An introduction to 3D imaging and 3D printing for Health Sciences

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I. Introduction

I.1. Overview

Three-dimensional (3D) scanning modalities and 3D models are gradually becoming more popular in biological anthropology within the forensic context. Three-dimensional modeling offers the preservation, visualization, manipulation, advanced analysis, and accessibility of skeletal remains (e.g., bone trauma) in a non-invasive way. Consequently, it facilitates the appreciation of the external (e.g., shape, size, distance, texture) and internal structure (e.g., bone density, thickness, and level of mineralization) of the relevant anatomical area studied. A significant type of 3D scanning modality exists such as, computerized tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), single-photon emission computed tomography (SPECT), ultrasound (US), functional MRI (fMRI), magnetic source imaging and surface light scanning. Each visualization of the mentioned techniques can be presented in two dimensions (2D) or 3D using a broad type of 3D imaging software namely, Avizo; MeVisLab, Meshlab, Dragonfly, and VG studio.

I.1.1. Three-dimensional scanning modalities and real-life forensic applications.

The application of 3D scanning modalities, such as photogrammetry, 3D surface, and Micro-XCT scanning, is frequently used in osteology and anthropology. However, developing new advanced methods and techniques involving 3D scanning for real-life forensic applications requires accessibility and practicality. The utilization of a Micro-XCT scanning modality could be counterproductive and a challenging process to integrate in forensic analyses due to the cost and the time consumption generated. Compared to the Micro-XCT modality, photogrammetry and 3D surface scanning modalities do not require X-ray computed tomography and professional training. Consequently, they appeared to be the ideal modality to be integrated into forensic analyses by making the scanning procedure more accessible and easier to utilize for forensic anthropologists.

As compared to the utilization of photogrammetry, a 3D surface scanning modality does not require specific software and a computer with a high capacity for 3D surface model generation. In contrast to 3D surface scanners, most photogrammetric procedures capture only shape information, raising a primary limitation in its practicability and accuracy when utilized in a forensic analysis procedure. The procedure will capture only the shape component if the metadata of the internal geometry of the camera used is included in the procedure or if the 3D reconstruction from the photogrammetry is manually calibrated based on a scale placed next to the object during scanning (Gonzales et al., 2009). Furthermore, the 3D surface scanner has proven to be more consistent in 3D reconstruction generation than photogrammetry software packages (Waltenberger et al., 2021). The generation of 3D reconstruction differs enormously in quality among photogrammetry types of software used (Waltenberger et al., 2021). Therefore, the introduction of 3D surface scanning modality might provide an efficient set of advanced techniques complementary to the existing metric forensic analysis.

Three-dimensional (3D) surface scanning is a collection of non-contact active and passive scanners that include handheld, structured light, and stereoscopic systems used to record an object's morphology, physical composition, and size . The 3D surface scanner used in this workshop is an EinScan H Hybrid LED and Infrared Light Source and Handheld Colour 3D scanner (EinScan, n.d.). The EinScan H is a safe 3D scanner based on the hybrid structure light technology of LED and invisible infrared light. The EinScan H has a built-in color camera and a large field view that provides high-quality 3D data with high texture rendering. The Hybrid structure light source technology integrates LED structured light and invisible infrared into one device. It incorporates advanced smart presetting in different scan modes allowing 3D scanning in a wide range of applications. The resolution of the EinScan H reaches an impressive high of 0.25mm. The accuracy of the scanned data can be as high as 0.05mm with a volumetric accuracy of 0.1mm/m, which improves the precision of 3D modeling in polygon meshes or a dense points cloud.

New 3D imaging methods might allow forensic analysts to assess specific patterns not readily revealed by the non-metric and metric methods. However, this does not undermine the significance of already standardized and widely used methods in forensic anthropology for analysis. Incorporating a virtual approach to actual traditional skeletal analysis could help identify an individual without compromising the physical remains. The utilization of 3D advanced methods might also increase bone trauma documentation accuracy such as the appreciation of fine fractures, and reveal additional information (e.g., the direction of the blow, sharp force trauma, and blunt object trauma). Furthermore, in a case where the evidence has completely disappeared (e.g., a cold case), 3D documentation can capture a wound accurately, allowing evaluation long after the existence of the evidence. Finally, 3D forensic evidence can easily be shared amongst academics as well as professionals, and forensic anthropologists can easily give a second opinion at any time.

I.1.2. 3D printing for education in related medical sciences.

Today, medical education relies on many resources as crucial elements such as cadavers and anatomical bone models in developing students' clinical competencies. However, acquiring these educational resources represents a considerable challenge for many institutions, not only for financial but also for various other reasons, including ethical, legal, and cultural. Consequently, with the rapid emergence and accessibility of 3D printing that has entered the biomedical fields in recent years, academics in related medical sciences have recently started to apply 3D printing technology for nearly all areas of education namely, anatomy, forensic and biological anthropology.

3D printing converts a computer-generated 3D image into a physical model allowing a human-specific anatomical model to be created. Depending on the type of 3D scanning modality used, a 3D model is created using the generated images in DICOM or Tiff format . DICOM images can be generated from CT and MRI scans. Tiff format images can be generated from Micro-XCT scans. A 3D model in polygon meshes or a dense points cloud can also be directly created using a 3D surface scanning modality such as EinScan H Hybrid LED and Infrared Light Source and Handheld Color 3D scanner. For scanning modality generating DICOM/Tiff images, images are imported into 3D imaging software for segmentation and 3D surface model generation. The software used that can be used for 3D imaging and 3D model generation are Avizo; MeVisLab, Meshlab, Dragonfly, and VG studio. The 3D reconstruction or generated model is then exported in the stereolithography (STL)format to make it readable by software (computer-aided design- CAD) used to design/print 3D objects.

Three dimensional (3D) printing works by "additive manufacturing," whereby the raw material is "added" layer by layer in a predetermined fashion, thereby achieving a precise 3D framework. Thus, 3D printing can make any complex shape solid and porous sections can be combined to provide optimal strength and performance. As bones are generally monochromatic and made of hard tissue, they are the most accessible component of the human body to duplicate in 3D printing, with high levels of accuracy, preserving both visual and haptic values of the natural tissue. Thus, medical students can have the opportunity to handle and examine bony elements previously not available for inspection due to their fragility, specifically those with bone trauma. Furthermore, a range of anatomical variations present in different human populations in health and disease can be easily accessible and graspable. Finally, once the appropriate infrastructure is in place, printing is the most cost-effective way of acquiring a large and representative osteological sample for educational purposes.

Within our 3D printer facilities at the Faculty of Health Sciences, University of Pretoria, we have acquired a set of 3D printers, from the Creality Ender 3 to the Ultimaker S5 and the Form 3L. The Ender-3 features a 220 x 220 x 250mm print volume uses 1.75mm filament and can print a wide variety of filaments for example. PLA filament for different professionals' applications to create an inexpensive fleet of printers for manufacturing.

Compared to the Ender-3, the Ultimaker S5 can provide more professional printers by achieving complex geometries and intricate designs with the Ultimaker S5's reliable dual extrusion technology and water-soluble technology support. Furthermore, the Ultimaker S5 can print in a range of engineering and support materials (e.g., Tough PLA, PLA, PETG, Nylon, ABS, PVA Support, Breakaway Support) for complete design freedom, minimal post-processing. Finally, it also offered an open and connected system, "The Ultimaker S5's connectivity, "allowing the connection of multiple printers together over Wi-Fi.

Form 3L printer is resin-based 3D printing with advanced Low Force Stereolithography (LFS)™ technology, offering a fast turnaround of industrial-quality parts. The Form 3L printer has a resolution of 25µm, a laser power of 250mW, and a layer thickness of 25 – 300µm. Low Force Stereolithography (LFS)™ uses a flexible tank and linear illumination to deliver groundbreaking print quality and printer reliability. In addition, two staggered Light Processing Units (LPUs) inside the printer use a compact system of lenses and mirrors to deliver accurate, repeatable prints. The two LPUs work simultaneously along an optimized print path to efficiently blaze through parts of all sizes allowing faster printing. Each high-density laser passes through a spatial filter to guarantee a clean laser spot. A parabolic mirror ensures that the laser prints perpendicular to the build plane, ensuring uniform print quality across the entire build platform. The Form 3L provides high material capacity by holding two easy-to-switch resin cartridges, preventing interruptions. Furthermore, the Form 3L allows closed-loop calibration by utilizing optical sensors continuously correct for scale and power and can even detect dust. Finally, the Light Processing Units, resin tank, rollers, and optics window can be replaced in-house, reducing the need for replacement printer shipments.

I.2. Medical imaging

Medical imaging is the process of creating a visual representation of the interior of the body for analysis, diagnosis and medical treatments. Medical imaging includes Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Ultrasound, Positron Emission Tomography (PET), X-Ray etc. In MRI, for example, a patient is passed through an MRI scanner, which uses fluctuating magnetic fields to form a view of the body, which is then processed into a DICOM file format.

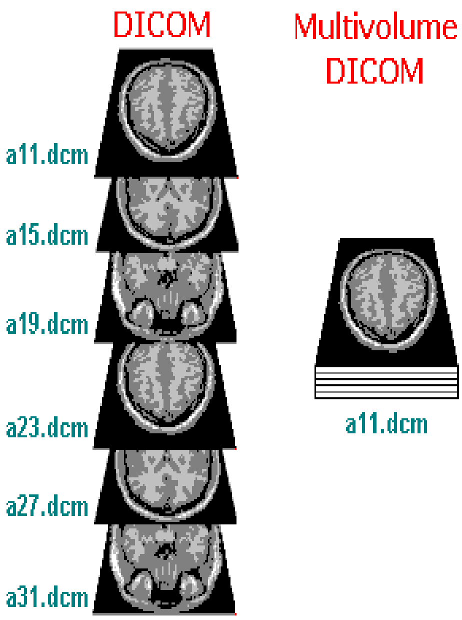


Figure 1*. Computed Tomography (CT) scanner.*

Most of the 3D imaging methods are based on the capability of X-rays to penetrate and propagate through an object, which will, according to its particular physical properties, attenuate these X-rays to a greater or lesser degree. The differences in attenuation of the beam going through the object are then mapped with different levels of grey values and are projected onto an X-ray sensitive detector system. In the case of a micro-CT, it is a panel. The sample is placed inside the micro-CT on a little platform that rotates at 360 degrees. And the projection of the beam during this rotation will generate 2D radiographic projections of the object at a constant interval (angle).

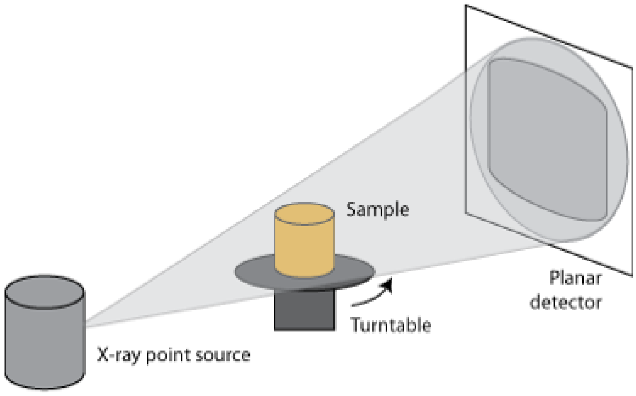


Figure 2. *Scanning principle.*

The difference for example with CBCT scanning is on the rotation. In micro-CT, the sample rotates on the platform, while in CBCT, the X-ray source and the detectors rotate around the sample (patient), who stays immobile.

Figure 3. *Example at Necsa: Nikon XT H 225L industrial Computed-Tomography system.*

Using specific algorithms, these 2D projections are then reconstructed into Digital Imaging and Communications in Medicine (DICOM) file format.

The DICOM are filed widely used and sophisticated set of standards for digital radiology. A stack of images, also called slices, from which a volumetric representation of the object can be generated. The files are produced by a range of medical imaging equipment, (MRI, CT, PET, Ultrasound, etc.), consisting of a series or stack of cross-sectional image slices across a region of interest in the body. A stack of slices represents a volume.

The DICOM file format also contains metadata, such as:

- Acquisition date and time
- Institution name
- Modality
- Patient name and details (sex, age, birthdate etc)
- Referring Physicians name
- Equipment details
- Data collection parameters

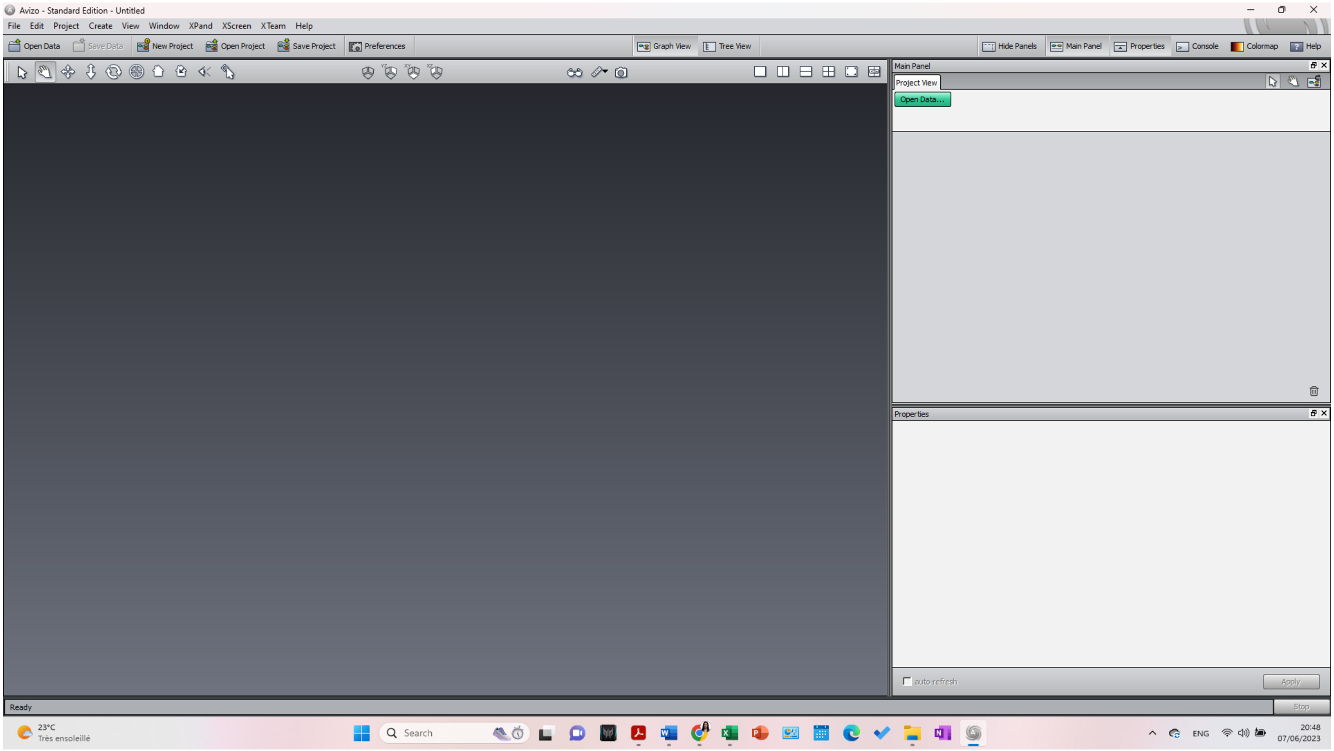
II. 3D imaging software

II.1. Avizo software

II.1.1. Introduction to Avizo

Avizo is a modular and object-oriented software system. Its basic system components are modules and data objects. Modules are used to visualize data objects or to perform some computational operations on them. The components are represented by little icons in Project View. Icons are connected by lines indicating processing dependencies between the components, i.e., which modules are to be applied to which data objects. Alternatively, modules and data objects can be displayed in a Project Tree View. Modules from data objects of specific types are created automatically from file input data when reading or as output of module computations. Modules matching an existing data object are created as instances of particular module types via a context-sensitive popup menu. Projects can be created with a minimal amount of user interaction. Parameters of data objects and modules can be modified in Avizo's interaction area. For some data objects such as surfaces or colormaps, there exist special-purpose interactive editors that allow the user to modify the objects. All Avizo components can be controlled via a Tcl command interface. Commands can be read from a script file or issued manually in a separate console window. The biggest part of the screen is occupied by a 3D graphics window. Additional 3D views can be created if necessary. Avizo is based on the latest release of Open Inventor by FEI SAS, a part of Thermo Fisher Scientific. In addition, several modules apply direct OpenGL rendering to achieve special rendering effects or to maximize performance. In total, there are more than 270 data object and module types. They allow the system to be used for a broad range of applications. Scripting can be used for customization and automation. User-defined extensions are facilitated by the Avizo developer version

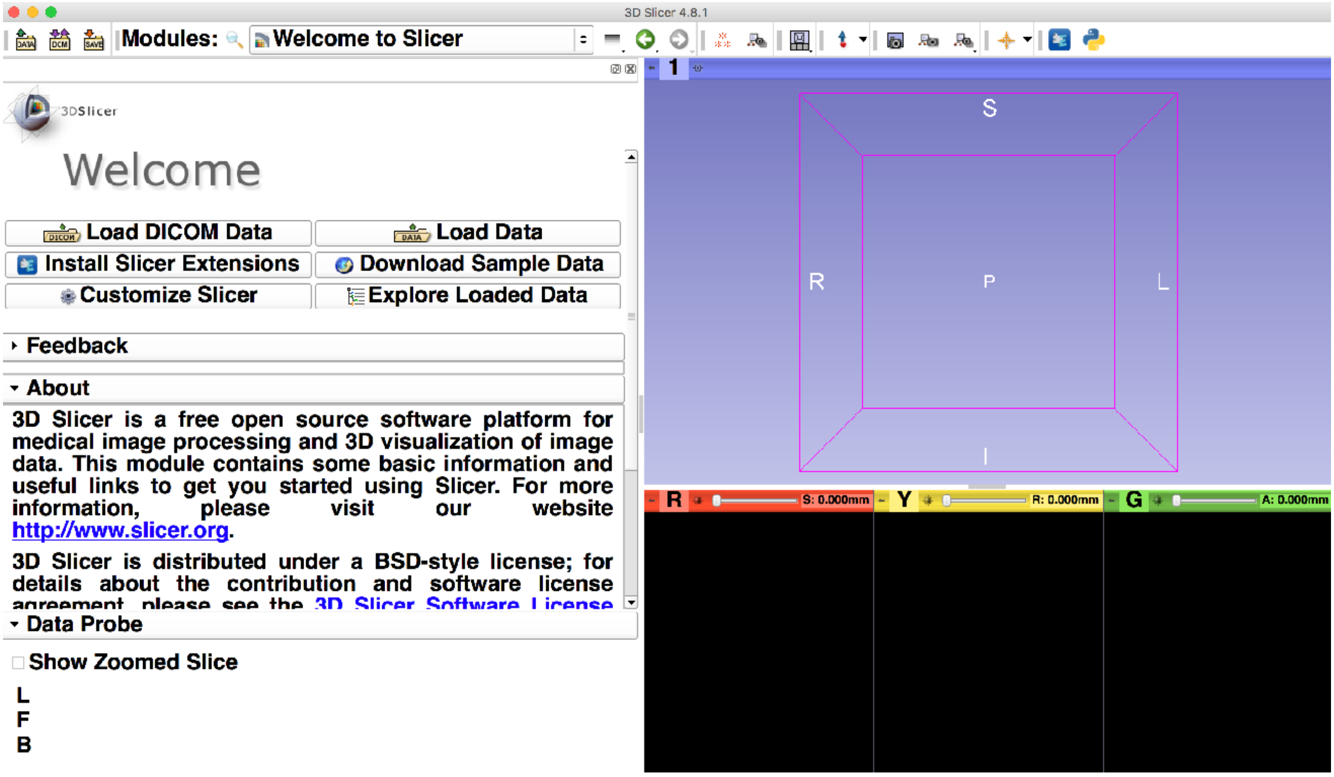
II.1.2. Avizo interface



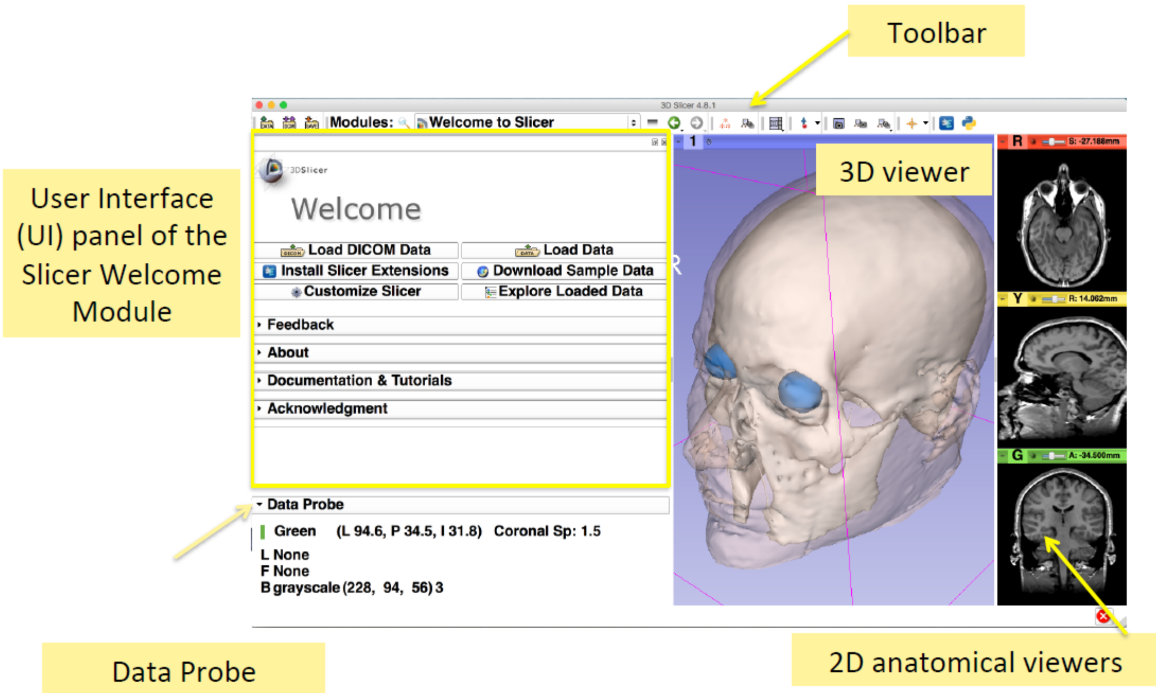
II.2. 3D slicer

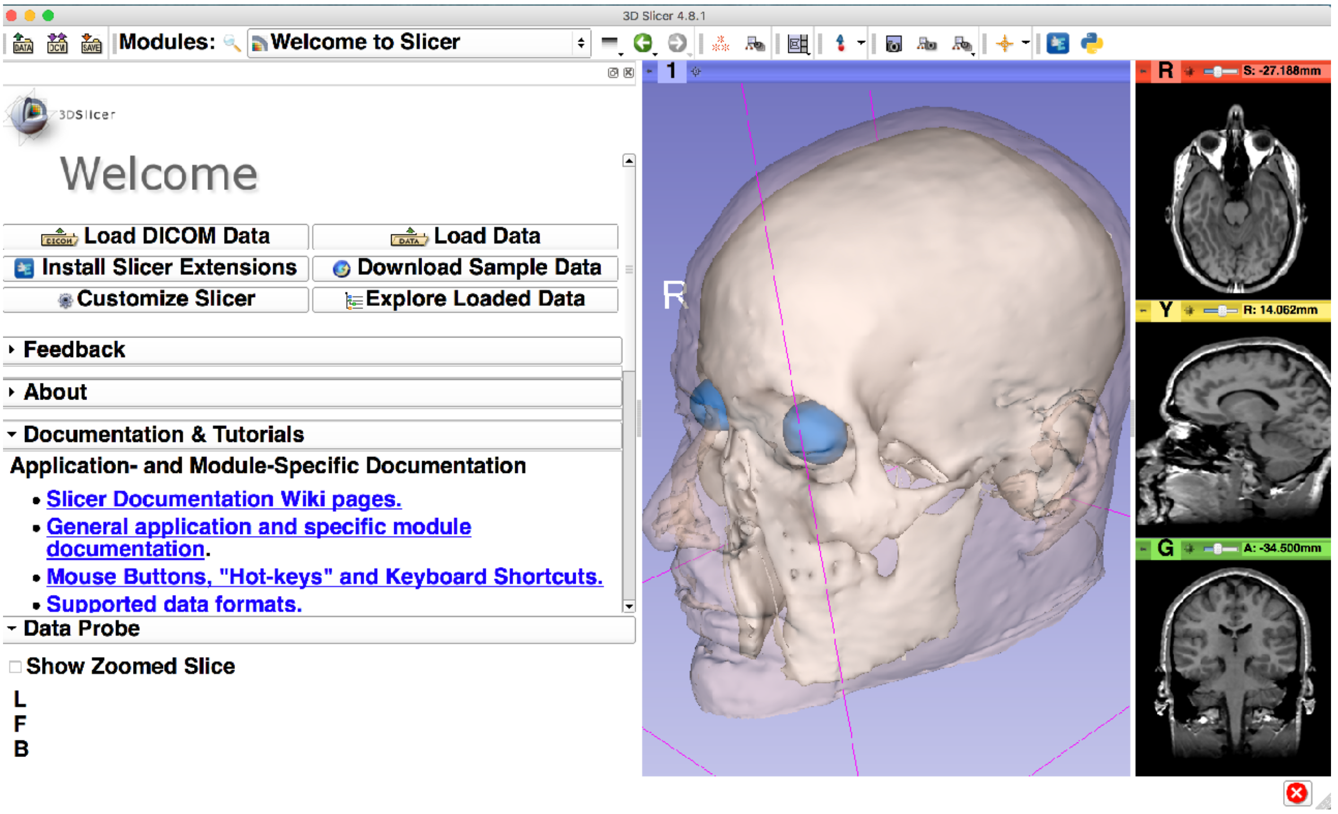
II.2.1. Introduction to 3D slicer

3D Slicer is a free, open source software package available for download on Windows, Linux and Mac Os X. 3D Slicer version 4.5 can be downloaded here. The development of 3D Slicer has been enabled by the participation of several large-scale NIH funded efforts, including the NA-MIC, NAC, BIRN, CIMIT, Harvard Catalyst and NCIGT communities. Slicer is an open-source software for segmentation, registration and visualization of medical imaging data. The Slicer software requires a minimum of 2 GB of RAM and a dedicated graphic accelerator with 64 MB of on-board graphic memory.

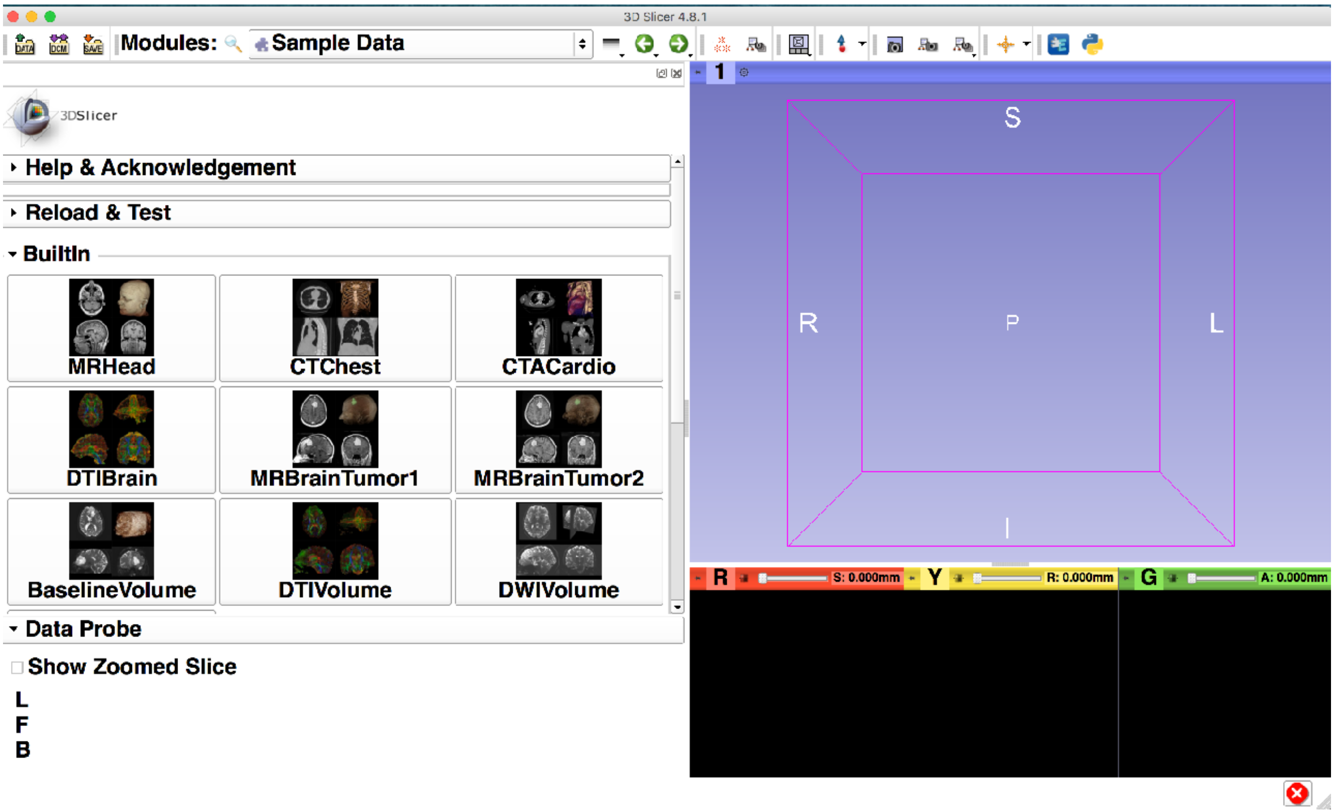


II.2.2. 3D slicer interface





- The Welcome module panel contains shortcuts for loading different types of data. A series of sample data is also available.
- Click on Download Sample Data to access the Sample Data Module.
- The Sample Data module contains links to different sample datasets that can be downloaded into Slicer.

