

# BME Design-Fall 2019 - Will Wightman Complete Notebook

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**Will Wightman**

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## Team contact Information

- Will Wightman - Sep 06, 2019 @03:02 PM CDT

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Van Horn	Cade	BWIG	cavanhorn@wisc.edu	(612) 850-0583	
Gaspar	Kylie	BPAG	kgaspar@wisc.edu	(630) 745-8030	



## Project description

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• Will Wightman • Oct 08, 2019 @10:07 PM CDT

**Course Number: BME 200/300**

**Project Name: VetMed: Design and Mechanical Analysis of Patient-Specific Mandibular Reconstruction Implants**

**Short Name: Dog Jaw**

**Project description/problem statement:**

Implanted bridging plates are used to supply structural support during the recovery period after treating mandibular fracture in canine patients. The design of these bridging plates, though simple in appearance, is complicated due to the need to provide certain mechanical properties and avoid tooth structures and mandibular vasculature, all of which can vary patient to patient. Currently, there does not exist a streamlined or time and material efficient process for generating these patient-specific bridging plates. The goal of this project is to create a computationally aided process that optimizes the dimensions of a set of implants used in mandibular reconstruction while avoiding problem areas such as tooth structure and mandibular vasculature on a patient-by-patient basis.

**About the client:**

This project was proposed to the BME department by Dr. Graham Thatcher and Dr. Jason Bleedorn. Dr. Graham Thatcher and Dr. Jason Bleedorn both currently work in the Department of Surgical Sciences within the School of Veterinary Medicine at the University of Wisconsin Madison. Dr. Graham Thatcher is currently a Clinical Assistant Professor for Dentistry and Oral Surgery, and manages dentoalveolar and orofacial related conditions. Dr. Jason Bleedorn is involved in the Comparative Orthopaedic Research Laboratory, and investigates biomechanics, augmentation of fracture healing, characterization of bone deformities, and mechanisms of cruciate ligament disease in dogs



## 2019/09/12 - Client Meeting - Introduction and Initial Discussion

- Will Wightman - Sep 15, 2019 @09:02 PM CDT

### **Title: Introduction and Initial Discussion**

**Date:** 2019/09/12

**Content by:** Will Wightman

**Present:** Entire team and client, Dr. Graham Thatcher

**Goals:** Meet client and begin defining project for the PDS. Ask client predetermined questions to determine the overarching goal of the project.

### **Content:**

Via research and provided resources, the team determined the over-arching goal of the project was to develop patient specific bridging plates for canine veterinary patients who had lost a significant portion of their mandible due to disease or trauma. Discussion revealed further requirements from the client, as well as insight as to where further resources could be obtained.

#### Function and use of the product

The client further described the overall purpose and desired function of the bridging plate. The client desires two distinct, custom designed products for each patient: one temporary and one to provide post-surgery support to the patient during their recovery period. The screw holes of this plate should avoid any remaining teeth within the mandible of the patient as well as the mandibular vascular tissue. However, given an entire cross section of the mandible is being removed, the client indicated avoidance of vascular tissue was less critical.

The purpose of the temporary plate is to both allow clean and easy removal of effected bone from the patient's mandible and to 'pre-drill' holes for the secondary but permanent bridging plate. Unlike the permanent bridging plate, the middle portion of the temporary plate corresponds to the region of the mandible that is to be removed and is spanned by a bar. This bar is positioned in such a way as to allow easy incision into the mandible letting the temporary plate act as a cutting guide. The ends of this temporary plate should be identical to the ends of the permanent plate. This includes both the custom topography of the side of the plate in contact with the bone and the placement of the screw-holes. This allows the surgeon to simply use the holes drilled for the temporary plate to act as guide for the permanent bridging plate.

The permanent bridging plate needs to match the mandible at either end of the incision, be able to handle all possible normal stresses, and provide a bracing for and be removable from a titanium mesh. As stated before, the bridging plate should match the topography mandible at either end of the gap and the screw-holes should line up with those previously drilled for the temporary brace. The plate should have any curvatures and dimensions tailored to the typical stressed for a typical canine of the same species as the patient. These factors should also be tailored to the variable size of possible incisions. This plate should also avoid encroaching too far along the proximal side of the mandible as to avoid damage to the mucosa (gums) closer to the joint. This bracing plate should also be used to hold a titanium mesh in place once the mesh is inserted. In case of infection, the bridging plate should be able to be independently removed from the mesh.

The purpose of the titanium mesh is to promote and guide natural bone regrowth in the jaw. This mesh should extend from one end of the incision to the other so as to provide a structure for osteogenesis to occur throughout. This mesh is filled with an autograph from a proximal limb. Additionally, this mesh could provide some structural support to the mandible if the bridging plate should ever need to be removed due to infection.

#### Software requirements and uses

#### Other resources

#### **Conclusions/action items:**

**Amendment: 2019/10/08 - Completion of post and action items**

## Software requirements and uses

The client specified that resulting project would ideally be used by typical veterinarians without any engineering background. This requires that the input from the user must be easy to use and understand, must be able to be used in a way that would be beneficiary to veterinarians at large, and would not bog down the user with engineering heavy IO. Some level of virtual surgery would be beneficial in the final product.

The software would ideally be able to be used for free so that the user would not be required to pay for expensive licenses.

The software would also have to be able to output 3D printable files.

## Other resources

According to Dr. Thatcher, there is a 3D printer capable of printing the titanium alloy needed somewhere on campus, allegedly in ECB. The team has yet to locate any reference or resource for this printer.

**Conclusions/action items:**

With this information, the team was able to quickly narrow down and specify the project to be in a workable scale. With this completed, the team was able to make rapid progress.

The team needs to continue to try and track down the 3D printer capable of printing metals as it will be crucial in final stages of development.



## 9/12/2019-Client Meeting

- KYLIE GASPAR - Sep 16, 2019 @05:57 PM CDT

**Title:** Client Meeting with Graham Thatcher

**Date:** 9/12/2019

**Content by:** Kylie Gaspar

**Present:** All

**Goals:** Meet with client to find out details and goals of the project.

**Content:**

Our teams role in the project- Answer questions on; strength, materials, screw placement, stress on bone,

Info- Design locks into first layer of bone, avoid nerve by mandibular canal

-mesh scaffold-titanium lattice-porous-solid-prevents compression

-screws have to also avoid tooth roots

-tooth roots are different per patient

Ideas-adapt to shape of jaw-not straight and flat

different sized tumors-don't need to cut out that much bone-plate doesn't have to be that big

Questions-is the mesh permanent? Answer- yes, it is there for replacement of titanium.

**Conclusions/action items:**

Determine methods to adapt replacement to individual patients, adapt replacement to the shape of jaw instead of just flat.

Experiment and test strain on jaw and replacement with strategically placed screws.





## 9/12/19 Client Meeting

• CADE VAN HORN • Sep 16, 2019 @08:25 PM CDT

**Title:** First Client Meeting

**Date:** 9/12/19

**Content by:** Cade Van Horn

**Present:** Whole Team, Dr. Graham

**Goals:** To talk to the client about our project and get a better idea of the project basics and goals.

**Content:**

- Have an understanding of how robust these implants need to be
- Does the mesh threshold/scaffold matter
- How tall or thick does the plate need to be, relative to the gap defect
- Printed so it fits the geography of the patient
- Avoid tooth structure
- Currently placing the screws kinda randomly, just avoiding tooth structure - how to optimize where to put the screws
- Where tooth roots are depends on the individual
- Look into access on MRI processing software and radiograph processing software - see if these files can be opened in Matlab or other programs we have access to
- The process of designing plates and titanium mesh scaffold is very ad hoc, they play by sight
- Using scaffold and mesh as a structural element
- Mesh cant provide structural support until bone has provided support around it (osseointegration)
- Want to be able to remove plate but not everything, so the rest will be integrated into bone if plate needs to be removed
- Collagen sponge? Printing with collagen? Try to integrate that
- Titanium 3D printing? Available somewhere at UW -- start asking around
- Mesh is printed separate but at the same time
- Probably has to thread it after because 3D printing isn't that precise
- More like a solid titanium lattice than mesh, still quite porous
- Taking the stress off screws
- Polyurethane as material is very accessible - how does that compare to an actual mandible
- Elasticity, ultimate strength, yield strength, develop polyurethane solution so polyurethane has same properties
- Forces come farther away from gap defect, so consider canine tooth
- Cutting guide and pre-drilled holes should prevent malocclusions

- To be safe you can bond canine teeth together so that nothing moves when the plate goes on
- Developing a software package or add on to develop the grafting site if you select the bonding areas -- still patient-specific
- Actual design of plate is quite simple rn

**Conclusions/action items:**

-Continue to research and get a better understanding of the project.



## 2019/09/20 - Advisor Meeting - Initial Meeting, PDS, ect

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- KYLIE GASPAR - Sep 23, 2019 @11:12 AM CDT

**Title:** Advisor Meeting - Initial Meeting, PDS, ect

**Date:** 2019/09/20

**Content by:** Will Wightman, Kylie Gaspar

**Present:** Entire team and adviser, Melissa Skalla

**Goals:**

Agenda:

- General discussion about project
  - Defined enough?
  - Any input or experience?
- Thoughts on preliminary design/process flow charts
- Feedback on initial PDS before final submission at 5 pm
- General semester flow
- Questions?

**Content:**

- Went over what our project is to explain the goals to professor Skalla
- Skalla points out that loading images in MATLAB may be problematic
- How to test forces?-Medical school
- Worst case we can do the whole project, testing included, virtually instead of physically
- Skalla recommends ...
  - that we focus on code
  - Design matrix- focus on cost
  - list different softwares-ask radiologists which is preferred
  - Thinking about computational time and complexity for each software
  - We can take budget out of PDS

**Conclusions/action items:**



## 2019/10/15 - Adviser Meeting - Bio-mechanics Professor - FEA

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• Will Wightman • Oct 15, 2019 @10:15 AM CDT

**Title:** Adviser Meeting - Bio-mechanics Professor -FEA

**Date:** 2019/10/15

**Content by:** Will

**Present:** Laura and Professor Christa Wille

**Goals:** Discuss get feedback on potential FEA resources and design project in general.

**Content:**

Professor Wille (BME) gave the team useful information and insight.

She suggested potentially limiting the scope of the design given this is a first semester project and FEA (Finite Element Analysis) is extremely complex. She suggested focusing on basic force analysis.

She suggested using FEBio and Ansys.

FEBio is open source, which is more ideal for our project. (<https://febio.org/>)

As UW Students, the team has access to Ansys. However, this is not ideal for the open source aspect of this project. (<https://www.ansys.com/>)

**Conclusions/action items:**

The team should research and play around with these soft wares to determine whether or not they will be useful to the team.



## 2019/09/16 - Team Meeting - PDS, Brainstorming, Design

- Will Wightman - Sep 19, 2019 @09:59 AM CDT

**Title:** Team Meeting - PDS, Brainstorming, Design

**Date:** 2019/09/16

**Content by:** Will Wightman, Cade Van Horn

**Present:** Entire Design Team (except Young)

**Goals:**

Agenda 9/16

- Arrive 7:30pm @ E-Hall
- 7:30-8:45pm - General Discussion
  - Discuss research
  - Feedback on notebook
  - Discuss client meeting (bridge to PDS)
  - Discuss PDS
- 8:45-9:00pm - Assignments
  - Delegate portions of PDS
  - Example in drive!

Assignments

- Research (Duh)
  - Biological/biomechanical/structural components
  - 3D printing techniques
  - Software research
  - 3D imaging research
  - Competing models?
- Design
  - At least one design
  - Add ons welcome!
  - We'll discuss these on Friday before our adviser meeting
- Adviser questions

**Content:**

Defining the Project:

- They have a solution, we make it more efficient (optimize and streamline)
  - Designing a process, not reinventing the plates
- Try not to use so many screws or too much material
- Needs to produce a normal bridging plate, one for a cut guide, and a titanium mesh
- Mechanics calculations needed to determine exact geometric properties needed
- Individualized/patient specific
  - Match either end of the incision
  - Look into 3D printing titanium
  - 3D imaging software, MRI files
- Force analysis Stress testing
  - Strain
  - Compressive forces
  - Torque
  - Likely use SolidWorks
- Screw placement
  - Avoid teeth and veins when putting screws in
  - Maybe min of 3 screws on each side - depends on the anatomy of the particular dog
  - The bone is going to be very dynamic after the surgery, need to probably secure in 3 spots (a plane)
  - Using Matlab to upload pics, optimize screw placement
- Mesh/lattice properties
  - Autographing - take existing cells for osteogenesis
  - Take sample from shoulder, grind up, put into mesh to encourage natural bone growth

- Collagen sponge printing
- Put into future works section

#### General Brainstorming and Discussion

- Helpful programming things:
  - Arduino
  - Matlab
  - Solidworks

#### Conclusions/action items:

- Action items:
  - intro to MatLab
  - source things with IEEE
  - ask Tracy about titanium 3D printing
  - research papers that client sent, take notes
    - include references in PDS
    - do PDS
    - be as specific as possible in PDS (concise)
  - process designs for "prototypes", steps, tools
- Adviser questions
  - Any insight into imaging softwares listed?
    - Importing STLs into matlab? Vice versa?
    - Calculating surface vectors?
- Continue research

After meeting with the client, it became apparent the client was looking for a process to generate a common surgical tool and was not looking for the team to reinvent this product. This fact allows the team to focus our research and project parameters.

This project is different from a typical BME design project where the students develop a singular, well-defined deliverable that is only used in specific cases.

The main challenges of this project will be in insuring the versatility of the process and insuring each team member will be able to contribute to the project given the more advanced knowledge needed to do each component well.



## 2019/09/20 - Team Meeting - Initial Design Ideas/Design Matrix

- KYLIE GASPAR - Sep 23, 2019 @11:08 AM CDT

**Title:** Team Meeting - Initial Design Ideas/Design Matrix

**Date:** 2019/09/20

**Content by:** Will Wightman, Kylie Gaspar

**Present:** Entire team.

**Goals:**

Agenda 2019/09/20:

**Content:**

- House keeping items, Will gave tips on PDS and labarchives
- Went over flow charts for design
  - Cade
    - Perform stress tests
    - Identify no go spots
    - Gives dimensions of where plate goes
    - Scan of jaw-3D imagine file
  - Young
    - Stress test implant
    - select where screws go with avoiding tooth roots and nerves-need to know where tooth roots are
    - 3D scan
  - Laura
    - Back to MATLAB for screw placement
    - Goes to Solidworks to test
    - Output-thickness and length of implant
    - Upload to MATLAB
    - Data file
  - Will
    - Implant
    - Testing
    - User selects portion to be removed or processing software selects portion
    - Upload to 3D software
    - Client scans jaw
  - Kylie
    - Use Solidworks to pinpoint main stresses on canine mandible
    - User removes part of mandible=new stress points
    - Research on titanium qualities
    - Put in MATLAB to avoid tooth roots
    - Overlay shape of solid implant on stress points
    - Remove 5mm screw holes where stress points are
- Team discussion-
  - Minimizing size would be cost efficient because you don't have to spend that money on extra titanium that isn't needed
  - MATLAB and Solidworks are expensive subscriptions, figure out something cheaper for client.

