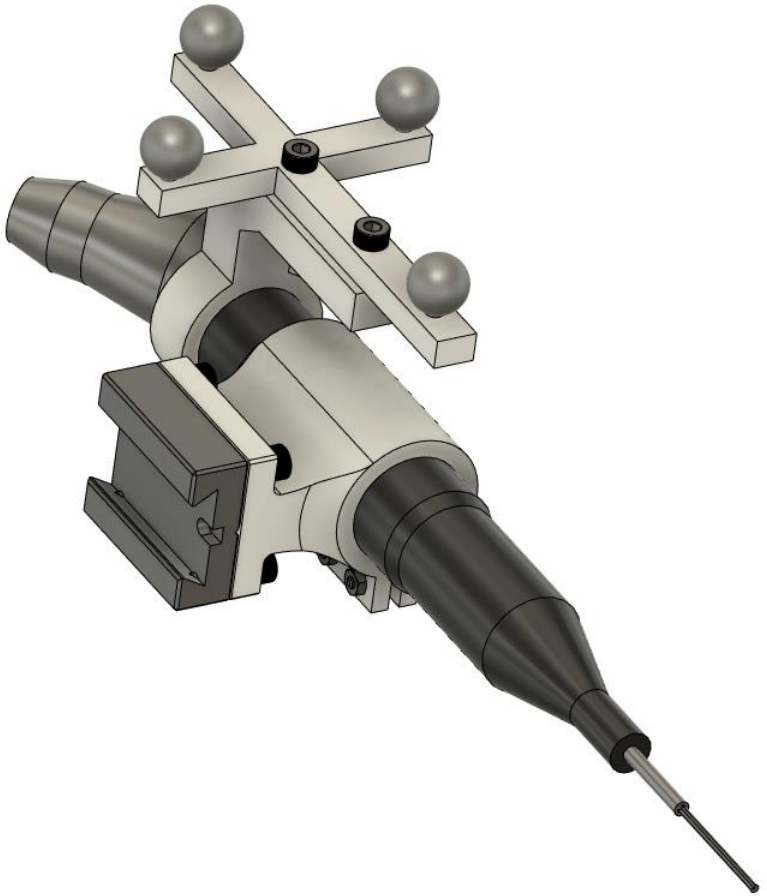
Printed Phantoms

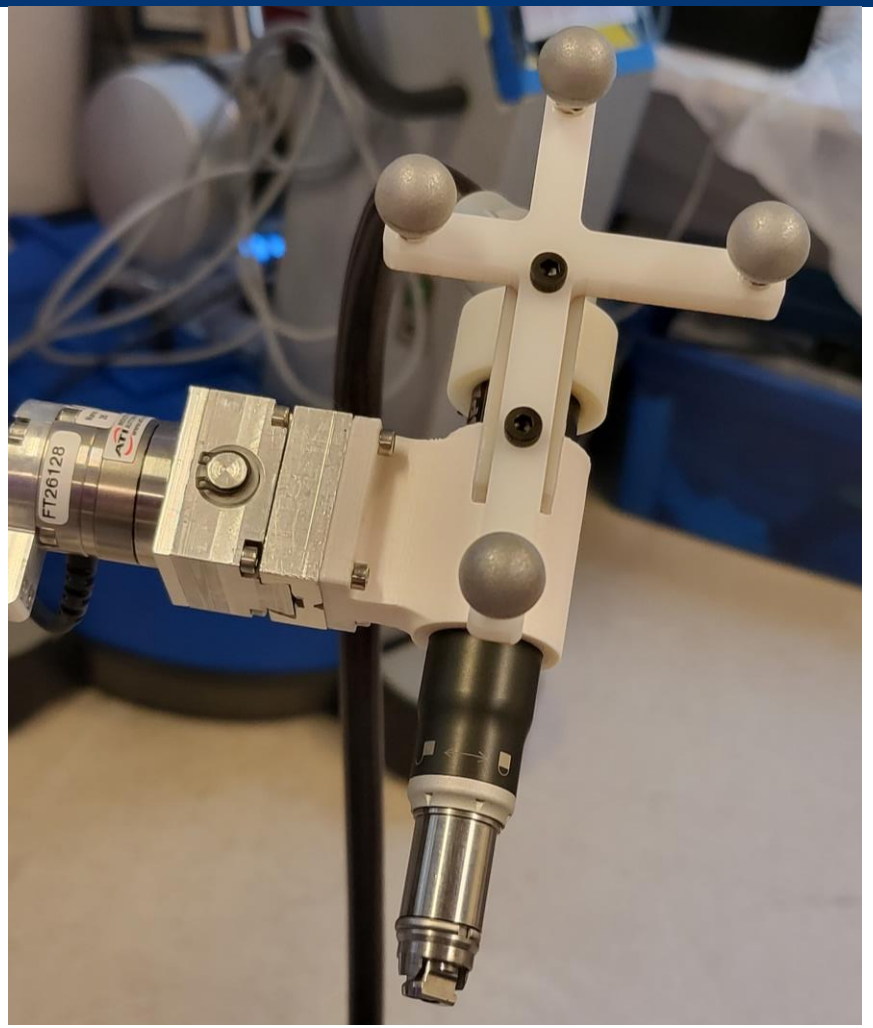
- **New model with more precise cortical bone segmentation and no maxilla**



