A Protocol of Using Open Access Resources to Perform Medical Imaging 3D Printing

Lucille A. Lee[1], Lee-Jae Jack Guo[1], Peter P. Nghiem[2], Vidya Sridhar[1], Egemen Tuzun[1]

[1] Institute for Preclinical Studies (TIPS), Texas A&M University

[2] Veterinary Integrative Biosciences, Texas A&M University

INTRODUCTION

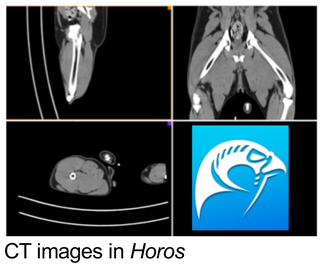
- Three-dimensional (3D) printing is a new technology in medical imaging, providing new sources for surgical planning, device development, and medical education.
- Performing medical 3D printing requires commercial software and the knowledge of post-imaging processing is restricted.
- We aimed to establish a protocol to perform medical 3D printing using open access resources.

MATERIALS AND METHODS

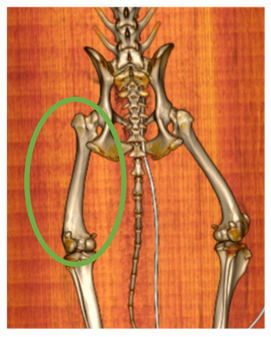
- Canine whole body computed tomography (CT) images were acquired using a Siemens 128 slice CT scanner (Fig. 1) at Texas A&M Institute for Preclinical Studies (TIPS).
- The scan was reconstructed as DICOM (digital imaging and communications in medicine) files for further processing.

Fig. 1) CT scanner at Texas A&M Institute for Preclinical Studies

- The files were transferred into *Horos* DICOM viewer. Under 3D volume rendering, we selected the femur as our target (Fig. 2).



CT images in *Horos*



Lower body image after contrast adjustments to highlight the left femur, circled in green

Fig. 2) 3D volume rendering process in *Horos*

- Using the toolbar, we targeted the left femur by isolating it using the cutting function (Fig. 3).

Fig. 3) Femur with part of the pelvic bone, tibia, and patella still attached during the cutting process

- Once the femur and patella were isolated, it was viewed using the 3D surface rendering and exported as a standard tessellation language (STL) file (Fig. 4).

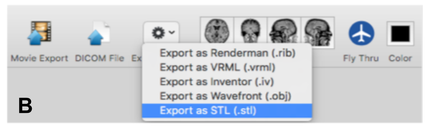


Fig. 4) (A) Femur and patella in the 3D surface rendering viewer. (B) The export button used to create the STL file.

- The STL file was imported into *Autodesk Meshmixer* where the "select", "edit", and "analysis" tools were used to remove the attached patella and to smooth and fill any gaps (Fig. 5).

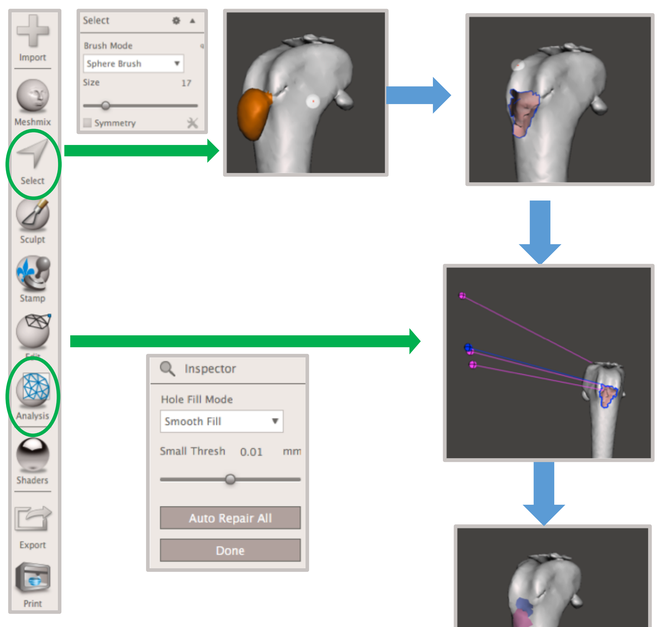


Fig. 5) The editing and filling process in *Meshmixer*

- Before exporting to print, the model was solidified using the "make solid" feature (Fig. 6).

