1. **Purpose**
   1.1. The purpose of this document is to outline the procedure for the fabrication of mandible phantoms. These phantoms were designed to replicate the machinability of real bone in the context of a Bilateral Sagittal Split Osteotomy.
2. **Equipment/Software**
   2.1. Anycubic Photon - SLA 3D Printer
   2.2. Flash Drive
   2.3. Fusion 360
   2.4. Glass Bowl
   2.5. Meshmixer
   2.6. Photon Workshop V2.1.26
   2.7. Razor Blade
   2.8. UV Lamp
   2.9. Wire Cutters
3. **Materials**
   3.1. Flexible Resin - Siraya Tech Tenacious 3D Printer Resin Flexible 405nm UV – Clear
   3.2. IPA 99% (or 70%)
   3.3. Mandible STL File
   3.4. Nitril Gloves
   3.5. Paper Towels
   3.6. Rigid Resin - ANYCUBIC 3D Printer Resin, 405nm – Grey (any opaque color will work)
4. **Procedure**
   4.1. Remove internal structures of the mandible.
      4.1.1. Open Fusion 360.
      4.1.2. Import the STL file.
      4.1.3. Select the “Direct Edit” feature under the “Mesh” tab.
      4.1.4. Delete faces that connect the internal structures to outside of the mandible.
      4.1.5. Delete all faces that comprise internal structures of the mandible.
      4.1.6. Select “Finish Direct Editing”.
      4.1.7. Select the “Repair” tool and use “Stitch and Remove”.
      4.1.8. Right click on the mesh and select “Save as Mesh”.
         4.1.8.1. “Format” should be “STL” and “Unit Type” should be “Millimeter”.
   4.2. Make model hollow and add lattice.
      4.2.1. Open Meshmixer.
      4.2.2. Import the modified STL file.
      4.2.3. Select the “Edit” tab.
      4.2.4. Select the “Hollow” tool.
      4.2.5. Enter “1mm” as the offset distance.
      4.2.6. Click “Accept”.
      4.2.7. Select “Export” and save the hollow mandible file. Make sure to name it in such a way that it can be recognized that it is the hollow version of the mandible.
      4.2.8. Select the “Edit” tab again.
      4.2.9. Use “Separate Shells”.

4.2.10. In the “Object Browser” that pops up, select the outside surface. Then click the delete key.
4.2.11. Close the object browser.
4.2.12. Click on the “Select” tool.
4.2.13. Press CTRL + A to select all the faces.
4.2.14. Select the “Edit…” dropdown menu and choose “Flip Normals”.
4.2.15. Go back to the “Edit” tab.
4.2.16. Select “Make Pattern”.
4.2.16.1. Pattern Type: Lattice
4.2.16.2. Element Dimension: 1mm
4.2.16.3. Element Spacing: 3mm
4.2.16.4. Composition Mode: Intersect
4.2.16.5. Clip to Surface: Deselected
4.2.16.6. Rotate the lattice 45 degrees about the frontal axis.

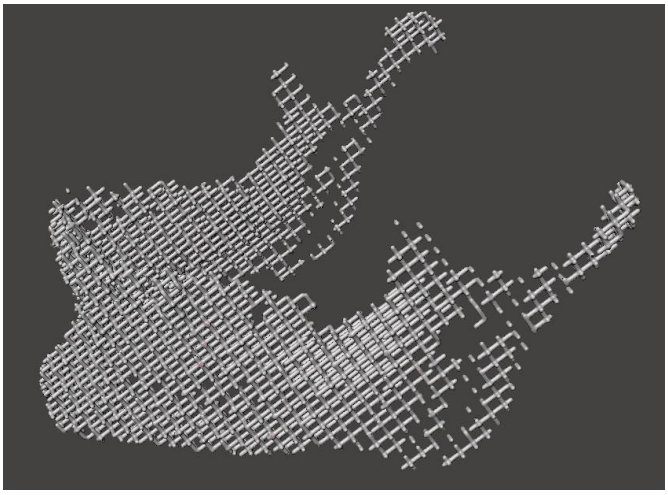

Figure 1. Internal lattice structure.