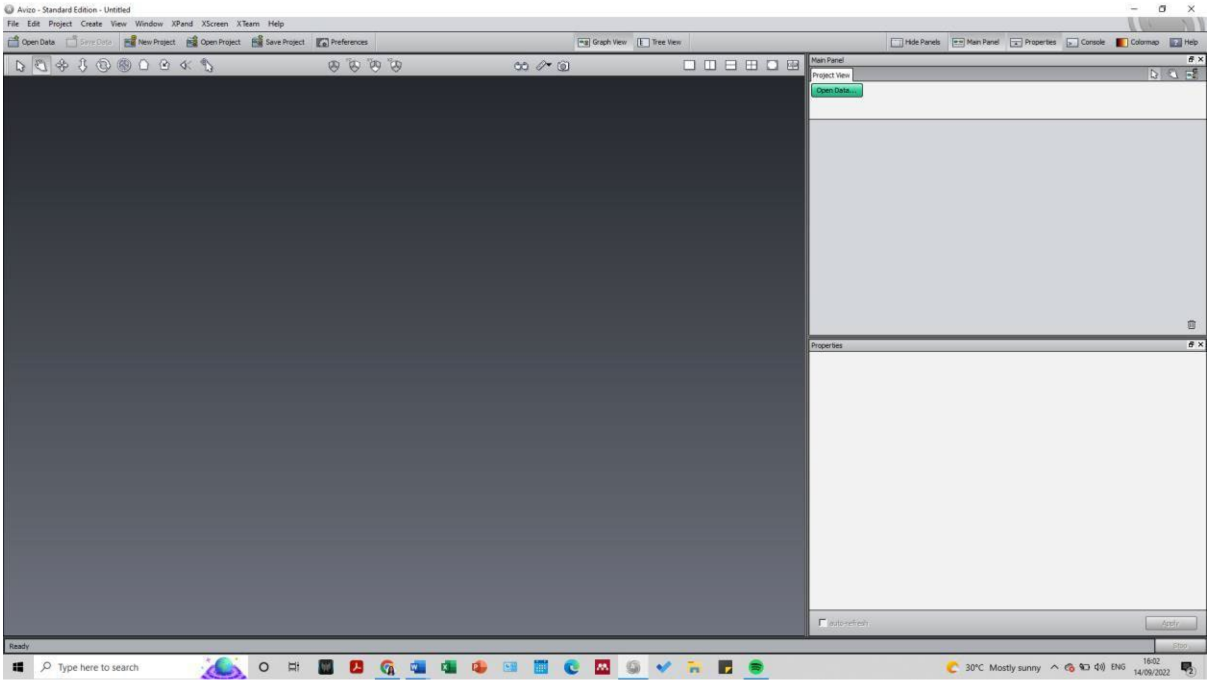

3D Slicer 4.8.1
Modules:
Sample Data
3DSlicer
Help & Acknowledgement
Reload & Test
BuiltIn
MRHead
CTChest
CTACardio
DTIBrain
MRBrainTumor1
MRBrainTumor2
BaselineVolume
DTIVolume
DWIVolume
Data Probe
Show Zoomed Slice
L
F
B
S
R
P
L
I
S: 0.000mm
R: 0.000mm
A: 0.000mm

III. Segmentation and creation of 3D model

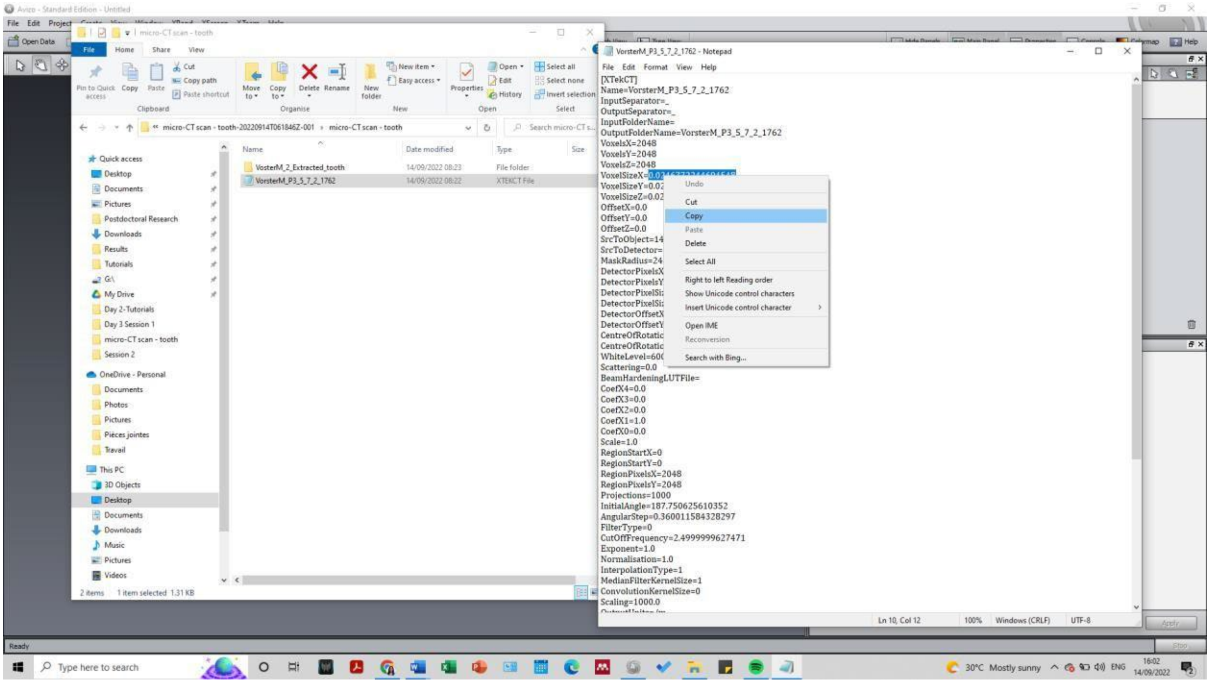
III.1. Avizo software: Segmentation and creation of 3D model

III.1.1. Open data

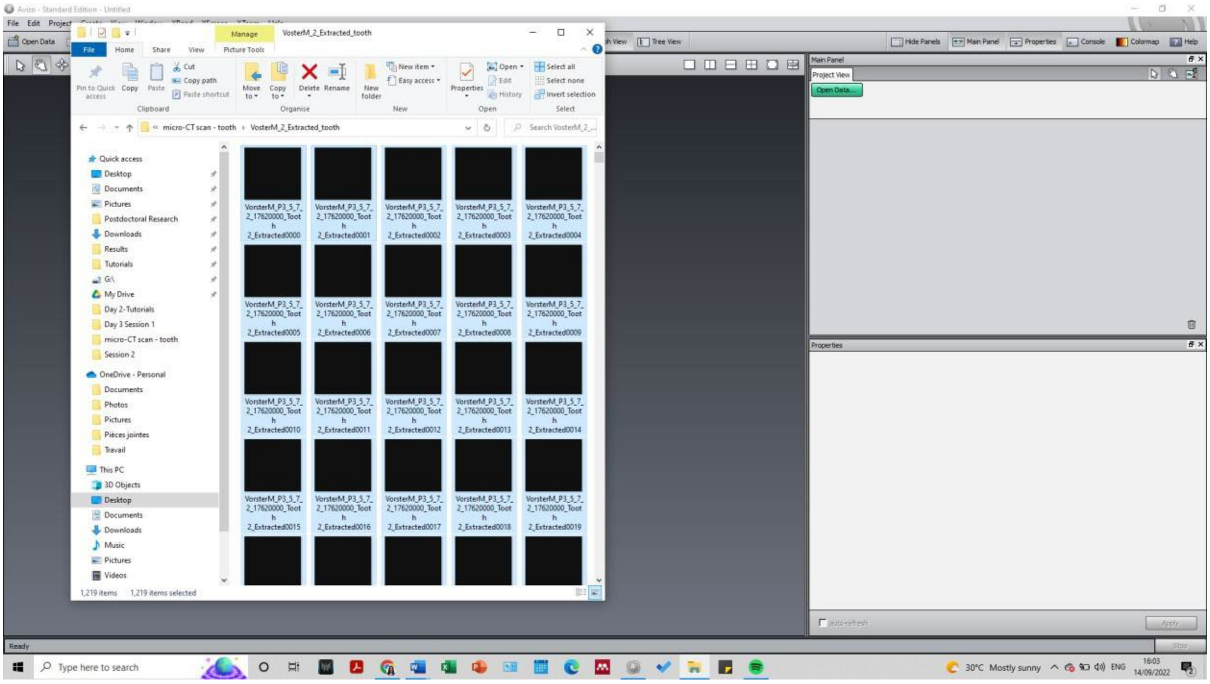
Step 1: Open Avizo software



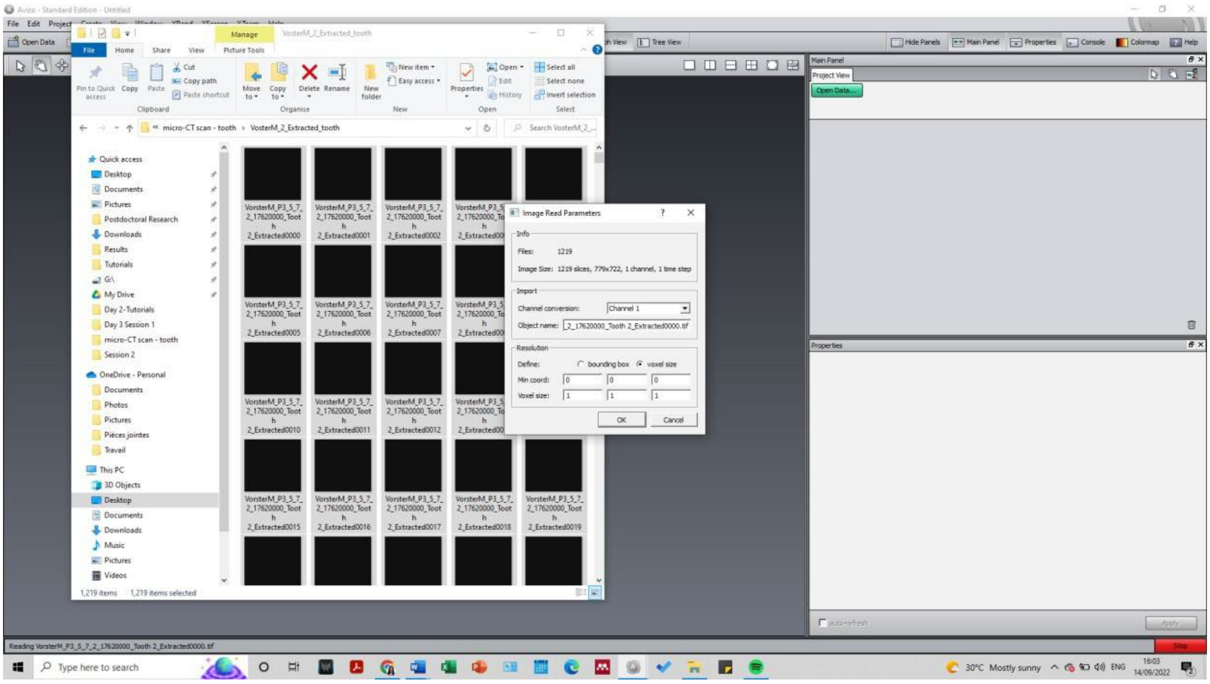
Step 2: In the case of loading a micro-XCT scan. Before to load anything you must look for the resolution (x,y,z) of the micro-XCT scan that you want to load in the associated notepad file for example an Xtekct file.


VorsterM_P3_5_7_2_1762 - Notepad
File Edit Format View Help
[XTekCT]
Name=VorsterM_P3_5_7_2_1762
InputSeparator=_
OutputSeparator=_
InputFolderName=
OutputFolderName=VorsterM_P3_5_7_2_1762
VoxelsX=2048
VoxelsY=2048
VoxelsZ=2048
Undo
Cut
Copy
Paste
Delete
Select All
Right to left Reading order
Show Unicode control characters
Insert Unicode control character
Open IME
Reconversion
Search with Bing...
Scattering=0.0
BeamHardeningLUTFile=
CoefX4=0.0
CoefX3=0.0
CoefX2=0.0
CoefX1=1.0
CoefX0=0.0
Scale=1.0
RegionStartX=0
RegionStartY=0
RegionPixelsX=2048
RegionPixelsY=2048
Projections=1000
InitialAngle=187.750625610352
AngularStep=0.360011584328297
FilterType=0
CutOffFrequency=2.4999999627471
Exponent=1.0
Normalisation=1.0
InterpolationType=1
MedianFilterKernelSize=1
ConvolutionKernelSize=0
Scaling=1000.0
Ln 10, Col 12
100%
Windows (CRLF)
UTF-8
VosterM_2_Extracted_tooth
VorsterM_P3_5_7_2_1762
Type here to search
30°C Mostly sunny

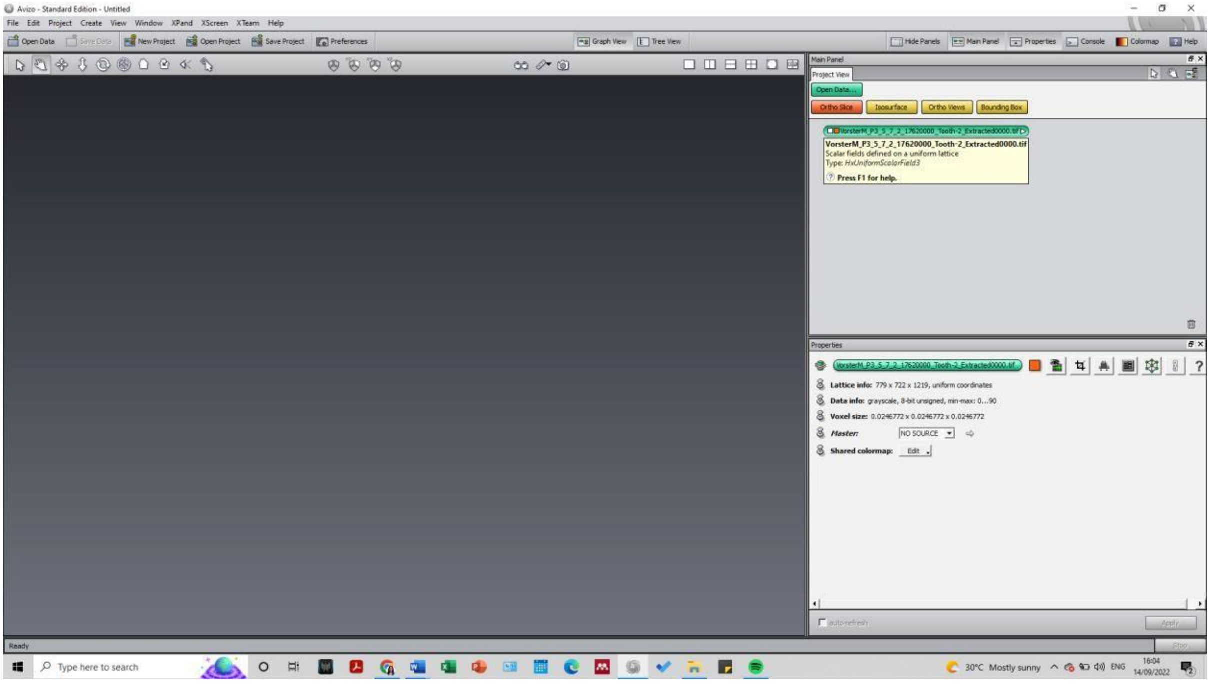
Step 3: Select all images of the scans or the scan file and drag them/it to the interface.



Step 4: In a case of micro-XCT, paste the resolution values in x, y, z.

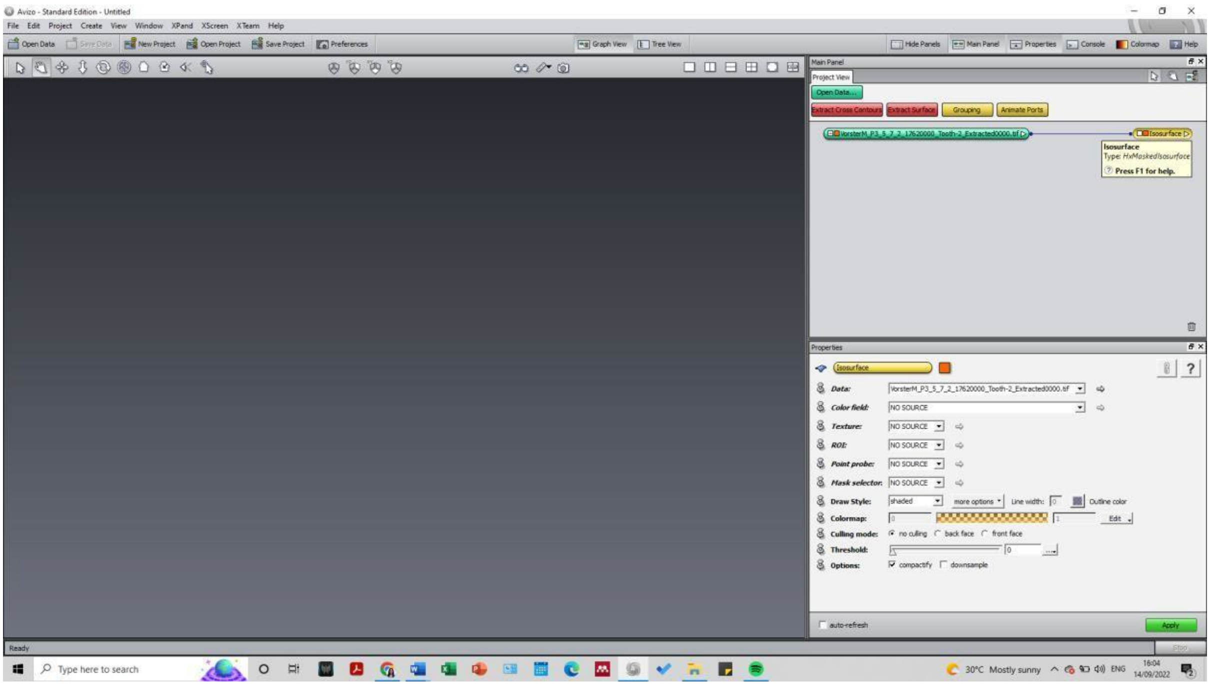


Your scan should appear in green as an object on the Avizo interface.

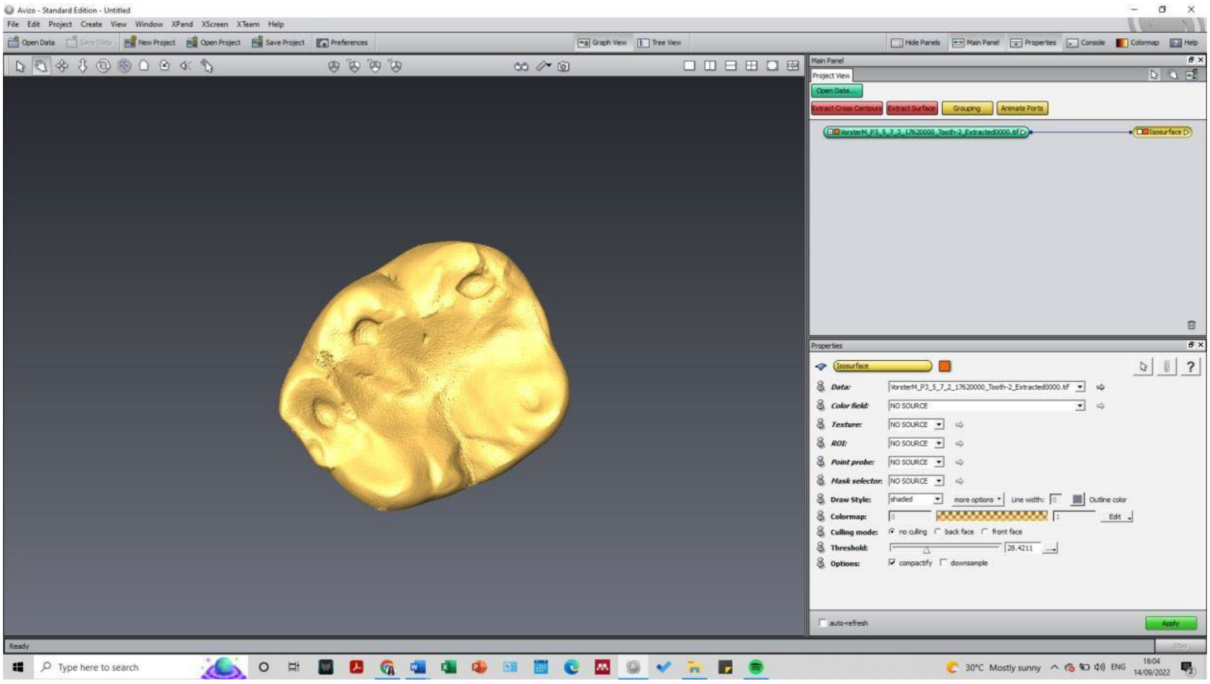


III.1.2.3D surface view

Step 1: To have a basic 3D visualization of your data, click on your green object and then on “surface view” (if not on the interface, click right).

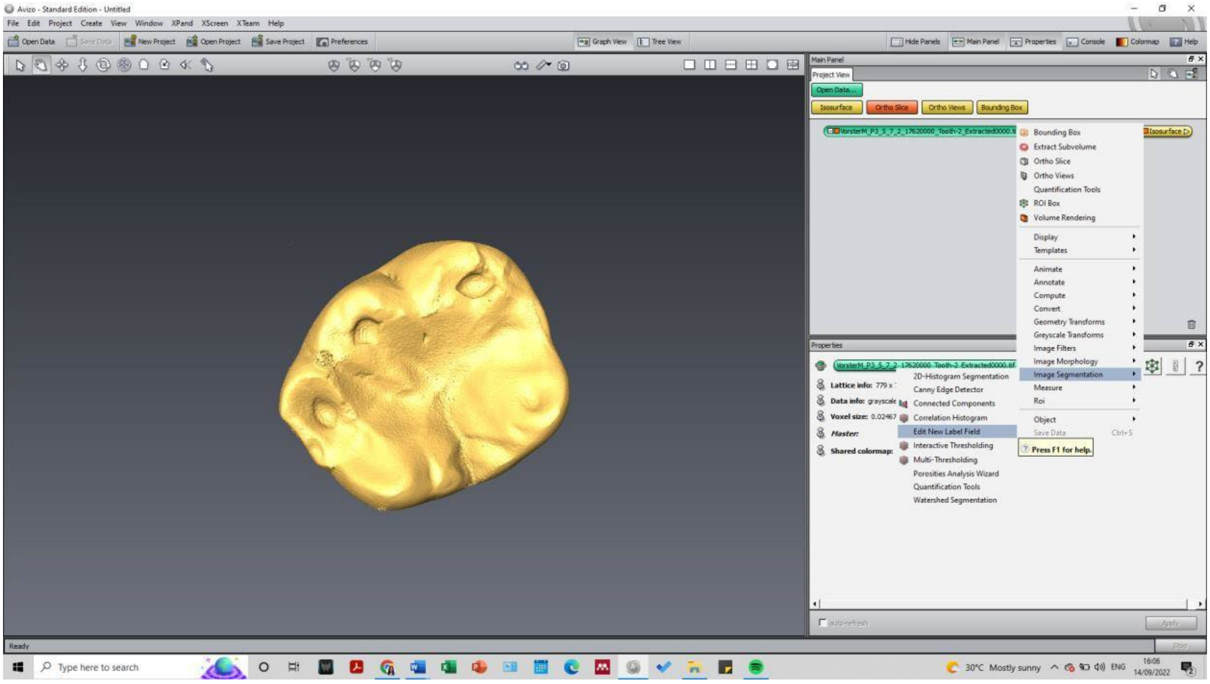


Step 2: In the properties panel (if no properties panel look on the top left and click on "properties" to put your properties panel), play with the threshold values and click on apply to have a visualization.

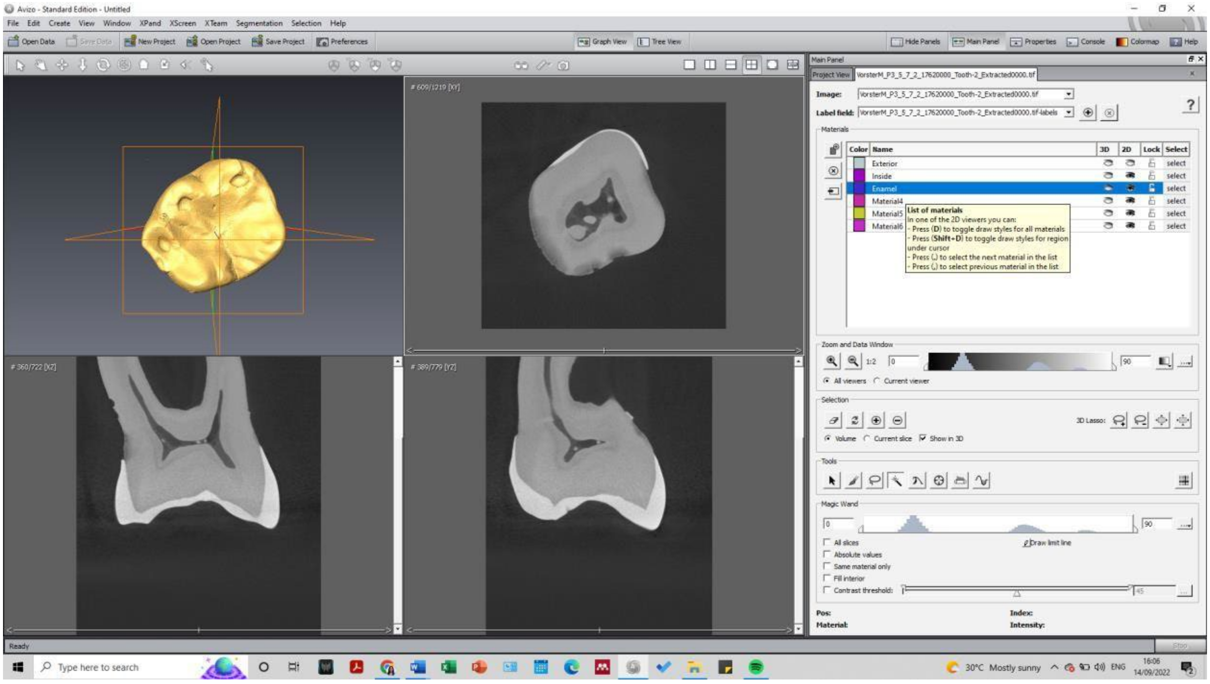


III.1.3. Image segmentation

Step 1: Click on your object in green. Click right and select "Image segmentation" and then "Edit new label field".

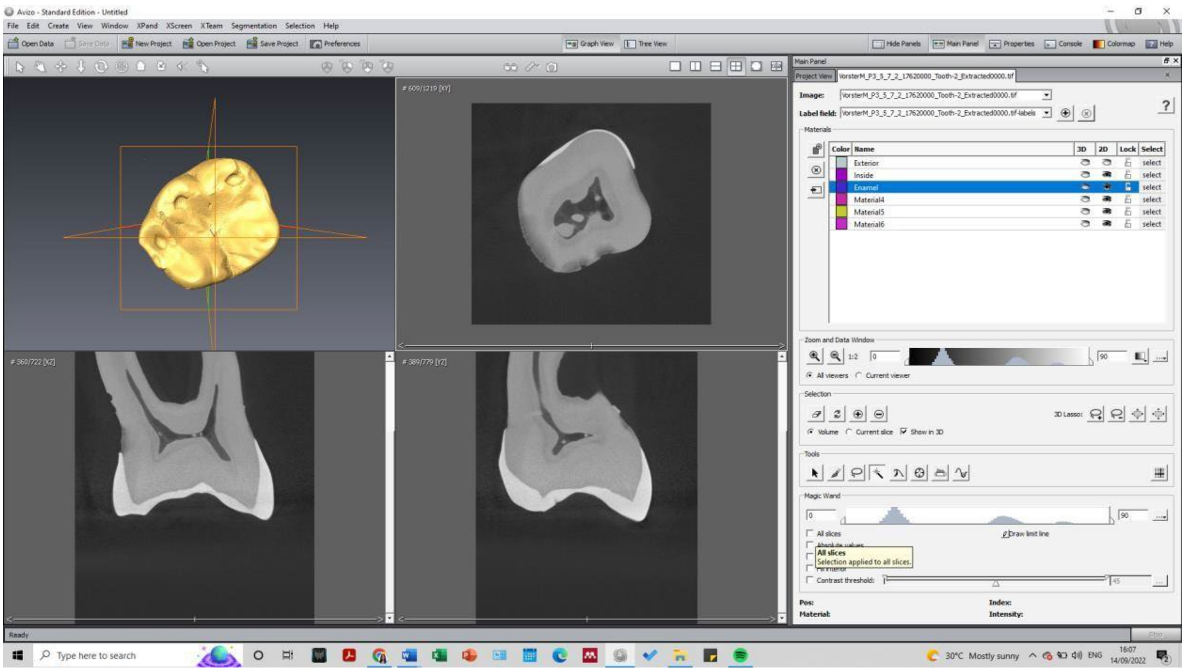


Step 2: Add the materials in the "Materials" panel. For example, here we want to segment the dentine, the enamel and the pulp, but also the exterior. So, I have created

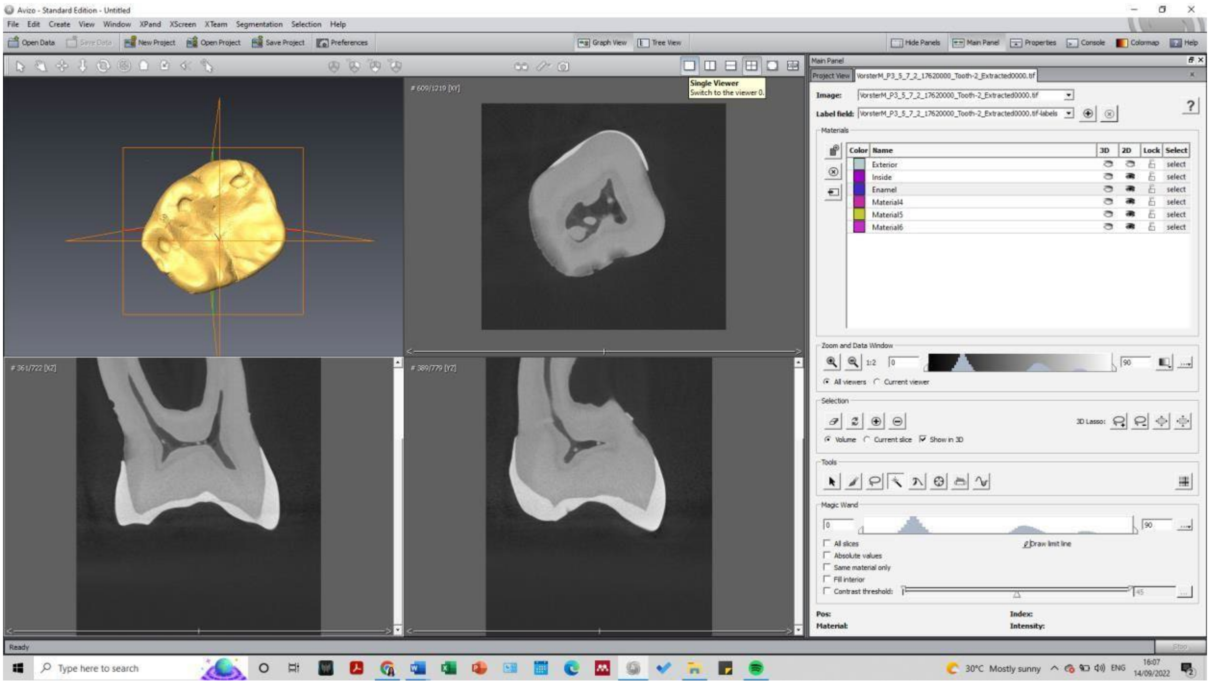


4 materials. You can rename them and attribute the color that you want.