**Conclusions/action items:**

This upcoming week we have to set up design matrix and start the outline for our presentation slides, all as a team. Individually we will all do more specific research to determine what parts of the project we want to take part in.







## 2019/09/23 - Team Meeting - Design Matrix

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• CADE VAN HORN • Sep 23, 2019 @08:26 PM CDT

**Title:** Team Meeting - Design Matrix

**Date:** 2019/09/23

**Content by:** Cade Van Horn

**Present:** Will, Kylie, Laura, and Young

**Goals:** The goals of this meeting are to create the design matrix and determine the best design based on the assigned scores.

**Content:**

Objectives: go over design matrix

- Design matrix should be based on process, not on the bone plate itself
- Focus on cost: think of different combos of software
- Cost should be at top of matrix
- Computational time should be in the matrix
- Keep ease of use
- Consider storage limitations as a category
- Quality of product - link to safety of dog
- Accessibility
- Convenience
- Ease of use - matlab is pretty easy for new people to use, others might not be as easy
- Quality of implants produced from the process
- The size of problem we have is limited to a few thousand data points - small computational time
- Cost should be one of most important
- Safety can stay at the bottom, not the biggest concern
- Computational time not the most important but top 4
- Convenience and accessibility more important

Final order of categories

1. Cost
2. Accessibility / compatibility
3. Convenience / ease of use
4. Computational time
5. Difficulty to program
6. Resolution of implant

7. Data storage limitations

8. Safety

- Created weights of categories
- Discussed our three designs

#### Design 1: Le Grilled Cheese: Bits and Pieces

- MatLab and Solidworks
- Ranked a 2 for cost - very expensive licenses

#### Design 2: Ground Coffee: Plug-in to Blender and Image-J

- Java
- Ranked 10 for cost - open source

#### Design 3: Hamburger Helper: Generative Design

- Give it parameters, let it generate designs
- Comes up with arbitrary random designs that fit specifications, then tweaks it and repeats the process
- Uses Blender
- Ranked 3 for cost - expensive license

#### Design 4: Easy Bake Oven: Stand Alone / Executable

- Ranked 10 for cost - open source

#### Other things:

- Kahn academy and maybe LinkedInLearning have tutorials on Java and other things
- Weighed all the categories, determined the plug into blender and image-J was actually the best option - which makes sense because that's what our advisor was suggesting

#### **Conclusions/action items:**

We need to turn in the design matrix, continue to do more specified research, and those of us who are less familiar with programming need to look into tutorials on programming.



## 2019/09/27 - Team Meeting

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- KYLIE GASPAR - Sep 27, 2019 @06:46 PM CDT

**Title:** Team Meeting

**Date:** 2019/09/27

**Content by:** Kylie Gaspar

**Present:** All

**Goals:**

**Content:**

Went over goals of presentation

Assigned sections of presentation and report

Talked about upcoming weeks

- Presentation due

- Need to start working on deliverables

- Figure out team tasks (Will and Cade code, etc)

**Conclusions/action items:**



## 2019/09/30- Team Meeting

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• KYLIE GASPAR • Oct 01, 2019 @08:45 PM CDT

**Title:** Team Meeting

**Date:** 2019/09/30

**Content by:** Kylie

**Present:** All

**Goals:** Practice preliminary presentation, make sure all information is important and included.

**Content:**

Discussed possible problems with project

-Stress testing for canine mandible doesn't exist

Practiced Preliminary Presentation

**Conclusions/action items:**

Refine presentation, wear blue on Friday.



## 2019/10/07 - Team Meeting - Preliminary/Midsemester report overview

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• Will Wightman • Oct 08, 2019 @10:02 PM CDT

**Title:** Team Meeting - Preliminary/Midsemester report overview

**Date:** 2019/09/07

**Content by:** Will Wightman

**Present:** All except Cade

**Goals:** Review and edit mid-semester together before submission

**Content:**

Present team members edited existing draft and clarified and assigned remaining portions.

**Conclusions/action items:**

Team discussed last minute needs and goals before report submission.



## 2019/10/11 - Team Meeting - Beginning to Prototype

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- CADE VAN HORN - Oct 12, 2019 @11:24 AM CDT

**Title:** Beginning to prototype and continuing to research

**Date:** 2019/10/11

**Content by:** Cade Van Horn

**Present:** All except Kylie

**Goals:** The goals of this meeting are to discuss what we will begin to do in the coming weeks as far as researching and prototyping.

**Content:**

- Break up the project, into math-heavy stuff and coding stuff
- This week: prepare to code
- Talk to biomechanics prof (Laura)
- Do-IT java introduction (Laura)
- Do research on the mechanics of the jaw, lookup types of forces, what kind of bending, bones, stresses, and strains, etc
- Coding team: research how plugins work, Image J, how to integrate with java and existing programs
- Find out how to use computation to load files
- Download Eclipse IDE (try night mode lol) → <https://www.eclipse.org/downloads/>
- General: research java, get eclipse and mess around in it, research biomechanics and objects
- Also look into GitHub

**Conclusions/action items:** We know that we need to do a lot more research and get more experience with coding, and make a decision on where to start with the prototype.



## 2019/10/14 - Team Meeting - Java Boot Camp 1

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- Will Wightman - Oct 15, 2019 @08:38 AM CDT

**Title:** Team Meeting - Java Boot Camp 1

**Date:** 2019/10/14

**Content by:** Will Wightman

**Present:** Entire Team

**Goals:** Give every member of the team a very brief and broad introduction to Java so they can have a leg up when exploring and teaching themselves Java.

Topics To Cover

1. Computer Architecture (Very Brief) - Stack vs Heap
2. Variables and Variable Types - Primitives vs Objects/Reference Variables
3. Arrays vs Array Lists
4. Naming Conventions
5. Functions and methods
6. Public, Private, and Protected Fields
7. Static vs Non-static/instance fields

**Content:**

Using the attached outline/teaching notes, I gave the team a 25 minute lecture about the basics of Java.

The following 35 minutes of the meeting, I led the team through a programming exercise in Eclipse to give them familiarity with the concepts that were just taught. Each member of the team wrote their own code and started their own files.

**Conclusions/action items:**

The team did well with the initial Java training. I don't think there will be a need for many more full team teaching sessions as the majority of the team seemed very comfortable with the content. Given the different levels of experience among team members, it is the most efficient use of everyone's time to research the content on their own and bring up any questions on a one-on-one or small group basis.

Better example code demonstrating objects, arrays, and general coding habits will be posted here soon.

Additional resources:

Java Visualizer - [https://cscircles.cemc.uwaterloo.ca/java\\_visualize/](https://cscircles.cemc.uwaterloo.ca/java_visualize/) - This website allows the user to write (basic) code and see how each element of it works. Under options, check the box next to "Show String/Integer/etc objects, not just values"

Java Jumpstart Tutorial 3 - "Basic" Theory  
 Will Wightman - Fall 2019

1. Stack vs Heap
  - a. Stack
    - i. Highly ordered, high priority memory, tightly trimmed and maintained
    - ii. Primitives, local object references, loops, and functions live here
    - iii. Small items compared to heap
    - iv. Think of like a banked table, or VIP parking where each slot has limited space
  - b. Heap
    - i. Less ordered, lower priority, trimmed and maintained occasionally
    - ii. Object bodies (be off the reference points) live here
    - iii. Larger than stack, can hold more than sequential information (like arrays)
2. Variables - Primitives vs Objects
  - a. Primitives
    - i. Can be represented with a simple string of binary (or hex) numbers
    - ii. Stored directly in the stack
    - iii. int (integer) - stored in stack - 1501, = 12<sub>16</sub>
    - iv. char (character) - 'a', 'f', '@', '\n'
    - v. double (floating point number) - 1.2, 4.567, 12.0
    - vi. float (floating point) 1.256 \* 10<sup>3</sup>
  - b. Objects
    - i. Has a reference, a "handle" that's written in binary like how primitives are written
    - ii. Like a box which can contain functions, variables, other objects, ect.
    - iii. The values stored in the stack for this object is like an address to the rest of the object (in pointer)
    - iv. The reference can be stored in stack or in heap, depending on if it is being held by another object or not
3. Arrays vs Array List
  - a. Both are objects/hold more variables
  - b. Can take any number of dimensions
  - c. Contains an ordered list of other "things"
  - d. Arrays
    - i. Can hold primitives or objects
    - ii. Declared like this - `ArrayType[] arrayName = new ArrayType[size];`
      1. `int[][] matrix = new int[3][3]; String[] strings = new String[5];`
      2. You add further dimensions by adding more brackets at declaration - `int[][][] = new 4-dimensional array;`
      3. Size MUST be an integer
    - iii. Set size - An array cannot be changed once you declare it (ie a 1D array with a size of 5 will always be 5 long)
      1. This EXACTLY mean the reference to an array stored in a variable cannot be swapped out. Must be the same number of dimensions
      2. `int array1 = new ObjectType[];`
    - iv. Accounting starts within a array
      1. `arrayName[coordinate_1][coordinate_2]...[coordinate_n]`

[Java\\_Jumpstart\\_Tutorial.docx\(23.6 KB\)](#) - [download](#) This document contains a brief summary of object oriented programming and was used as a teaching guide during the meeting





## 2019/11/11-Team Meeting - Coding Check up

---

• KYLIE GASPAR • Nov 11, 2019 @08:23 PM CST

**Title:** Team Meeting - Checkup

**Date:** 2019/11/11

**Content by:** Kylie Gaspar

**Present:** All

**Goals:** Ideas for continuation of project

**Content:**

- Talked about peer feed back and what we can fix from that
- Divided up work on final report and poster
- SolidWorks group will continue with SolidWorks and FEBio
- Normal vectors and how to simplify stl files with the triangles

**Conclusions/action items:**

Keep working on SolidWorks, code, triangles, and final deliverables



## 2019/11/04-Template - Elevator Pitch

---

• KYLIE GASPAR • Nov 11, 2019 @08:16 PM CST

**Title:** Team Meeting - Elevator Pitch

**Date:** 2019/11/11

**Content by:** Kylie Gaspar

**Present:** All

**Goals:** Come up with a good presentation for peer review and feed back on Friday.

**Content:**

-Team check up

- Coding team converting files

- SolidWorks Team shape of simplified design

-Everyone took part in writing part of our "Elevator Pitch"

-We went over and edited the Pitch to make sure people could understand and give good feedback without knowing too many details about the project.

**Conclusions/action items:**

Keep working on SolidWorks and code, give Pitch on Friday.



## 2019/11/22-Team Meeting Final Reports

---

• KYLIE GASPAR • Nov 22, 2019 @12:16 PM CST

**Title:** Team Meeting- Final Report and Presentation

**Date:** 2019/11/22

**Content by:** Kylie Gaspar

**Present:** All

**Goals:** Check in and start working on final deliverables.

**Content:**

What we want as our final results-FEBio and SolidWorks, changing dimensions and comparing between FEBio and SolidWorks for different sizes.

- Want graphs on posters
- Finish poster by Monday, December 2nd

**Conclusions/action items:**



## 2019/12/5 -Team Meeting- Final Report and Poster

---

• CADE VAN HORN • Dec 05, 2019 @05:44 PM CST

**Title:** Poster Presentation Practice and Final Report Rough Draft

**Date:** 2019/12/05

**Content by:** Cade Van Horn

**Present:** Whole Group

**Goals:** The goals of this meeting were to practice our presentation for the poster session, and to communicate how we will finish the final report.

**Content:**

We met to practice the poster presentation. We discussed things we could do better after we practiced our presentation and gave each other constructive feedback. We also made sure we all knew the details of the presentation and coordinated what we would wear. We also touched base on who would finish which parts of the final report rough draft that we intend to finish by tonight.

**Conclusions/action items:**

Tomorrow, we will present our project at the final poster presentation, and we will finish a rough draft of our final report.



## 2019/10/18-BPAG notes

• KYLIE GASPAR • Oct 18, 2019 @12:37 PM CDT

**Title:** BPAG Notes

**Date:** 2019/10/18

**Content by:** Kylie Gaspar

**Present:** Kylie

**Goals:** Learn correct techniques for funding of all engineering projects.

**Content:**

Client purchases directly >>>> getting reimbursed after paying for ourselves

Keep track of all expenses

- important for future teams
- keep receipts in notebook
- table of expenses - notebook, progress report, and report

Easier to find all parts in one place to make it easy for client and you

If NOT using UW funds

-Can buy anything- make sure to get reimbursed by end of the semester (if client doesn't pay directly)

If UW funds

- have to follow UW purchasing rules
- Client pays, makes everything easier
  - Funding string (makerspace account)
  - Shop@UW (MD number)
    - If something is not on shop@UW you have to prove it's not there and client has to use their card for outside purchase
- If you pay, it makes reimbursement harder (90 day rule)

Client has NO UW affiliation

- can request BME funding for rehab project-then follow UW funds rules
- If you don't get BME funding then anything is fair game, client can pay or you can pay and get reimbursed.

Only the BPAG can ask for reimbursement- can distribute funds back to team afterwards

e-reimbursement from UW clients

- need hard copies of receipts (date, purchaser name, vendor details, itemized, total cost)
- not a screenshot, not edited, printed email is OK, paper is OK
- no reimbursement beyond 90 days of purchase (allow 10 days for processing)

Contact-Susan Sauer susan.sauer@wisc.edu

Table (example on website) with all vital info (Item, description, supplier, part #, Link to part, quantity, date, price, total)

-this is so people can go buy it again if they want to make the design again or need replacement

\*\*when looking for parts, find your part on a shop uw vendor first, then go to shop UW and find the exact part

\*\*even if didn't BUY something (free sample), put it in table

**Conclusions/action items:**

Get client to buy things, reimbursement is hard



## 2019/10/08 - Biology and Physiology - Bite forces of canines and cats

• Will Wightman • Oct 08, 2019 @04:45 PM CDT

**Title:** Biology and Physiology - Bite forces of canines and cats

**Date:** 2019/10/08

**Content by:** Will Wightman and Kylie Gaspar

**Present:**

**Goals:** Learn more about typical magnitude of forces distributed through animal mandibles.

**Content:**

The motion of a canine's mandible is mostly in the sagittal plane with very little lateral movement [1]. Movement of the jaw is achieved through the temporomandibular joint (TMJ) which is a synovial condylar joint that connects the lower mandible to the skull [1]. Acting around the temporomandibular joint as seen in Figure I, the jaw adductor muscles are responsible for the majority of bite force generation. These jaw adductor muscles are comprised of the masseter pterygoid, and temporal muscles [1]. The muscles only need to generate movement in the sagittal plane given the canine and feline animals have molar and premolar teeth that participate in a scissor-like action [1]. As stated earlier, motion of the jaw is achieved by jaw adductors and abductors. The bite force, which determines the stress on the mandible and our implant, comes from the already discussed jaw adductor muscles. These muscles' actions are as follows: the temporal muscles adduct the mandible and is opposed by the masseter muscle, the digastric muscles move the jaw posteriorly and also partake in abduction, the pterygoid muscle moves the jaw anteriorly.

