3D Printed Cutting Guide for Orthopedic Surgery

Team Members: Anuar Acosta, Andrew Knoeppel, Chelsie Metz, Daniel Simmons
Client: Dr. Jason Bleedorn
Advisors: Erick Oberstar, Joseph Towles

Abstract

By 3D printing bone cutting guides for orthopedic surgery in-house, the cost of surgery is dramatically lowered. However, this technology is new and the usefulness of 3D printed cutting guides in a clinical setting is not known. By testing the accuracy, safety, and applicability of these guides, their feasibility will be determined.

Problem Definition

Statement

Dr. Jason Bleedorn, a veterinary surgeon at the UW Vet Hospital has tasked us with designing and analyzing the biocompatibility, accuracy, and fabrication process of 3D printing orthopaedic cutting guides for bone deformation surgery in animals.

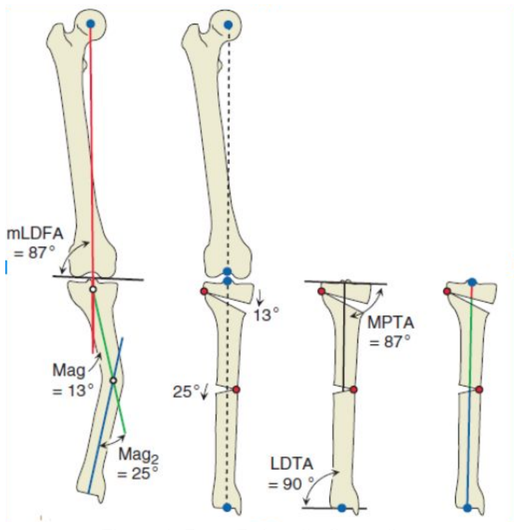

Figure 1. Bone Deformity Correction

Background

- Bone deformities occur at any stage of life and for many reasons [1]
- Often very painful, and can be fatal if not treated.
- Corrective osteotomy most common method to fix

Motivation

- High level of accuracy needed
- Costly methods of current custom cutting guides
- Patient Safety

Current Products

- Visionaire knee replacement cutting guides[2]
- Stratasys 3D printed jigs[3]
- Patents

Guide Design

Previous

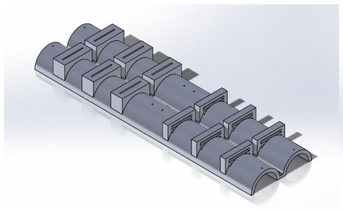

Figure 2: Allowed for multiple guides to be printed at once, but could not shed debris

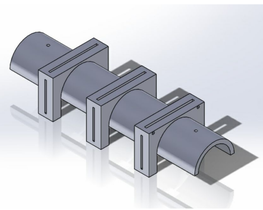

Figure 3: Added vents to shed debris. Could make 3 basic cuts

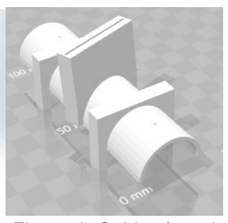

Figure 4: Guide altered to make a single, complex cut

Current

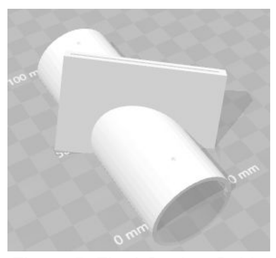

Figure 5: Final Cutting Guide

- Legs were removed in favor of pinning the guide to the jig
- Cutting slot was extended for greater ease of cutting
- Plastic thickness increased to minimize deformity
- Cutting angle: 30° in the frontal and sagittal planes

Accuracy Testing

Phase 1: Standardized Jig

1. Fabricate two or more testing jigs
   a. PVC pipe lathed to 6in
   b. 3in flat with a depth of 0.1in is milled into the jig
      i. This serves as a reference in analysis
2. Design and print a guide to fit around the round portion of the jig
3. Pin the guide in place on the jig
4. Fasten the jig to the table for stability
5. Cut the piece with a surgical saw
6. Scan the jig with a micro CT
7. Analyze the cut with volumetric software
8. Repeat steps 4-7 on a new jig without using a guide
9. Continue to perform these tests until an adequate sample size is acquired

Figure 6: Testing Jig Model

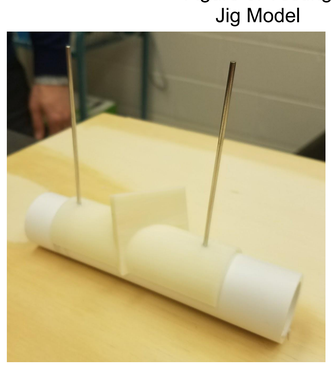

Figure 7: Guide pinned to testing jig

Phase 2: Simulated Bone

1. Obtain a CT scan of a deformed bone in need of surgery
2. Determine how the bone needs to be cut in order to correct its deformity
3. Design a guide to correct the deformity in Mimics
4. 3D print the guide and at least two copies of the bone
5. Pin the bone and guide in place
6. Cut the bone with a surgical saw
7. Scan the bone with a micro CT scanner
8. Analyze the cut with volumetric software
9. Repeat steps 5-8 without the use of a cutting guide
10. Continue to perform these tests until an adequate sample size is acquired