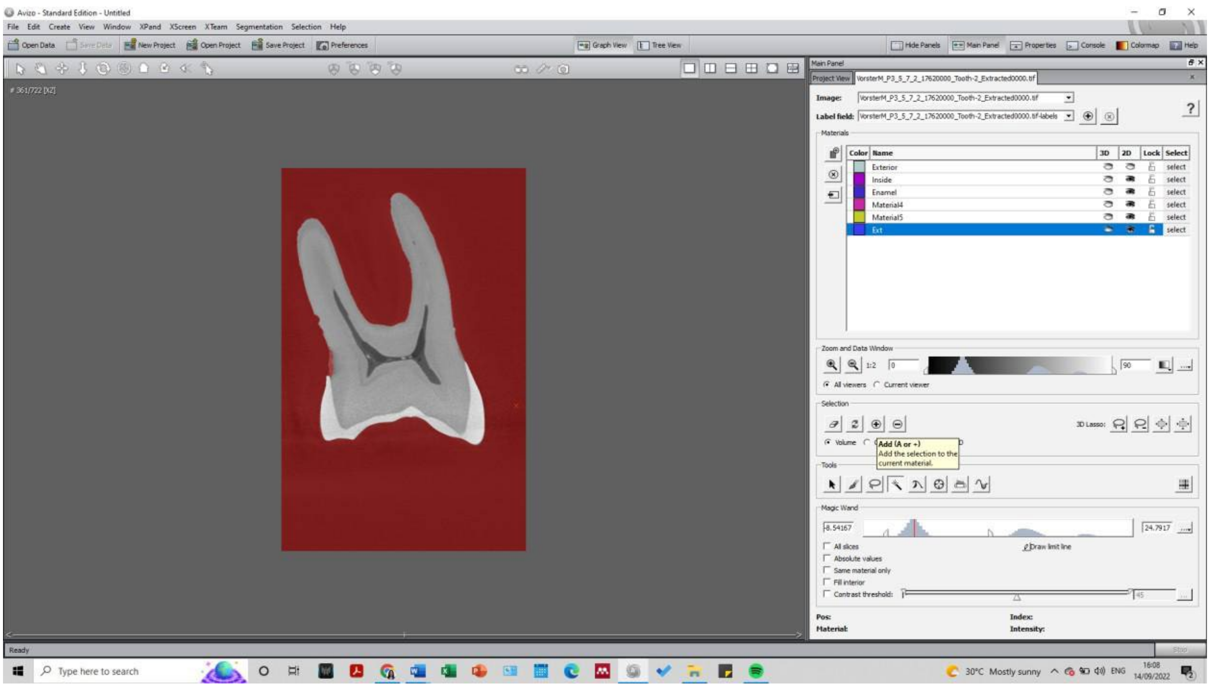
Step 3: Using the tools in the properties bar you are going to attribute "gray values" from the images to each of the corresponding "Materials".



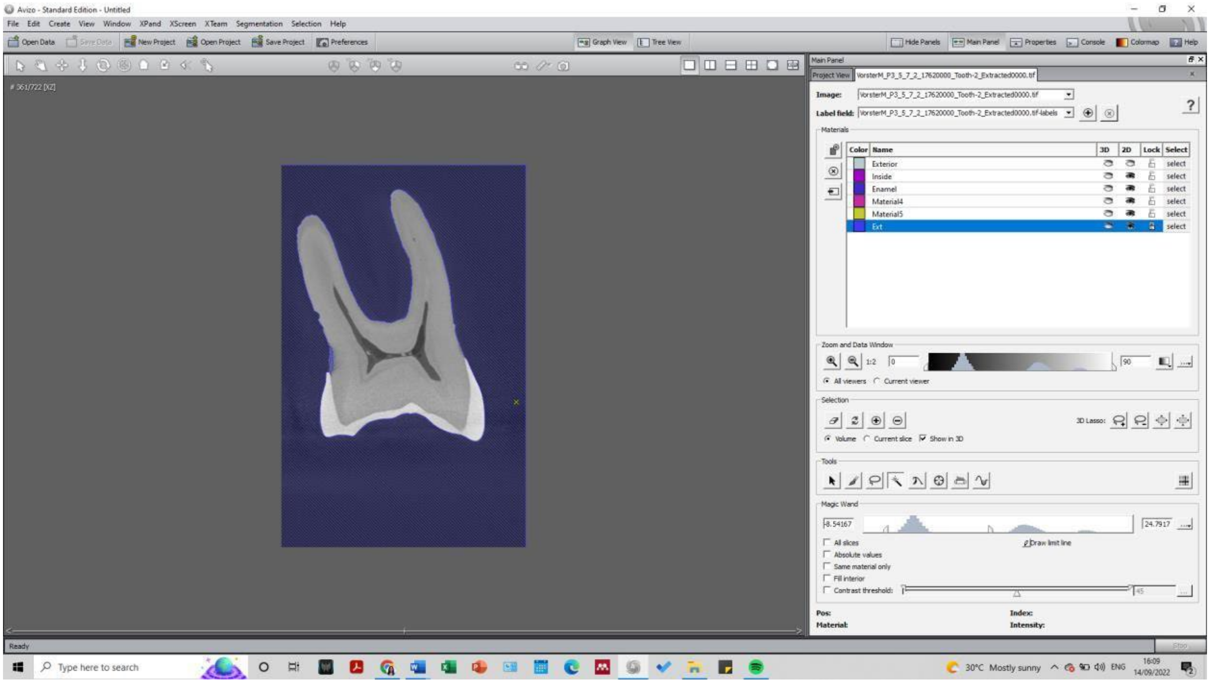
Step 4: To have access to only one view, click on the view that you want and then on the option “simple view” on the top.



Step 5: Select each material on one slide.

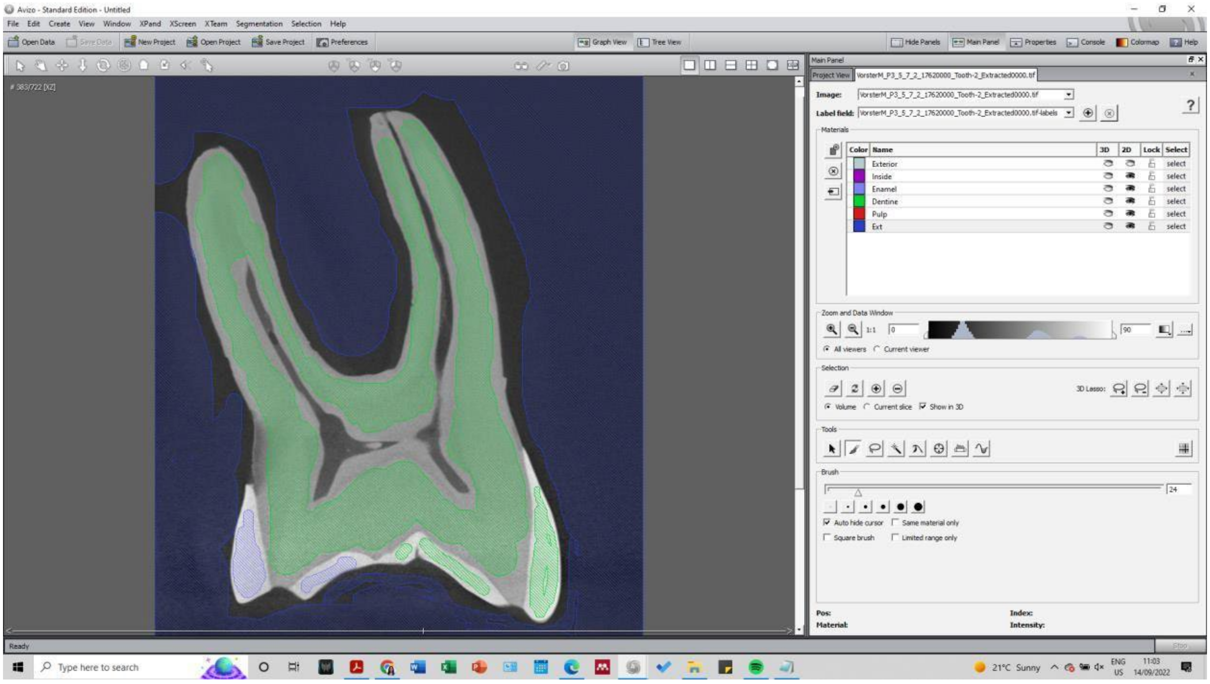


Step 6: Click on the + to add that selection to the named material. For example, here I have selected the exterior grey values (in blue) and I have attributed these grey values to

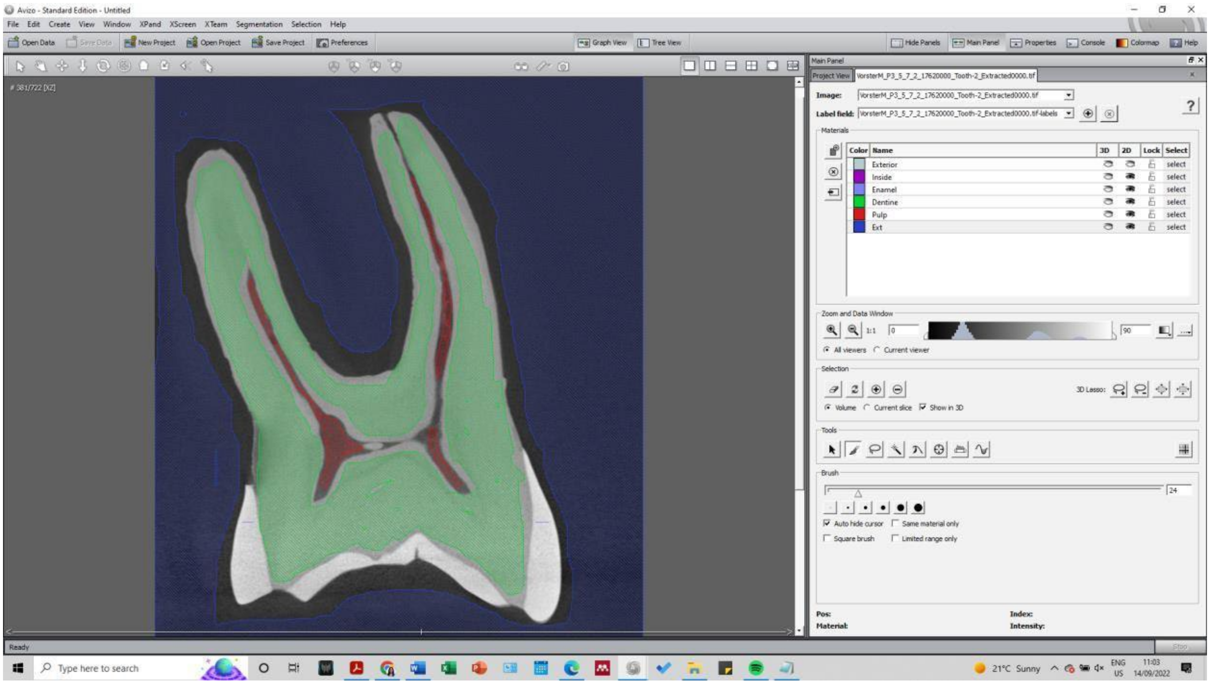


my “Ext” Material.

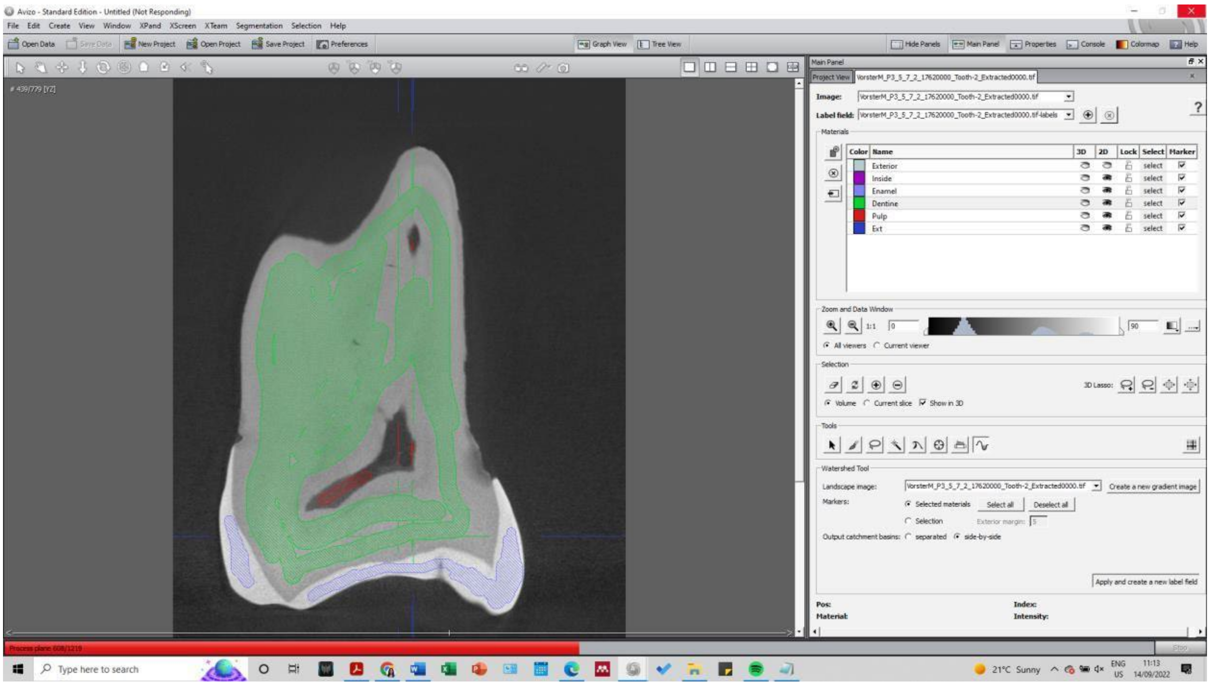
Step 7: Step 6 must be repeated for each material. Following the resolution of your data you need to do it on several slices.



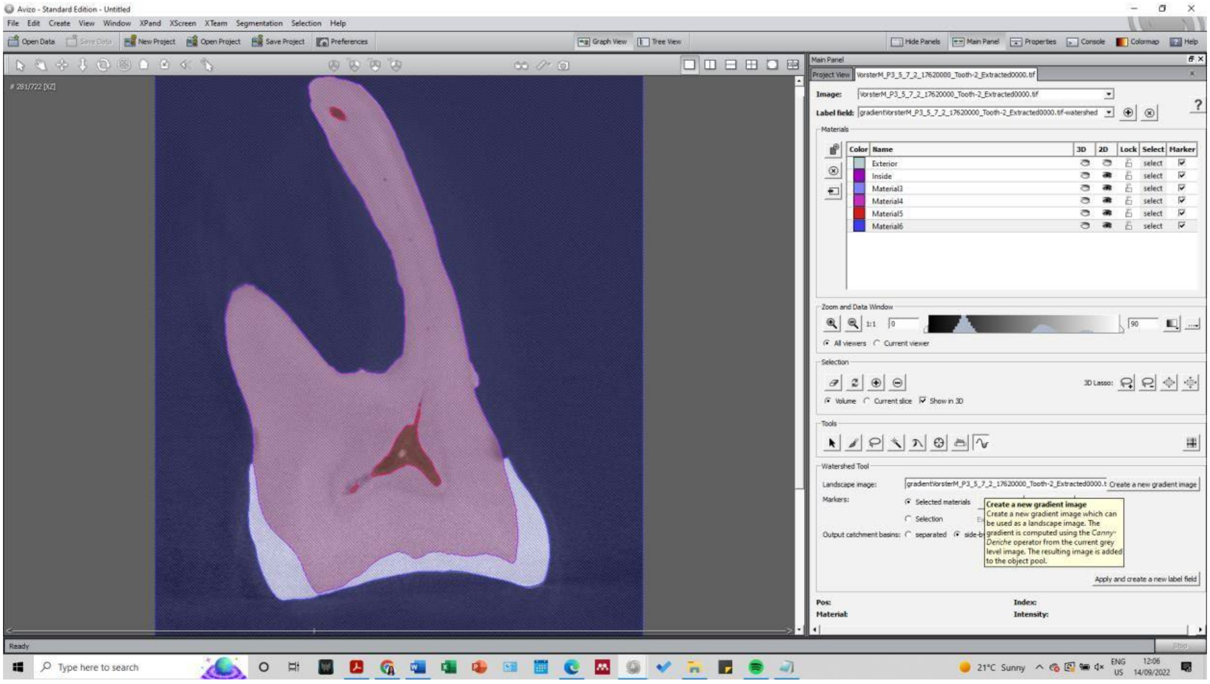
Step 8: When you are done with the selection of your material. In the tool bar (in Properties) click on "watershed".



Step 9: Click on “create a new gradient image” (run) then click on “Apply and create a new label field.

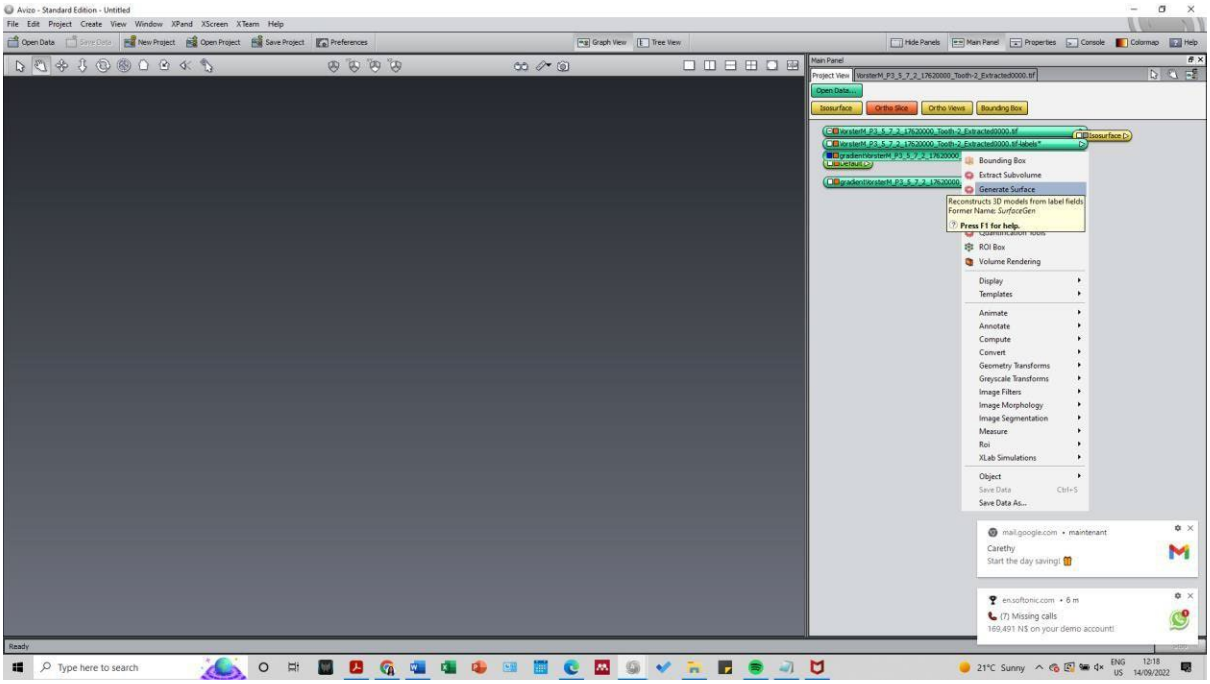


Step 10: All the slices must have a selection of each material on them.

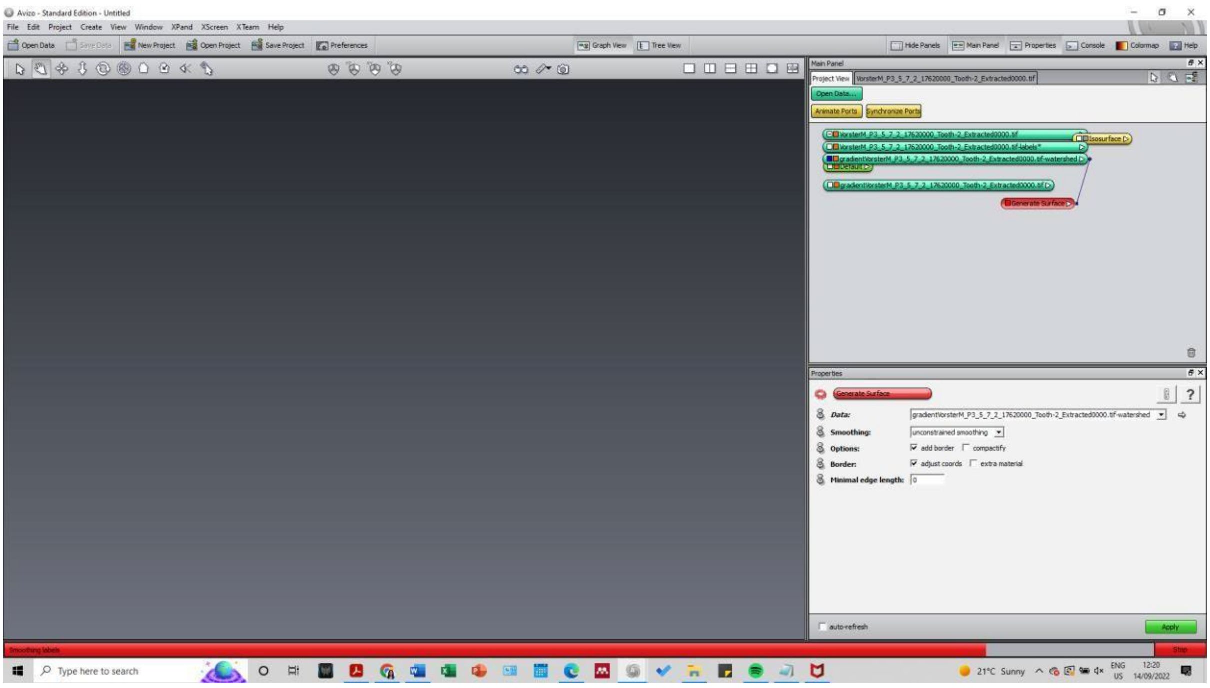


III.1.4. Generate 3D model from segmentation

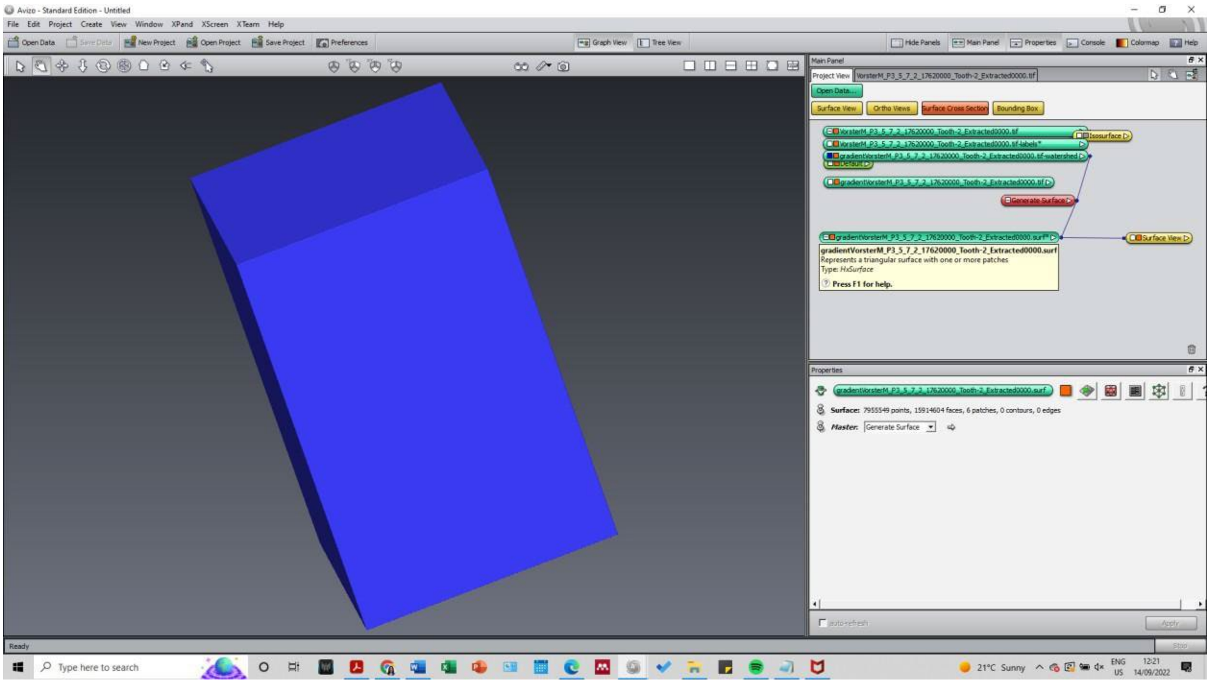
Step 1: Click on “Project view” to go back to the main panel. Click on the object ending by “watershed”. Click right and select “Generate Surface”.



***Note**: A new red object must be on the interface now.*

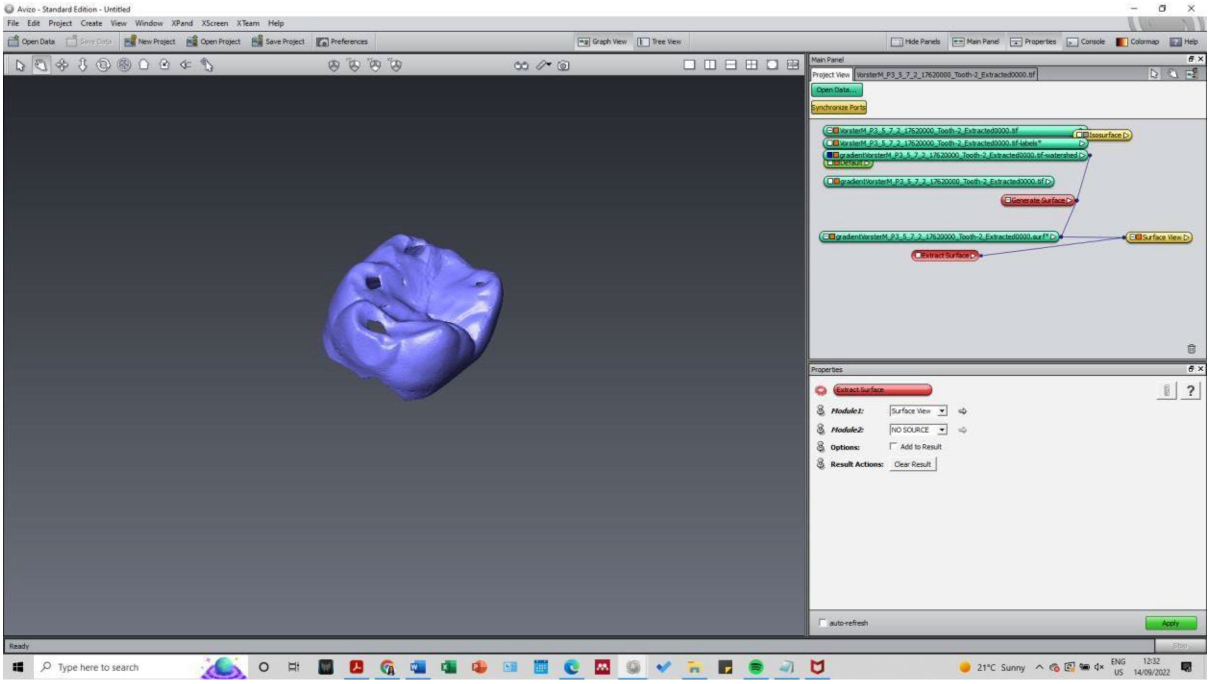


Step 2: Click on the Generate Surface object and select "Surface View".