The size, location, and thus the strength of all these muscles is dependent on the size and breed of canine. Canine skeletal structure of the skull varies widely species to species and even individual to individual [1]. This difference in structure leads to variations in insertions and originations of the many muscles in the jaw, confounding an already complex system. These confounding variables lead to a wide range of possible bite forces across canines, seen in Table I. This indicates that a large factor of safety is needed to guarantee that the implant will not fail.

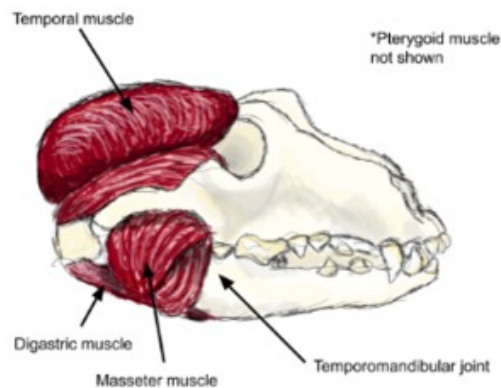
Sources:

[1] Kim, S., Arzi, B., Garcia, T. and Verstraete, F. (2018). Bite Forces and Their Measurement in Dogs and Cats. *Frontiers in Veterinary Science*, 5.

**Conclusions/action items:**

This information is not only essential for gaining a deeper understanding of the biology of canines' jaws, but also the types of forces needing to be withstood and the wide variety of forces the patients will be able to produce.

• Will Wightman • Oct 08, 2019 @04:41 PM CDT



**Figure I:** This figure demonstrates the basic musculature of a canine skull in reference to the mandible. Pterygoid muscles not shown, but located between the roof of the canine's mouth and the posterior-medial edge of the mandible.



**DogMuscles\_White.png(595.2 KB) - download** Attached is Figure I demonstrating the musculature and anatomy of the Dog's Jaw

• Will Wightman • Oct 08, 2019 @04:43 PM CDT

Measured/Estimated Location	Bite Force (N)	Measurement/Estimation Method
Not specified	13–1,394	Measured by chewing transducer rolled with the rawhide
Canine teeth Molar teeth	147–926 574–3,417	Maximum bite force measurement by electronic stimulations
Canine teeth	300* 340* 571* 588*	Bite force estimation using equations of Kiltie Thomason Kiltie (adjusted) Thomason (adjusted)
Molar teeth	755* 849* 1,949* 2,036*	Kiltie Thomason Kiltie (adjusted) Thomason(adjusted)
Canine teeth Carnassial teeth	351.5* 549.8*	Bite force estimation using Thomason's equation
Canine teeth Carnassial teeth	231.99–511.80 620.33–1,091.1	Bite force estimation using finite element analysis

**Muscle\_Force\_Table.PNG(30 KB) - download** Table I demonstrates the wide variety of muscle forces recorded occurring in dogs [1].





## 2019/12/05 - Biology and Physiology - Biomechanical properties

**jaw**

- Will Wightman - Dec 11, 2019 @12:03 AM CST

**Title:** Biology and Physiology - Biomechanical properties jaw

**Date:** 2019/12/05

**Content by:** Will Wightman

**Present:** N/A

**Goals:** Gather final data for final report

**Content:**

The complex muscular system in the jaw, as stated in previous posts, is further complicated by the properties of bone.

- Bone is non-LEHI
  - nonlinear
  - non-isotropic
  - non-homogenous
  - viscoelastic
- Effected by factors...
  - water content
  - the angle of application of a load
  - the rate at which a load is applied
- However, bone is often assumed to be LEHI in order to simplify the calculations for modeling the system.
  - Typically, a modulus of elasticity of 1.7 GPa to 7.5 GPa and Poisson ratios of 0.39 to 0.4 are used to model this tissue

Sources:

[x] Kim, S., Arzi, B., Garcia, T. and Verstraete, F. (2018). Bite Forces and Their Measurement in Dog and Cats. *Frontiers in Veterinary Science*, 5.

**Conclusions/action items:**

This provides insight to the team to provide engineering insight and solutions to a biological problem.



## 2019/09/11 - Competing Designs - Bridging Plate

- Will Wightman - Sep 12, 2019 @02:32 AM CDT

**Title:** Competing Designs - Bridging Plate

**Date:** 2019/09/11

**Content by:** Will Wightman

**Present:** N/A

**Goals:** Develop a deeper understanding of the currently existing products and the clients needs

**Content:**

### Summary of bridging plates:

In order to allow continued use and normal function of the mandible of veterinary canine patients who for one reason or another are lacking a portion of their jaw, veterinary surgeons must use one of a variety of grafting techniques. One such grafting technique is the bridging plate.

The general bridging plate is an alloplastic insert, usually made of titanium or some other non-reactive and bio-compatible material. The plate's main purpose is to provide mechanical reinforcement and resistance throughout the canine patient's recovery period. This general category of implant does not actively induce osteogenesis and other such crucial components of bone regrowth and patient recovery. However, some designs do take measures to insure that the periosteum remains as undamaged as possible.

In order to leave this extremely active, living, and dynamic portion of the bone alone so as not to hinder its normal function and to allow the plate greater patient-to-patient adaptability, some designs limit the direct contact with the bone. Given location of the implant and quality of bone along the jaw matters (IE different regions within the jaw may have different bio-mechanical properties that can be related to periosteum health and various force distributions), maintaining the health of the remaining bone is crucial.

Multiple bridging plates of different sizes were used to accommodate the diversity in both size and oral strength of the canine family. Ideally, the plate should be as small as possible to limit obstruction to the canine's normal lifestyle and its interactions with its environment. However, both the increased power of the bites of larger dogs and the potential for larger gaps in their mandibles intuitively indicates that the bridging plates for the larger and more powerful dogs must be larger and probably more obstructive to distribute these forces effectively.

### Immediately relevant information

Primary design development and Finite Element Testing was done using CAD software (SolidWorks) in order to reduce amount rapid fabrication needed. First, three dimensional images of the skulls of various canine species were used to develop models of typical jaws. Those scanned jaws were then integrated with the various designs for the bridging plates and tested using Finite Element Testing.

Sources:

[1] E.P. Freitas, S.C. Rahal, A.C. Shimano, J.P. Lopes da Silva, P.Y. Noritomi, A.O. El-Warrak, and A. Melchert. "Bridging Plate Development for Treatment of Segmental Bone Defects of the Canine Mandible: Mechanical Tests and Finite Element Method," *Journal of Veterinary Dentistry*, vol. 33, p.18, 2016. [Online] [sagepub.com/journalsPermissions.nav](http://sagepub.com/journalsPermissions.nav) [Accessed September 11, 2019]

**Conclusions/action items:**

Based on the resources provide by the client, it is safe to assume the condition of each patient is likely to be "diagnosed" via analysis of some three dimensional scan of the patient. Given this information and that the goal of the team is to develop a system to design a wide variety of solutions for patient specific bridging plates, it is apparent some sort of computation based design method will be necessary. Perhaps this computation based design could be integrated into some sort of plug in that can be used by the client. Research should be done into the nature of such plug ins as well as current computation based design methods and automated 3D design.



## 2019/09/18 - Regulations and Standards - FDA regulations for Veterinary Research

• Will Wightman • Oct 08, 2019 @01:11 AM CDT

### Title: Regulations and Standards - FDA regulations for Veterinary Research

Date: 2019/09/18

Content by: Will Wightman

Present: N/A

**Goals:** Gain a deeper understanding of federal requirements for animal study to not only develop a legally compliant product but to also understand the ethical requirements of animal research in general

### Content:

Human experimentation and drug and medical device research is strongly regulated by the FDA.

A branch of the FDA insures that animal experimentation and research is done ethically and humanely. In general, these guidelines and enforcing agencies are less strict than their medical research counterparts.

Most federal guidelines are directed towards the ethical treatment of "typical" lab animals like rats, mice, monkeys, and birds. These requirements include (but are not limited to)...

1. Experimentation must not cause undue and unnecessary harm beyond the potential weighted benefits
2. Like in human research, animal based research protocols must be reviewed by an institutional review board (must contain at least one non-scientifically related professional like a clergyman or non-scientific historian) [1]
3. Any scientist wishing with an approved protocol must be willing and able to submit to inspections from Inspections Services and the Institutional Animal Care and use Committee [1]
4. Any experimental animals housed in a lab must be provided at least a minimum quality of care (ie clean environment, healthy nutrition (unless dietary modifications are a part of the approved experimental procedure), and socialization and activity (unless modifications to activity are a part of the approved experimental procedure).

Veterinary surgical research has fewer restrictions than normal animal experimentation. However, researchers must still have oversight and must follow certain regulations.

1. All experimentation for veterinary purposes must comply with federal regulations such as the Animal Welfare Act, the Laboratory Animal Welfare Act and must be overseen by organizations like the Animal and Plant Health
2. However, if an experiment or new surgical procedure is simply a small modification of an existing product, it does not require oversight

As with human medical devices, veterinary devices must meet certain requirements. However, these requirements are much less strict than the requirements for human medical devices.

1. In order to mitigate accidental human misuse and to comply with the FDA's Compliance Policy Guide (CPG Sec. 607.100), the product (computational process or implant) would have to be clearly designated for animal use only.
2. If radiation emitting, a product would need to comply with 21 CFR 1000-1050
3. If classifiable as a drug (by chemical process alters physiological processes of an animal), the product would need premarket approval.

### Sources:

[8] National Research Council (US) Committee to Update Science, Medicine, and Animals. Science, Medicine, and Animals. (2004). [Online] Washington (DC): National Academies Press (US); Regulation of Animal Research. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK24650/> [Accessed 18 Sep. 2019]

### Conclusions/action items:

Given this experiment does not intentionally cause harm for research purposes and is a modification of a well-known and tried technique, it requires almost no oversight from the previously mentioned boards. This means neither the team nor client will be required to submit a protocol to the Animal and Plant Health or an institutional review board.

In order to comply with CPG Sec. 607.100 and avoid accidental human misuse, the team will clearly mark the procedural software and the resulting implants with markings indicating the products are not intended to be used on human patients.

Neither the program nor the resulting implants can be considered radioactive. Not the program, the bridging plate, nor the surgical guide plate can in any application be considered a drug. If the titanium lattice/mesh was laced with osteogenic chemicals and growth factors, then the team and client would be required to get premarket approval before releasing the product to the market.



## 2019/10/23 - DICOMM Conversion to STL

• Will Wightman • Oct 24, 2019 @01:34 AM CDT

**Title:** Converting DICOMM Files to STLs via 3D-Slicer, blender, and AutoDesk MeshMixer

**Date:** 2019/10/23

**Content by:** Will Wightman

**Present:** NA

**Goals:**

Find an open source method to convert CT scan data to STL files which can more easily be used in common FEA.

This approach is more for the team's benefit than a potential process for the client.

**Content:**

In order to begin the process of converting DICOM files storing data from CT scans into an easy to use STL file, I followed a tutorial on YouTube [1].

Given the tutorial goes in depth into every step of the process, I will only give a brief overview of the majority of the steps and will only comment on any additional difficulties or tricks I discovered.

This tutorial made use of 3 programs, each with a specific set of purposes.

### 1. Slicer

Slicer is a CAD software that is capable of converting DICOM files containing CT scan data into other more computationally friendly formats [2].

It is an open source software developed by the NIH in order to allow easy, 3D visualizations of patient data.

Unfortunately, as the software is open source and does not get frequently updated, it does not maintain FDA guidelines and has some restrictions with its usage in medical practices.

However, given the client is looking to solely apply this process for veterinary patients, the FDA guidelines are far more lax.

Further research is needed as to whether this software is viable as a permanent solution to the problem for the client.

#### Description of Process:

In this software, the user imports a DICOM file with patient data. The user must first ensure any folder containing the DICOM data is unzipped.

After importing this data and setting various contrasts, the tutorial instructs the user to select the "Edit" option in the drop down menu. The software has since been updated and the feature is now listed under the "Legacy" option in the same drop down menu.

### 2. blender

blender is an open source CAD environment that is able to be used for a wide variety of applications, from 3D modeling to kinetic simulation and even to video game animation [3].

#### Description of Process:

In this tutorial, blender is used to remove any noise left from the conversion from DICOM to STL and to smooth the STL file.

The tutorial explains this portion of the process and it is easy to use. In theory, similar results can be achieved in AutoDesk MeshMixer, but in practice it is more efficient to use blender. It's far less finicky.

### 3. MeshMixer

MeshMixer is a free software that is used to easily clean, edit, and break apart STL files. STL files can, in a way, be thought of like PDFs. Lacking in metadata, these files are highly simplified surface models of the 3D files. MeshMixer allows the user to edit these "primitive" STL files and sew together any holes in the images.

#### Description of Process:

Here is where the team's process deviates from the tutorial. In the tutorial, the bone being extracted did not need to be separated at any joints. In the team's process, the jaw needs to be removed from the rest of the skull. This can be a finicky process to say the least.

First, select edit and generate surface groups. This will allow the user to crop out any remaining noise in the image as well as easily remove random, disconnected bones.

Use the select tool and select on of the color coded groups on the STL (just draw on it a little). Select modify, and then have it expand to rest of group or connected pieces.

You can delete parts using the 'x' key or click 'i' to invert the selected area so you can invert and delete or keep. Whatever you prefer.

#### Sources:

- [1] YouTube Tutorial - [https://youtu.be/B\\_SC\\_WZgb5A](https://youtu.be/B_SC_WZgb5A)
- [2] Slicer.org - <https://www.slicer.org/>
- [3] blender - <https://www.blender.org/>
- [4] MeshMixer - <http://www.meshmixer.com/>

#### Conclusions/action items:

This process, though easy with the tutorial, was laborious and confusing at times. Ideally, the user should be familiar with their preferred method of DICOM to STL conversion.

Having experience with the conversion process does provide some insight into current methods of implant development, in particular how the team's project can reduce discomfort for the client.

Now that the team has access to the files and software needed to edit the STL files of the patient's mandibles, the team should be able to proceed to stress testing (FEA) and printing presentation aids.