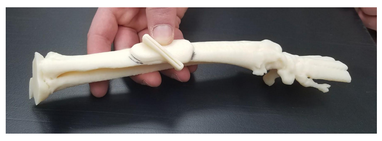

Figure 8: 3D printed bone and guide

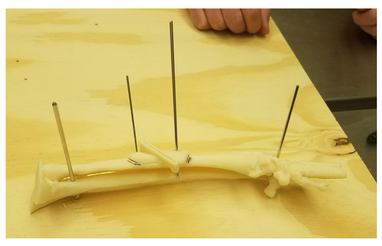

Figure 9: Guide and bone pinned in place for cutting

Analysis

1. Import scanned test piece into volumetric software
2. Set reference points
   a. Testing Jig: Flat end, 3in flat
   b. 3D Printed Bone: flat ends
3. Using the 3-point angle tool to set an angle
4. Align the angle to the face of the cut
5. Repeat steps 1-4 with the remaining test pieces
6. Compare the angles on the test pieces
   a. Determine how accurate each cut was
   b. Compare the accuracy of the guided cuts versus their freehand counterparts

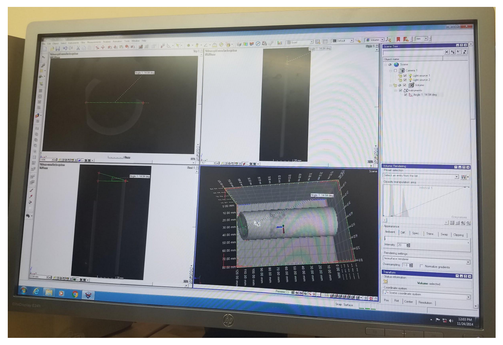

Figure 10: Angle measurement on a testing jig

Future Work

Application with Humans

While 3D printed cutting guides have seen some use in veterinary practices, their use in human surgery is extremely limited. They have been used by doctors to practice making a cut, but are not actually used in a surgical setting. By proving the capability of 3D printed cutting guides in a veterinary setting, hospitals will become more eager to apply the same technology with humans.

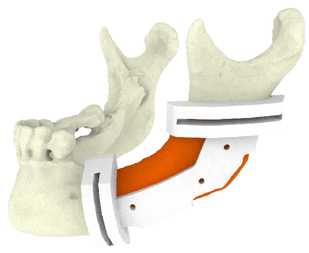

Figure 11: Cutting guide model made by Xilloc for practicing mandibular surgery[4]

3D Printing with Other Materials

Throughout the duration of this project, all guides were printed with plastic filaments. However, current 3D printing technology allows for printing in many other materials such as metals and resins. It would be worthwhile to redo heat and wear testing with guides composed of different materials to determine the most effective material to be used in these surgeries.

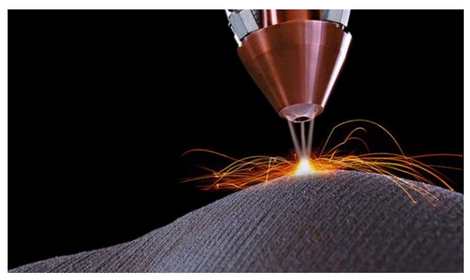

Figure 12: Trumpf 3D laser printer for printing with metals

Results

	Target Cut	Free Hand	Tolerance	Target Cut	Guide	Tolerance
Testing Jig	30	27.01	2.99	30	34.35	4.35
	15	13.24	1.76	30	27.95	2.05
	Total		**2.375**			**6.40**
Printed Bone	30	33.44	3.44	30	29.30	0.70
	15	17.31	2.31	15	15.10	0.10
	Total		**2.875**			**0.80**

Our results showed improved accuracy for the tests on printed Bone. Accuracy was decreased for tests on the testing jig. With a larger sample size, it is believed that the accuracy of tests on the jig would increase with the use of a cutting guide.

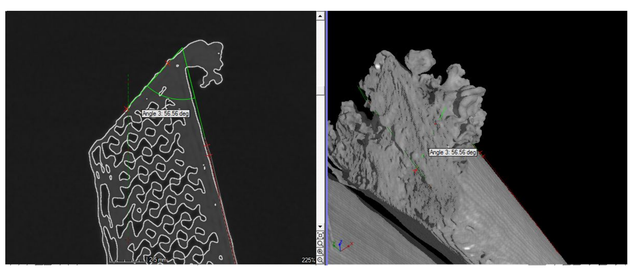

Figure 13: Analysis of freehand cut, frontal plane

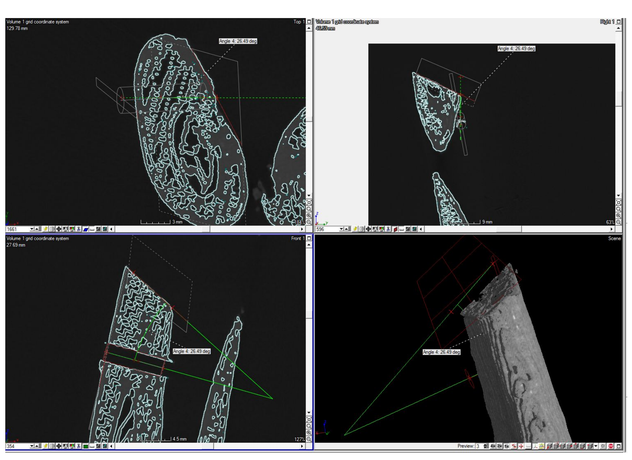

Figure 14: Analysis of guided cut

References

1. "Bone Deformities | RIAO", *Lifebridgehealth.org*, 2017. [Online]. Available: http://www.lifebridgehealth.org/RIAO/BoneDeformities.aspx. [Accessed: 08- Dec- 2017].
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