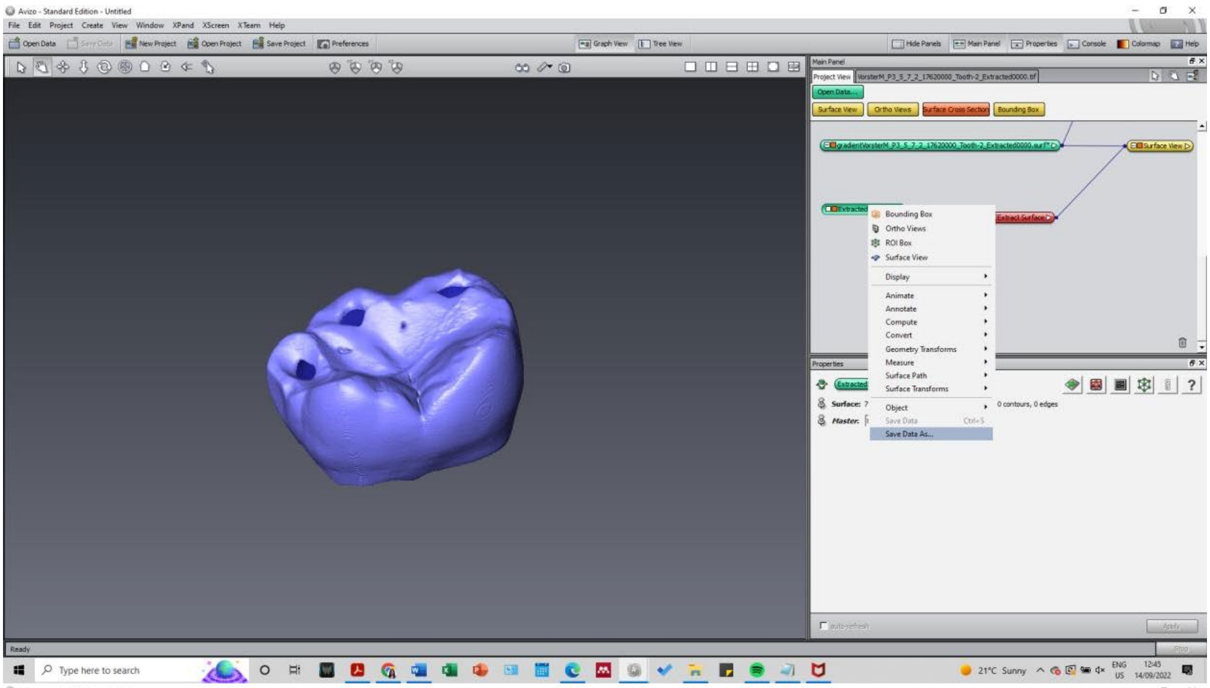


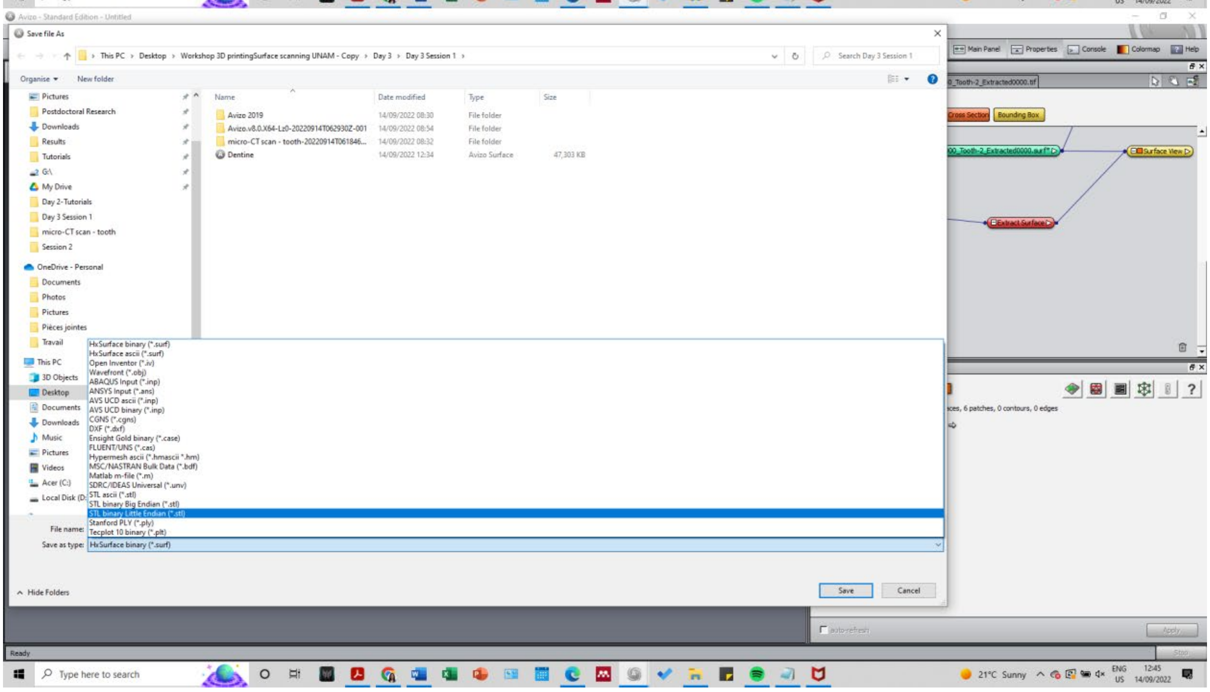
Step 3: Click on "Surface View" and in the Properties select the Materials that you want to add or remove. Materials: All Ext (remove) / All Dentine (Add)/All Enamel(Add)/ All Dentine (remove)/ All Enamel (Remove)/ All Pulp (Add)/

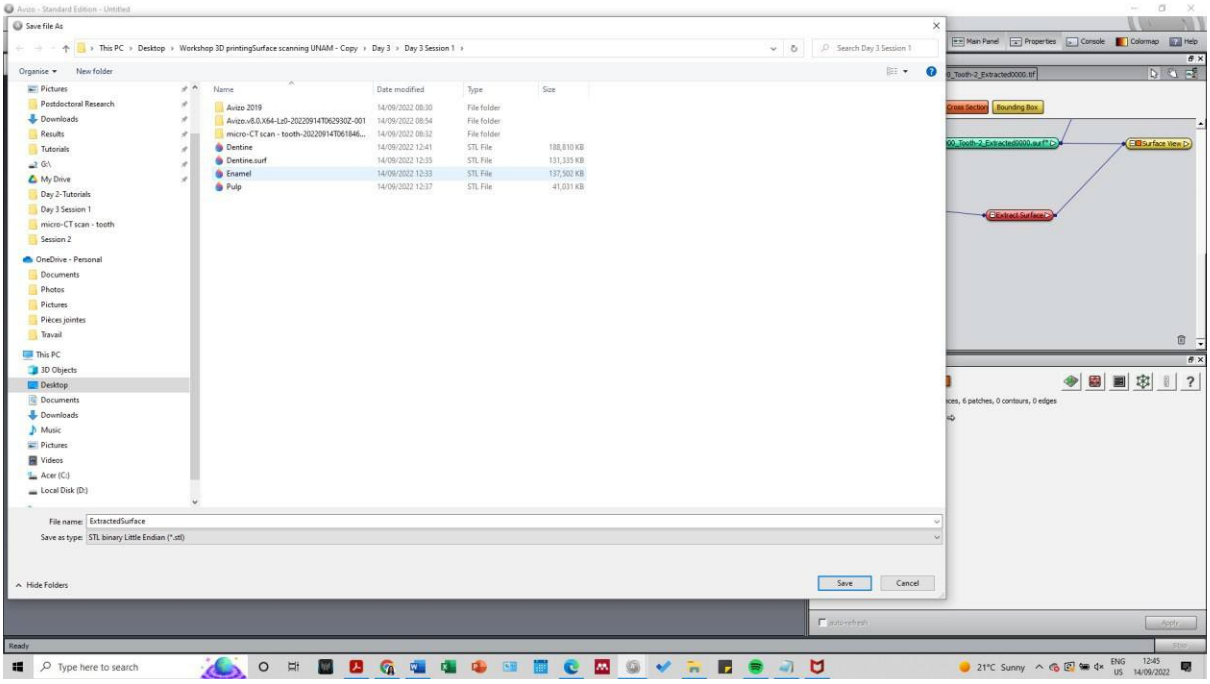
Step 4: Following which 3D model, you want to save (Dentine/Enamel or Pulp) you need to use "Extract surface" for each of them separately. Then click on apply in the properties panel.



Step 5: Save the "Extracted surface" object in green in any format that you want (stl, ply, etc) and attribute a name to your 3D model.


Bounding Box
Ortho Views
ROI Box
Surface View
Display
Animate
Annotate
Compute
Convert
Geometry Transforms
Measure
Surface Path
Surface Transforms
Object
Save Data
Save Data As...

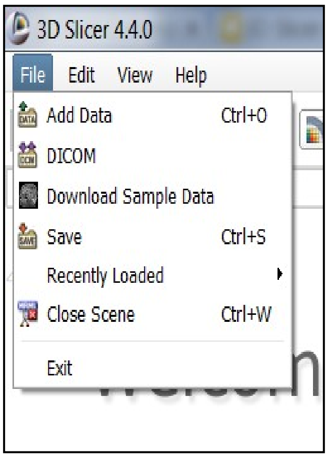

Save File As
HxSurface binary (*.surf)
HxSurface ascii (*.surf)
Open Inventor (*.iv)
Wavefront (*.obj)
ABAQUS Input (*.inp)
ANSYS Input (*.ans)
AVS UCD ascii (*.inp)
AVS UCD binary (*.inp)
CGNS (*.cgns)
DXF (*.dxf)
Ensight Gold binary (*.case)
FLUENT/UNS (*.cas)
Hypermesh ascii (*.hmascii *.hm)
MSC/NASTRAN Bulk Data (*.bdf)
Matlab m-file (*.m)
SDRC/IDEAS Universal (*.unv)
STL ascii (*.stl)
STL binary Big Endian (*.stl)
STL binary Little Endian (*.stl)
Stanford PLY (*.ply)
Tecplot 10 binary (*.plt)
Save
Cancel


Save file As
Organise
New folder
Name
Date modified
Type
Size
Avizo 2019
Dentine
Dentine.surf
Enamel
Pulp
File name: ExtractedSurface
Save as type: STL binary Little Endian (*.stl)
Hide Folders
Save
Cancel
Cross Section
Bounding Box
Surface View
Extract Surface

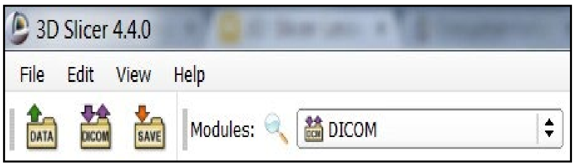
III.2. 3D slicer software: Segmentation and creation of 3D model

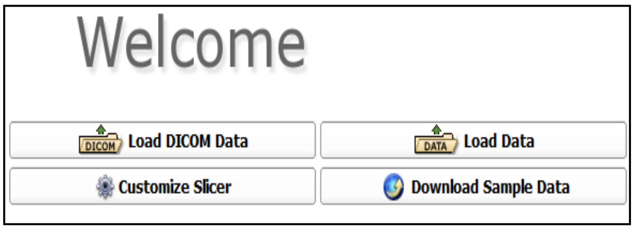
III.2.1. Open data

Step 1: Select file then add data

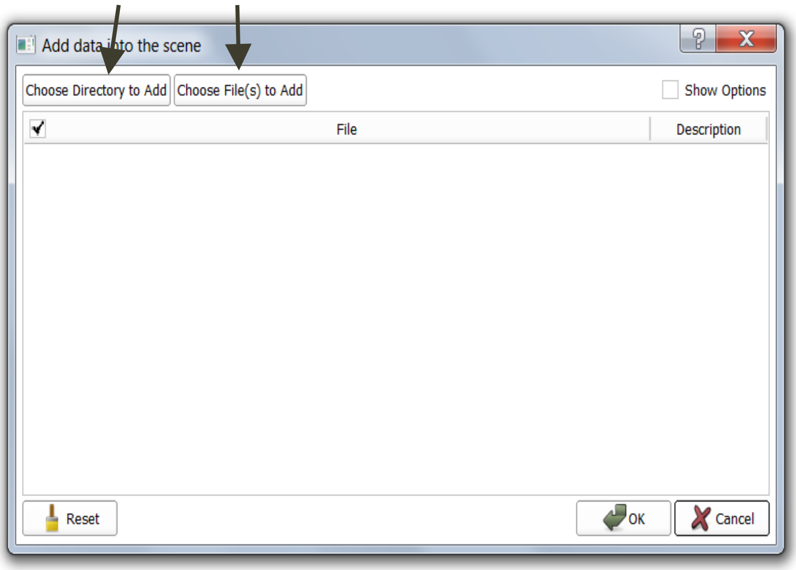


Step 2: Welcome to Slicer module, then Load data



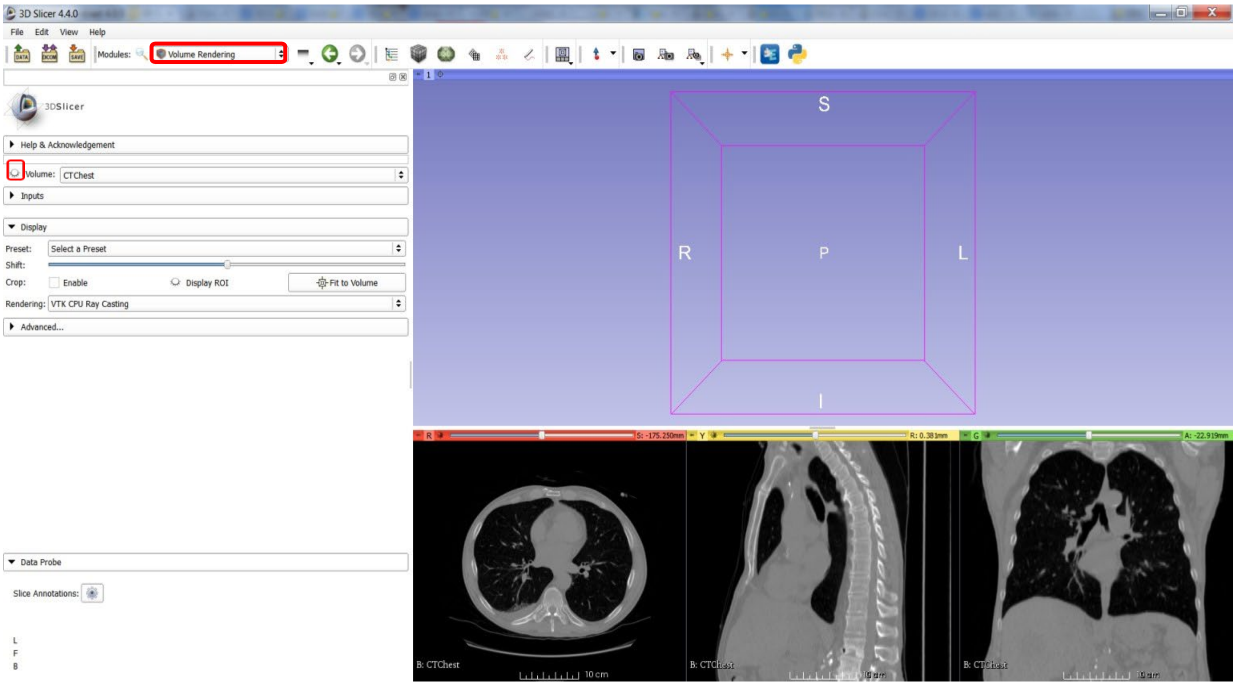


Step 3: Find DATA icon in toolbar

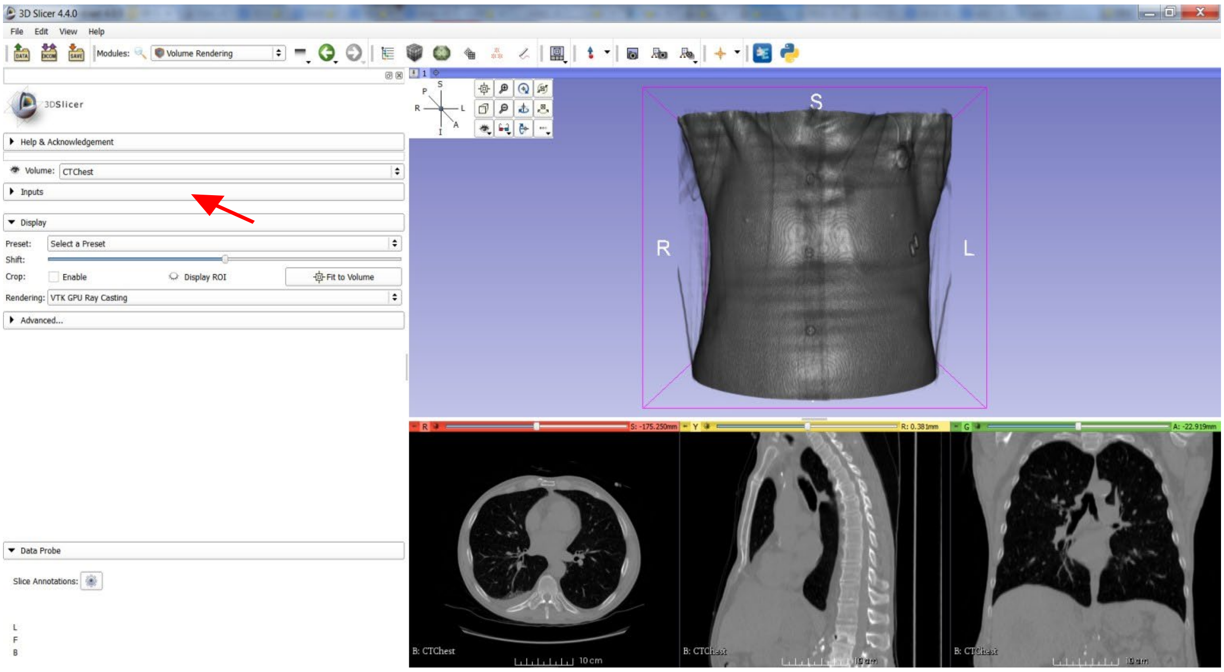

Add data into the scene
Choose Directory to Add
Choose File(s) to Add
Show Options
File
Description
Reset
OK
Cancel

III.2.2. 3D surface view

Step 1: Use the volume rendering tool to visualise the ‘CTChest’ dataset in 3D space.



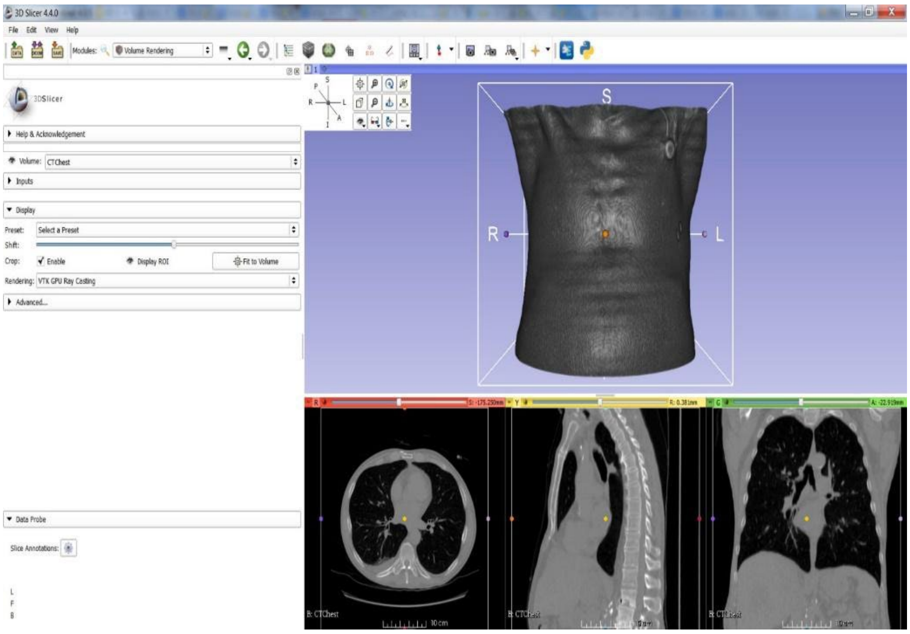
Step 2: Download ‘CTChest’ Sample Data from ‘Welcome to Slicer’ module.

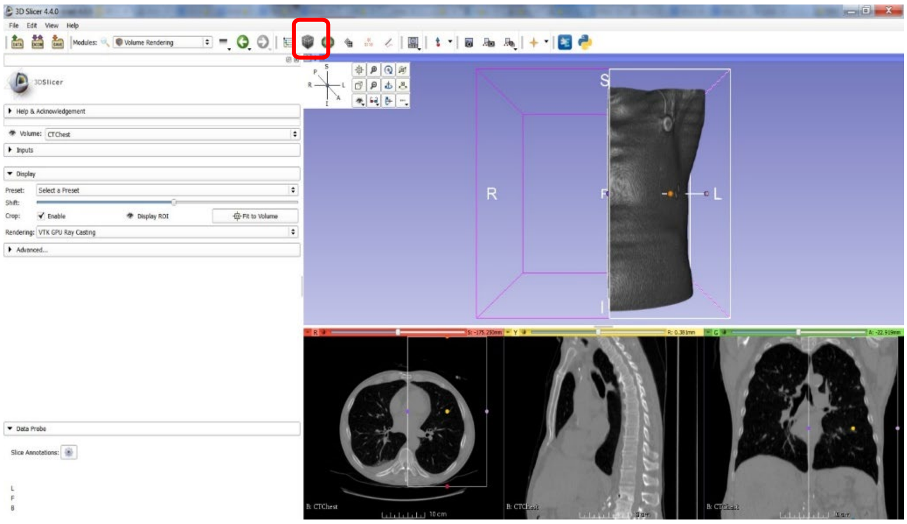


Step 3: Select **'Volume Rendering'** module.

Step 4: Open eye icon next to 'Volume' to generate 3D rendering of DICOM volume. Adjust view as required.

Step 5: Under 'Display' menu, adjust 'Shift' slider to remove noise.





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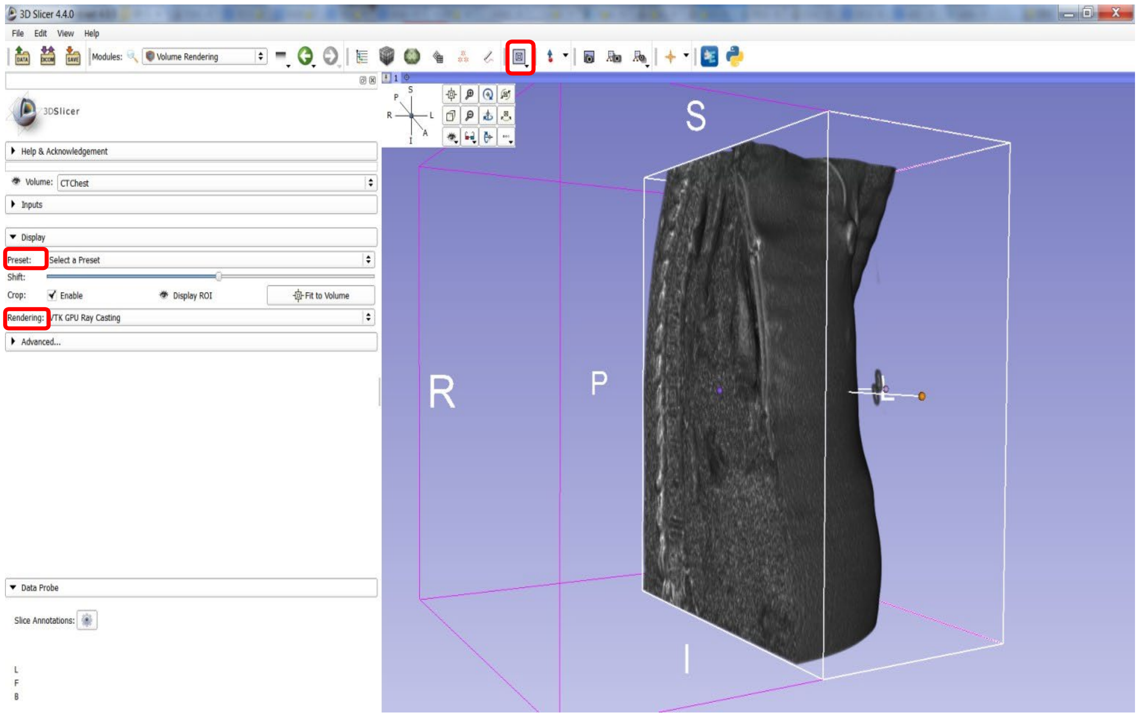
HELPING EACH OTHER DO Dirisana+



Step 6: Tick box 'Crop: Enable' and select 'Display ROI'. An adjustable window will appear in the 2D and 3D viewers. Adjust to crop out half of the volume in the Sagittal plane.

Step 7: Rotate the view in 3D space to display the exposed internal view.

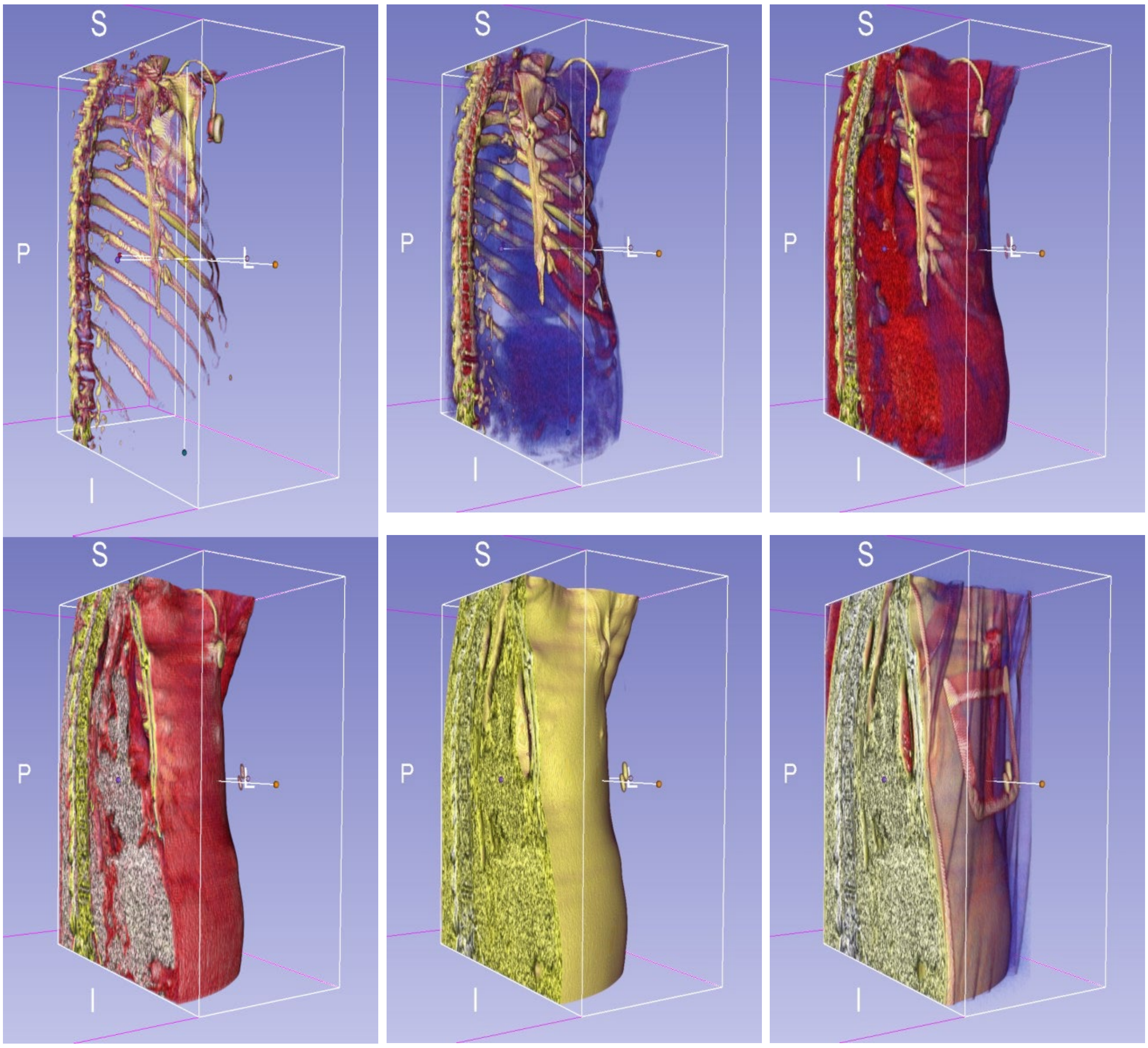
Step 8: Change layout of viewers to display 3D viewing window only.

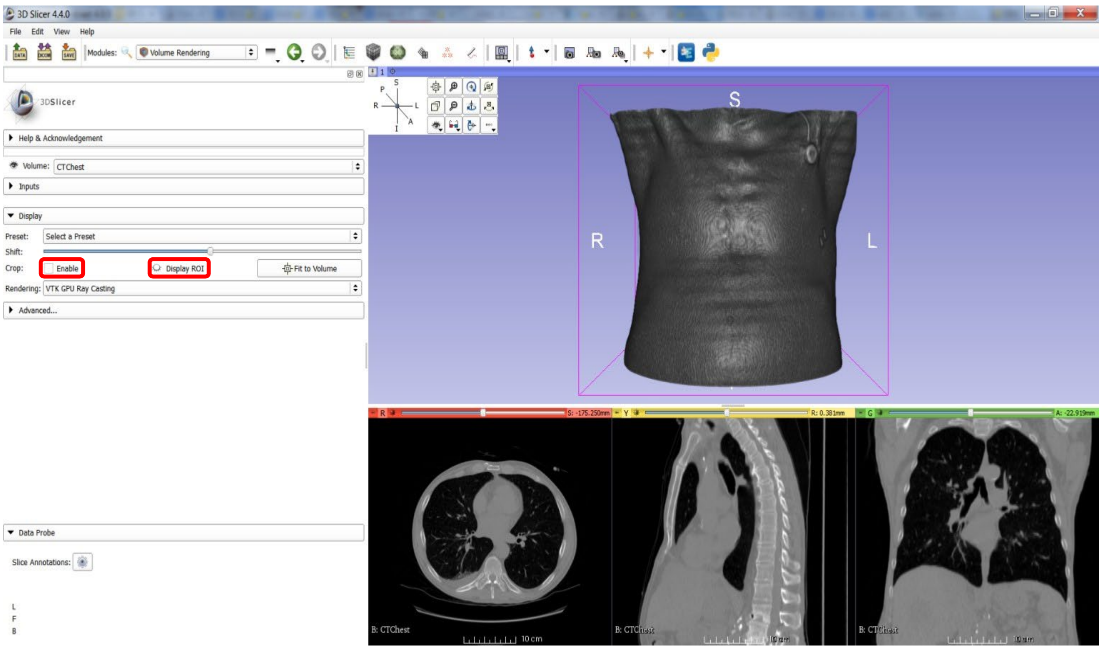
Step 9: Experiment with the presets; adjusting the 'shift' slider to change the thresholding.

Step 10: We can take a snapshot of the volume rendering using the 'screenshot' buttons in the toolbar. Then export the screenshot as a .png (or .jpg etc) using 'save'.

Note:

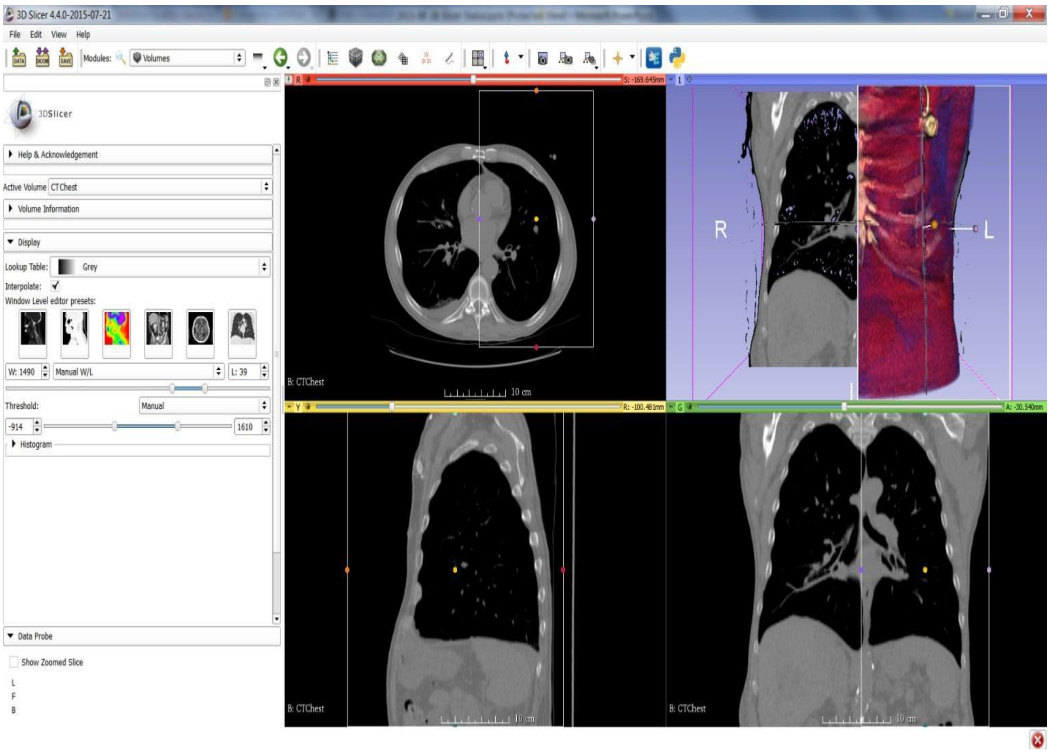
The Volume Rendering module can also be used to visualise labelmaps in 3D space. We will explore this more later.


S
P
L
I


3D Slicer 4.4.0
File Edit View Help
Modules: Volume Rendering
3DSlicer
Help & Acknowledgement
Volume: CTChest
Inputs
Display
Preset: Select a Preset
Shift:
Crop: Enable Display ROI Fit to Volume
Rendering: VTK GPU Ray Casting
Advanced...
Data Probe
Slice Annotations:
S
R
L
B: CTChest
10 cm

Step 11: The volumes module can be used to change the appearance of :volume data. Unlike the Volume Rendering module, a 3D representation of the data is not rendered. Rather, the visual appearance in the 2D slice views changes. Can be used to make areas of a slice layer differently coloured or even transparent.

Step 12: Turn on visibility of slices in 3D viewing window.
Step 13: Go to ‘Volumes’ module.
Step 14: Select last preset (CT lung).
Step 15: Adjust the threshold slider to change the visual representation of the 2D slices.