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• Will Wightman • Oct 24, 2019 @01:13 AM CDT



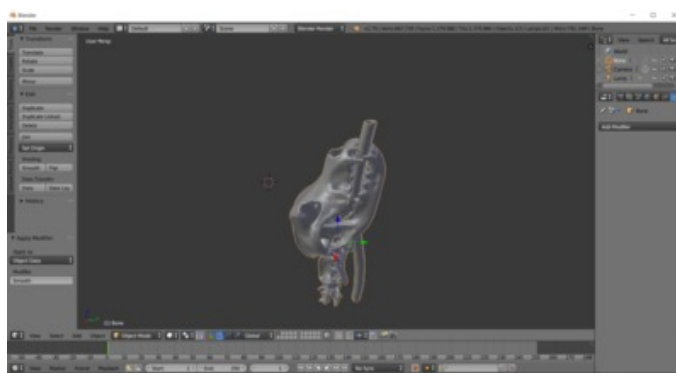
CleanedUpFullSkull.stl(45.2 MB) - [download](#)

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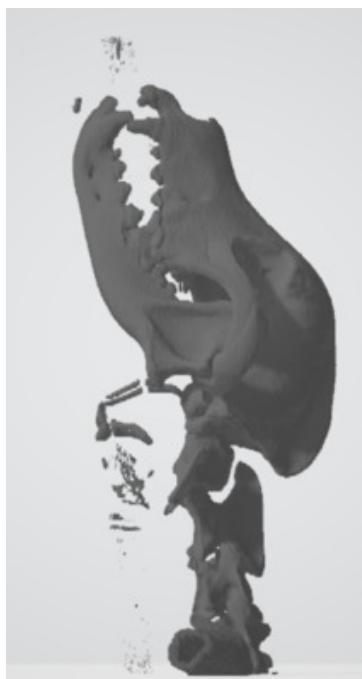
• Will Wightman • Oct 24, 2019 @01:13 AM CDT



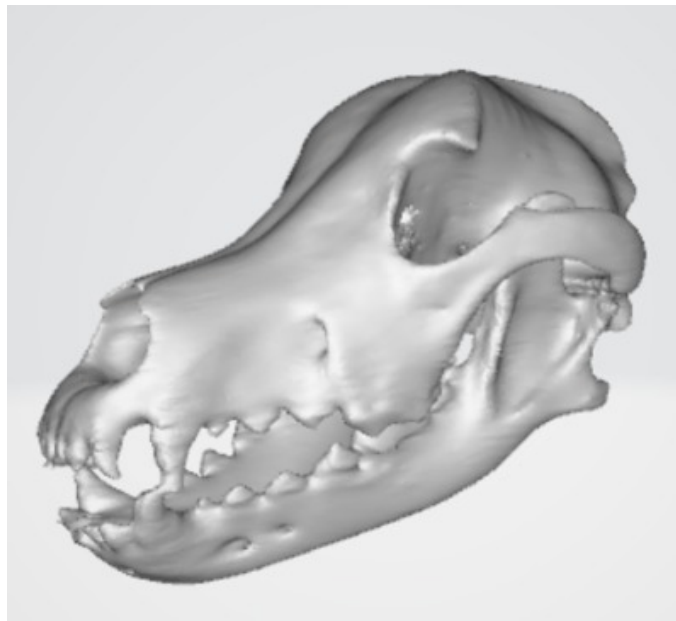
CleanedUpJaw.stl(11 MB) - [download](#)



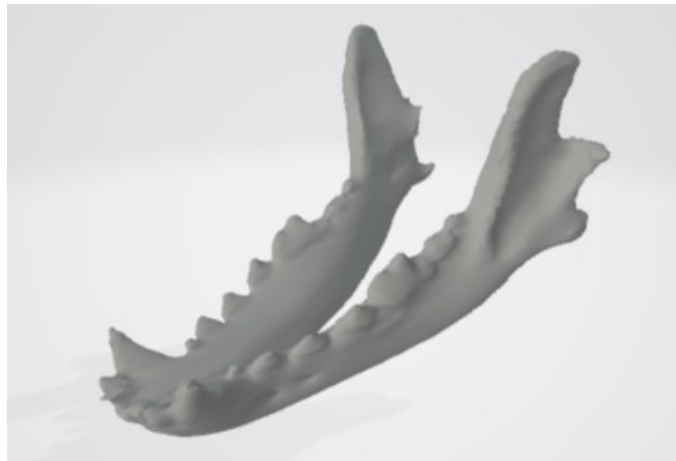
**blenderCleanAndSmooth.PNG(301.5 KB) - [download](#)** This image shows the STL file that was output from Slicer being edited in blender



**UneditedSlicer.PNG(144.3 KB) - [download](#)** This shows an un-smoothed and unedited STL output from Slicer



**FullSkull.PNG(109.7 KB)** - [download](#) This shows the smoothed and cleaned skull 3D image after initial processing in MeshMixer



**ExtractedJaw.PNG(124.9 KB)** - [download](#) This image shows the final isolated, smoothed, cleaned, and fixed jaw





## 2019/11/03 - Development of data structures

- Will Wightman - Dec 10, 2019 @10:20 PM CST

**Title:** Development of data structures

**Date:** 2019/11/03

**Content by:** Will Wightman

**Present:** N/A

**Goals:** Develop a data structure and file system in order to begin development of algorithms

**Content:**

In order to write algorithms involving STL objects, it is first necessary to have a way of representing STL objects in computational spaces.

### **Triangle.java**

The functional unit of the STL, as defined in previous posts, is the triangle. These triangles are represented by the coordinates of their corners, and a unit vector that is perpendicular to the surface pointing away from the inner body of the STL.

The Triangle class both stores these coordinates and normal vector and also contains methods that calculates the area of the triangle, the angles from the coordinate system, and the cross product to calculate the normal vector.

### **BinarySTLio.java**

In order to work with STL objects, it's necessary to be able to load these objects from files. Large files often use a more compact file format that is unable to be read with a typical ASCII text reader, as discussed in previous posts.

In order to load these compact files, a byte stream was used to read the data from the files byte by byte. This class will eventually contain methods in order to both read and write binary files.

### **STLFile.java**

This class is a collection of Triangle objects which will contain grouping algorithms.

**Conclusions/action items:**

These classes will allow the team to be able to begin working with algorithms that may be needed in the project without the necessity of coding in C++



## 2019/11/11 - Simplification of STL file IO

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- Will Wightman - Dec 10, 2019 @11:25 PM CST

**Title:** Simplification of STL file IO Edit Page Name

**Date:** 2019/11/11

**Content by:** Will Wightman

**Present:** N/A

**Goals:** Simply file architecture and smooth program flow

**Content:**

**BinarySTLio.java + ASCII STLio.jav => STLio.java**

Combined separate IO classes for different versions of file format to a single file to allow for more stream-lined program flow.

In addition to simplifying the overall architecture, STLio.java was modified to more accurately read data files.

**Conclusions/action items:**

These additions will allow future ease in programming and algorithm development.



## 2019/11/28 - Development of simplification algorithms

- Will Wightman - Dec 11, 2019 @01:56 AM CST

**Title:** Development of essential functions for simplification algorithms

**Date:** 2019/11/28

**Content by:** Will Wightman

**Present:** N/A

**Goals:** Develop essential functions for simplification algorithms

**Content:**

### Centroid of a Triangle

A useful function which can be used in determining the grouping of triangles into faces or the translation of a model around a point.

$$\textit{Centroid} = \sum_{i=1}^3 \frac{\textit{Corner}_i}{3}$$

### Weighted Area Vector

A function that can be used in grouping algorithms when simplifying faces of geometries.

$$\textit{AreaVector} = \sum_{i=1}^N \textit{Area}_i * \textit{Normal}_i$$

### Area of a Triangle

This function is essential for many algorithms including the simplification of faces

$$\textit{Area} = \frac{|r_1 \times r_2|}{2}$$

**Conclusions/action items:**

Each of these equations is essential for more complicated algorithms



## 2019/11/26 - FEBio Analysis - Importing manually simplified models

- Will Wightman - Dec 11, 2019 @01:03 AM CST

**Title:** FEBio Analysis - Importing manually simplified models

**Date:** 2019/11/26

**Content by:** Will Wightman

**Present:** N/A

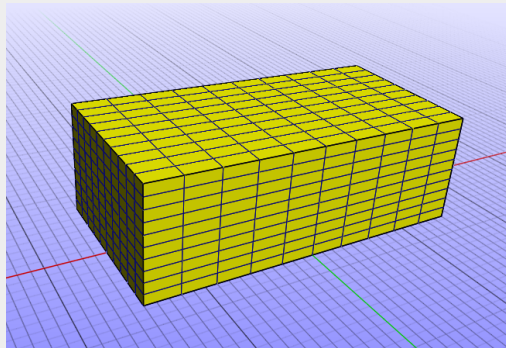
**Goals:** Attempt to run finite element analysis on simplified models

**Content:**

Given the complexity of FEBio, a step-wise approach was used when attempting to analyse the simplified models of jaws and implants.

### Prism Modeling

First, a simple prism defined with the same material properties as cortical bone. This was modeled using an uncoupled elastic material property with a Young's Modulus of 7.5 GPa with a Poisson ratio of 0.4 was used per previous research. This model was analysed using an even pressure applied to the top most face of the model. This system compiled and analysis was easily completed.

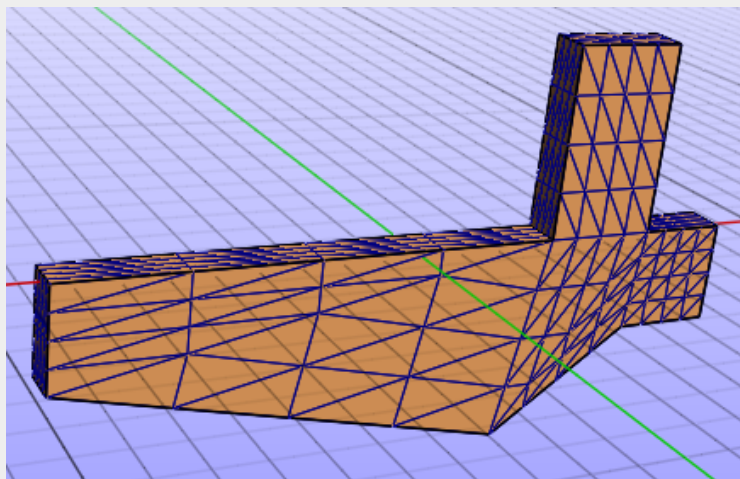


**Model Prism** - Simplified model to practice analysis with atypical force types and material properties.

This geometry was then subjected to a point load using the Nodal Load option. The combination of atypical load type and complex material properties led to errors in compilation. The issue resolved itself after the model was reloaded into the system. More research is needed as to the inner workings of FEBio.

### Simplified Jaw Modeling

Next, a simplified model of the canine mandible developed by Laura Richmond was imported into FEBio. This model was converted to a mesh with an element count greater than 300 to allow more accurate stress analysis. This model was first defined with standard but irrelevant material properties in order to test the application of different types of loads. The first load applied was a simple surface pressure and the system compiled easily.



**Meshed Simplified Jaw** - This image shows a meshed version of one of the simplified mandible models

When this model was subjected to a nodal load, the system did not compile. The system was reloaded and defined multiple times and the system continued to not compile. More work is needed.

**Conclusions/action items:**

These preliminary tests allow the team to begin testing the functional differences between SolidWorks and FEBio.

Further research is needed into the inner workings of FEBio to understand where the program is failing to compile.



## 2014/12/02 - FEBio Analysis - Simplified analysis

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- Will Wightman - Dec 11, 2019 @01:23 PM CST

**Title:** FEBio Analysis - Simplified analysis

**Date:** 2019/12/02

**Content by:** Will Wightman

**Present:** NA

**Goals:** Complete any level of stress analysis in FEBio

**Content:**

Final stress analysis was completed using nodal face selection with simple pressure loads

**Conclusions/action items:**

In order to use FEBio to its full potential, it is absolutely necessary that any future teams must work with FEBio experts and staff specialists on campus from the beginning.



## 2019/09/19 - Brain Storming - Process flow charts

---

- Will Wightman - Sep 21, 2019 @01:03 PM CDT

**Title: Brain Storming - Plug-in Flow Chart**

**Date:** 2019/09/19

**Content by:** William Wightman

**Present:** N/A

**Goals:**

Develop a flow chart that will cover every key elements of the optimization process and all key components

Discuss specific implementations of the process

**Content:**

General Flow

The process should have all of the below listed steps, in one form or another.

See attached photo for general flow chart.

Specific Implementations

As an end goal, this product should be easily accessible and easy to use by members of the veterinary community. In order to do this, the optimization software must be able to run in a common platform and have as few separate components as possible.

In order to meet these needs, I propose the development of a plug-in for a common CAD software like SolidWorks, Auto desk, or Blendr. This way the product could be easily accessible to veterinarians without the need to purchase expensive licenses.

**Conclusions/action items:**

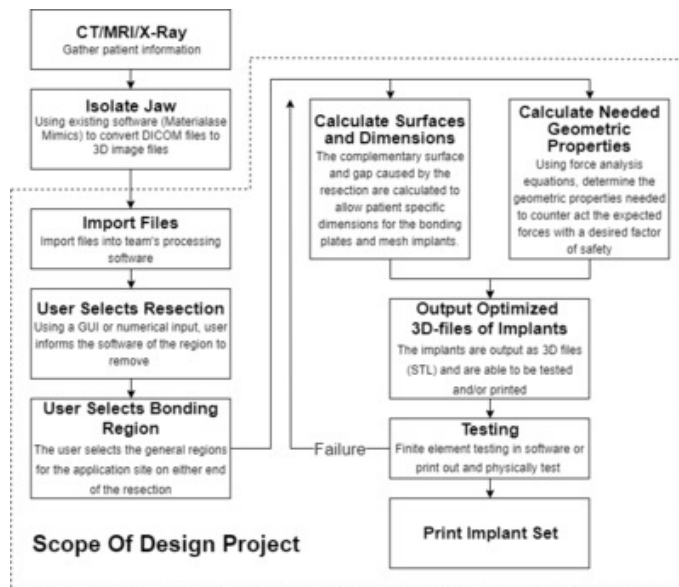
General Flow

Given this project is not a typical BME project in which one standard device is generated and optimized for the client, it is important to clearly layout and define the process. This will insure the entire team is working toward the same goal.

Specific Implementations

The plug-in implementation is an end-goal product. With the experience of team members considered, this is not likely a feasible goal for a single semester.

It is important to keep this option in mind as the licensing fees for several of these soft wares can reach prices in the thousands of dollars.



20190919\_Process\_Flow.png(65.2 KB) - download General Implementation - This flowchart defines every step necessary to the design process





## 2019/09/19 - Brain Storming - User Interface

• Will Wightman • Sep 19, 2019 @11:33 PM CDT

**Title:** Brain Storming - User Interface

**Date:** 2019/09/19

**Content by:** Will Wightman

**Present:** N/A

**Goals:** Develop a general idea of what a user interface for this project could look like.

**Content:**

In order to make the process for generating these patient specific mandibular plates as accessible and easy to use as possible, the software user's involvement must be as pain-free as possible. One way to reduce some of the front end complexity of a task such as our process is to use a graphic user interface (GUI).

Given the potential variation from patient to patient and its associated need to tweak certain complex factors, the GUI would need to be precise, robust, and easy to use. The user should be able to receive accurate precise numerical feedback while not being encumbered with doing complex and insightful analysis. The user should be able to reach the same end goal by intuition as they would if they were intimately trained on the matter.

General Description:

- 3D model representation of the jaw, pre-fracture removal, would be loaded into the window
- the user can then select the region of the mandible that will be removed with a simple drag and drop mechanism
- An x-ray of the mandible, which would provide information such as the location of critical areas like the roots of teeth, could be overlaid on the 3D model for easier region selection
- The user could then drag and drop or highlight the region of the jaw when bridging plate insertion would be ideal
  - Maybe the GUI could auto-suggest certain regions?

**Conclusions/action items:**

GUIs allow individuals the ability to directly control a complex process without needing to know many implementation details. This could allow our product to be used by almost any veterinary dental surgeon who, though experts in surgery and canine physiology, are not experts in the mechanics behind graft optimization.