4.2.17. Click “Accept”.
4.2.18. From the Object Browser select the inside mesh (not the lattice) and click the delete key.
4.2.19. Select “Import” and choose “Append”.
4.2.20. Select the hollow mesh created previously.
4.2.21. In the Object Browser select both the lattice and the hollow model.
4.2.22. Select “Combine” in the popup menu.
4.2.23. Click “Export” and save the model as an STL file.

4.3. Prepare file for printing.

4.3.1. Open Fusion 360.
4.3.2. Open the Fusion 360 containing the mounting setup.
4.3.2.1. If necessary, use the “Offset Face” tool in the “Solid” tab to increase the size of any surfaces mounting with the mandible phantom. This will ensure the components will mate properly together.

4.3.2.2. Make sure to remove the offset before creating the mounting.

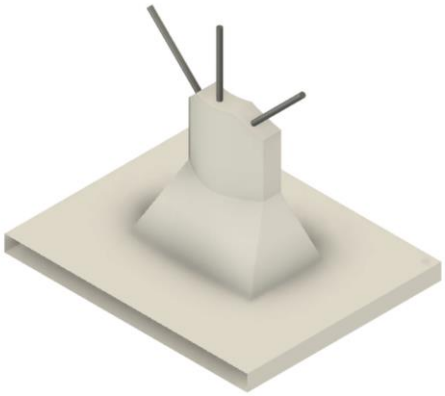

Figure 2. Mounting Setup.

4.3.3. Click “Insert” and then “Insert Mesh”.

4.3.4. Select the edited mandible STL file.

4.3.5. Use the “Move” tool to position the mandible onto the mounting plate in the desired location.

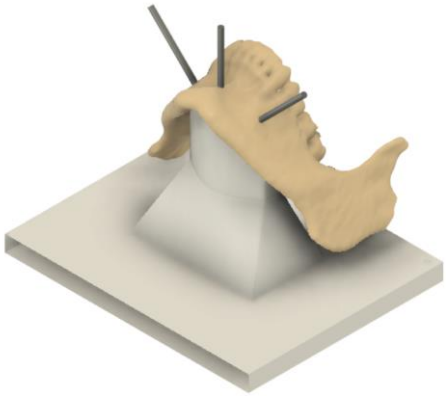

Figure 3. Mandible oriented onto mounting setup.

4.3.6. Ensure the mounting plate and any other relevant bodies (such as the screw axes shown in the picture) are meshes.

4.3.6.1. If not, convert the solid bodies to meshes using the “Tessellate” tool in the “Mesh” tab.

4.3.7. Then use the “Combine” tool in the “Mesh” tab to subtract the mounting from the mandible.

4.3.7.1. Target Body: Select the mandible

4.3.7.2. Tool Bodies: Select any relevant mounting bodies

4.3.7.3. Operation: Cut

4.3.7.4. Keep tool: Selected

4.3.8. Save the resulting body as an STL.

4.3.8.1. Right click on the body.

4.3.8.2. Select “Save As Mesh” and choose STL.

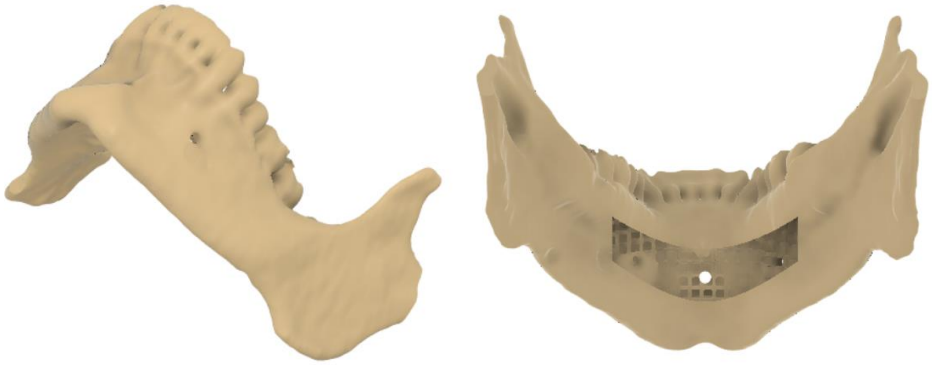

Figure 4. Resulting mandible phantom mesh.