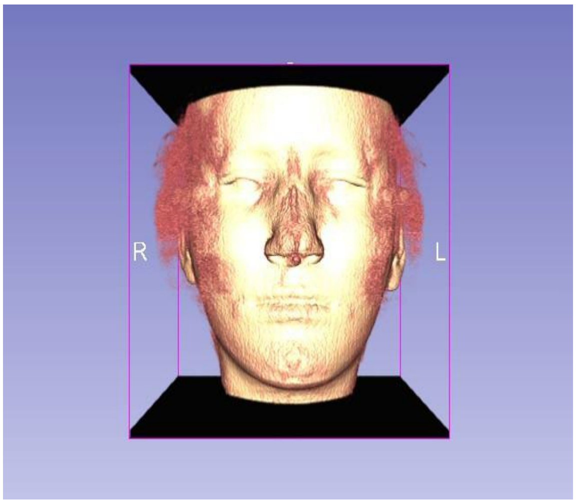


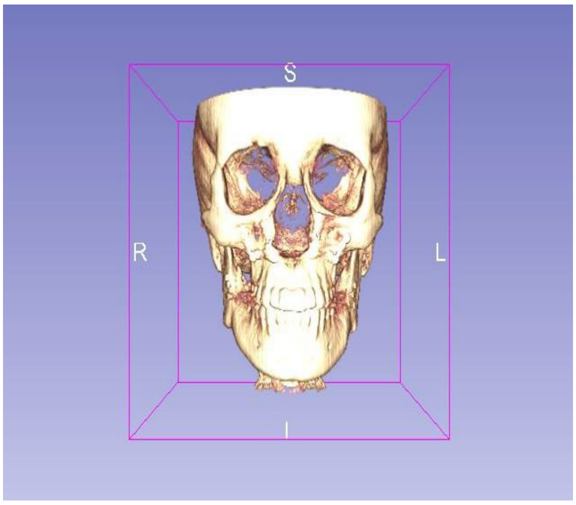
III.2.3. Image segmentation

Step 1: Load sample dataset CBCTDentalSurgery.

Step 2: Firstly, have a look at the data using the Volume Rendering tool. E.g., use CT-bone preset

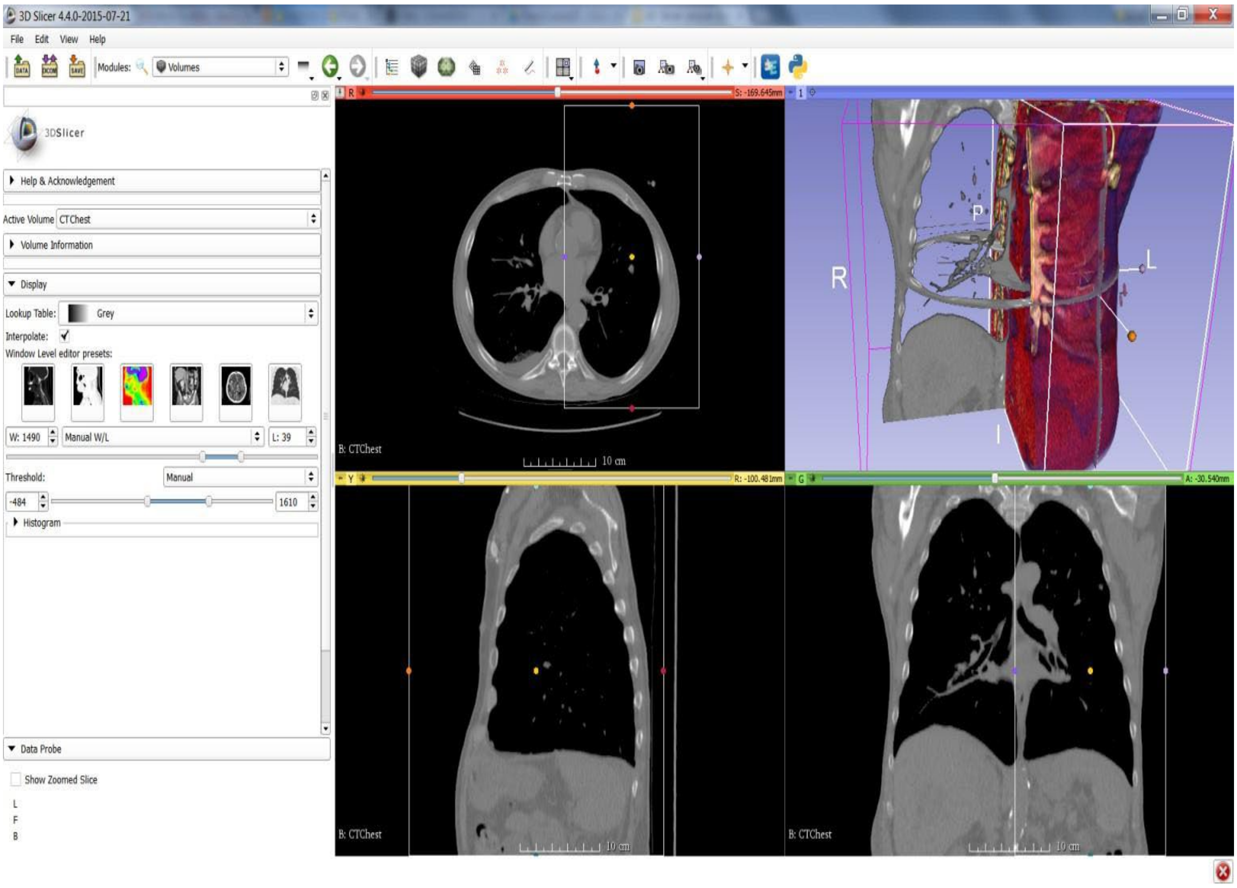
Step 3: This dataset was selected for thresholding because of the well-defined bone-soft tissue interface.





Step 4: Open the ‘Editor’ module. This module can be used for automatic and manual segmentation.

Step 5: When the Editor module is opened, you will be asked create a merge label map. Select ‘Apply’ for GenericAnatomyColours.

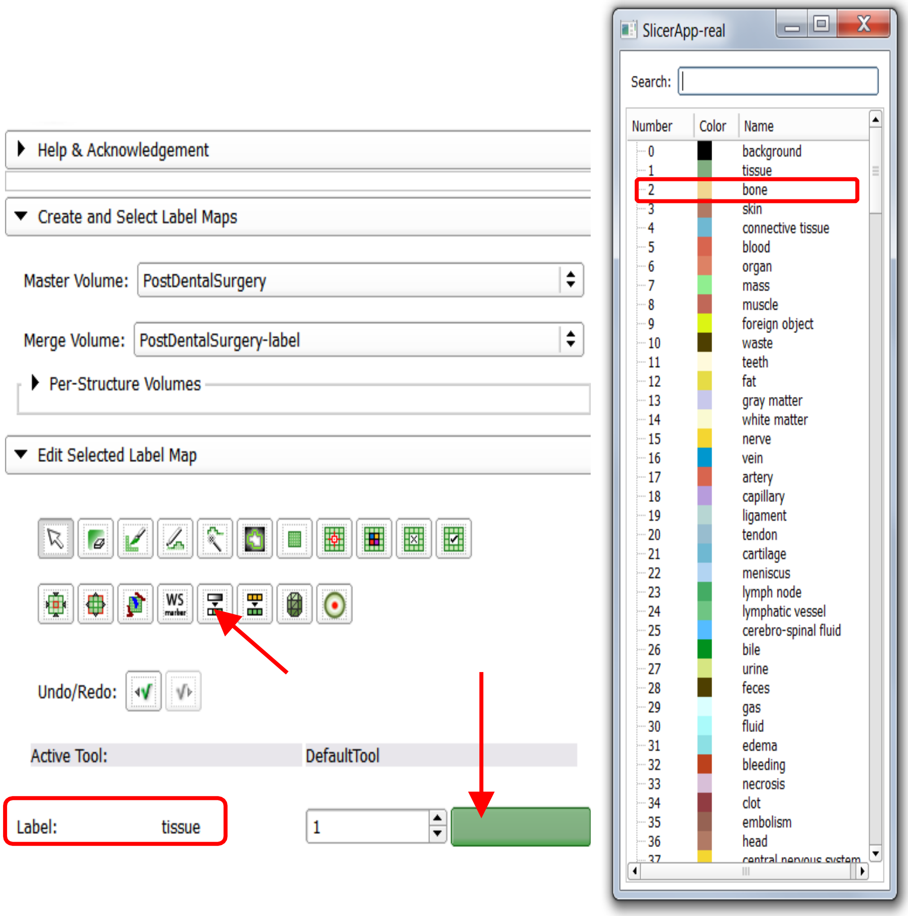


Step 6: In Editor module, set Master Volume to ‘PostDentalSurgery’.

Step 7: Next to ‘Label:’ Click on coloured box.

Step 8: This will bring up a number/colour key for different types of tissues. Select ‘bone’.

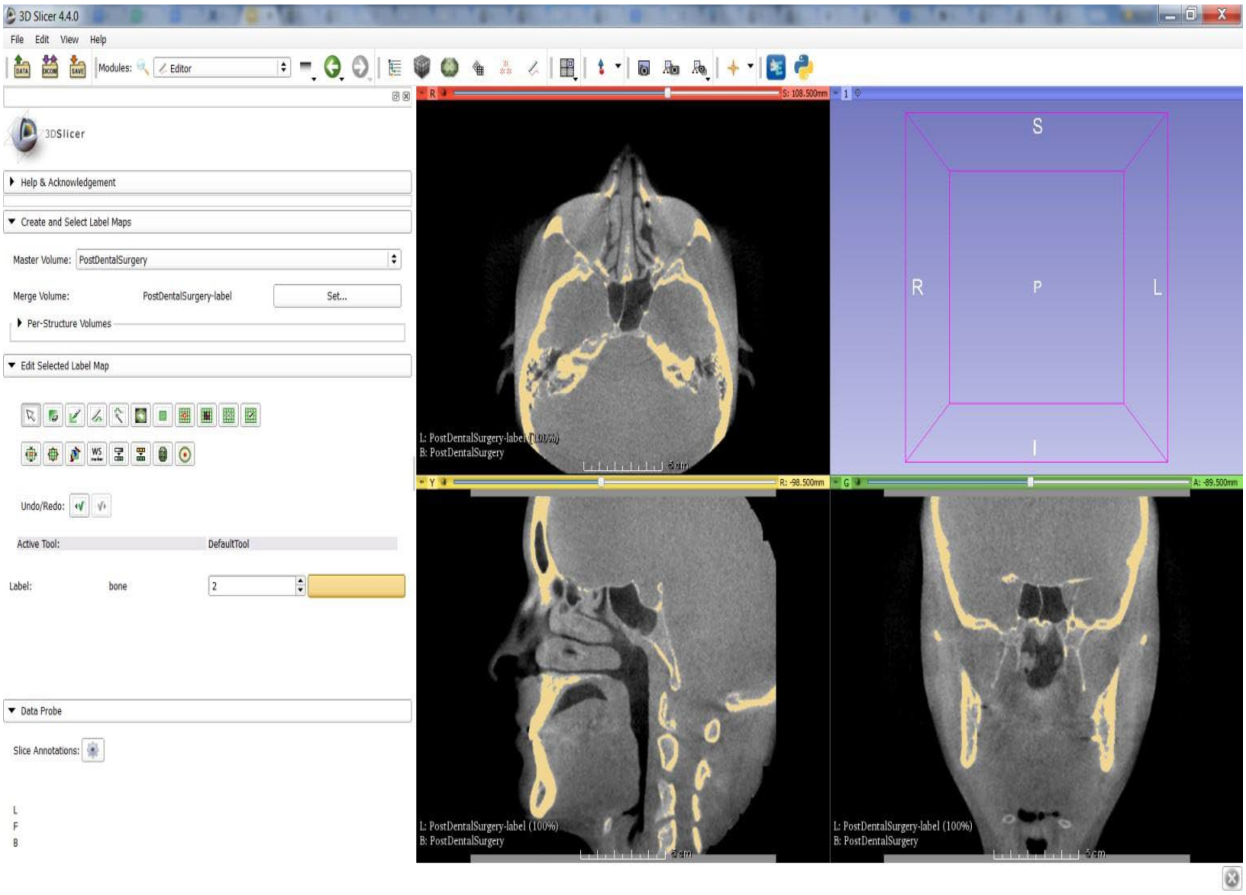
Step 9: Select the ‘Threshold Effect’ tool.



Step 10: Once 'Threshold Effect' is selected, you will see flashing regions of that coloured label appear over the volume in the 2D viewers.

Step 11: Adjust the threshold range using the sliders, to select bone as accurately as you can. Use the sliders in the 2D viewing windows to check the selection across the specimen (but don't worry, it won't be perfect.)

Step 12: Click 'Apply', and the labelmap will be set.



III.2.4. Generate 3D model from segmentation.

Step 1: Once we have created a labelmap via segmentation, we can generate a 3D surface model representing that selection, using the ‘Model Maker’ module.

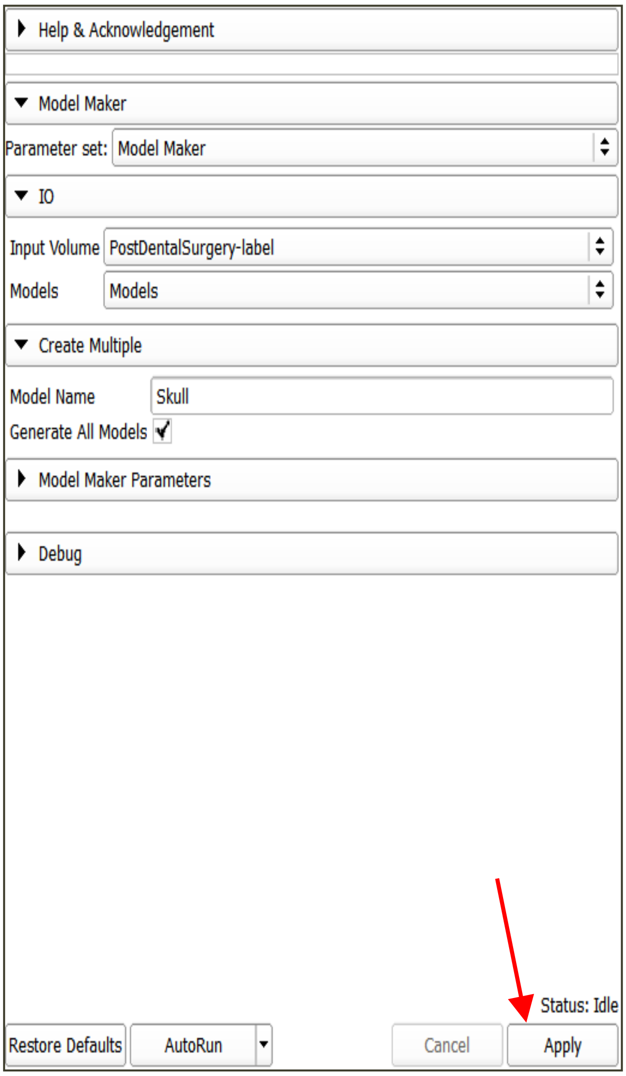
Step 2: In ‘Model Maker’ module, input volume should read ‘PostDentalSurgery-label’.

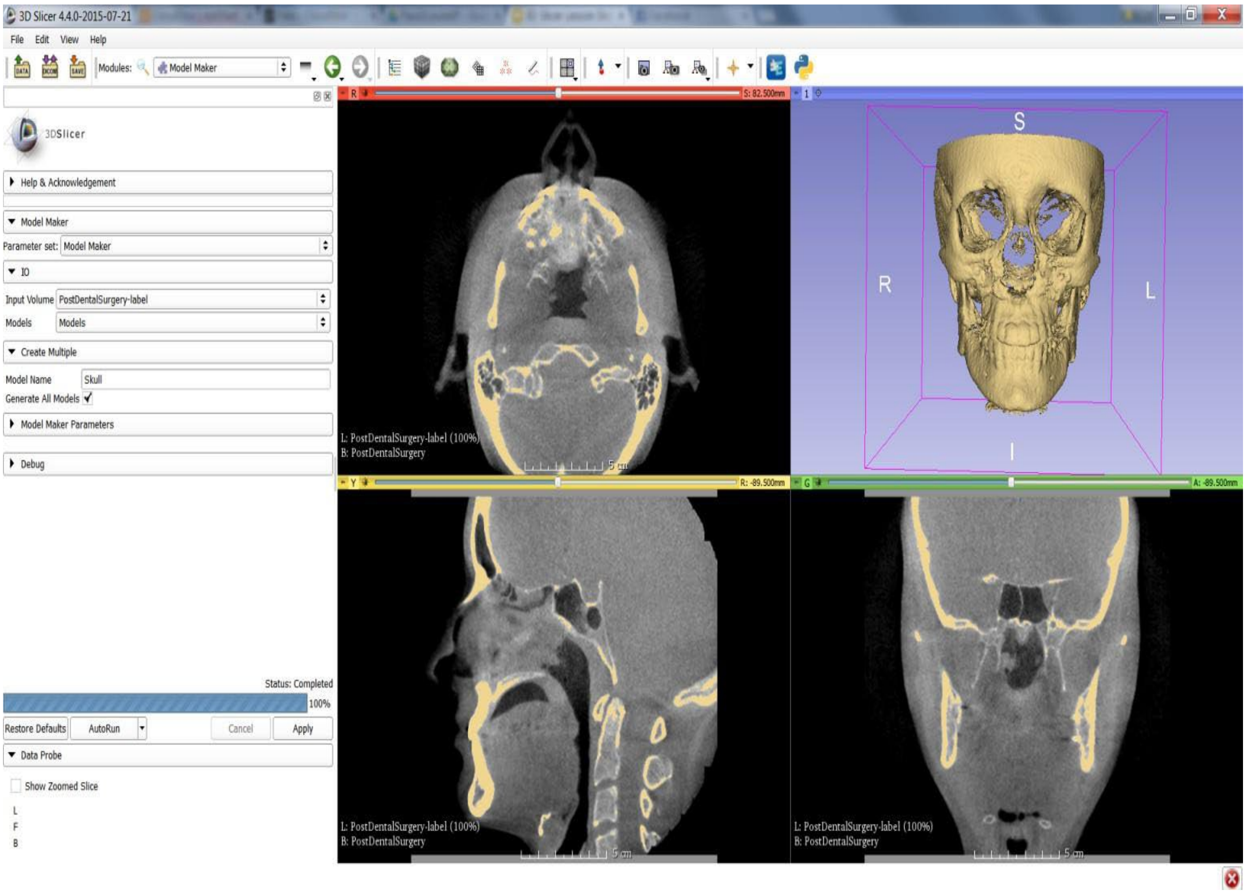
Step 3: Models: Create new ModelHierachy

Step 4: Model name: (your choice) In this tutorial I will name it ‘Skull’

Step 5: Click ‘Apply’.

Step 6: Model will generate.


Help & Acknowledgement
Model Maker
Parameter set: Model Maker
IO
Input Volume PostDentalSurgery-label
Models Models
Create Multiple
Model Name Skull
Generate All Models
Model Maker Parameters
Debug
Status: Idle
Restore Defaults
AutoRun
Cancel
Apply



III.2.5. Save 3D model

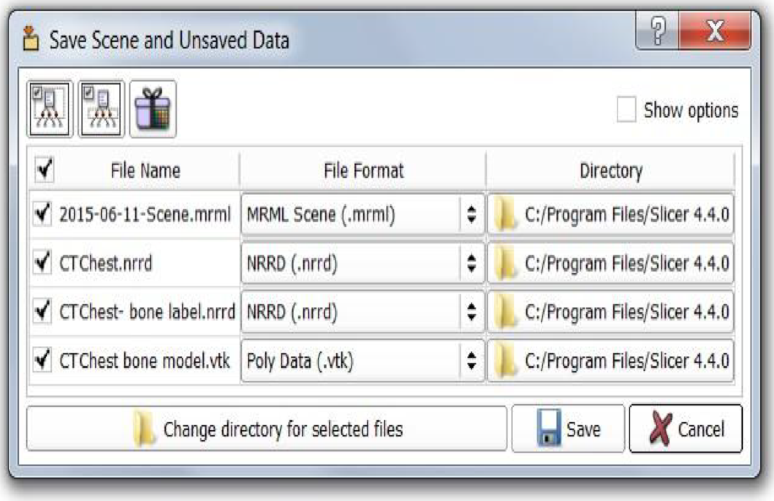
Step 1: 3D Slicer provides a rich set of options for saving data. The "Save Data" panel is accessed through the File menu using File->Save.

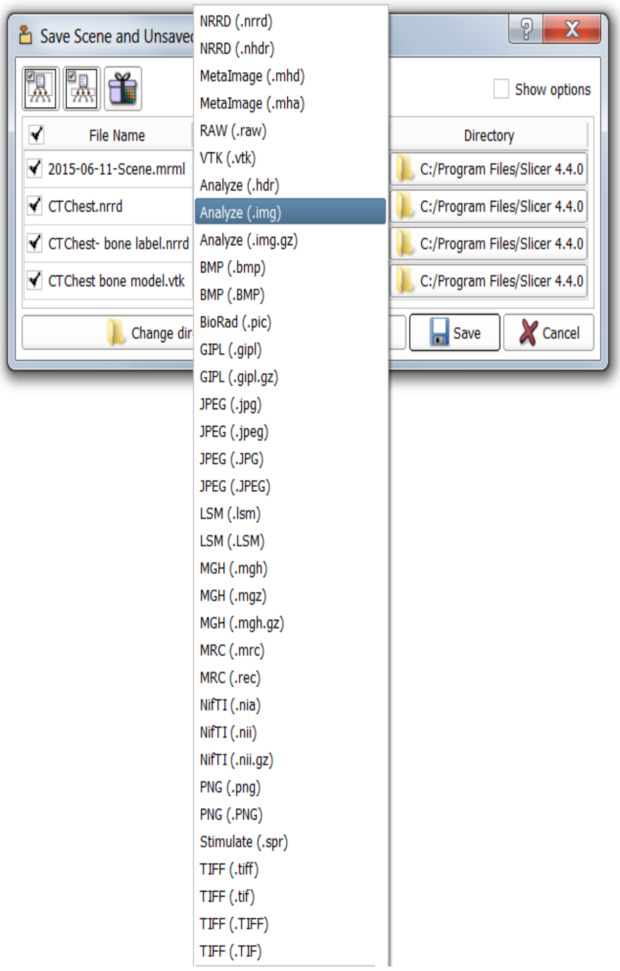
Step 2: The user is given options to save the overall state of the program at a given time (MRML scene), as well as any other components, such as label maps, 3D models etc.

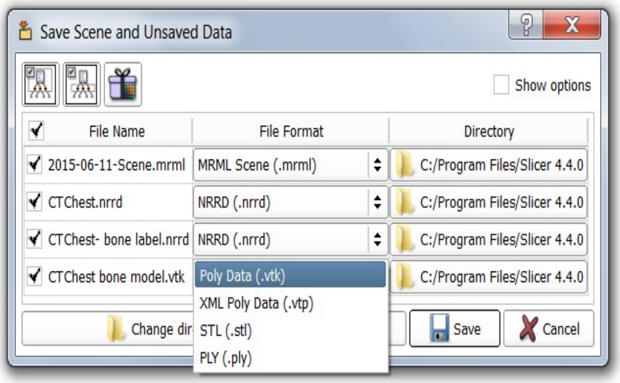
Step 3: Users can select which components to save (checkboxes), the file format for each, and the directory in which it is saved.

Step 4: Different file formats can be selected for different components.

Step 5: Some file types are more ‘lossy’ than others, i.e., they may not contain all of the original metadata. e.g., Can change model to .stl format, a widely compatible file type.


Save Scene and Unsaved Data
Show options
File Name
File Format
Directory
2015-06-11-Scene.mrml
MRML Scene (.mrml)
C:/Program Files/Slicer 4.4.0
CTChest.nrrd
NRRD (.nrrd)
C:/Program Files/Slicer 4.4.0
CTChest- bone label.nrrd
NRRD (.nrrd)
C:/Program Files/Slicer 4.4.0
CTChest bone model.vtk
Poly Data (.vtk)
C:/Program Files/Slicer 4.4.0
Change directory for selected files
Save
Cancel


Save Scene and Unsaved
Show options
File Name
Directory
2015-06-11-Scene.mrml
CTChest.nrrd
CTChest- bone label.nrrd
CTChest bone model.vtk
C:/Program Files/Slicer 4.4.0
Change dir
Save
Cancel
NRRD (.nrrd)
NRRD (.nhdr)
MetaImage (.mhd)
MetaImage (.mha)
RAW (.raw)
VTK (.vtk)
Analyze (.hdr)
Analyze (.img)
Analyze (.img.gz)
BMP (.bmp)
BMP (.BMP)
BioRad (.pic)
GIPL (.gipl)
GIPL (.gipl.gz)
JPEG (.jpg)
JPEG (.jpeg)
JPEG (.JPG)
JPEG (.JPEG)
LSM (.lsm)
LSM (.LSM)
MGH (.mgh)
MGH (.mgz)
MGH (.mgh.gz)
MRC (.mrc)
MRC (.rec)
NifTI (.nia)
NifTI (.nii)
NifTI (.nii.gz)
PNG (.png)
PNG (.PNG)
Stimulate (.spr)
TIFF (.tiff)
TIFF (.tif)
TIFF (.TIFF)
TIFF (.TIF)


Save Scene and Unsaved Data
Show options
File Name
File Format
Directory
2015-06-11-Scene.mrml
MRML Scene (.mrml)
CTChest.nrrd
NRRD (.nrrd)
CTChest- bone label.nrrd
NRRD (.nrrd)
CTChest bone model.vtk
Poly Data (.vtk)
XML Poly Data (.vtp)
STL (.stl)
PLY (.ply)
C:/Program Files/Slicer 4.4.0
Change dir
Save
Cancel

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IV. Computer-aided (CAD) software for 3D printing

IV.1. Filament printer: MakerBot CAD software

IV.1.1. Equipment

MakerBot software

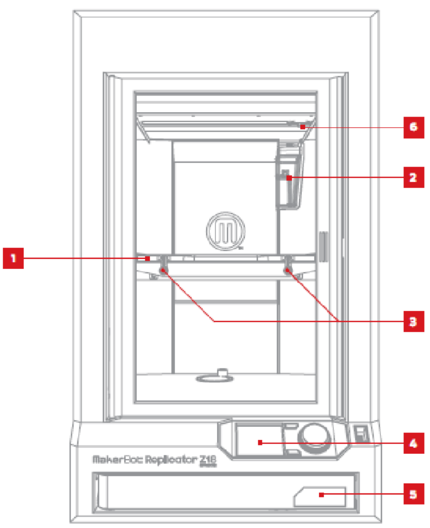
Computer/system requirements: A computer integrating the following system requirements must be used for the utilisation of MakerBot software software:

Handheld model	NEXTENGINE Ultra-HD 3D scanner and the NEXTENGINE ScanStudio software.	
	required	recommended
Graphics card	Nvidia GeForce GTX 660/Nvidia Quadro P1000	Nvidia GTX serial cards higher than GTX1080
USB port	1 OF 3.0 port	
OS	win10 64bits	
Video memory	> 4G	>8G
RAM	8GB	32 GB
CPU	i5 3th Gen	i7-8700 or higher
Screen resolution	1920*1080 DPI:100%; 125% 3840*2106 DPI: 100%;200%	

Storage: USB key.

IV.1.2. Hardware Installation

3D printer



Build plate
Filament waste bin
Build plate latches
Control panel

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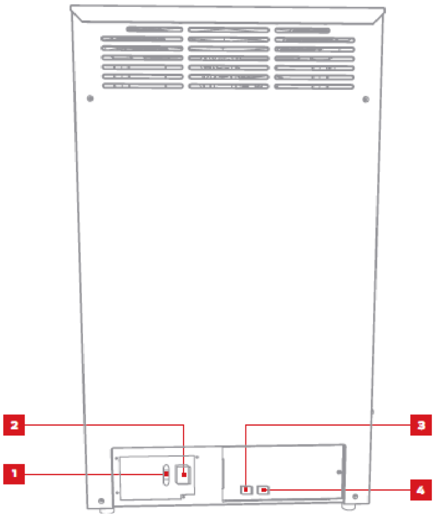
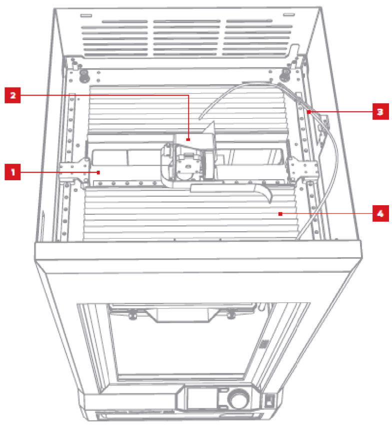


Power switch
Power input port
USB port
Ethernet port



Gantry

Extruder carriage

Filament guide tube

Bellows

IV.1.3. Software Installation

Downloading and Installing MakerBot Desktop

Step 1: Open a browser session and go to makerbot.com/desktop. Click the Download button.

Step 2: Select your operating system from the dropdown menu on the download pack and click Download. A system-specific installer will download to your computer.

Step 3: Double-click the MakerBot Desktop installer to run the installation wizard. Follow the installation instructions.

Step 4: When you open MakerBot Desktop for the first time, you will be asked to log in.

Step 5: If you have ever logged into MakerBot Thingiverse™ or the MakerBot Store, you already have an account. If not, you can create one now. This account can be used to log into any MakerBot software or website.

Step 6: You can use MakerBot Desktop without logging in, but logging in will allow you to access your MakerBot Cloud Library and additional features in the Explore, Prepare and Store sections.

Step 7: Select how you will connect your MakerBot Replicator Z18 to your computer. If you will print only via USB drive, click Skip. You will be asked to choose a MakerBot 3D Printer. Choose Replicator Z18.

Note:

You can connect to your MakerBot Replicator via USB cable, Ethernet or Wi-Fi at any time.

WI-FI

Step 1: *Connect the USB cable to your MakerBot Replicator Z18 and to your computer. MakerBot Desktop will automatically connect to your MakerBot Replicator Z18.*

Step 2: *Go to the Devices menu and select Device Preferences.*

Step 3: *Click the Network tab.*

Step 4: *Select your network from the dropdown menu and enter your password. Your MakerBot Replicator Z18 will automatically be connected to your Wi-Fi network.*

Step 5: *Go to the Devices menu and select Connect to a New Device.*

Step 6: *Select your MakerBot Replicator Z18 from the list of available devices.*

ETHERNET

Step 1*: Connect an Ethernet cable to your MakerBot Replicator Z18 and to your computer.*

Step 2: *Go to the Devices menu and select Connect to a New Device.*

Step 3: *Select your MakerBot Replicator Z18 from the list of available devices.*

USB

Step 1: *Connect the USB cable to your MakerBot Replicator Z18 and to your computer. MakerBot Desktop will automatically connect to your MakerBot Replicator Z18.*

IV.2. 3D printing from MakerBot desktop.

IV.2.1. Finding a 3D model

Step 1: If you design a 3D model yourself, export it from your 3D modeling application in STL or OBJ format. If you don't have a 3D model, download one from Thingiverse, either through the website at Thingiverse.com or through the Explore view in MakerBot Desktop.

Step 2: To open a model from Thingiverse, go into the Explore view in MakerBot Desktop, locate the "Thing" you want to print, and click Prepare to open it in the Prepare view.