• Will Wightman • Sep 19, 2019 @11:06 PM CDT



20190919\_MatlabVeiw\_RegionSelection.png(748 KB) - [download](#) Figure 01: This drawing shows a very rough sketch of a potential user interface for the design process



## 2019/09/30 - Product Research - STL File Format

- Will Wightman - Sep 30, 2019 @06:14 PM CDT

**Title:** Development Research - STL File Format

**Date:** 2019/09/30

**Content by:** Will Wightman

**Present:** N/A

**Goals:** Gain a deep understanding of the STL file format for use in reading/writing/saving STLs

**Content:**

STL (Standard Triangle Language) files are 3D image files that approximate the surface of a 3D object with triangles.

Each triangle is represented by 12 floating point numbers. 3 for the normal surface vector and three for each point of the triangle defined in 3D Cartesian space.

This format has two main form factors, one binary, one ASCII.

**ASCII**

The ASCII factor is easy to write by hand and needs to be written in the following format.

```

solid fileName
    facet normal 0.00000E+000 0.00000E+000 0.00000E+000
        outer loop
            vertex 0.00000E+000 0.00000E+000 0.00000E+000
            vertex 1.00000E+000 0.00000E+000 0.00000E+000
            vertex 0.00000E+000 1.00000E+000 0.00000E+000
        endloop
    endfacet
    facet normal 0.00000E+000 0.00000E+000 0.00000E+000
        outer loop
            vertex 0.00000E+000 0.00000E+000 0.00000E+000
            vertex 1.00000E+000 0.00000E+000 0.00000E+000
            vertex 0.00000E+000 1.00000E+000 0.00000E+000
        endloop
    endfacet
endsolid fileName

```

Each polynomial requires 1 facet loop. The code above shows two triangles, seen in their own loops. STLs can only (reliably) handle triangles, so don't write squares or other polynomials.

**Binary**

The binary format is much harder for humans to read by eye and write by hand but is much more storage efficient and easier for computers to read.

The binary format has an 80 character ASCII header followed by binary representations of each triangle, each triangle being represented by 12 floating point numbers, as listed above.

**Sources:**

[1] - <https://danboscott.ghost.io/writing-an-stl-file-from-scratch/>

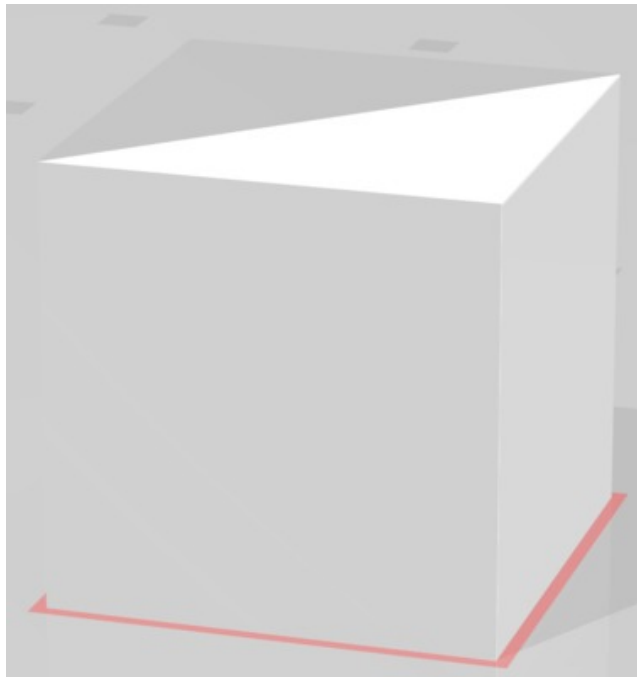
[2] - [http://www.fabbers.com/tech/STL\\_Format#Sct\\_binary](http://www.fabbers.com/tech/STL_Format#Sct_binary)

**Conclusions/action items:**

This information is critical for this project as we are to be opening, reading, and writing STL constantly. Having an in-depth knowledge of this format, which is the most common and standard format of 3D image file, can be useful when determining algorithms for modifying and saving these new files. Knowing the different formats for STLs can also help in decision making about data and storage usage.

More research is needed into STL readers, writers, and editors, particularly those that can handle STLs

• Will Wightman • Sep 30, 2019 @06:08 PM CDT



**STL\_CUBE.PNG(19.8 KB) - download** This STL file was written by hand using the ASCII encoding for STL files. This is what the file looks like in a 3D image veiwier.

• Will Wightman • Sep 30, 2019 @06:10 PM CDT

```
solid testTri
  facet normal 0.000000e+000 0.000000e+000 -1.000000e+000
    outer loop
      vertex 0.000000e+000 0.000000e+000 0.000000e+000
      vertex 1.000000e+000 0.000000e+000 0.000000e+000
      vertex 0.000000e+000 1.000000e+000 0.000000e+000
    endloop
  endfacet
  facet normal 0.000000e+000 0.000000e+000 -1.000000e+000
    outer loop
      vertex 1.000000e+000 0.000000e+000 0.000000e+000
      vertex 0.000000e+000 1.000000e+000 0.000000e+000
      vertex 1.000000e+000 1.000000e+000 0.000000e+000
    endloop
  endfacet
  facet normal 1.000000e+000 0.000000e+000 0.000000e+000
    outer loop
      vertex 1.000000e+000 0.000000e+000 0.000000e+000
      vertex 1.000000e+000 0.000000e+000 1.000000e+000
      vertex 2.000000e+000 1.000000e+000 0.000000e+000
    endloop
  endfacet
  facet normal 1.000000e+000 0.000000e+000 0.000000e+000
    outer loop
      vertex 1.000000e+000 0.000000e+000 1.000000e+000
      vertex 2.000000e+000 1.000000e+000 1.000000e+000
      vertex 1.000000e+000 1.000000e+000 0.000000e+000
    endloop
  endfacet
  facet normal 0.000000e+000 1.000000e+000 0.000000e+000
    outer loop
      vertex 0.000000e+000 1.000000e+000 0.000000e+000
      vertex 2.000000e+000 1.000000e+000 0.000000e+000
      vertex 1.000000e+000 1.000000e+000 1.000000e+000
    endloop
  endfacet
  facet normal 0.000000e+000 1.000000e+000 0.000000e+000
    outer loop
      vertex 0.000000e+000 1.000000e+000 1.000000e+000
      vertex 0.000000e+000 2.000000e+000 1.000000e+000
      vertex 1.000000e+000 1.000000e+000 1.000000e+000
    endloop
  endfacet
  facet normal -1.000000e+000 0.000000e+000 0.000000e+000
    outer loop
      vertex 0.000000e+000 0.000000e+000 0.000000e+000
      vertex 0.000000e+000 1.000000e+000 0.000000e+000
      vertex 0.000000e+000 1.000000e+000 1.000000e+000
    endloop
  endfacet
  facet normal -1.000000e+000 0.000000e+000 0.000000e+000
    outer loop
      vertex 0.000000e+000 0.000000e+000 0.000000e+000
      vertex 0.000000e+000 0.000000e+000 1.000000e+000
      vertex 0.000000e+000 1.000000e+000 1.000000e+000
    endloop
  endfacet
  facet normal 0.000000e+000 -1.000000e+000 0.000000e+000
    outer loop
      vertex 0.000000e+000 0.000000e+000 0.000000e+000
      vertex 1.000000e+000 0.000000e+000 0.000000e+000
      vertex 1.000000e+000 0.000000e+000 1.000000e+000
    endloop
  endfacet
  facet normal 0.000000e+000 -1.000000e+000 0.000000e+000
    outer loop
      vertex 0.000000e+000 0.000000e+000 0.000000e+000
      vertex 1.000000e+000 0.000000e+000 0.000000e+000
      vertex 2.000000e+000 0.000000e+000 1.000000e+000
    endloop
  endfacet
endsolid
```

**testTri.txt(3.4 KB) - download** This file contains the ASCII encoding of this STL file



**testTri.stl(3.4 KB) - [download](#)** This is the official STL file for the cube above. The only difference between the text file and this STL file is the extension type



## 2019/10/05 - Brain Storming - Using properties of STLs to generate implants

- Will Wightman - Oct 08, 2019 @01:13 AM CDT

**Title:** Development Research - Using properties of STLs to generate implants

**Date:** 2019/10/05

**Content by:** Will Wightman

**Present:** N/A

**Goals:** Begin brainstorming methods for how to implement user interface

**Content:**

STL files are a representation of a 3D object using triangles. Each of these triangles is represented with a 3D surface vector and 3 points in 3D space. (See Product Research - STL Format).

These properties can be used to provide the user with a lot of information.

Using vector magnitudes and component percentages to determine planes of interest within an STL file

It is difficult to teach a computer to know which components of a given image file from a patient correspond to important anatomical features. However, this information can be obtained by looking at the magnitudes and directions of each triangle in the model (Figure 1). Using the area of the triangle as a weight, the direction of the surface vectors can help determine the directions of anatomical planes.

The area of each triangle can be obtained by taking the cross product of two of the arms of the triangle and dividing it by two [1] ( $A = \frac{\|a_1 \times a_2\|}{2}$ )

The area of an individual triangle in a desired plane can be used as a weight for that surface vector to determine the average surface vector for a plane of interest (Figure 2). This surface vector for the plane of interest will provide the needed orientation of the bridging plates and surgical guidance plates.

The normal bridging plates will be roughly co-planar with the summed and average planes. The surgical guidance implant will have its bonding locations co-planar with the summed plane, but will have its guidance tracks orthogonal to both the summed plane and the angles of incision.

Sources:

[1] Properties of the Cross Product

- <https://math.oregonstate.edu/home/programs/undergrad/CalculusQuestStudyGuides/vcalc/crossprod/crossprod.html>

**Conclusions/action items:**

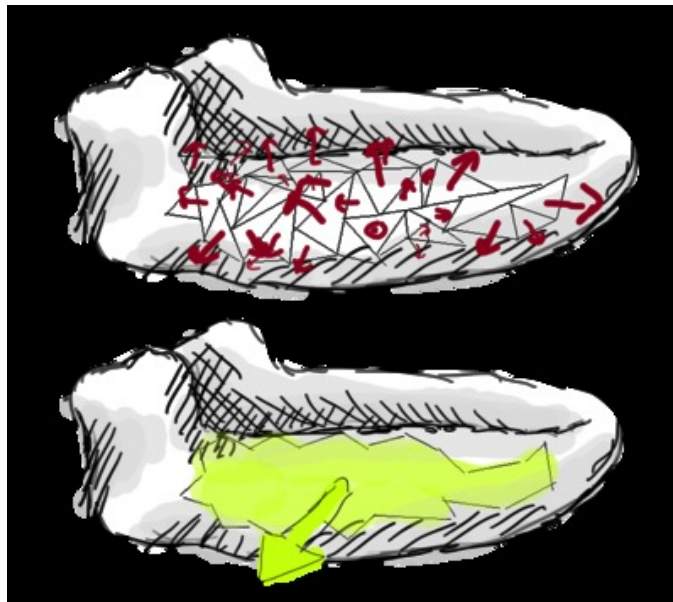
This approach will offer the team a starting point for finding an anatomically significant plane. Additionally, this approach is mostly mathematical, meaning team members with less coding experience will be able to more easily participate.

Research should be done to determine if more efficient algorithms or pre-existing ImageJ or Java packages exist. If so, this will make the process even easier.

More research into Java's 3D viewing/processing library is necessary before beginning to build an entire package. Specifically, the way STL files are represented in the existing frameworks.



**STL\_JawSurfaceVectors.png(145 KB) - download** Figure 1: This figure shows a representation of the cross surface vectors of the triangles on a 3D image of a dog's jaw



**STL\_JawSurfaceVectors\_Summed.png(307 KB) - download** Figure 2: This image shows the pre-weighted summation of the surface vectors (top) and the post-weighted summation with an approximately perpendicular surface



## 2019/09/30 - Brainstorming - Initial Design Idea Flow Charts

• Will Wightman • Oct 08, 2019 @12:07 AM CDT

**Title:** Brainstorming - Initial Design Idea Flow Charts

**Date:** 2019/09/30

**Content by:** Will Wightman

**Present:** Laura Richmond

**Goals:** Rewrite and organize proposed ideas

**Content:**

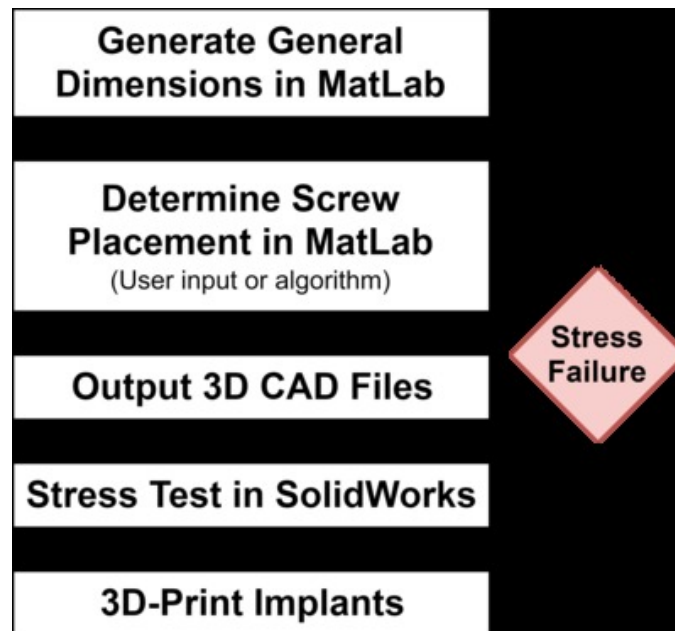
See attached images for the Tiered, Monolithic, Iterator, and Square One designs.

**Conclusions/action items:**

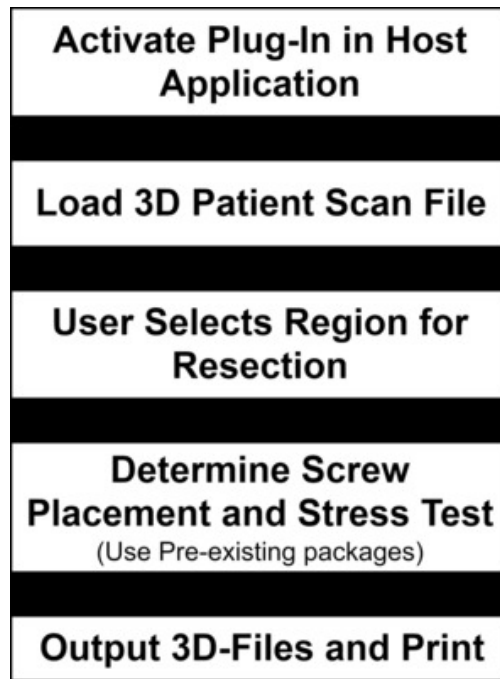
These figures will be used in the preliminary presentation and report to help clarify and convey the team's design ideas.

Hopefully, these diagrams will convey the concepts well enough to prompt good questions and feedback.