Galen Configuration

- **Adaptor created to mount Anspach drill to Galen**





Optical tracking markers added by Hongchao Shu and Ruixing Liang

Current Surgical Workflow

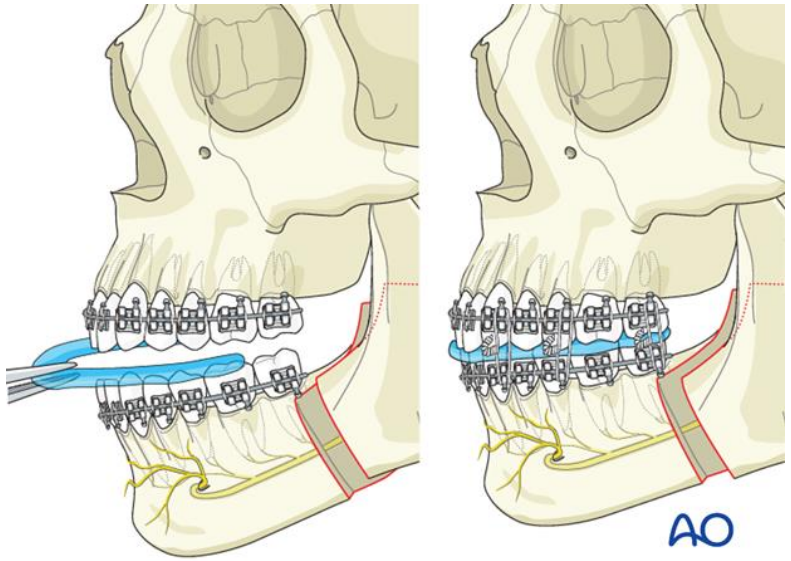
CT and Surface Scans

Vendor Produces Segmentation

Vendor and Surgeon Create Plan

Vendor Produces splints, brackets, plates

Surgeon Performs Procedure freehand