Step 3: To open a model saved in your Library, go to the Library view and select a folder to

browse. Mouse over a list item to show a menu icon. Click the icon and select

Step 4: Prepare to open the model in the Prepare view.

Step 5: To open a file saved to your local computer, go to the Prepare view, click Add File, and navigate to the location of the saved file. Select the file and click Open to import it into MakerBot Desktop.

IV.2.2. Downloading and printing a model from Thingiverse

Step 1: Click Explore at the top of the MakerBot Desktop screen.

Step 2: See featured Things, browse categories and collections, or use the search bar to look for something specific. Once you have found something you want to print, click the title or thumbnail to go to the Thing page.

Step 3: On the Thing page, you will see additional information about the Thing, including any instructions the designer has included and pictures of copies of the Thing made by other members of the Thingiverse community. To get the file or files you will need to print the Thing, click the Prepare button at the right of the page.

Step 4: You will be shown a list of available files. Next to each listed file is another Prepare button. Click Prepare next to any STL or OBJ file. MakerBot Desktop will download your file and open it in the Prepare view. To add an additional part from the same Thing, return to the Explore view and click Prepare next to the additional part

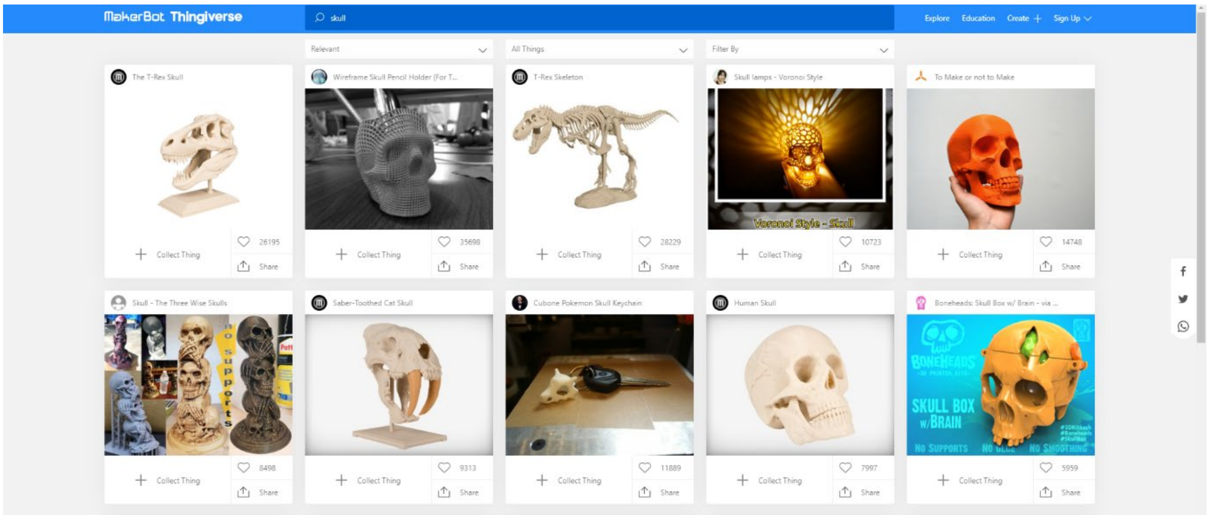


Figure 1. Thingivers website.

IV.2.3. MakerBot software interface

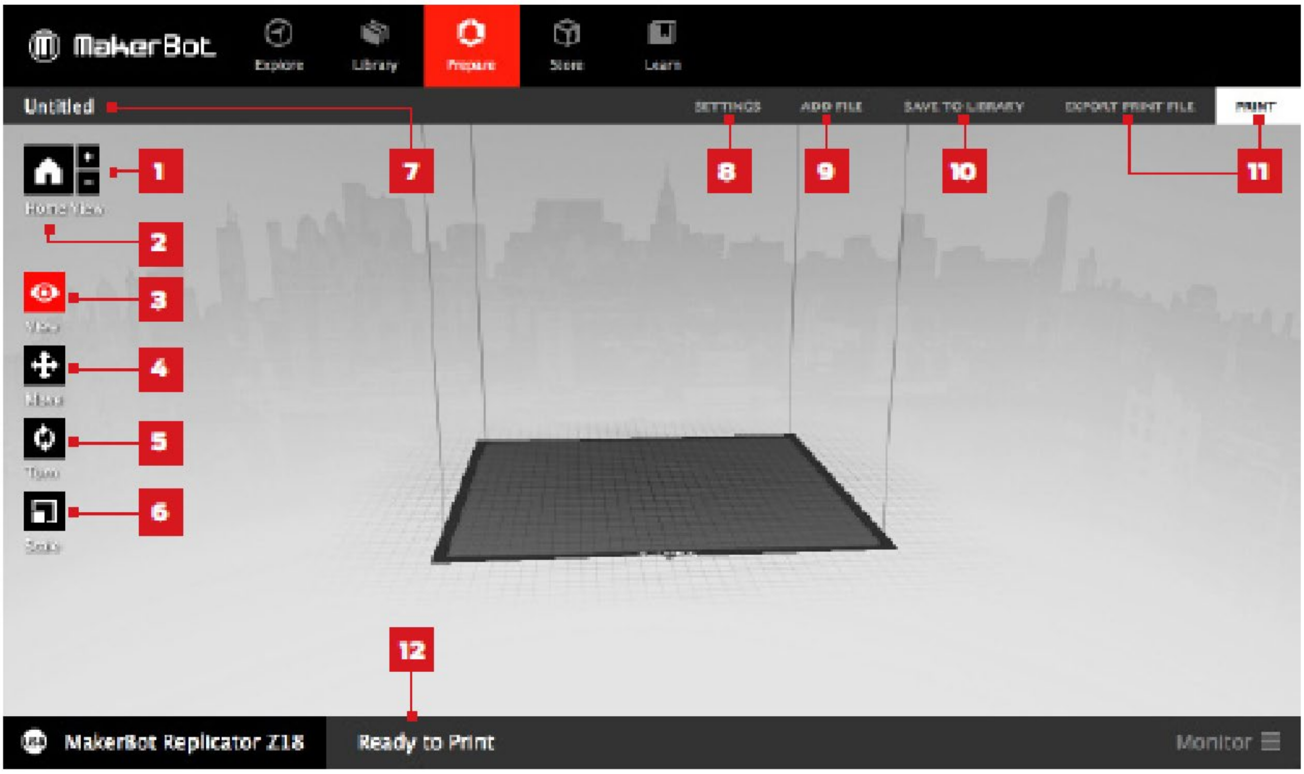


Figure 2. MakerBot software desktop interface.

Step 1: +/–

- Click the Plus and Minus buttons to zoom in and out.
- You can also zoom using a track pad or the scroll wheel on your mouse.

Step 2: Home

- Click the Home button to reset MakerBot Desktop to the default view of the build plate.

Step 3: View

- Click the View button or press the V key to go into view mode.
- In View mode, click and drag with your mouse to rotate the build plate.
- In View mode, hold the Shift key and click and drag with your mouse to pan.
- Click the View button again to open the Change View submenu and access preset views.

Step 4: Move

- Click the Move button or press the M key to go into Move mode.

- In Move mode, click and drag with your mouse to move your model around on the build plate.
- In Move mode, hold down the Shift key and click and drag with your mouse to move your model up and down along the z-axis.
- Click the Move button again to open the Change Position submenu and center your object or move it by a specific distance along the x-, y-, or z-axis.

Step 5: Turn
- Click the Turn button or press the T key to go into Turn mode.
- In Turn mode, click and drag with your mouse to rotate your model around the z-axis.
- Click the Turn button again to open the Change Rotation submenu and lay your object flat or rotate it by a specific number of degrees around the x-, y-, or z-axis.

Step 6: Scale
- Click the Scale button or press the S key to go into Scale mode.
- In Scale mode, click and drag with your mouse to shrink or enlarge your model.
- Click the Scale button again to open the Change Dimensions submenu and scale your object by a specific amount on the x-, y-, or z-axis.

Step 7: File Name
- The file name bar displays the name of the file or layout currently open. Thing files can include multiple layouts, or arrangements of models on the plate.

Step 8: Settings
- Click Settings to open the settings dialog.
- Use the dialog to change print settings for the current object or layout.

Step 9: Add File
- Click Add File to open an Open File dialog.
- Navigate to the location of any STL, OBJ, or Thing file and select the file to add a model to the build plate.
- You can add as many models to the plate as will fit. Use the keyboard shortcut Ctrl/Command + L to automatically arrange multiple models on the plate.
- Duplicate models already on the plate using the Copy and Paste options in the Edit menu or the keyboard shortcuts Ctrl/Command+C and Ctrl/Command+V.

Step 10: Save to Library

- Click Save to Library to open a Save dialog.
- If you are logged into your MakerBot account, you can choose to save an STL or Thing file to your Library or to your local computer. See makerbot.com/support for more information on your MakerBot Cloud Library.
- If you are not logged into your MakerBot account or if you are working offline, you will be able to save your file only to your local computer.
- If you are working in an existing Thing file, you can rearrange the models on the plate and save this new layout to the Thing file without overwriting earlier layouts.

Step 11: Print/Export Print File

- Click Print to send a print file to your MakerBot Replicator Z18.
- If MakerBot Desktop is not connected to your MakerBot Replicator Z18, you can export a file by clicking Export Print File.

Step 12: Status

- The status bar displays the connection status of any connected MakerBot 3D Printer.
- It also displays print progress.
- Click to open a print monitor panel.
- The print monitor panel displays more detailed information about any connected MakerBot 3D Printer and a camera view of the build area of any fifth generation MakerBot 3D Printer connected via a network.

If you want to change any settings before printing, click Settings. This is where you can specify options that will affect the quality of your printed object, like print resolution and object strength.

To print with standard or previously specified settings, skip this step and go straight to printing.

Step 1: Resolution

- Choose Low, Standard, or High resolution to specify the surface quality of your 3D print.
- Objects sliced with the Standard resolution profile will be printed using the default settings.

- Standard resolution prints will print quickly and have good surface quality.
- Objects sliced using the Low-resolution profile will be printed with thicker layers and will print faster.
- Objects sliced with the High-resolution profile will have finer layers and will print more slowly.

Step 2: Raft

- Select this checkbox to have your object built on a raft. The raft acts as a base for your object and any support structures and ensures that everything adheres well to the build plate. The raft will be easily removable once you remove your finished object from the build plate.

Step 3: Supports

- Select this checkbox to have your object printed with support structures. MakerBot Desktop will automatically generate supports for any overhanging sections of your object. Supports will be easily removable once you remove your finished object from the build plate. If your model does not contain overhangs, do not select this checkbox.

Step 4: Advanced

Click Advanced for additional options, including print speed and object strength. For information on what the advanced settings are and how to use them, go to makerbot.com/support.

If you would like to turn the heated build chamber on, use the advanced settings to create a custom profile. Go to mbot.co/15pwxXo to see the specific custom profile settings needed to turn the heated build chamber on.

Step 5: Cancel

Click Cancel to return to the Prepare view without saving changes. Any print settings you have selected will be discarded.

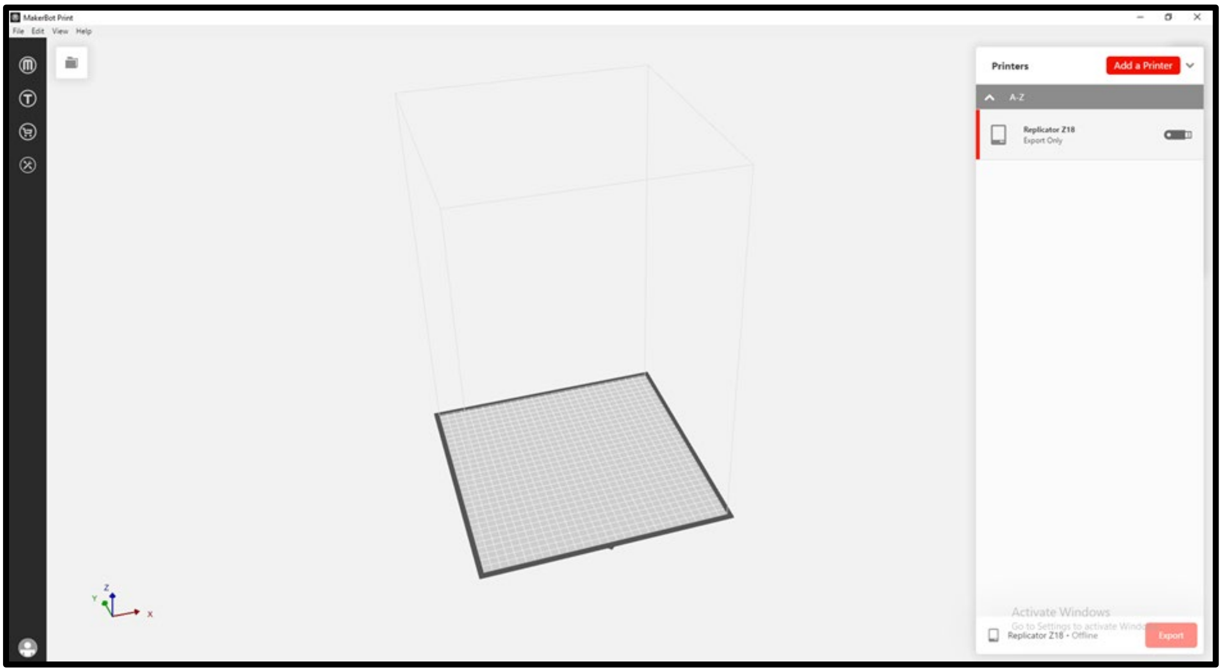
Step 6: Save Settings

When you are finished, click Save Settings. The saved settings will be used to slice your model next time you print or export a print file.

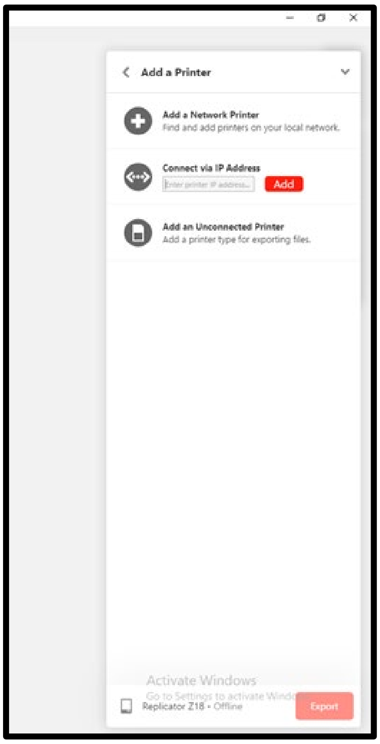
IV.2.4. Basic procedure to prepare a 3D mesh for 3D printing.

Step 1: Select the 3D printer that you are going to use for 3D printing:

Step 2: Open printer tab and select add a printer:

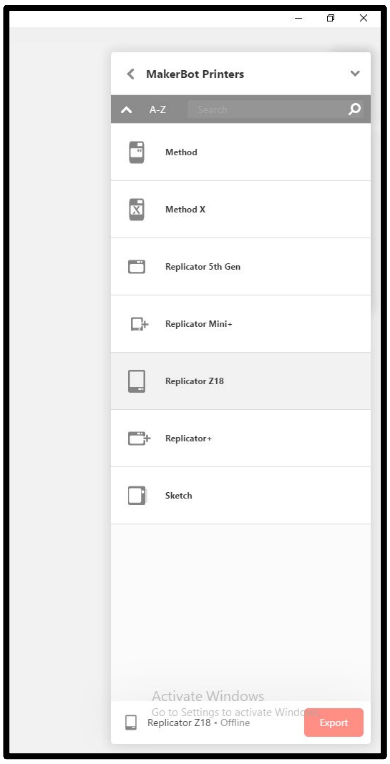


If you are not connected to a 3D printer, select add an unconnected printer:



<u>Note:</u>

If you are connected to a 3D printer, select the printer:

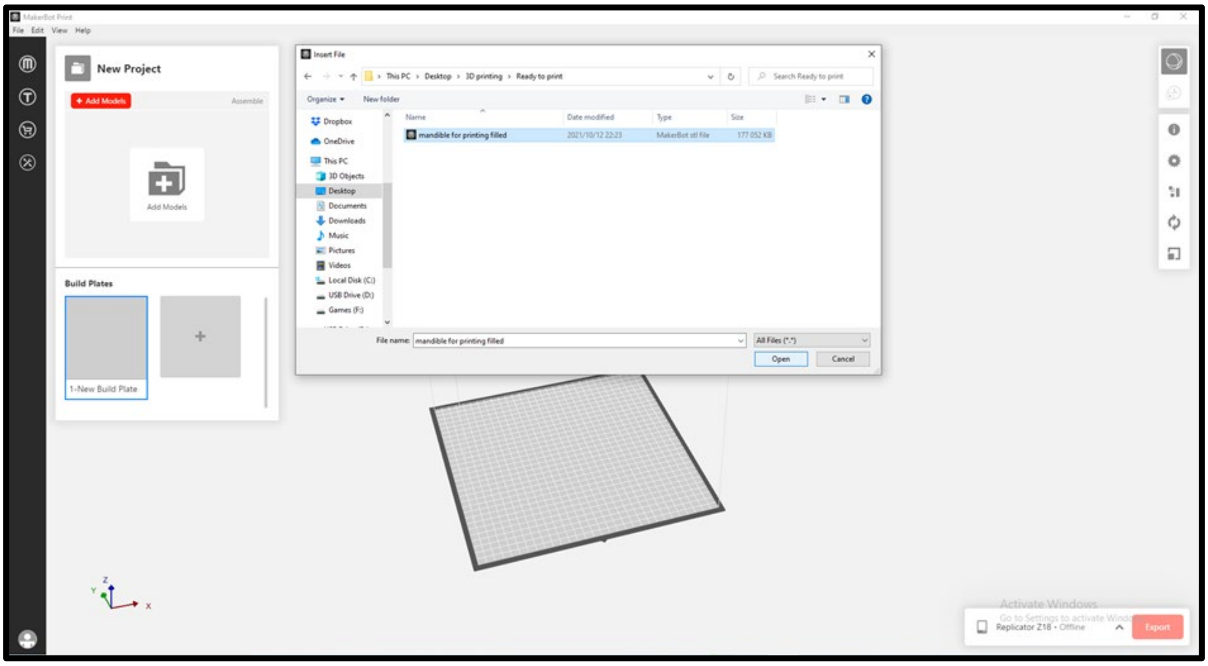


Step 3: Add your 3D model (s):

Step 4: Open New Project

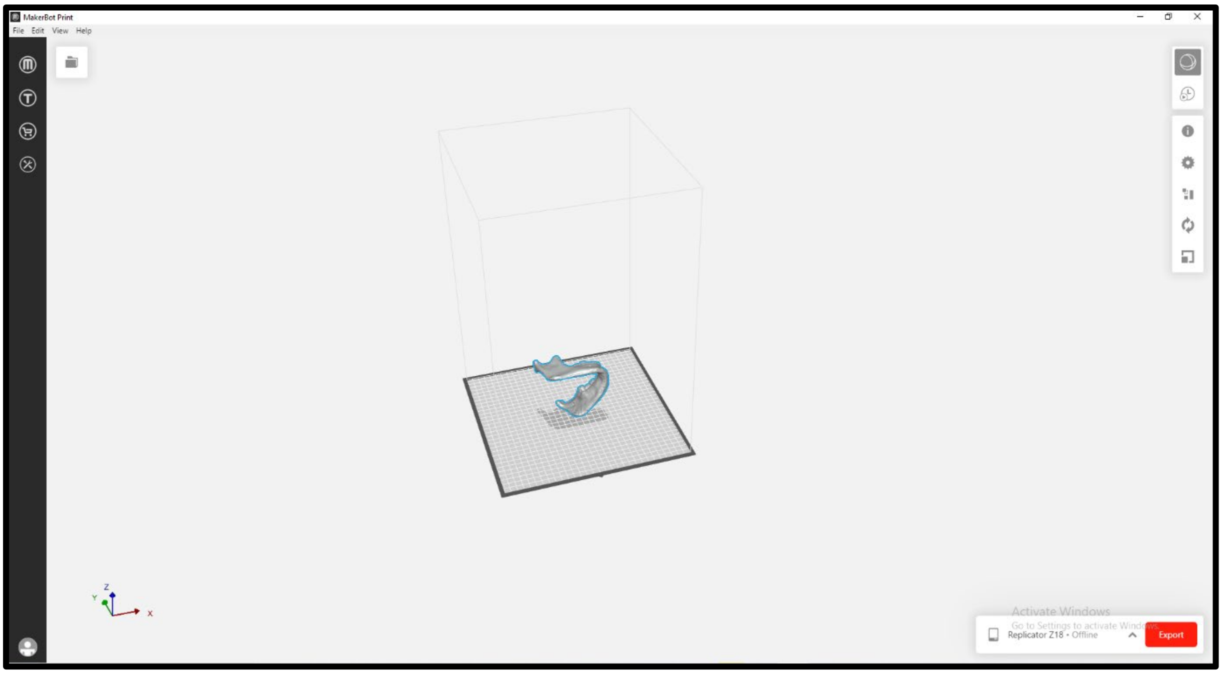
Step 5: Select Add Models

Step 6: Navigate to your 3D model and open



Note: *Multiple models can be added to a single build plate.*

Step 7: Use interface and controls to orient your 3D model(s):



Note:

Middle mouse wheel

Scroll to zoom

Click and hold to move the screen

Right mouse button

Click and hold to rotate the screen

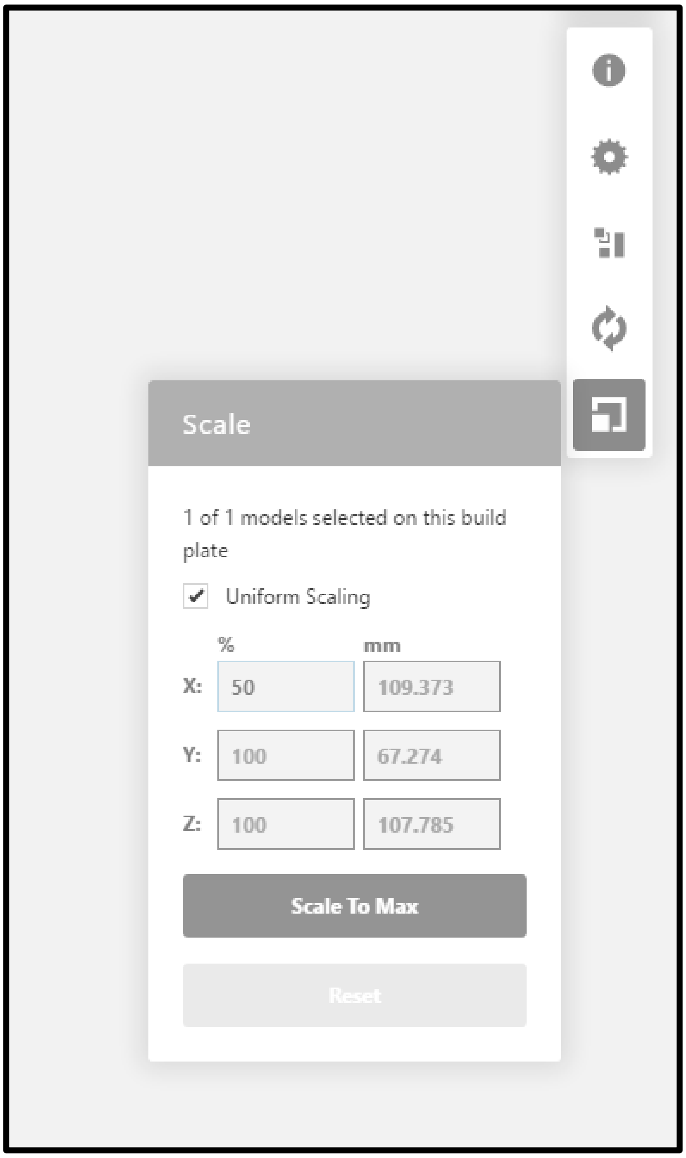
Left mouse button

Click on models to select them

Click and hold to move models

Step 8: Step Click on Scale to scale the 3D model to a percentage of its current size:

- Use Uniform Scaling to scale everything equally
- Type in your desired size and press enter

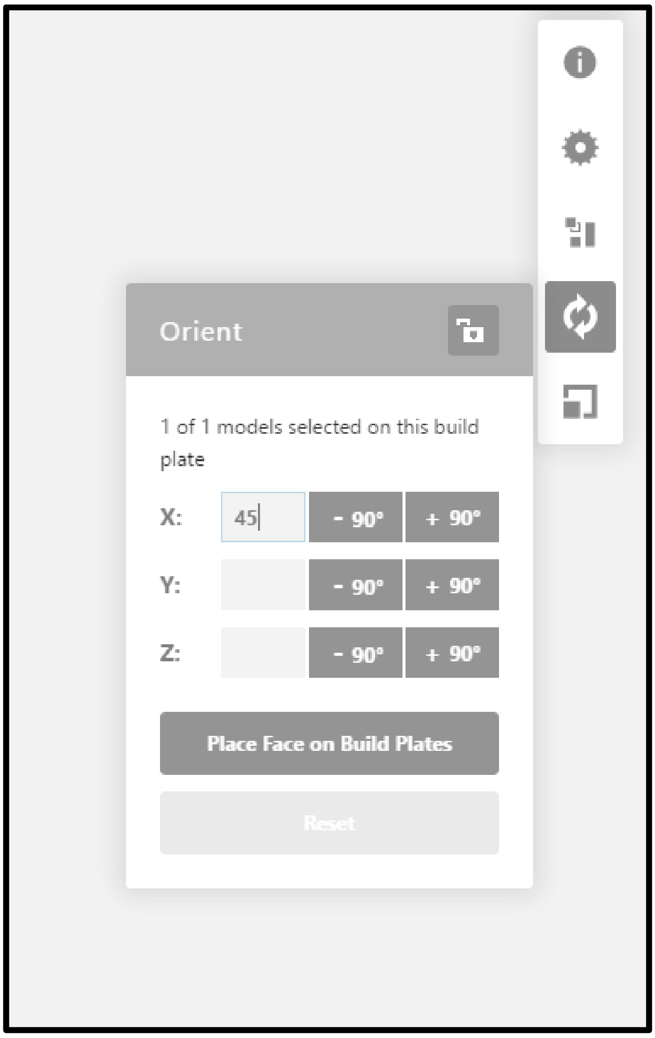


Note:

Larger sizes take longer to print and use more material.

Step 9: Click on Rotate to rotate the 3D model in the three different axes:

- Add a certain amount of rotation to the current orientation in the specified axis and press enter:
- It can be done in small increments additively
- Or in quick increments of 90 degrees

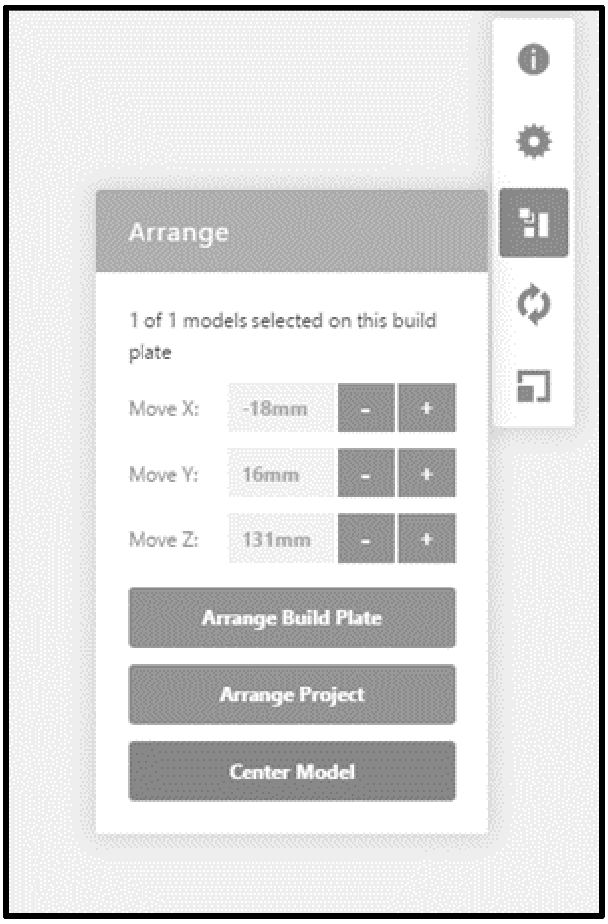


Note:

It is important to select the most stable side as the base. Normally the largest surface unless it is possible to have the least number of overhanging arches or bridges.

Step 10: Click on Arrange to arrange the placement of the 3D model(s) on the build plate:

- Move the model in the three different axes.



Note:

It can be done in small increments additively

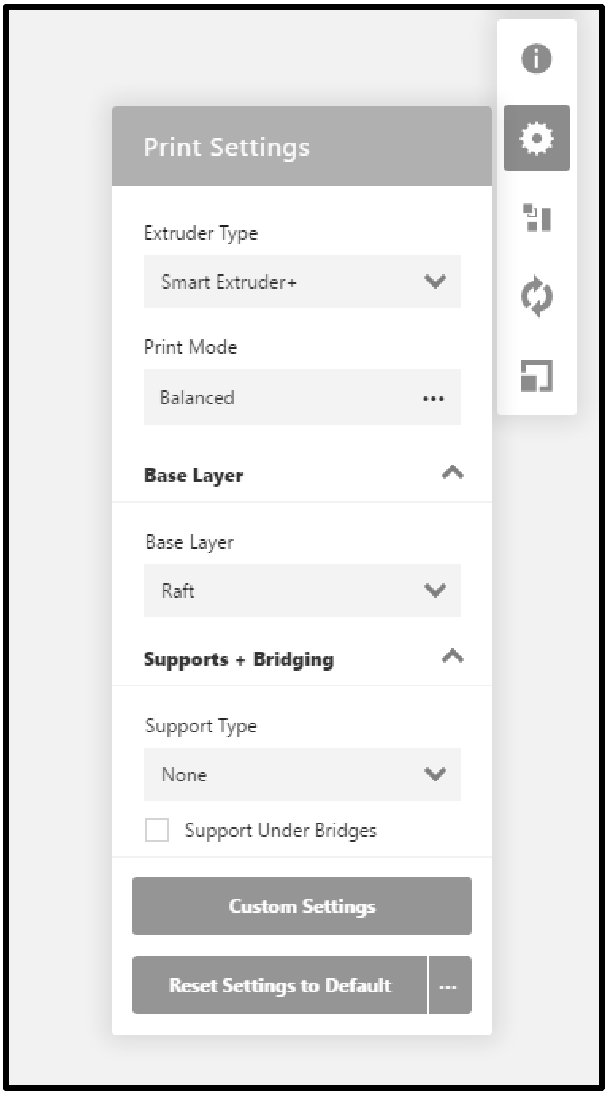
If printing multiple models on the same build plate use this to automatically arrange them

If printing multiple projects use this to automatically arrange them

Place the model in the center automatically.