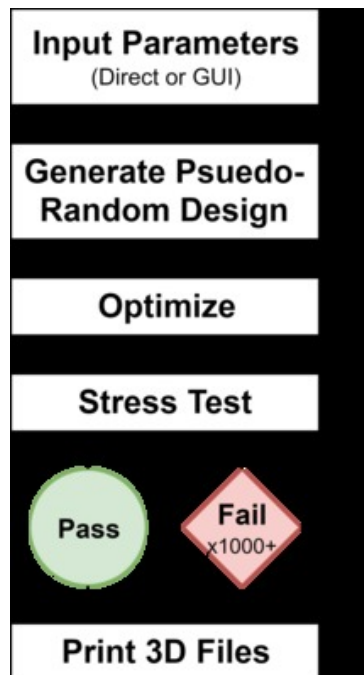
• Will Wightman • Oct 08, 2019 @12:13 AM CDT



**TheTiered\_20190930.png(351.7 KB) - [download](#)** The Tiered Approach - The tiered approach uses a modular approach to complete the general algorithm. Dimensions and screw placement are calculated in MatLab and stress testing is done in SolidWorks. (Image is transparent - If over black background, arrows flow down from Generate General to 3D-print implants with a "negative feedback" loop between stress testing and determine screw placement)

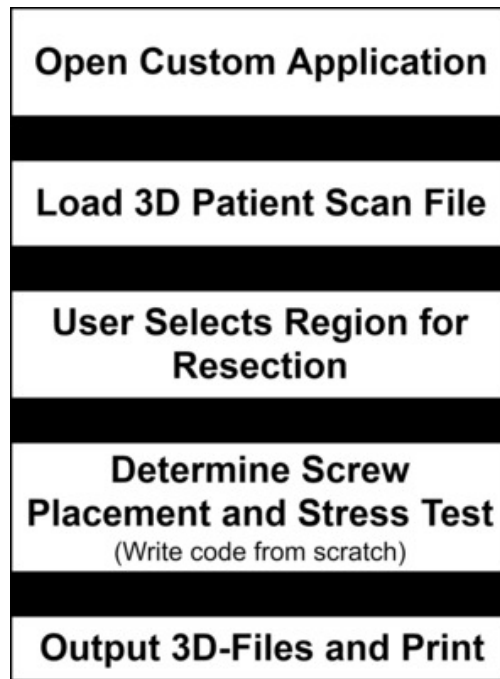


**TheMonolithic\_20190930.png(311.2 KB) - download** The Monolithic Approach - This approach is built as an plug-in for ImageJ, making use of existing packages for ImageJ and Java. (Image is transparent - If over black background, arrows flow from the top of the diagram to the bottom)



**TheIterator\_20190930.png(267.8 KB) - download** The Iterator Approach - The iterator makes use of the concept of generative design. Using a subscription service, the loop of stress testing and optimization is run thousands of times resulting in a highly optimized set of implants. (Image is transparent - If over black background, arrows flow from "Generate Psuedo-Random" to "pass" to "Print 3D Files". Alternate negative feedback bath flow from stress test to "Failure" to "Optimize")





**TheSquareOne\_20190930.png(297 KB) - download** The Square One Approach - The algorithm would be completed using a custom built application. It is similar in many ways to the Monolithic approach. (Image is transparent. If over a black background, arrows flow from top to bottom)



# 2018/09/17 - Red Pass

- Will Wightman - Sep 17, 2018 @12:36 AM CDT



RedPass.JPEG(28.7 KB) - [download](#)



## 2018/10/03 - SolidWorks

• Will Wightman • Oct 09, 2018 @12:10 AM CDT

**Title: SolidWorks Self-Training**

**Date:** 2018/10/03

**Content by:** Will Wightman

**Present:** N/A

**Goals:** Learn how to make moving assembly in SolidWorks in order to represent complex mechanisms.

**Content:**

In order to make a moving assembly, the initial parts must be made well defined

- Every place the part interacts with another part must have a very well defined structure (ie a locked diameter of a circle, an exactly placed midpoint of a line, parallel features)
- The parts must be well measured and able to line up well

The parts must be mated to each other properly

- Axial joints must be concentrically fixed
- Pieces that should not move in relation to each other should be locked together
- Pieces that should not move through each other (ie breaking the general laws of physics) should be fixed together

In order to make an animation of moving parts, a motion study must be done on the assembly

- If a piece is constantly rotating, an axial motor can be used at its joint
- If simple movement relative between two pieces is needed, simply select the time in the motion study you want that particular motion to end, then move the part to its final position
- If a motion is complicated, repeating the above step in small integral steps can be very helpful.

Sources:

- "SolidWorks For Dummies" - Greg Jabowski, 2008, ISBN: 978-0-470-12978-4
- YouTube - <https://youtu.be/pZZrP3fSctY>

**Conclusions/action items:**

In order to do this easily, designed parts must be clearly thought out and drafted before SolidWorks prototyping so that the entire process is easier.

A well thought out and defined piece is easier to integrate into an assembly than a sloppy one.



## 2018/10/09 - HIPPA, BioSafety, Bloodborn Pathogen Training

• Will Wightman • Dec 11, 2018 @01:47 PM CST

**Title:** HIPPA, BioSafety, Bloodborn Pathogen Training Certification

**Date:** 2018/10/09

**Content by:** Will Wightman

**Present:** N/A

**Goals:**

**Content:**

See attached image.

**Conclusions/action items:**

• Will Wightman • Oct 09, 2018 @12:18 AM CDT

University of Wisconsin-Madison

This certifies that WILL WIGHTMAN has completed training for the following course(s):

Curriculum	Group Name	Completion Date	Expiration Date
Basic/Refresher Course - Human Subjects Research	UW Biomedical Course	5/21/2018	5/20/2021
Biosafety Required Training Quiz	Biosafety Required Training	5/18/2018	
Bloodborne Pathogens Safety in Research	Biosafety 102: Bloodborne Pathogens for Laboratory and Research	5/11/2018	
HIPAA 2018-19 Completion Verification Quiz	2018-19 HIPAA Privacy & Security Training	6/18/2018	
HIPAA Privacy at UW	2017-2018 HIPAA Privacy & Security Training	5/21/2018	
The Basics of Effort Reporting	The Basics of Effort Reporting - UWM Course	5/21/2018	

Data Effective: Mon Oct 8 23:37:24 2018  
Report Generated: Tue Oct 9 00:13:00 2018

Screenshot\_51\_.png(569.9 KB) - [download](#)



## 2019/02/28 - Green Pass

• Will Wightman • Feb 28, 2019 @09:00 PM CST



GreenPassPermit.JPEG(40.8 KB) - [download](#)

• Will Wightman • Feb 28, 2019 @09:02 PM CST

**Title:** Green Pass

**Date:** 2019/02/28

See attached Image



## 2019/10/15 - Java Boot Camp - General Overview

• Will Wightman • Oct 15, 2019 @10:47 AM CDT

### Title: Java Boot Camp - General Overview

Date: 2019/10/14

Content by: Will Wightman

Present: N/A

Goals: Develop an brief overview of Java to inform the team before the team begins their own research

### Content:

Attached is a word document containing a brief overview of Java.

Also attached is a zip file containing code that exemplifies Object Oriented Programming in Java

### Conclusions/action items:

This should allow the team to dip their toes enough into Java that they will be able to better teach themselves from various tutorials online

• Will Wightman • Oct 15, 2019 @10:47 AM CDT

```

Java Jumpstart Tutorial 1 - "Stack" Theory
Will Wightman - Fall 2019

1. Stack vs Heap
  a. Stack
     I. Highly ordered, high priority memory, highly trimmed and maintained
     II. Functions, local object references, loops, and function calls live here
     III. Small size compared to heap
     IV. Think of like a labeled table, or a VIP parking where each slot has limited space
  b. Heap
     I. Less ordered, lower priority, trimmed and maintained occasionally
     II. Object bodies (the stuff the references point to) live here
     III. Larger than stack, can hold many bits of sequential information (like arrays)

2. Variables - Primitives vs Objects
  a. Primitives
     I. Can be represented with a simple string of binary (or hex) numbers
     II. Stored directly in the stack
     III. int (integer) - stored in stack - 1001, = 1010
     IV. char (character) - 'a', 'f', 'g', 'j'
     V. double (decimal point number) - 1.2, 4.567, 12.0
     VI. float (floating point) 1.595*10-3
  b. Objects
     I. Has a reference, a "name tag" that's written in binary like how primitives are written
     II. Like a box while it can contain functions, variables, other objects, ect.
     III. The values stored in the stack for this object is like an address to the end of the object (a pointer)
     IV. The reference can be stored in stack or in heap, depending on if it's being held by another object or not

3. Arrays vs Array List
  a. Both are objects/reference variables
  b. Can be any number of dimensions
  c. Can store an ordered list of other "things"
  d. Arrays
     I. Can hold primitives or objects
     II. Declared like this - ArrayType[] arrayName = new ArrayType[size];
        1. int[] matrix = new int[4][5]; String[] strings = new String[5];
        2. You add further dimensions by adding more brackets at declaration -
           int[][][] = a 4 dimensional array;
        3. Size MUST be an integer
     III. Set size - Arrays cannot be changed once you declare it (ie a 1D array with a size of 5 will always be 5 long)
        1. This DOESN'T mean the reference to an array stored in a variable cannot be swapped out. Must be the same number of dimensions
        2. int array1 = new ObjectType[];
     IV. Accessing data within an array
        1. arrayName[coordinate_1][coordinate_2]...[coordinate_n]

```

[Java\\_Jumpstart\\_Tutorial.docx\(23.6 KB\) - download](#) Fall 2019 - This document contains a very brief overview of most of the essentials of Java

• Will Wightman • Oct 23, 2019 @11:43 PM CDT

### Update - 2019/10/23

Shortly after the Java boot camp, the team began to pursue FEBio as an alternative to ImageJ given its already existing ability to test force distribution in biological systems.

FEBio is written primarily in C++. Given this, it was determined that developing a full library of example Java code would have been a waste of time for the leader and the team as a whole, at least until a final decision is made between FEBio and ImageJ



## 12/10/2019 - Ethics of this semester

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• LAURA RICHMOND • Dec 10, 2019 @12:50 PM CST

**Title:** Ethical considerations for this semester

**Date:** 12/10/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To clarify some ethical contributions to the team's decisions

**Content:**

This semester, a large impact on the decisions made came from the dogs themselves. While our clients wish to reduce waste of materials, the priority should be the dog's safety. While a large portion of our project was code, which poses no threat to the patient. The team had to be careful when testing to be sure the results were accurate to an appropriate degree in order to guarantee the safety of the patients.

Our clients did not want us to change the design of the implant. They wanted a process in which there was a computational way to minimize waste while creating an implant that would not fail under the force of the dog's jaw. Our solution used simplifications to do finite element testing as using the real implant was too complicated. With simplifications comes the risk that the model is not entirely accurate. To determine whether the simplifications were accurate enough, see results.

To compensate for the simplifications and to reduce the risk of injury to the dog, a higher than normal alpha value was chosen. This increases our confidence level and reduces the risk of our results being wrong.

**Conclusions/action items:**

Because of the adjustments made during testing, the team believes that there is minimal risk of injury to the patients if they were to use our process.



## 09/08/2019 - Mandibular Reconstruction

• LAURA RICHMOND • Sep 08, 2019 @05:05 PM CDT

**Title:** Mandibular Reconstruction

**Date:** 09/08/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To learn more about the surgical process of mandibular reconstruction.

**Content:**

- After tumors are removed there are issues in jaw continuity that impairs the patient. Mandibular reconstruction restores the jaw continuity with a osseous, or biocompatible, plate.
- Currently, the chosen material is titanium as it is biocompatible and can utilize locking screws which improve biomechanical movement.
- Some typical complications are plate exposure, plate fracture, and loss screws.

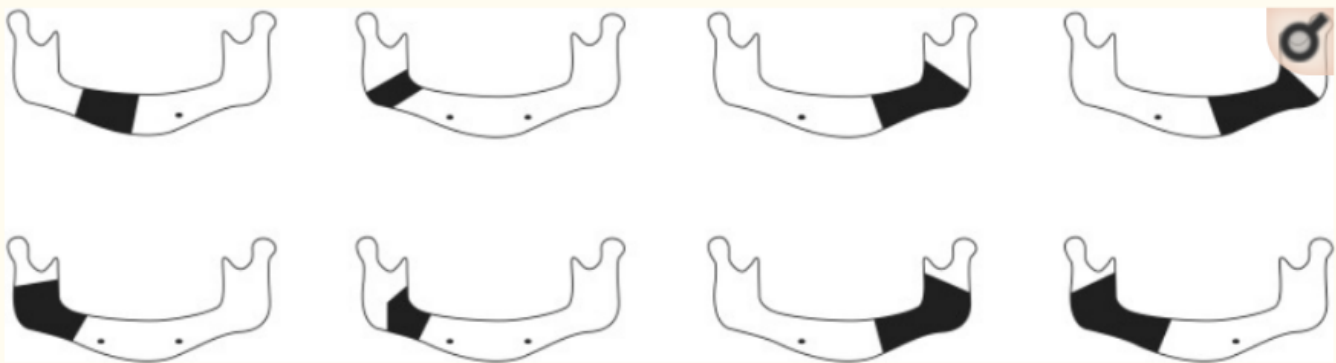


Fig. 6

Schematic images representing cases in which complications developed. A defect of the mandibular angle present in almost all cases.

- goals of mandibular reconstruction restore function and continuity to the jaw, maintain soft tissue, and improve postoperative quality of life.
- Plate fractures occur (sometimes cause by fatigue)
- Masticatory pressure contributes to vertical stress on the plates. This can lead to bone resorption around the screw which can cause the screw to loosen.
- Most complications are caused by moment and shear forces. eg. mastication (grinding of food) cause mechanical stress
- The forces caused by contraction of masticatory muscles (temporalis muscle, lateral and medial pterygoid muscle, masseter muscle). They act directly on the mandible.
- Plate fracture might be more statistically likely if the operation happens without bone grafts
- Coronoidectomy can reduce mechanical complications

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4279976/>

**Conclusions/action items:**

This article was specifically for human mandibular reconstruction. However, this information will still pertain to our project as we can now focus on the mandibular arch, the area most likely to have complications, as part of our research on the forces of a dogs bite. There is also other things we need to consider from this research. With a baseline of human mandibular reconstruction, I can now focus my research on the anatomy of a dog's jaw and the forces that will need to be considered in order to design a proper implant.





## 09/16/2019-Strongest Dog Bites

• LAURA RICHMOND • Oct 07, 2019 @08:28 AM CDT

**Title:** Strongest Dog Bites

**Date:** 09/16/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To research common forces in various breeds of dog.

**Content:**

This article looked at 10 different breeds of dogs and their corresponding bite forces. The dog with the highest bite force was the Kangal with 743 PSI! This is significantly higher up than the runner ups. The breed with the second strongest bite force was found to be an English Mastiff with a Bite Force of 556 PSI. The third strongest was the Wolfdog with a Bite Force of 406. These are significantly higher than the average pet dog. The Rottweiler, African Wild Dog, American Bull Dog, Doberman, and German Shepherd have bite forces of 328 PSI, 317 PSI, 305 PSI, 245 PSI, and 238 PSI respectively.