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Proposed Surgical Workflow

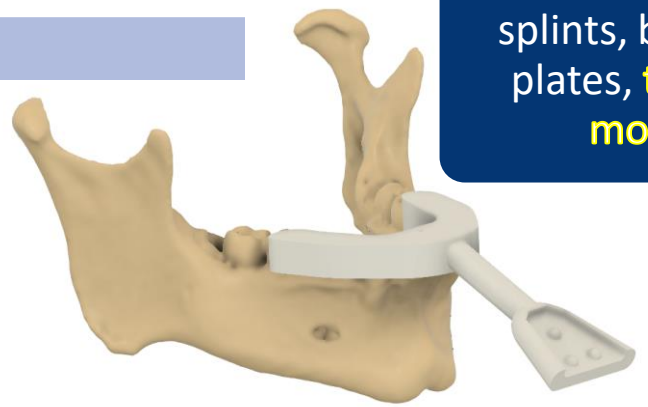
CT and Surface Scans

Vendor Produces Segmentation

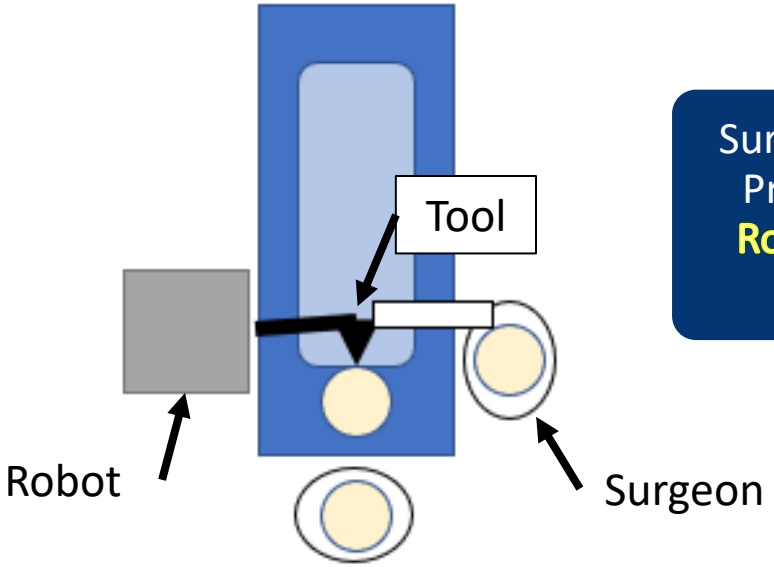
Vendor and Surgeon Create Plan

Plan and Segmentation used to Generate Virtual Plan

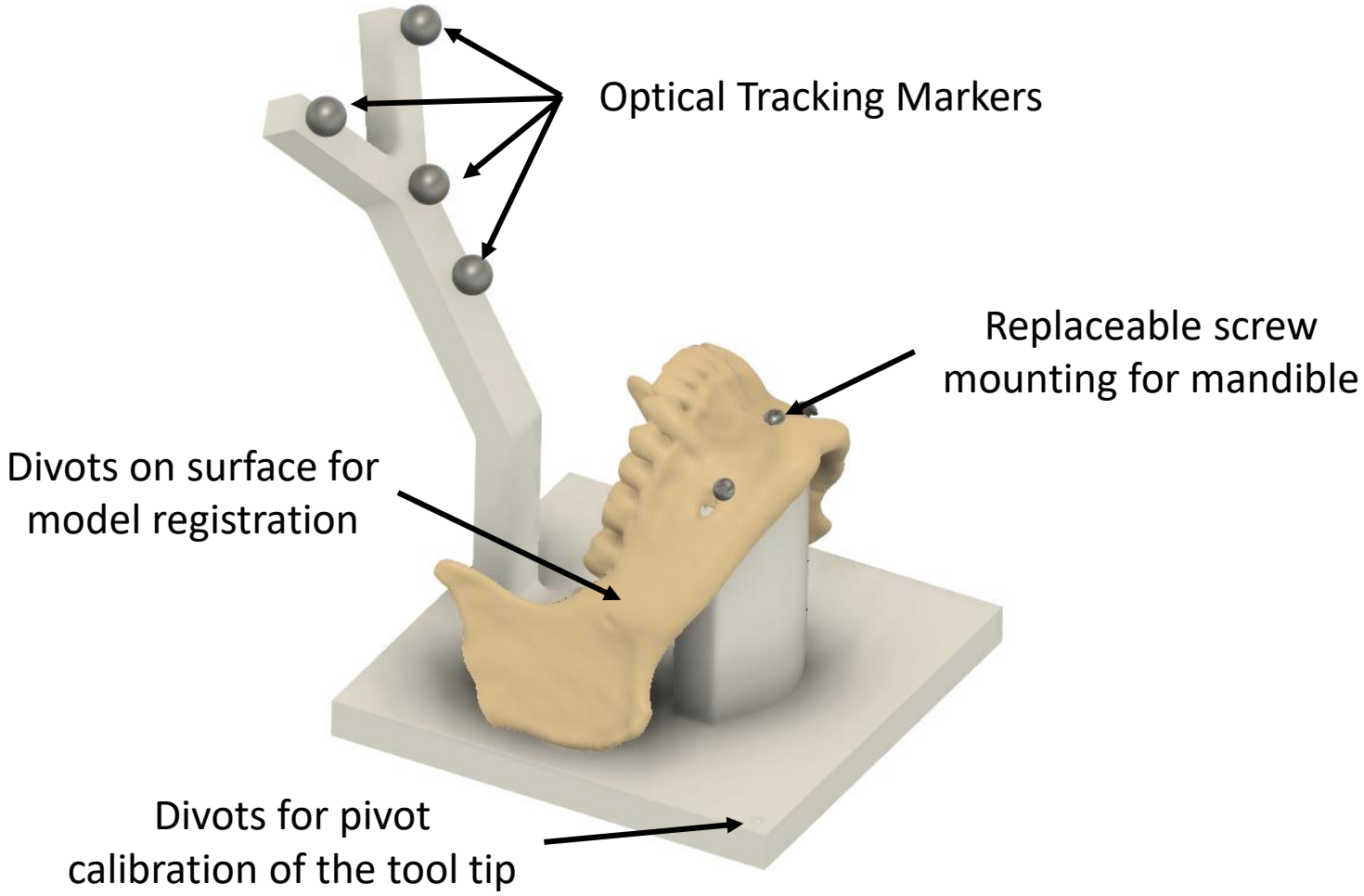
Vendor Produces splints, brackets, plates, **tracking mount**