Step 11: Click on print settings to adjust print settings:

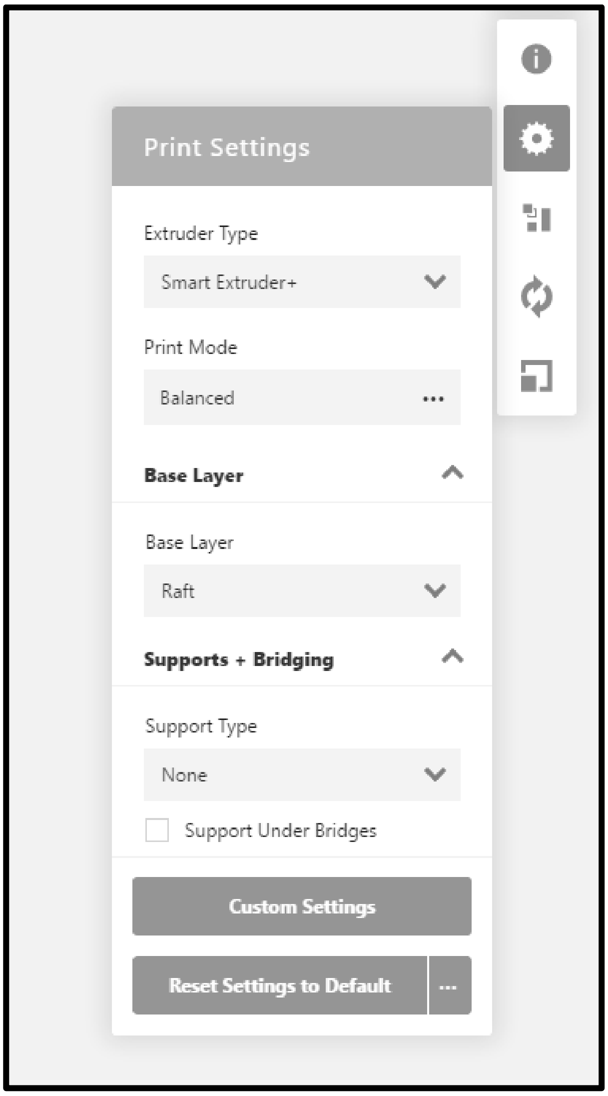
- The type of extruder used by the printer can be seen on the printer itself
- To adjust the quality of the print
- Balanced – Standard
- Draft – Quicker printing (lower quality)
- MinFill – Minimum material for internal structure (weaker)



The layer on which the model will be printed

Used to keep the structure in place

Bad adhesion of the base layer to the build plate can cause curling and a miss print.



<u>Note:</u>

Curling refers to the base layer loosening from the build plate causing the model to move as printing continues and eventually a miss print

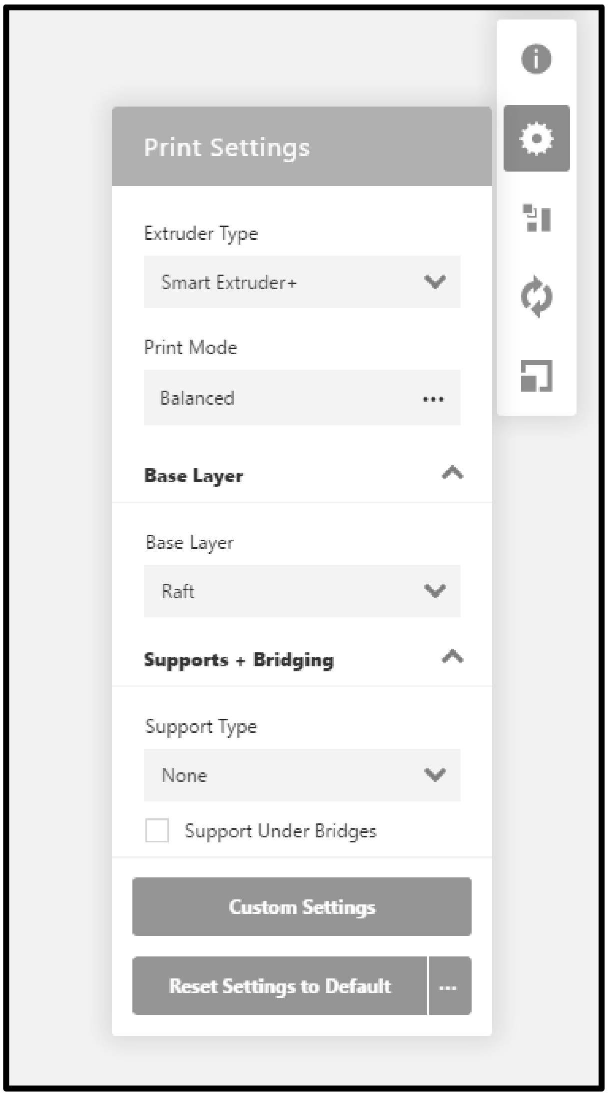
Types of base layers:

Raft – Strong base

Padded Base – Quicker and uses less material

Padded base + brims – Used for wide models that curls

Supports are used to help print overhanging structures or bridges to increase accuracy.



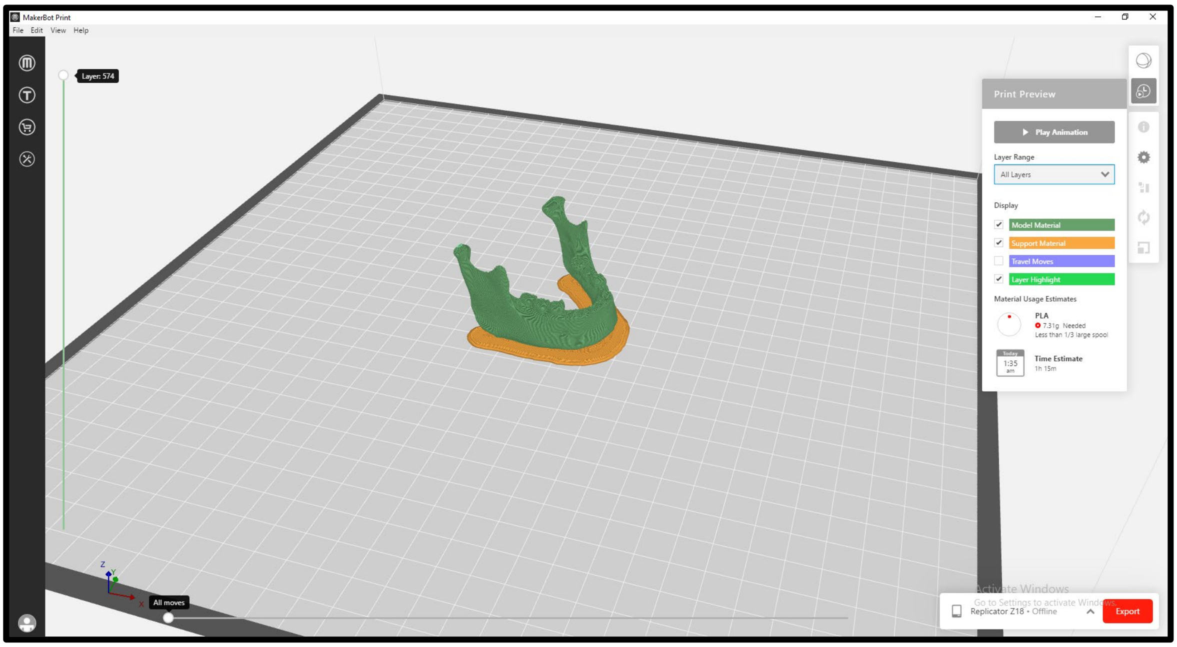
<u>Note:</u>

Can be removed after printing is finished

For more precise adjustments use Custom Settings

Step 12: Click on print preview to generate a preview of the printing process:

- After all settings have been set, use the print preview to generate a preview of the printing process.



Note:

The print preview provides you with information on:

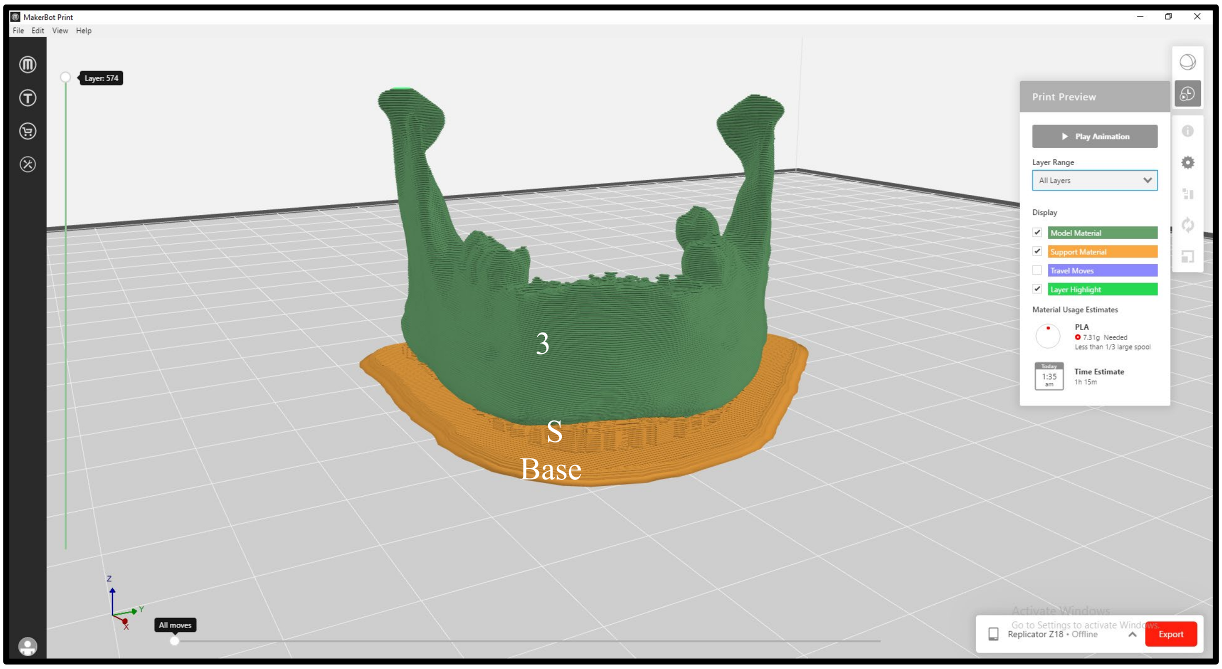
The layer you are currently viewing of the print

The layer/s that must be visible

The material that must be visible

The amount of material needed

Time taken to complete the print



Step 13: Click Print to slice the model using the current settings and send a MakerBot print file to your MakerBot Replicator Z18.

Note:

- *If MakerBot Desktop is connected to your MakerBot Replicator Z18, the print file will be sent directly to your 3D printer. Click the control panel dial to confirm and start your print.*
- *If you are not currently connected to a MakerBot 3D printer, the Print button will be disabled. Click Export to save a file to transfer to your MakerBot 3D printer via a USB drive or to print at a later time.*
- *Click Print Preview in the Print or Export dialog after your object is sliced to open a preview of the sliced model.*

IV.3. Resin printer: PreForm CAD software

IV.3.1. Equipment

IV.3.1.1. Form 3 3D printer

PreForm software

Computer/ System requirements: a computer integrating the following system requirements must be used for the utilisation of **PreForm** software:

Printer		
	Technology	Low Force Stereolithography (LFS)™
	XY Resolution	25 microns
	Laser Spot Size	85 microns
	Laser Power	Two 250 mW lasers
	Build Volume (W x D x H)	33.5 × 20 × 30 cm 13.2 × 7.9 × 11.8 in
	Layer Thickness[b]	25– 300 microns[c] .001 – .012 in
Printing		
	Technology	Low Force Stereolithography (LFS)™
	Resin Fill System	Automated
	Build Volume (W x D x H)	33.5 × 20 × 30 cm 13.2 × 7.9 × 11.8 in
	Layer Thickness (Axis Resolution)[b]	25[c] – 300 microns .001 – .012 in
	XY Resolution[a]	25 microns 0.001 in
	Laser Spot Size	85 microns 0.0033 in
	Resin Cartridges	2
	Biocompatible Materials	No (available on Form 3BL)
	Supports	Auto Generated Light-Touch Removal
Hardware		
	Minimum Access Dimensions (W × D × H)	90 × 96 × 104 cm 35.4 × 37.8 × 41 in

	Printer Dimensions (W × D × H)	77 × 52 × 74 cm 30.3 × 20.5 × 29.1 in
	Weight	54.4 kg 120 lb
	Internal Temperature	Auto-heats to 35 °C Auto-heats to 95 °F

	Temperature Control	Air-heated print chamber
	Operating Environment	18 – 28 °C 64 – 82 °F
	Power Requirements	100–240 VAC 8.5A MAX 50/60HZ 650W
	Laser Specifications	2 Light Processing Units EN 60825-1:2007 certified Class 1 Laser Product 405 nm wavelength 250 mW power 85 micron (0.0033 in) laser spot
	Connectivity	Wi-Fi (2.4, 5 GHz) Ethernet (1000 Mbit) USB 2.0
	Printer Control	5.5" interactive touchscreen 1280 × 720 resolution
	Alerts	Touchscreen alerts SMS/email via Dashboard Two LED status indicators Speaker for audio alerts
Software		
	System Requirements	Windows 7 (64-bit) and up Mac OS X 10.12 and up OpenGL 2.1 4 GB RAM (8 GB recommended)
	Hardware Requirements	Form 3+
	File Types	STL and OBJ file input FORM file output

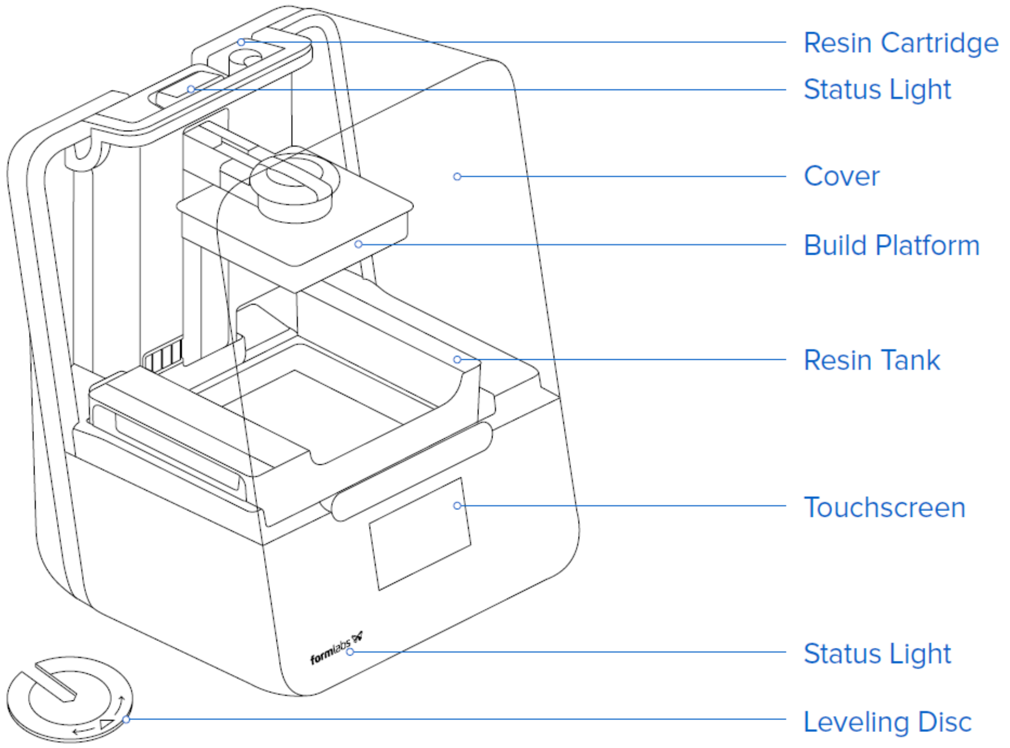
	PreForm Print Setup Features	One-Click Print Adaptive layer thickness for faster printing with fine details Remote Print Auto-orient for optimal print position Auto-mesh repair Auto-generation of supports Rotate, scale, duplicate, and mirror Layer slicer for path inspection Available in multiple languages

	Dashboard Printer Management Features	Manage prints and printers via the cloud Track resin and tank usage over time SMS and email alerts Create enterprise group accounts with admins to more easily share printers and control access

STORAGE: USB key.

IV.3.1.2. Hardware Installation

- *3D printer*



<u>Note:</u>

*The Form 3 display includes a touchscreen and status lights. The touchscreen displays print information, settings, and error messages. It serves as the user interface for the Form 3. The status lights indicate the printer's state. Refer to messages on the touchscreen to understand the meaning of the status lights. For detailed guidance and visual assistance, search on **support.formlabs.com.***

IV.3.1.3. Software Installation

1. Visit the PreForm product webpage to download the latest version: formlabs.com/tools/preform
2. Learn to use PreForm from the tutorials available in the software menu.
3. For detailed guidance and visual assistance, search on **support.formlabs.com.**

Note:

Connect to the Form 3 to upload and manage prints over Wi-Fi, USB, and Ethernet. The Form 3 can connect directly to a computer with a USB cable. For remote uploading and monitoring the Form 3 supports both wired (Ethernet) and wireless (Wi-Fi) connections. Connect PreForm print preparation software to the same localarea network (LAN) as the printer in order to send a print job. For a Windows operating system, after installing PreForm, check to ensure that Bonjour is properly installed. Bonjour is a piece of third-party software that is required to connect over Wi-Fi or Ethernet. See support.apple.com for assistance with Bonjour. The USB connection can still be used while the Form 3 is connected to a LAN. When the Form 3 is connected to a LAN, its current status and print progress can be monitored with Dashboard: ***formlabs.com/dashboard.***

Connect with USB

Use the included USB cable for connecting a computer directly to the printer.

Step 1: *Plug one end of the USB cable into the back of the Form 3.*

Step 2: *Connect the other end to a computer's USB port.*

Connect with Ethernet

The rear of the unit is equipped with a RJ-45 Ethernet (10BASE-T/100BASE-TX/1000BASE- T)

LAN Port . Connect to a LAN with an Ethernet cable (not included): minimum Cat5, or Cat5e or Cat6 for 1000BASE-T.

Step 1: *Plug one end of the Ethernet cable into the back of the Form 3.*

Step 2: *Connect the other end to your LAN.*

Connect with Wi-Fi

The Form 3's built-in Wi-Fi (IEEE 802.11 b/g/n) supports WPA/WPA2 security.

Use the Form 3's

touchscreen to configure a wireless network connection.

When connected to an active Ethernet connection or available Wi-Fi network, the Form 3 can be configured with a static IP address.

To connect with Wi-Fi using a manual IP configuration:

Step 1: *With an established Ethernet or available Wi-Fi connection, open the printer's Settings menu on the touchscreen.*

a. For Wi-Fi networks, tap Wi-Fi, then the desired wireless network.

b. For Ethernet connections, open Ethernet from the Settings menu.

Step 2: *Toggle the Manual IP settings to "ON".*

Step 3:*Input the appropriate IP Address, Subnet Mask, Default Gateway, and Name Server.*

IV.3.2. 3D printing from preform cad software

IV.3.2.1. Finding a 3D model

If you design a 3D model yourself, export it from your 3D modeling application in STL or OBJ format. If you don't have a 3D model, download one from Thingiverse using the website at Thingiverse.com.

1. Click **Explore** at the top of the MakerBot Desktop screen.
2. See featured Things, browse categories and collections, or use the search bar to look for something specific. Once you have found something you want to print, click the title or thumbnail to go to the Thing page.
3. On the Thing page, you will see additional information about the Thing, including any instructions the designer has included and pictures of copies of the Thing made by other members of the Thingiverse community. To get the file or files you will need to print the Thing, click the **Prepare** button at the right of the page.
4. You will be shown a list of available files. Next to each listed file is another Prepare button. Click Prepare next to any STL or OBJ file. MakerBot Desktop will download your file and open it in the Prepare view. To add an additional part from the same Thing, return to the Explore view and click **Prepare** next to the additional part

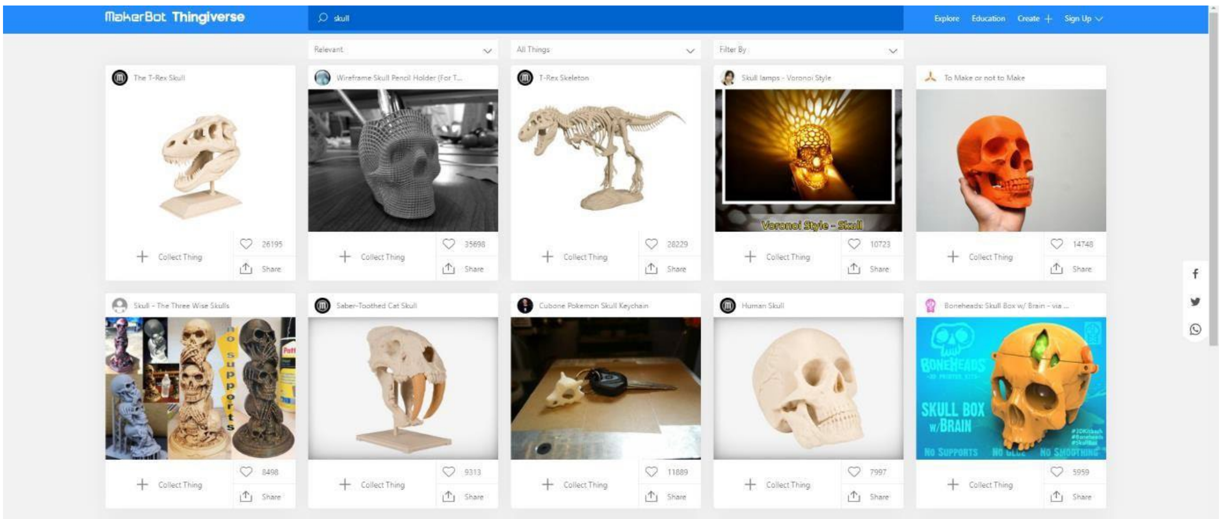
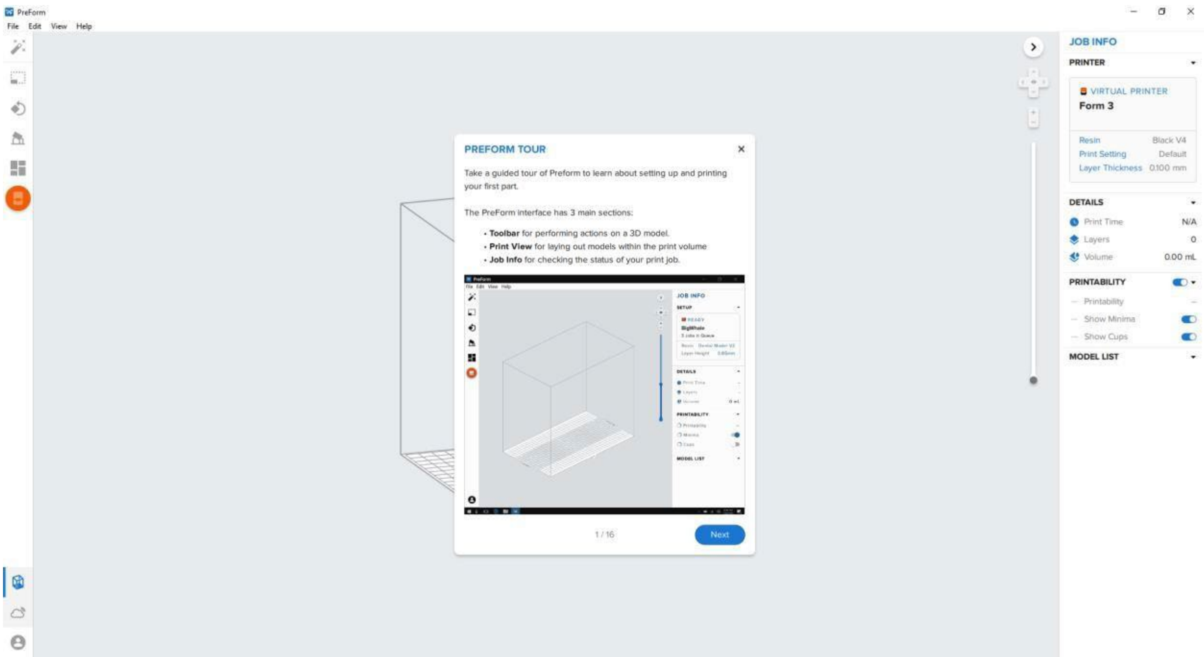


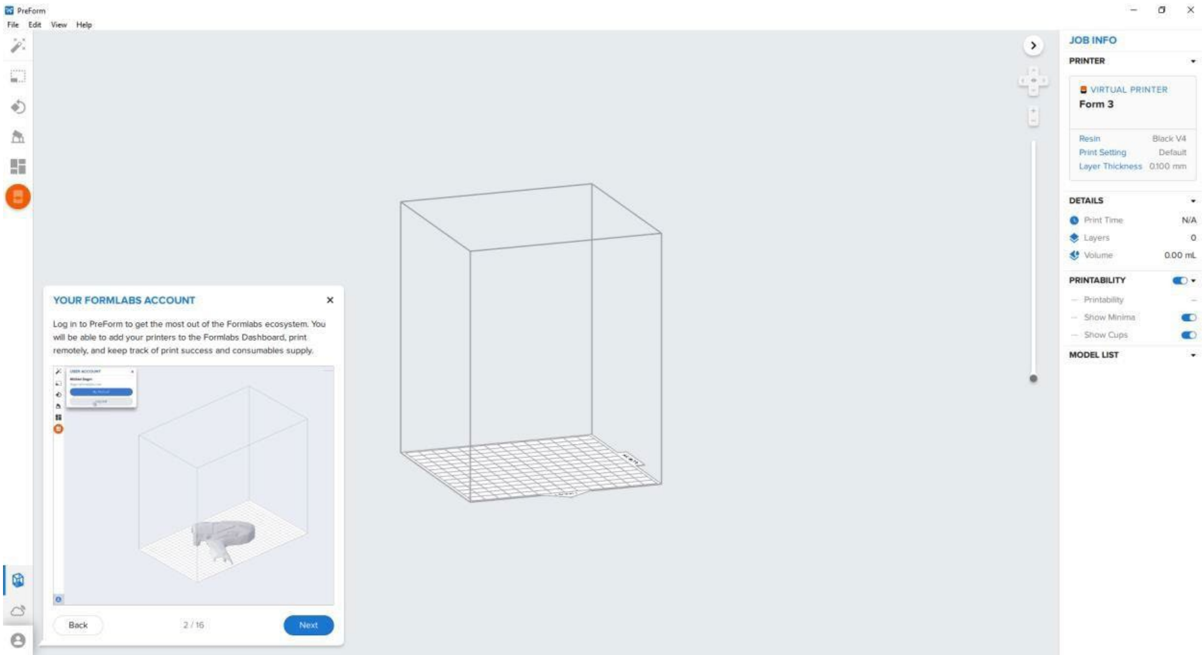
Figure 1. Thingivers website.

IV.3.2.2. PreForm software Interface

1. The PreForm interface has 3 main sections:
    - Toolbar for performing actions on a 3D model.
    - Print View for laying out models within the print volume
    - Job Info for checking the status of your print job.



2. Your Formlabs account
    - Log in to PreForm to get the most out of the Formlabs ecosystem. You will be able to add your printers to the Formlabs Dashboard, print remotely, and keep track of print success and consumables supply.


PreForm
File Edit View Help
JOB INFO
PRINTER
VIRTUAL PRINTER
Form 3
Resin Black V4
Print Setting Default
Layer Thickness 0.100 mm
DETAILS
Print Time N/A
Layers 0
Volume 0.00 mL
PRINTABILITY
Printability
Show Minima
Show Cups
MODEL LIST
YOUR FORMLABS ACCOUNT
Log in to PreForm to get the most out of the Formlabs ecosystem. You will be able to add your printers to the Formlabs Dashboard, print remotely, and keep track of print success and consumables supply.
Back
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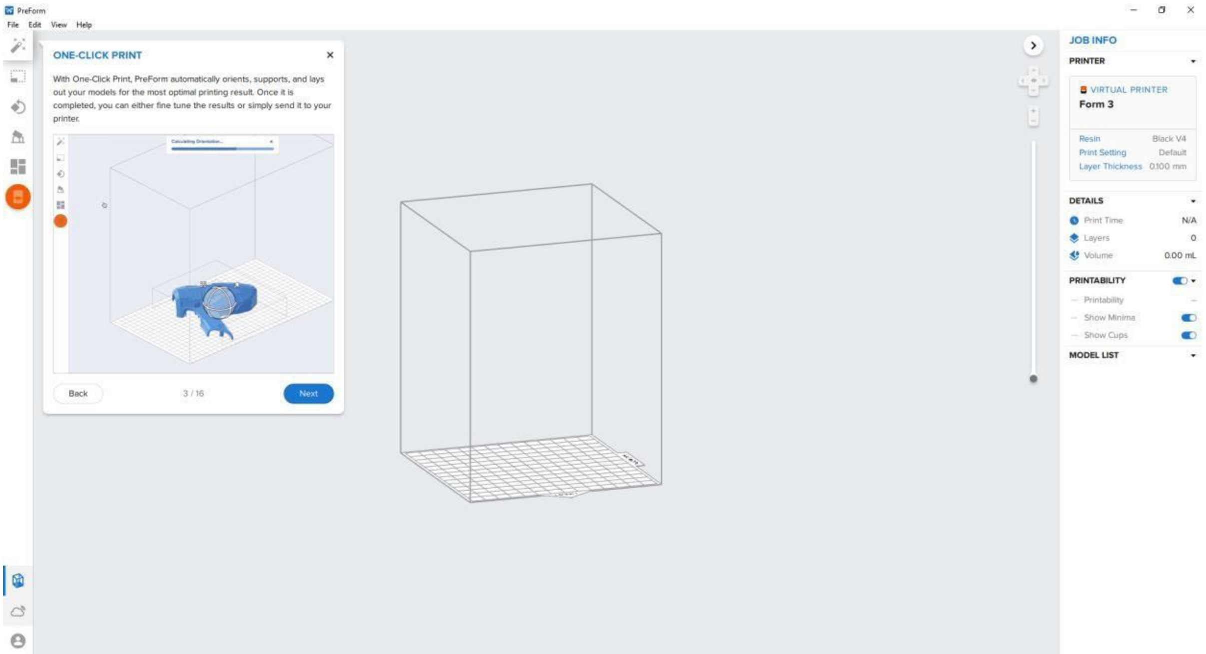
Next

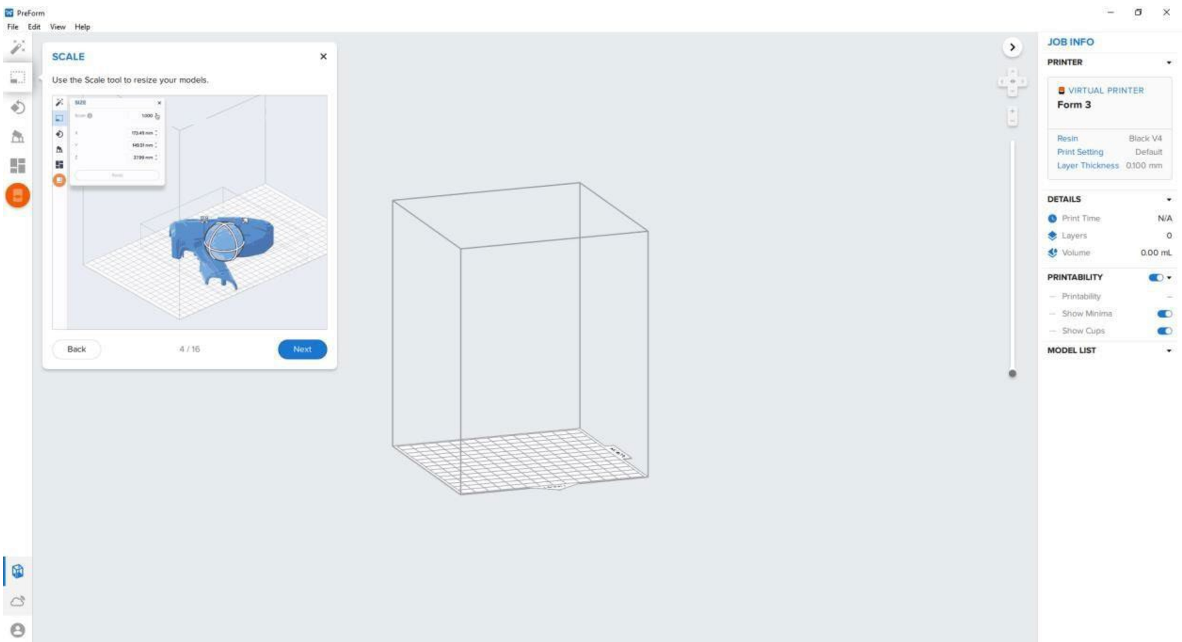
3. One-click print

- With One-Click print, PreForm automatically orients, supports, and lays out your models for the most optimal printing result. Once it is completed, you can either fin tune the results or simply send it to your printer.