PSI stands for pounds per square inch and is used to measure the pressure applied over one square inch of a pound. It is the English system.

The PSI was found using a digital bite meter. In general, the bigger the dog, the stronger the biting force.

**Conclusions/action items:**

A good question to ask the client is which units will they use when creating the implant. In general, Americans use the English system however engineers use the metric system. Another thing this article is helpful with is just gaining knowledge on the maximum values that the implant will have to withstand. The article also indicates a correspondence between the weight of a dog and its biting force. In order to maximum efficiency, we could perform a linearization of weight vs bite force data and implement the equation in our code. The vet would enter the weight of the dog into the code along with the area of resection and anatomy and the program could use all that information to optimize an implant.

Rottweiler Life. (2019). *Strongest Dog Bite - Top 10 Dogs You should not Mess With*. [online] Available at: <https://www.rottweilerlife.com/strongest-dog-bite/> [Accessed 16 Sep. 2019].



## 10/01/2019-Dog Anatomy and Bite Forces

• LAURA RICHMOND • Oct 07, 2019 @11:35 AM CDT

**Title:** Cranial dimensions and forces of biting in the domestic dog

**Date:** 10/01/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To understand the anatomy of a dog's jaw and its related forces.

**Content:**

There are two considerations when determining the biting force of a domestic dog. The first is the interaction between the magnitudes of the biting force to the trophic specialization among species with a higher taxa. The second consideration is the control of craniofacial development by the genome and the epigenetic influenced during the ontogeny within a species.

The skull shape has been determined to be a factor in the strength of a domestic dog's bite force.

Table of Dog Database sorted by skull shape and size

Dog ID	Dog breed	Skull shape a	Skull size b	Sex c	Age d	Dog ID	Dog breed	Skull shape a	Skull size b	Sex c	Age d
13	Great dane	B	L	-	-	35	Afghan hound	M	L	F	A
22	Irish wolfhound	B	L	-	-	67	Afghan hound	M	L	M	A
89	Irish wolfhound	B	L	M	A	34	Berner sennenhund	M	L	F	A
95	Mastiff	B	L	M	-	66	Berner sennenhund	M	L	F	A
19	Newfoundland	B	L	-	-	2	Black lab retriever	M	L	-	-
25	St. Bernard	B	L	-	-	41	Collie	M	L	M	A
12	Boxer	B	M	-	-	79	Collie	M	L	M	A
33	Boxer	B	M	F	-	78	Collie	M	L	-	-
71	Boxer	B	M	F	J	83	German shepherd	M	L	M	A
72	Boxer	B	M	M	A	84	German shepherd	M	L	M	A
73	Boxer	B	M	M	A	36	Golden retriever	M	L	F	A
74	Boxer	B	M	M	A	81	Golden retriever	M	L	M	A
10	Bull mastiff	B	M	-	-	82	Golden retriever	M	L	M	A
18	Chow chow	B	M	-	-	14	Great dane	M	L	-	-
85	English bulldog	B	M	F	A	92	Greyhound	M	L	M	A
1	Boston terrier	B	S	-	-	45	Irish wolfhound	M	L	F	A
63	Boston terrier	B	S	M	A	52	Lab retriever	M	L	F	A
115	Boston terrier	B	S	F	A	20	Newfoundland	M	L	-	-
113	Bulldog	B	S	F	-	28	Rough collie	M	L	-	-
47	Griffon bruxellois	B	S	M	A	102	Siberian husky	M	L	M	A
91	Griffon bruxellois	B	S	F	A	26	St. Bernard	M	L	-	-
127	Griffon bruxellois	B	S	F	A	27	St. Bernard	M	L	-	-
42	King Charles spaniel	B	S	F	A	6	American pointer	M	M	-	-
53	King Charles spaniel	B	S	F	-	116	Berner sennenhund	M	M	F	-
97	King Charles spaniel	B	S	M	A	11	Boxer	M	M	-	-
98	King Charles spaniel	B	S	M	A	8	Caim terrier	M	M	-	-
21	Miniature poodle	B	S	-	-	32	Cocker spaniel	M	M	M	A
93	Pekingese	B	S	M	-	69	Cocker spaniel	M	M	F	A
68	Afghan hound	D	L	M	J	16	Dalmatian	M	M	-	-
30	Collie	D	L	F	A	15	English bull terrier	M	M	-	-
48	Saluki	D	L	F	A	38	English bulldog	M	M	F	A
5	Basset hound	D	M	-	-	86	English bulldog	M	M	F	A
4	Beagle	D	M	-	-	119	Greyhound	M	M	F	A

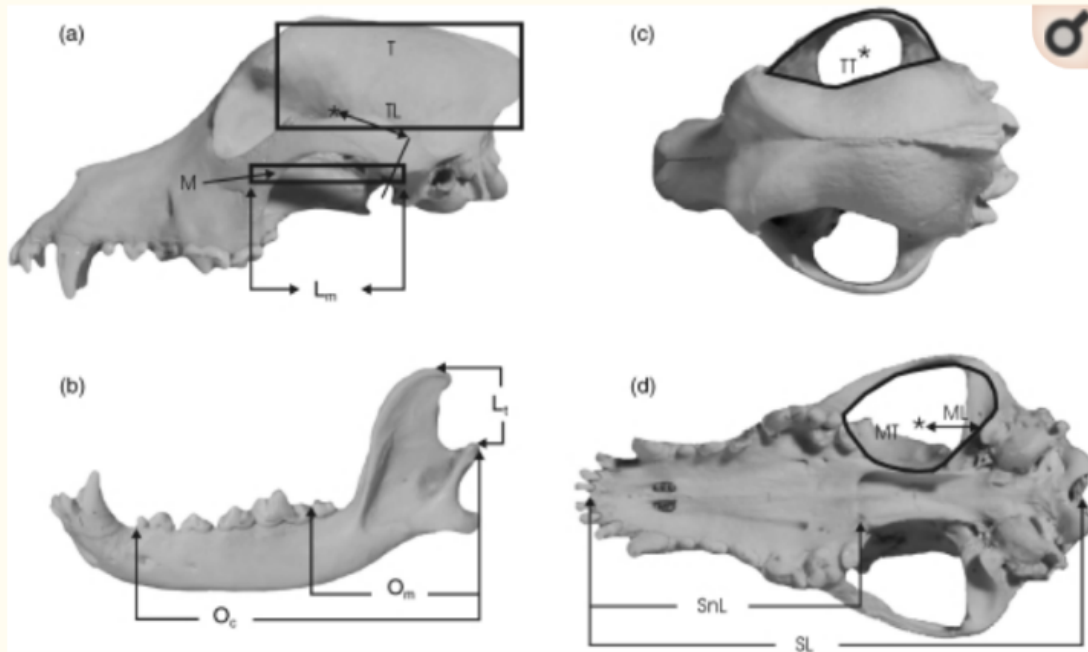
aSkull shape categorization determined by facial ratio, where B is brachycephalic, D is dolichocephalic and M is mesaticephalic skull shape.

bDog size categorization determined by skull length, where S is small, M is medium and L is large skull size.

cSex, where M = male, F = female.

dAge, where A = adult, J = juvenile.

Other things to consider is when determining bite force is breed, age, and sex.



These are key measurements that should be utilized in the calculation of bite force. The moments and forces are important for finite element testing.

Bite force can be estimated using the measurements above and utilizing lever mechanics. To predict the biting force of a dog, a bilateral contraction of the jaw adducting musculature is assumed.

### lever model 1

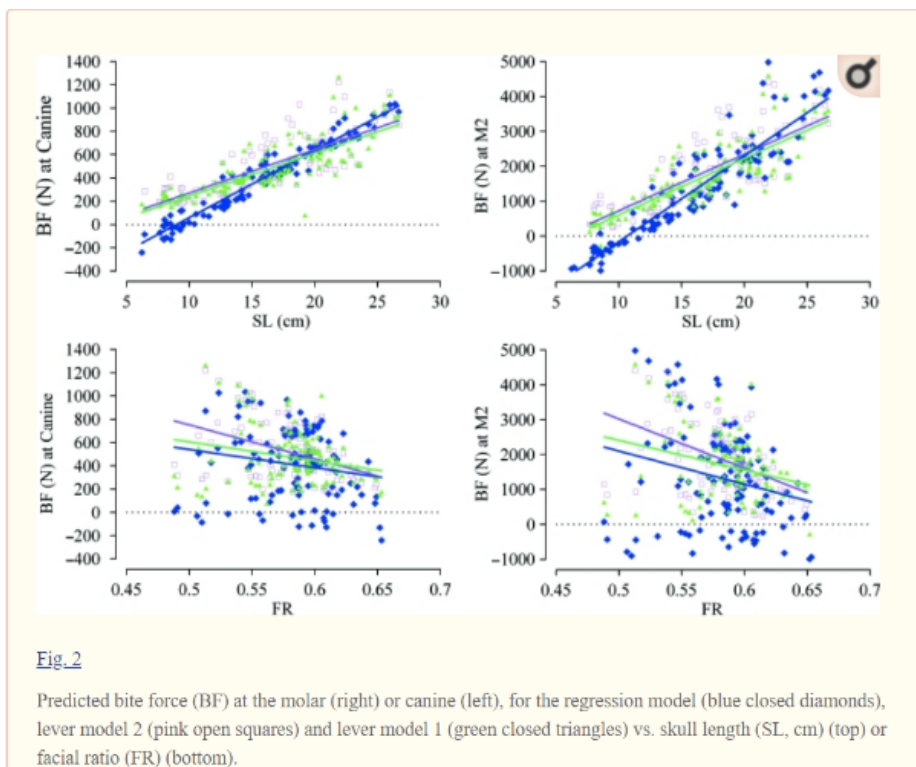
$$CBF_1 = (Lm \times M + Lt \times T)FPA/O_c \quad [1a]$$

$$MBF_1 = (Lm \times M + Lt \times T)FPA/O_m \quad [1b]$$

### lever model 2

$$CBF_2 = 2(MT \times ML + TT \times TL)FPA/O_c \quad [2a]$$

$$MBF_2 = 2(MT \times ML + TT \times TL)FPA/O_m \quad [2b]$$



Regression lines of the models are shown. The results were statistically significant meaning the level model would be a suitable way for us to predict the forces of the jaw.

#### Conclusions/action items:

From this article, we can get an idea of how we are going to have to calculate the different forces in a dog's jaw. Simplifications of the anatomy include a single degree of freedom and a treating the dog's jaw as a hinge joint (or a lever as it states in the article). This was fairly accurate according to this study and will be sufficient enough for our design specifications. We can utilize this study in order to start our finite element analysis.

Ellis, J., Thomason, J., Kebreab, E., Zubair, K. and France, J. (2019). *Cranial dimensions and forces of biting in the domestic dog*. [online] US National Library of Medicine. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2673787/> [Accessed 1 Oct. 2019].



# 9/16/2019-Current Designs

• LAURA RICHMOND • Oct 05, 2019 @05:08 PM CDT

**Title:** Prosthesis-to-bone interface system

**Date:** 9/16/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:**

The goals of this research was to see what kind of solutions to the project statement might already be out there.

**Content:**

This particular patent is similar to the lattice described to us by the client. It consists of a woven basket that incorporates bone cement which is basically a PMMA polymer that encourages bone growth. This is very similar to the lattice that is incorporated in our current project. Our lattice is inserted in with the implant so that when failure occurs a second implant is not necessary and the lattice has created a bridge of natural bone that will be permanent. Something that is unique to this invention is that the way that it is made improves the distribution of forces.

**Conclusions/action items:**

Although our client wishes for us to focus on the programming part of this design, it is important to know what kind of implants are out there to decide if we want our program to be compatible with existing ideas. This particular design was also relevant as it makes us consider that the lattice might need to be a consideration in the distribution of forces when we are creating the finite element testing program.

Burstein A., Koslin B., (1977). *Prosthesis-to-bone interface system*. US4064567A. [Accessed 16 Sep. 2019].

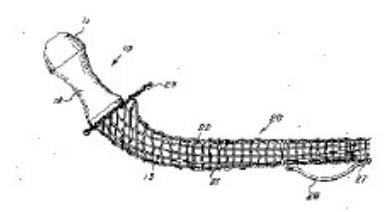
• LAURA RICHMOND • Oct 05, 2019 @05:03 PM CDT

**United States Patent** (11) **4,064,567**  
 Burstein et al. (51) **Dec. 22, 1977**

154 **PROSTHESIS-TO-BONE INTERFACE SYSTEM** 5/40/77 11/970 Free 3,770 CA  
 FOREIGN PATENT DOCUMENTS  
 2/4/64 4/1978 Germany 1A,5  
 CIVIL PUBLICATIONS  
 United States Patent, Issued by Patent  
 Co., New York, N.Y., 1964, p. 11, Volume: West-  
 No. 639 1964/1964  
 From my invention: ROBERT L. BURSTEIN  
 et al., supra, supra to Prostheses, Burstein,  
 Steven H. Pollock  
 [17] **ABSTRACT**  
 A woven basket is placed over the ends of a prosthesis  
 and bone to form a cement structure and thereby to  
 interface. The resulting prostheses-bone interface  
 greatly improves the distribution of forces transferred  
 to the bone.

13 **Clara H. Dawkins, Boston**

U.S. PATENT DOCUMENTS  
 1/24/69 5/2/70 1 day, et al. 3/1/70  
 1/26/67 5/2/70 1 day, et al. 3/1/70



US4064567.pdf(587.4 KB) - [download](#)



# 9/16/2019-Current Designs

LAURA RICHMOND • Oct 05, 2019 @06:35 PM CDT

**Title:** Modular prosthesis for mandibular reconstruction

**Date:** 09/16/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To continue researching current designs

**Content:**

This particular design uses a series of prosthetic modules that are connected to each other. Something unique about this particular model is that it allows bending adjustments to conform to the contour of the jaw's shape. There are specific segments for different parts of the jaw. This design is similar to ours in that it creates an implant that is created to fit exactly the shape of the jaw they are working on. Although ours should be more accurate as it is directly printed from scans of the dog's jaw while this design uses segments to conform to the desired shape. Another downside of this design is that it is really made for a specific section of the jaw and has specific locations where it would be inserted. Our project statement includes non-specificity as they want to be able to choose the area of resection and also want it to be unique for every breed and every patient.

**Conclusions/action items:**

This design is interesting because of the segmental aspect, but it has major problems in regard to our problem statement. Our client already has a method of printing an implant with the desired shape doesn't want the implant to only work in a specific location. Our current design has two parts. One that is used to make the cut and one that is implanted afterward. Considerations of adopting the segmental idea and only having to print one implant may be something to continue to research or raise in our next client meeting.

Lee, Sherman (2005). Articulated bone reconstruction bar. *Modular prosthesis for mandibular reconstruction*. [Accessed 16 Sep. 2019].

