Using computer-aided design and 3D printing to create a juvenile nasopharyngeal angiofibroma simulator

Yuri Chen[1], Zahra Nourmahammadi PhD MSc[1], Ross Michaels[3], David Zopf MD MS[2,4]

[1]University of Michigan College of Engineering, Ann Arbor, MI
[2]University of Michigan Biomedical Engineering Department, Ann Arbor MI
[3]University of Michigan Medical School, Ann Arbor, MI
[4]Department of Otolaryngology Head and Neck Surgery, Ann Arbor, MI

UROP
UNIVERSITY OF MICHIGAN

Introduction

Juvenile nasopharyngeal angiofibroma (JNA) is a rare benign tumor that appears in the upper part of the pharynx and behind the nasopharynx. While it is benign, it can invade surrounding tissues and shift bone structure around the nasal area due to pressure(Figure 1B). The prevalence is about 1 case per 150,000 individuals, or about 50 new incidences per year in the U.S., with young male adults being the most affected. Surgery is the most common treatment for a JNA tumor. Since there aren't many cases of JNA tumors, there are not many surgeons with experience operating on a JNA tumor, and therefore it would be helpful if surgeons could practice on realistic models before operating on the patient. There are currently no surgical models of a JNA tumor.

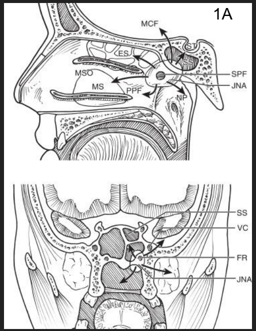


Figure 1A. A drawn image of how a JNA tumor grows and affects the surrounding areas and bone structures.

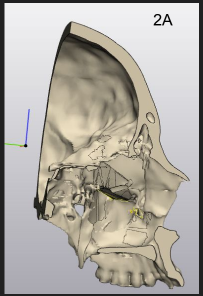
Figure 1B. A CT scan of a patient with JNA tumor, showing how the bone structure is shifted due to the tumor.

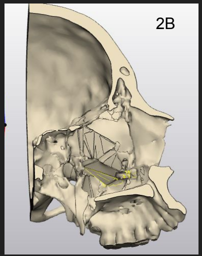
Objective

To design a 3D printed model of the patient's skull and JNA tumor to provide a vital road map to help doctors preparing for surgery.

Methods

A CAT scan was done on a person with a JNA tumor. Using Mimics and 3-matic software, a bio-medical focused CAD(computer aided design) program, a complete model of the skull was created on the computer using the original CAT scans. The skull is then printed via FFF(fused filament fabrication) in PLA(polylactic acid).
To increase the fidelity of the skull, modifications were made in 3-matics. Missing parts in the skull were filled as shown(Figure 3). The middle turbinate bone in the nose was added. The septum was straightened so it would represent a greater percentage of patients with JNA as this specific CT scan was an extreme case of JNA.





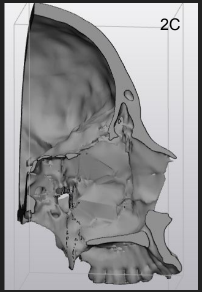
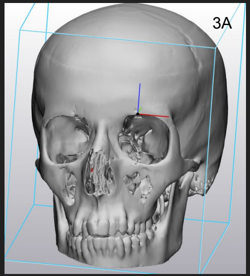
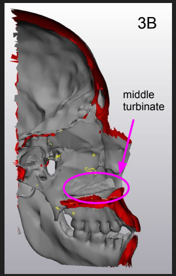


Figure 2A. A screenshot from 3-matics showing holes that need to be filled in the skull
Figure 2B. Showing the progress of filling in holes
Figure 2C. A completed filled. smoothed surface for the skull

Results





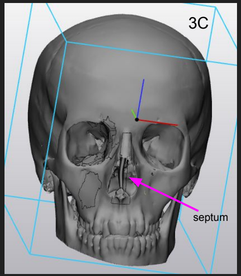


Figure 3A. The original STL file created by the CT scan. There are many holes as converting the CT scan into an STL didn't pick up all of the bone.
Figure 3B. The middle turbinate bone structure (shown in the pink circle)
Figure 3C. The completed skull with all holes filled with the middle turbinate was added and the septum straightened.

Conclusions

This project was a success in fulfilling its purpose of creating a 3D printed skull model. There are just minor edits and finishes left to implement, such as potentially creating a stand for the skull. In the future, this model will be demonstrated in a convention where surgeons can use it and provide feedback on how realistic the simulation is. This model is significant because it allows for practice on a uncommon surgery: this will benefit both the patient and surgeon by having the potential to increase confidence and accuracy of the surgeon.

References

Makhasana, Jashika Adil Shroff et al. "Juvenile nasopharyngeal angiofibroma." *Journal of oral and maxillofacial pathology : JOMFP* vol. 20,2 (2016): 330. doi:10.4103/0973-029X.185908
Gaillard, Frank. "Juvenile Nasopharyngeal Angiofibroma: Radiology Reference Article." *Radiopaedia Blog RSS*, radiopaedia.org/articles/juvenile-nasopharyngeal-angiofibroma.