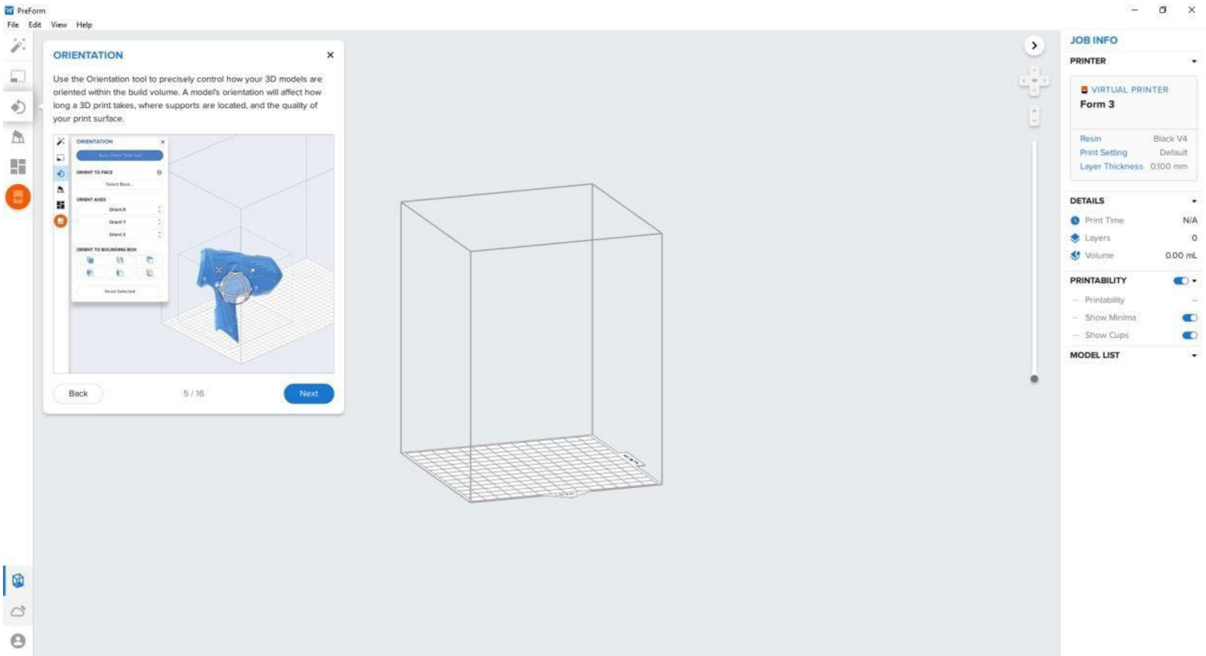
4. Scale

- Use the Scale tool to resize your models.



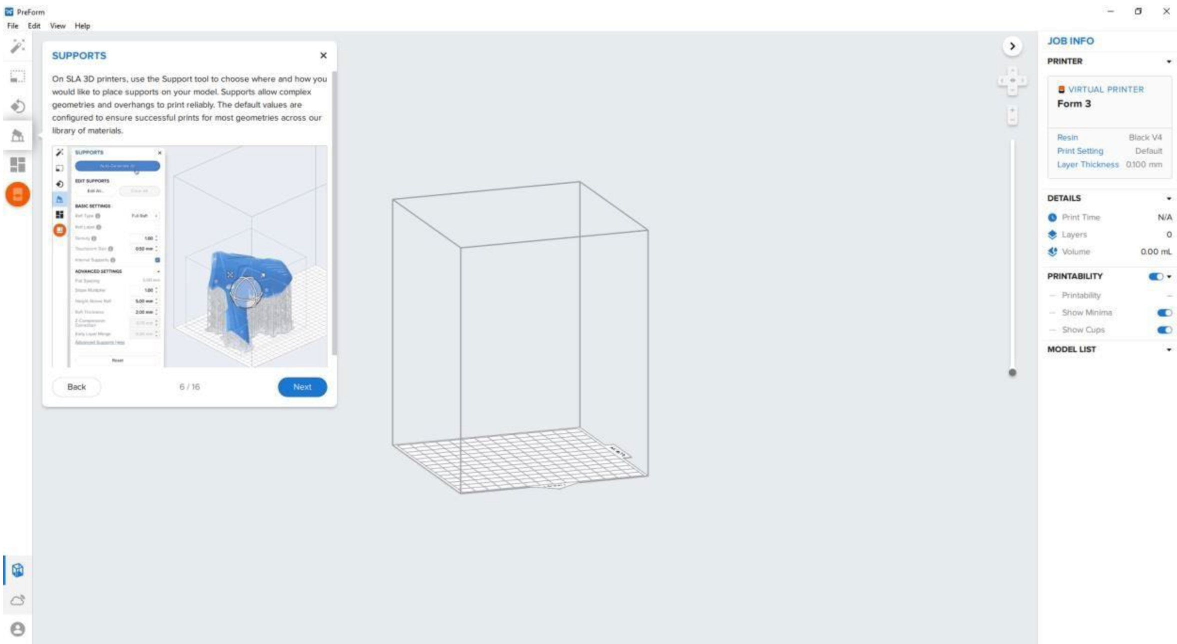
5. Orientation

- Use the Orientation tool to precisely control how your 3D models are oriented within the build volume. A model's orientation will affect how long a 3D print takes, where supports are located, and the quality of your print surface.



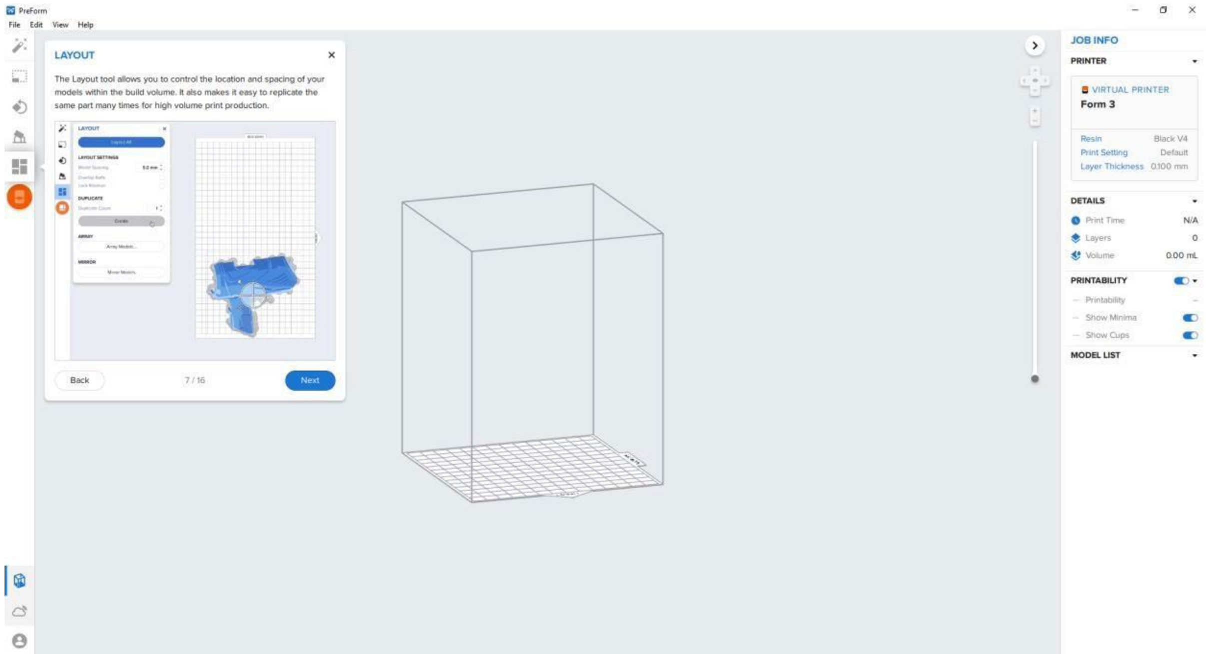
6. Supports

- On SLA 3D printers, use the Support tool to choose where and how you would like to place supports on your model. Supports allow complex geometries and overhangs to print reliably. The default values are configuring to ensure successful prints for most geometries across our library of materials.



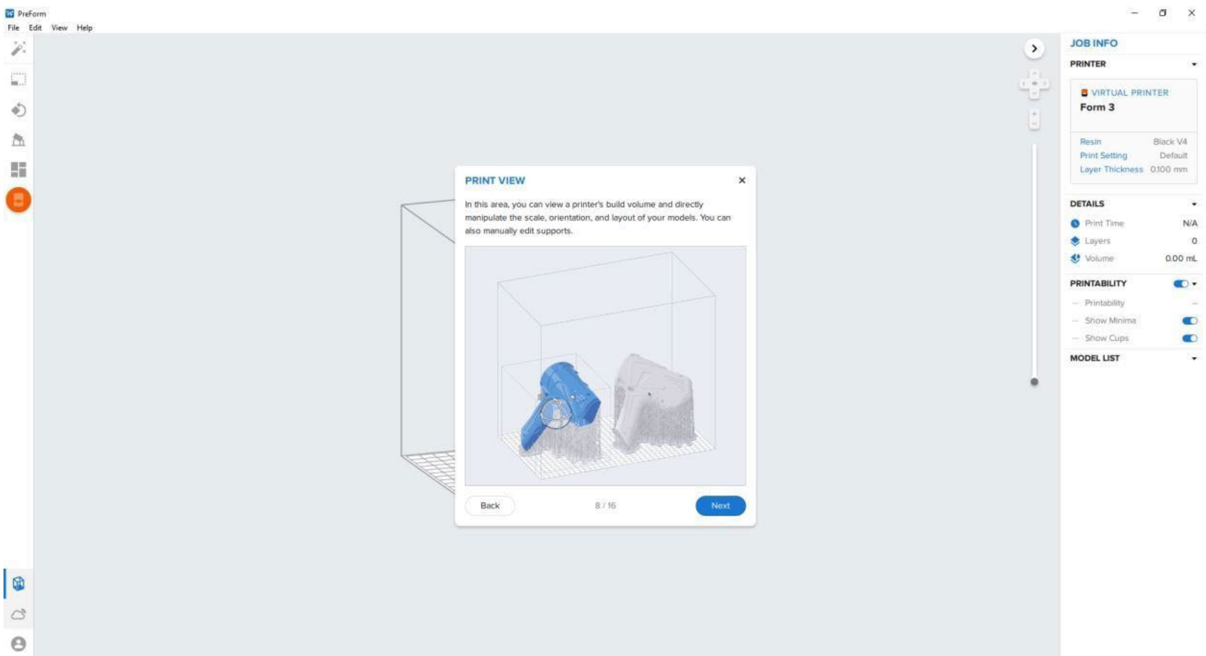
7. Layout

- The Layout tool allows you to control the location and spacing of your models within the build volume. It also makes it easy to replicate the same part many times for high volume print production.



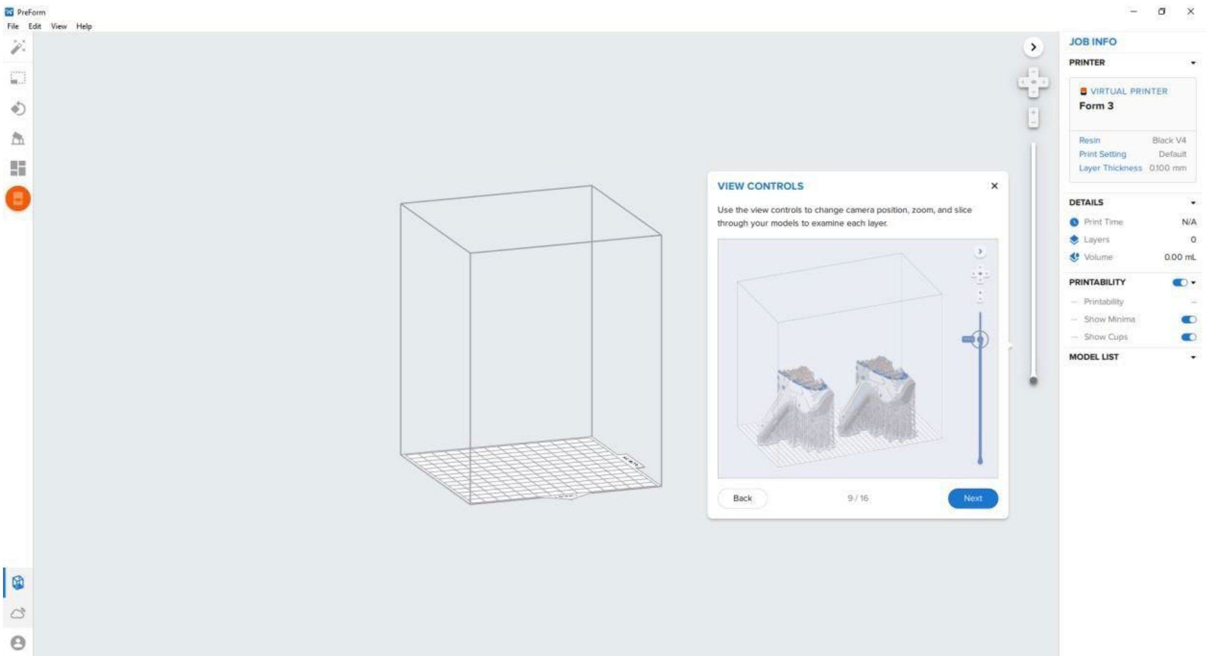
8. Print view

- In this area, you can view a printer’s build volume and directly manipulate the scale, orientation, and layout of your models. You can also manually edit supports.



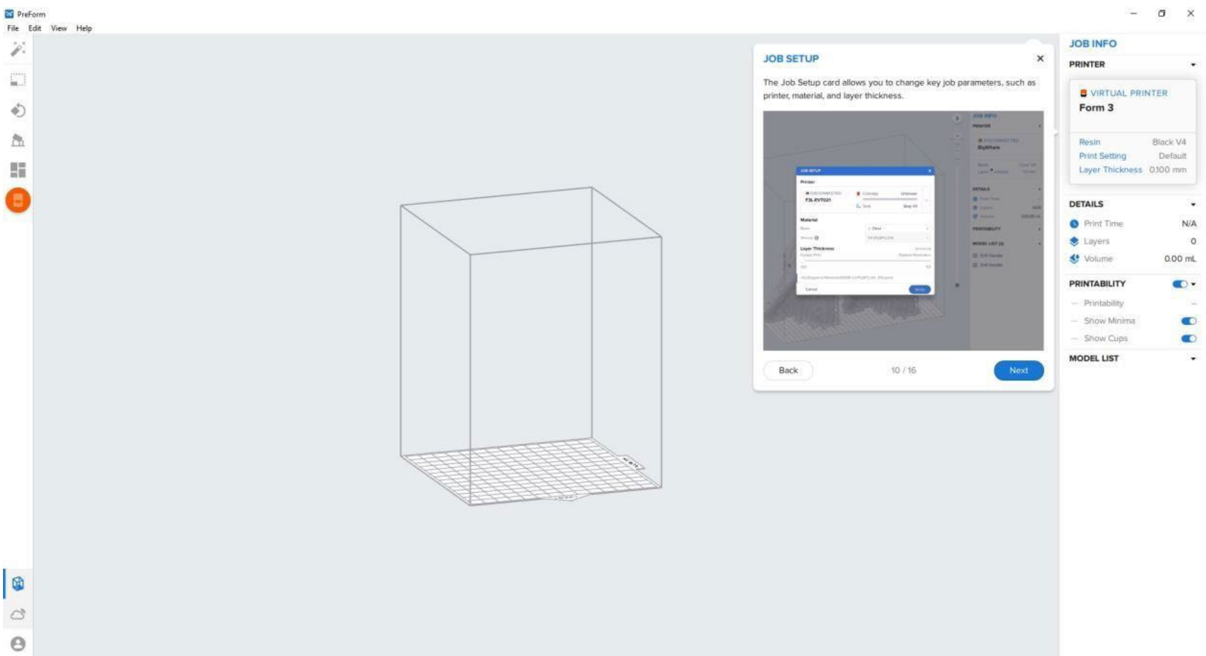
9. View controls

- Use the view controls to change camera position, zoom, and slice through your models to examine each layer.



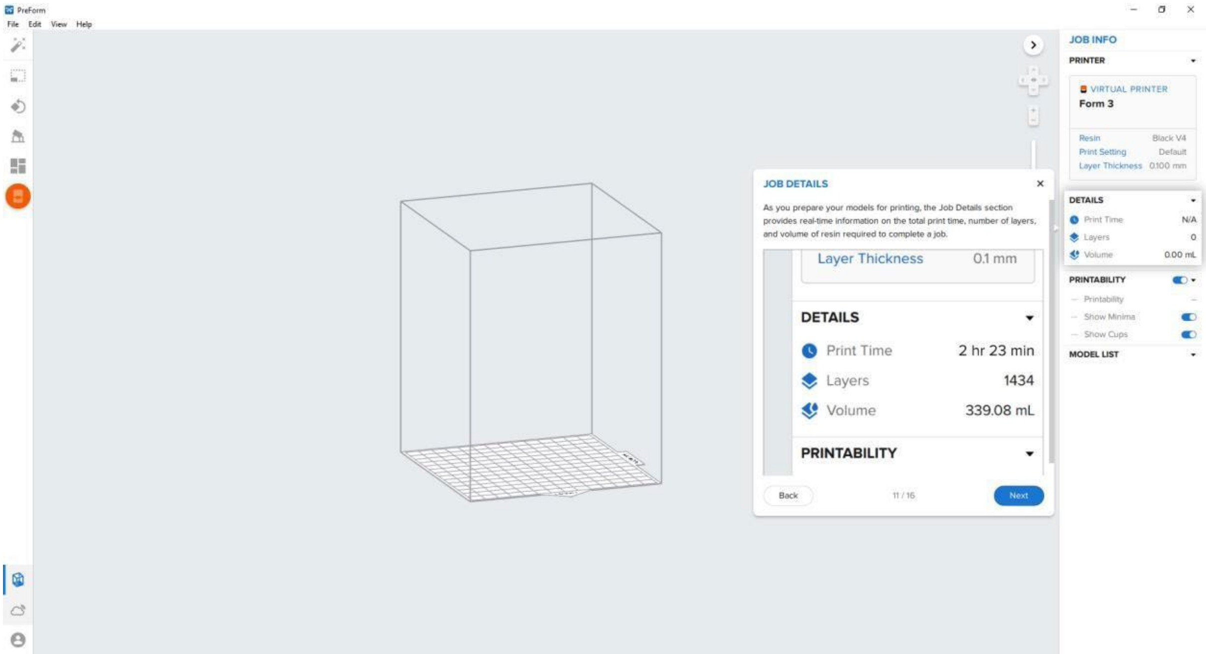
10. Job Setup

- The Job Setup card allows you to change key job parameters, such as printer, material, and layer thickness.



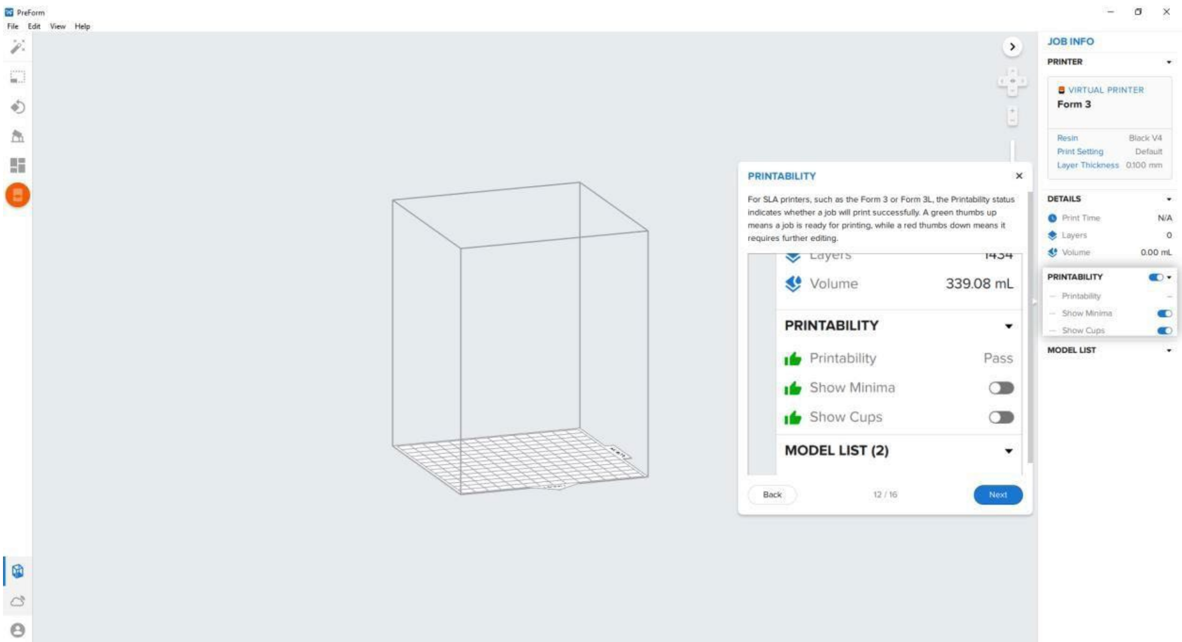
11. Job Details

- As you prepare your models for printing, the Job Details section provides real-time information on the total print time, number of layers, and volume of resin required to complete a job.



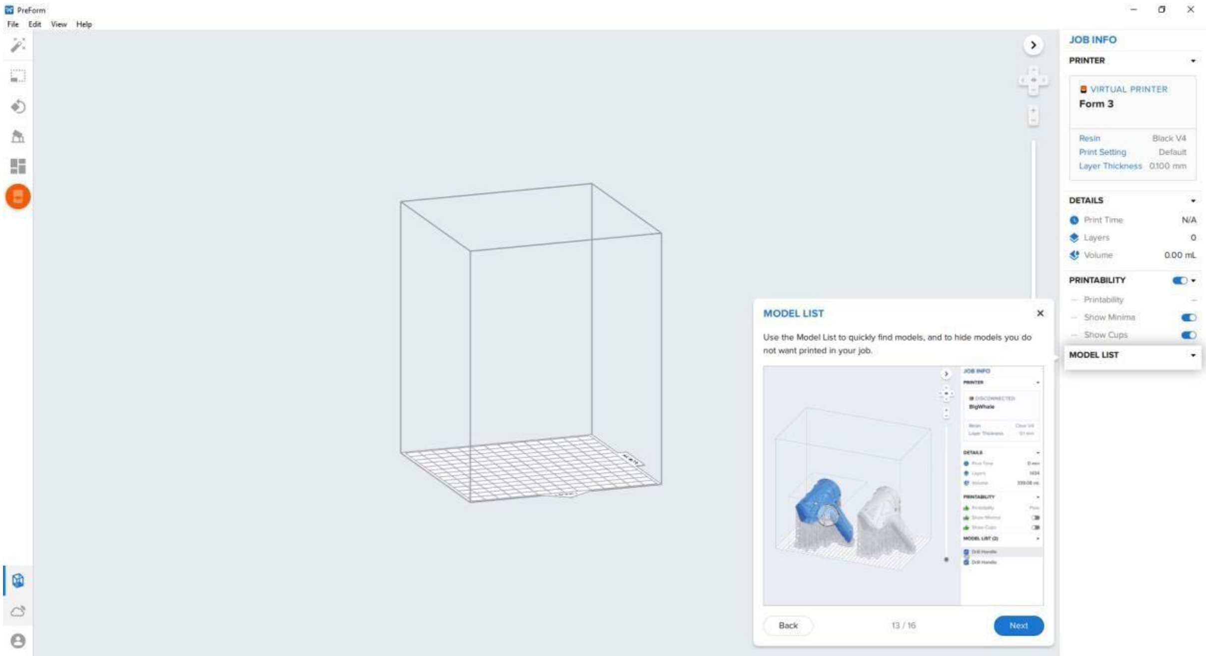
12. Printability

- For SLA printers, such as the Form 3 or Form 3L, the Printability status indicates whether a job will print successfully. A green thumbs up means a job is ready for printing, while a red thumbs down means it requires further editing.



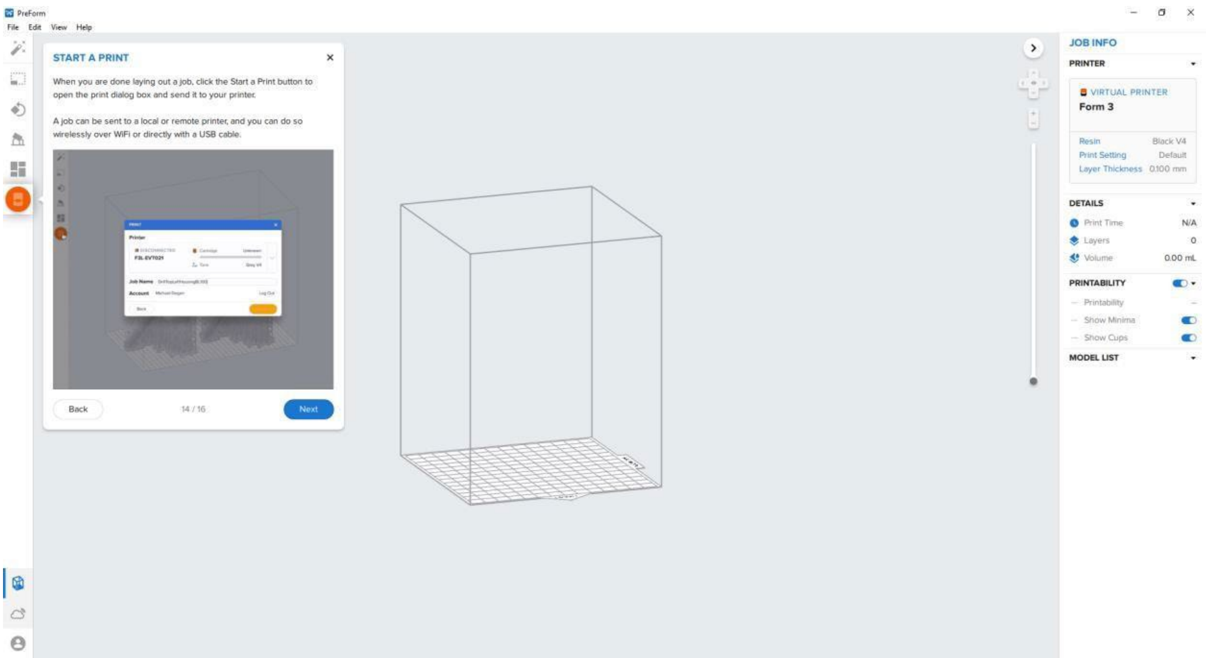
13. Model list

- Use the Model List to quickly find models, and to hide models you do not want printed in your job.



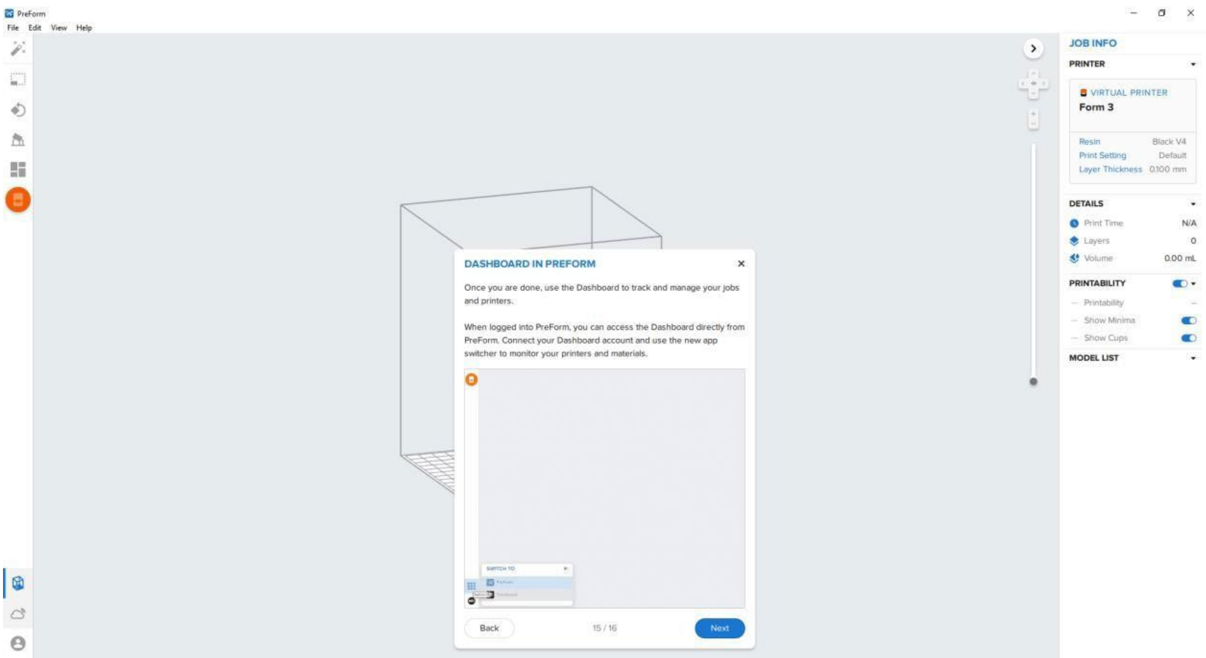
14. Start a print

- When you are done laying out a job, click the Start a Print button to open the print dialog bow and send it to your printer. A job can be sent to a local or remote printer, and you can do so wirelessly over WIFI or directly with a USB cable.



15. Dashboard in PreForm

- Once you are done, use the Dashboard to track and manage jobs and printers. When logged into PreForm, you can access the Dashboard directly from PreForm. Connect your Dashboard account and use the new app switcher to monitor your printers and materials.



IV.3.2.3. Basic procedure to prepare a 3D mesh for 3D printing.