4.4. Print Mandible Phantom

4.4.1. Make sure to use nitrile gloves whenever using the UV Resin or IPA. Clean up any mess using paper towels and IPA.

4.4.2. Prepare an approximately 20% Flexible resin and 80% rigid resin solution.

4.4.3. Pour the solution into the vat of the Anycubic printer.

4.4.4. Open up Photon Workshop

4.4.5. Select “Open” and navigate to the mandible STL file.

4.4.6. Orient the mandible as shown in the picture below.

4.4.6.1. After orienting the mandible, translate it along the Z axis by 5mm.

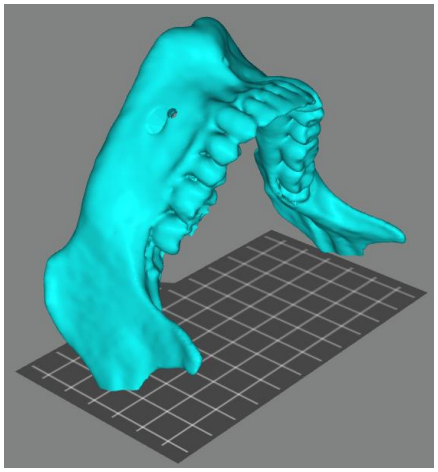

Figure 5. Model orientation in Photon Workshop.

4.4.7. Add support structures on the posterior medial side of the mandible as shown in the picture below.

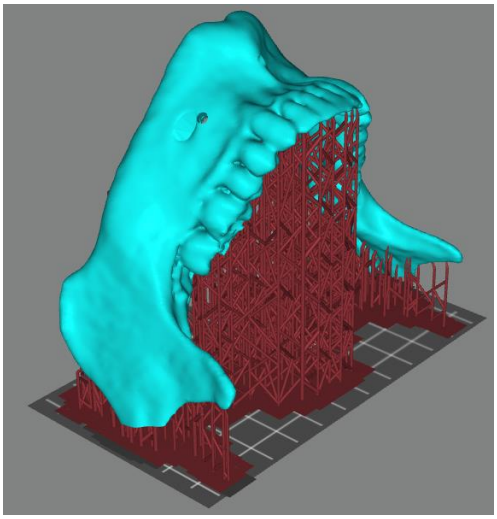

Figure 6. Stupport strutures in Photon Workshop.

4.4.8. Enter the following settings into the slicer:
- 4.4.8.1. Layer Thickness: 0.050mm
- 4.4.8.2. Normal Exposure Time: 12 seconds
- 4.4.8.3. Off Time: 1 second
- 4.4.8.4. Bottom Exposure Time: 80 seconds
- 4.4.8.5. Bottom Layers: 6
- 4.4.8.6. Z Lift Distance: 6mm
- 4.4.8.7. Z Lift Speed: 3 mm/s
- 4.4.8.8. Z Retract Speed: 3 mm/s
- 4.4.8.9. Anti-alias: 1

4.4.9. Click the slice button to finish.

4.4.10. Save the file to a flash drive.
- 4.4.10.1. Use the file extension ".photon" for the original Anycubic photon printer.

4.4.11. Insert the flash drive into the Anycubic Printer.

4.4.12. Select "Print" and select the prepared slicer file.

4.4.13. Print will finish in approximately 9.5 hours.

4.5. Post Processing

4.5.1. Make sure to use nitrile gloves whenever using the UV Resin or IPA. Clean up any mess using paper towels and IPA.

4.5.2. Use a razor blade to remove the mandible from the build plate.

4.5.3. Break off and discard any support material by hand.

4.5.4. Vigorously rinse the excess resin off of the mandible using IPA in the glass bowl.

4.5.5. Lightly dry the mandible.

4.5.6. Place the mandible under a UV lamp, rotating occasionally.

4.5.7. Repeat until all surfaces are no longer sticky.

4.5.8. Use wire cutters to remove any remaining support structures.

4.6. Testing and Approval

4.6.1. Mandible phantom will be tested by a physician using an Anspach EG1 drill. Physician will verify if mandible machineability is clinically representative.

4.6.2. Signature documenting physician's approval will be recorded below.

Approval of phantom outlined in this procedure:

Name	Signature	Date

Name	Signature	Date