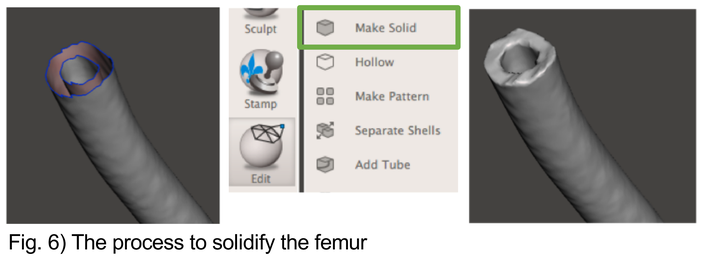
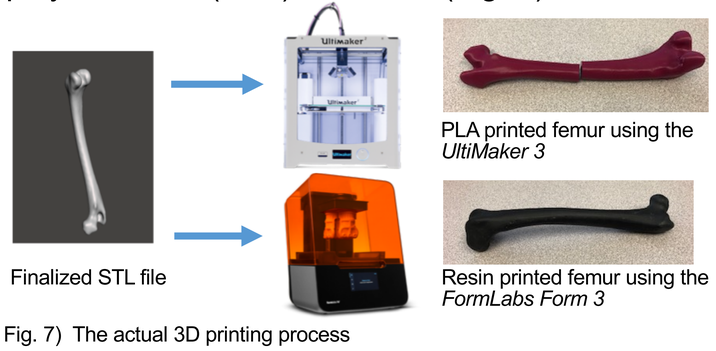


Fig. 6) The process to solidify the femur

- The STL file was exported to be printed in polyactic acid (PLA) and resin (Fig. 7).



Finalized STL file

PLA printed femur using the *UltiMaker 3*

Resin printed femur using the *FormLabs Form 3*

Fig. 7) The actual 3D printing process

RESULTS

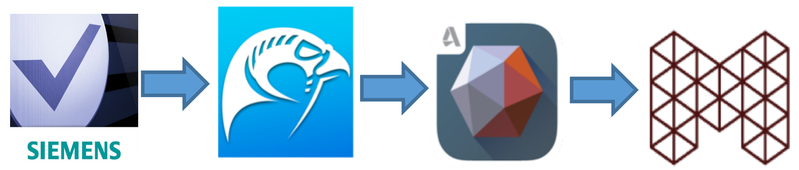


Fig. 8) Multiple softwares were used during the whole process to transform the medical DICOM images into the 3D printed models. The average time of post-processing took about 1 hour, depending on the complexity of the desired target.

Table 1) A comparison of PLA and resin printing methods

PLA Printing	Resin Printing
• Light weight • < 3 hours to print • Can have water soluble or PLA supports • Lower cost • Sufficient anatomic details • Visible layers	• Heavier • > 7 hours to print • Resin supports only - must be removed by hand • Higher cost • Sufficient anatomic details

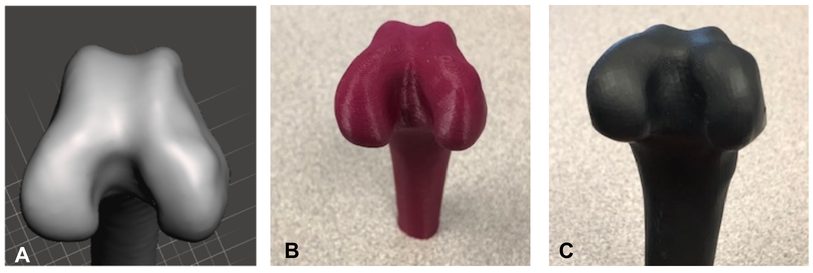


Fig. 9) Femoral condyle image in *Meshmixer* before printing (A). The PLA printed model showed the layers of the material (B). The resin model showed minimal layering (C). Both models showed suffiencent anatomic details.

DISCUSSION AND CONCLUSIONS

- We established a 3D printing protocol using open access resources to post-process CT images and create a printable file.
- Printing with PLA provided a time efficient method. Both of the PLA and resin femur models had sufficient anatomic details.
- The PLA model was used to demonstrate the cortical thickness of the femur in a separate bone related study.
- We believe this protocol can be applied to 3D print other body structures and be used for potential applications in medical imaging.

ACKNOWLEDGEMENTS

A special thanks to Savannah Wilkinson, Annie Hedman, and Allison Hargraves for their assistance with this project, and to the *MakerPlace* in the College of Architecture for assisting with the 3D printing.