Surgeon Performs Procedure with **Robot Enforcing Virtual Plan**



Bench Workflow



Bench Workflow

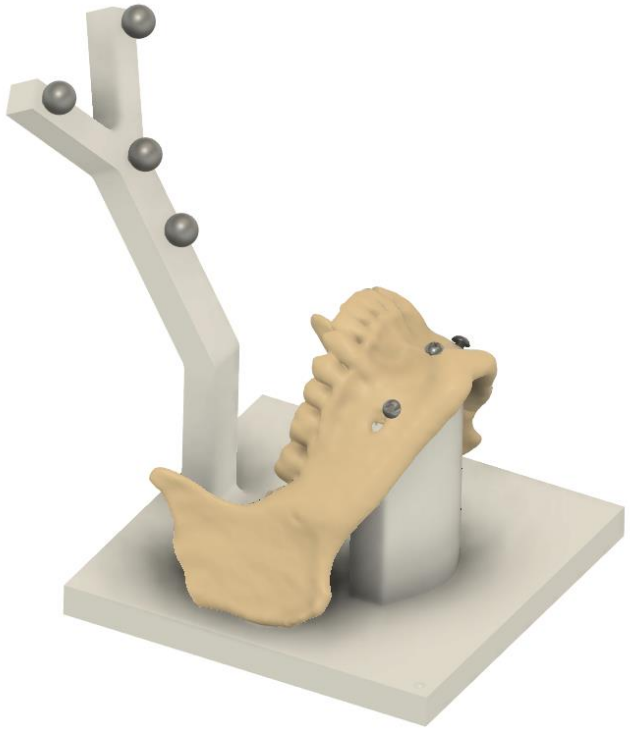
Phantom Fixed to Mount

Tool Tip Cal. On Mount Divots

Divots in Phantom use to Register Model

Phantom is cut with Galen Robot

Post-op CT used to compare plan with cut



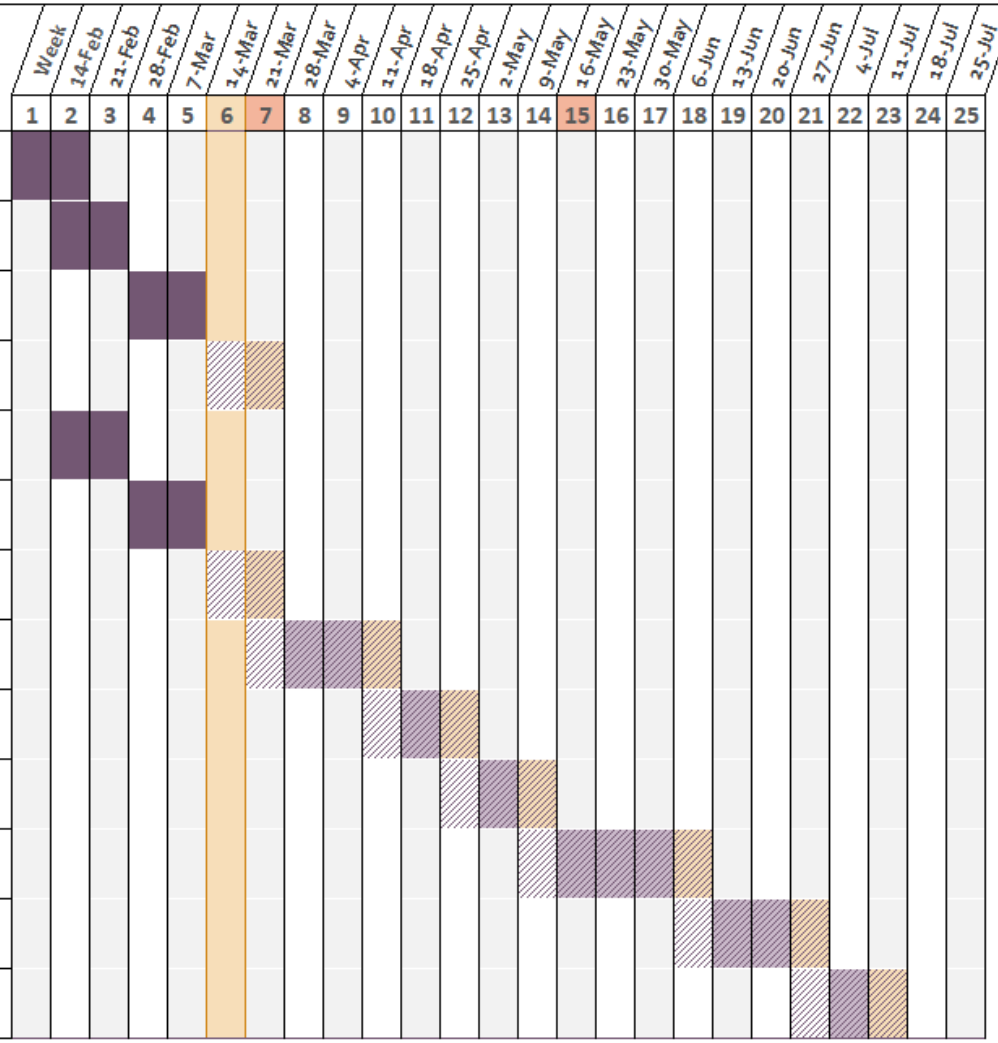
Problems

- **IRB delay**
  - CT Data from NMDID was used in place
- **Scope creep**
  - Phantom design was getting too complex for an initial proof of concept

Image: [6]

Gantt Chart

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Project Plan and Webpage	1	2	1	2	100%
Prepare segmented models for printing	2	2	2	2	100%
Create phantom mandibles	4	2	4	2	100%
Gather phantom feedback from Dr. Yang and Dr. Creighton	6	1	7	1	0%
Gather tooling for mandibular procedure	2	2	2	2	100%
Setup Galen for procedure	4	2	4	2	100%
Gather Galen feedback from Dr. Yang and Dr. Creighton	6	1	7	1	0%
Modify Galen Setup based on feedback	7	3	8	3	0%
Develop mandible registration with the Galen	10	2	11	2	0%
Prepare Final Report and Poster	12	2	13	2	0%
Develop algorithm to enforce virtual barriers	14	4	15	4	0%
Pre and post op CT scans to measure effectiveness	18	3	19	3	0%
Create documentation for workflow	21	2	22	2	0%



Thank You!

References

1. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5392880/
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