LAURA RICHMOND • Oct 05, 2019 @05:40 PM CDT

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(42) International Filing Date  
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(43) Filing Language  
English

(44) Publication Language  
English

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(48) Designated States (unless otherwise indicated, for every  
class of national patentable availability):  
AE, AU, AT, BE, BR, CA, CN, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IL, IN, JP, KR, LK, LU, LV, MA, MG, MK, MN, MW, MX, MY, NZ, PA, PE, PG, PH, PL, PT, RU, SE, SI, SK, SL, SV, TH, TN, TR, TT, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW

(49) Designated States (unless otherwise indicated, for every  
class of national patentable availability):  
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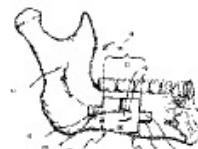
(50) Designated States (unless otherwise indicated, for every  
class of national patentable availability):  
AE, AU, AT, BE, BR, CA, CN, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IL, IN, JP, KR, LK, LU, LV, MA, MG, MK, MN, MW, MX, MY, NZ, PA, PE, PG, PH, PL, PT, RU, SE, SI, SK, SL, SV, TH, TN, TR, TT, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW

(51) International Publication Number  
WO 2007/061382 A1

(52) International Classification  
A61C 8/00 (2006.01)

(53) International Application Number  
PCT/SG2006/00001

(54) Title: MODULAR PROSTHESES FOR MANDIBULAR RECONSTRUCTION



(57) Abstract: A modular prosthesis for reconstructing a mandible includes a segmented prosthesis, comprising 5 types of prosthetic modules which may be connected to one another in order to bridge the resection and anchored upon the segmented mandible (110). The anchoring and connection between the modules are achieved by tongue (210) and slot (310) means which allows adjustments to treat the newly formed mandible as consistent to the desired contour of the mandible. One of the modules is designed as essentially uniform in width to ensure proper fit to the mandible. The other 2 modules are designed to bridge the resection back of the mandible and are preferably constructed in a block 2 mm below the resection and 4 mm above the resection for each 100 mm of the

WO2007061382 A1.pdf(1.6 MB) - download



# 9/17/2019-Current Designs

LAURA RICHMOND • Oct 05, 2019 @06:36 PM CDT

**Title:** Articulated Bone Reconstruction Bar

**Date:** 9/17/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To continue patent research and use the current designs to further understanding of the project scope and start brainstorming ideas.

An articulated bone reconstruction bar includes a series of short segments connected by fixable axles. The length of the bar is adjusted by varying the number of segments. Before the fixable axles are tightened, the bar is positioned across a discontinuity on a bone. It is adjusted to match the contour of the bone, and the fixable axles are tightened to fixate the connections between the segments and make the bar rigid. The bar is then attached to the bone with mounting screws extending through the segments. Fixable axles with long posts may be used for mounting a dental support plate at the gum line in an area where bone has been lost or removed. If failure occurs, the fixable axles enable the broken segments to be replaced without replacing the entire bar.

**Content:**

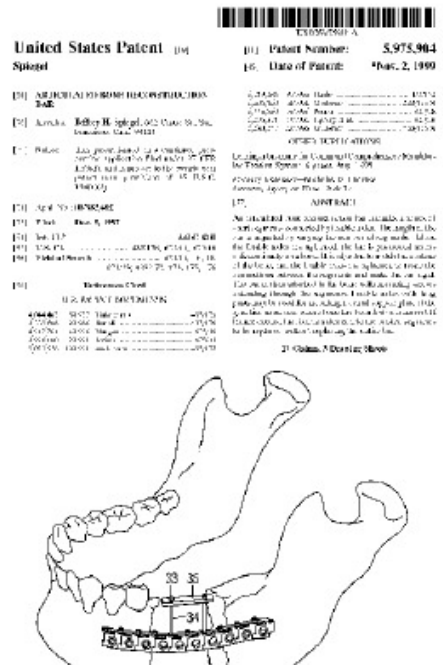
This design also uses a segmental approach. It has an adjustable length. This is achieved by varying the number of segments. This means you would have to consider the optimization of the size of the segments and the range of motion you wish to occur. The bar is also adjusted to fit the contour of the bone, however our client already uses the most accurate way of creating an implant that matches the bone shape. This particular design also uses mounting screws. A unique thing about this design is that the broken segments could be removed without having to remove the entire implant.

**Conclusions/action items:**

This design also had a segmental approach which suggests the team might want to bring these designs to the client in order to combine the two current designs into one. The program designed may be modified to determine the optimal amount of segments.

Spiegel, J. (1997). Articulated bone reconstruction bar. US5975904A. [Accessed 17 Sep. 2019].

LAURA RICHMOND • Oct 05, 2019 @05:51 PM CDT



US5975904.pdf(529.9 KB) - download



# 9/17/2019-Current Designs

• LAURA RICHMOND • Oct 05, 2019 @06:36 PM CDT

**Title:** Modular mandibular prosthesis

**Date:** 09/17/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To continue researching current mandibular reconstruction implants in order to brainstorm improvements of the current design.

**Content:**


This design specifically includes two components. An anchor plate and connector members. The anchor plate attaches to the mandible and at least one connector is connected between two anchor plates. Addition connectors can be used. A unique thing about this design is the utilization of swivel coupling which allows three dimensional movement at each connection. This allows for the facilitation of the orientation and installation of the prosthetic.

**Conclusions/action items:**

This research confirms that a multicomponent prosthetic is very common and opportunities may exist to improve the current design of the prosthetic by limiting waste of materials through finite element analysis, but through also combining the resection component with the actual implant to minimize waste.

Manolidis, S. (1998). *Modular mandibular prosthesis*. US6060641A. [Accessed 17 Sep. 2019]

• LAURA RICHMOND • Oct 05, 2019 @05:59 PM CDT



**United States Patent** [14]

**Manolidis**

[11] **Patent Number:** 6,060,641  
[6] **Date of Patent:** May 9, 2000

[51] **Classification:** A61C 17/00  
[52] **Field of Search:** A61C 17/00


[54] **Abstract:** A modular mandibular prosthesis comprising a plurality of anchor plates and a plurality of connector members. The anchor plates are adapted to be attached to the mandible and the connector members are adapted to be attached to the anchor plates. The anchor plates and the connector members are adapted to be attached to the mandible and the anchor plates, respectively, in a manner that allows for three-dimensional movement at each connection.

[57] **Claims:** 1. A modular mandibular prosthesis comprising a plurality of anchor plates and a plurality of connector members. The anchor plates are adapted to be attached to the mandible and the connector members are adapted to be attached to the anchor plates. The anchor plates and the connector members are adapted to be attached to the mandible and the anchor plates, respectively, in a manner that allows for three-dimensional movement at each connection.

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**US6060641.pdf(1.2 MB) - download**





**Title:** Implantable material and appliances and method of stabilizing body implants

**Date:** 09/18/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** A lot of research has been done considering the implant portion of our project. This research looks at the lattice portion competition.

**Content:**

This design creates a material that is a biocompatible composition of porous fibrous structure that has a specific surface tension. This composition is preferred to be created with a porous structure of carbon or graphite fibers that are bonded together by sintered polytetrafluoroethylene. This is so that the surface area is increased.

This design also considers another material that could be suitable for in vivo implantation. It includes carbon fibers and polytetrafluoroethylene resin. It is processed in a way where alignment of carbon fibers and wear surfaces occurs.

**Conclusions/action items:**

The lattice utilized right now is simple and only made of titanium. Improvements could possibly be made to improve the lattice component of the design.

Homsy, C. (1974). *Implantable material and appliances and method of stabilizing body implants*. US3992725A. [Accessed 18 Sep. 2019].

428-468 98  
11/25/74 No 3,992,725

**United States Patent** (43)  
Homsy  
(11) 3,992,725  
(43) Nov. 23, 1976

[54] **IMPLANTABLE MATERIAL AND APPLIANCES AND METHOD OF STABILIZING BODY IMPLANTS**

[57] **Inventor:** Charles A. Homsy, 11519 Parkway Circle, Phoenix, Ariz. 85024

[22] Filed: Oct. 17, 1974

[31] Appl. No. 819,640

**Related U.S. Application Data**

[68] Continuation-in-part of Ser. No. 416,241, Nov. 16, 1973, abandoned, which is a continuation of Ser. No. 14,297, filed Feb. 28, 1971, abandoned.

[52] U.S. Cl. 501, 502, 518, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000.

[51] **Int. Cl.** A61F 1/04

[59] **Field of Search:** 301, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000.

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[57] **ABSTRACT**

A composition of material suitable for in vivo implantation as a porous or fibrous structure in which normal tissue growth is favored with a composition of a porous fibrous structure in which the porous surface tension of the device is 50 dynes per centimeter or higher. This composition in the preferred form is a porous structure of carbon or graphite fibers bonded together by sintered polytetrafluoroethylene in a manner to control mechanical strength of the surface.

Another composition of material suitable for implantation for wear surfaces includes carbon fibers and polytetrafluoroethylene resin and is processed to align the carbon fibers with the wear surfaces. The method of preparing both types of implants includes the steps of mixing, drying, compressing, sintering, and drying. The method of stabilizing appliances or implants includes bonding the upper surfaces to the appliance at implant. Also the combination of the improved material with appliances, having polytetrafluoroethylene and resin bonded are included.



# 9/18/2019-Current Designs

• LAURA RICHMOND • Oct 05, 2019 @06:14 PM CDT

**Title:** Mandibular prosthetic apparatus

**Date:** 09/18/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To continue researching designs that are more relevant to the project.

**Content:**

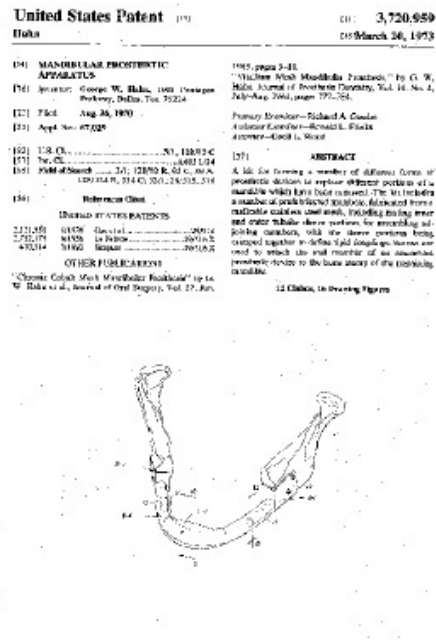
This design was unique in that instead of a single design, it is a kit that can form a number of different kinds of prosthetic devices that could be utilized to replace different components of the mandible includes prefabricated members, fabricated from a malleable stainless steel mesh, including mating inner and outer tubular sleeve portions for assembling adjoining members, with the sleeve portions being crimped together to define rigid couplings. Screws are used to attach the end member of an assembled prosthetic device to the bone stump of the remaining mandible.

**Conclusions/action items:**

This design is very similar to what we want to achieve. It's lack of specificity is similar to the level desired. However, the process of which they make the implant is not the scope of the project. The optimization of the implants is the main goal. The components in this kit that considers the different kinds of prosthetics used at different portions of the mandible might be useful when considering the forces or optimization of implants.

Hahn, G. (1970). *Mandibular prosthetic apparatus*. US3720959A. [Accessed 18 Sep. 2019].

• LAURA RICHMOND • Oct 05, 2019 @06:14 PM CDT



US3720959.pdf(1.1 MB) - download



## 9/18/2019-Current Designs

• LAURA RICHMOND • Oct 05, 2019 @06:26 PM CDT

**Title:** Design Optimization MSC Software Corporation

**Date:** 09/18/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To start researching designs that relate to the programming portion of this project.

**Content:**

This is a website that seems to be able to do CAE simulations. One of the many products they have is a design optimization where they will do what the client is asking of us. This however, will get costly as they are practically a consulting company. If they can come up with their own process and program then it will be a lot cheaper. While expensive, the CAE simulations at MSC will be more accurate and consider more types of optimizations than we are able to consider with our backgrounds of statics, mechanics of materials, and dynamics.

**MSC Software is used for many types of design optimizations:**

- Automated External Superelement Optimization (AESO)
- Bead Design of thin structures using Topography Optimization
- Design of Experiment (DOE) and Conservative Discrete Design (CDD)
- Equivalent Static Loads Approach
- Optional externally calculated responses
- Fully Stressed Design
- Include manufacturing constraints when optimizing
- Model multiple models across multiple analysis disciplines simultaneously
- Nonlinear Response Optimization
- Optimal thickness distribution using Topometry/Free-Size Optimization
- Optimize for the linear and nonlinear domain
- Optimize model parameters, such as material properties and geometric dimensions
- Parametric Design and Analysis
- Reduce high stress concentrations with shape optimization
- Specialized optimization for Composites
- Stochastic Studies

They have a wide variety of option just in their design optimization category.

As students, we would be able to obtain some of MCS's simulation software for free, however like matlab there would be substantial fees involved if we were to consider implementing this design into our solution. An open source program with simplifications and a large factor of safety would be an improvement of the procedure now even though it will be less accurate than a professional application.

**Conclusions/action items:**

Since we have access to these simulations for free, we could use this as a source of testing. We could put the parameters into their simulation and run our program and compare the results. We could also use it as a reference when writing our code in order to decide which factors to include and which are negligible.

Mscsoftware.com. (2019). *Student Editions*. [online] Available at: <https://www.mscsoftware.com/student-editions> [Accessed 5 Oct. 2019].

• LAURA RICHMOND • Oct 05, 2019 @06:27 PM CDT

<https://www.mscsoftware.com/>



## 10/15/2019 - FEBio Research

• LAURA RICHMOND • Dec 08, 2019 @04:09 PM CST

**Title:** Research of Software that could be used for finite element analysis

**Date:** 10/15/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To determine if there is a software that can be used for finite element analysis instead of creating the equations by hand.

**Content:**

After meeting with Professor Wille there were two open source Softwares that could be used for finite element analysis. One software was a typical finite element analysis software, Ansys.

Ansys is an engineering simulation and 3D design software. There is software available that would be free for students. However, that would not apply to our clients. Ansys also is typically used for mechanical designs rather than biological.

<https://www.ansys.com/>

The second option was FEBio. This software came highly recommended. There were several pros to working with FEBio. FEBio is open source which would let us implement a code and would make it free for our clients. Another feature of FEBio is that it was specifically designed for biomechanics and bioengineering technologies.

<https://febio.org/>

**Conclusions/action items:**

After talking to Professor Wille about the two Software options, FEBio was chosen as the finite element analysis software we will be implementing. It was chosen for its compatibility with biological systems and because it is open sourced.



## 10/30/2019 - Obtained Files and Printed

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• LAURA RICHMOND • Dec 08, 2019 @04:14 PM CST

**Title:** Obtained Files and Printed

**Date:** 10/30/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To receive the proper files from our client and print them in the makerspace.

**Content:**

Several files were given to us. They were of two categories:

- CT scans of patients
- STL files of bones and implants

**Conclusions/action items:**

With these files, we were able to print props for show and tell and for the final presentation. We were also able to start trying to import the files into software for finite element analysis.



## 11/05/2019 - Simplified Bone Jaw

• LAURA RICHMOND • Dec 08, 2019 @04:17 PM CST

**Title:** Simplified Bone Jaw Prototype

**Date:** 11/05/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To create a simplified jaw for finite element testing.

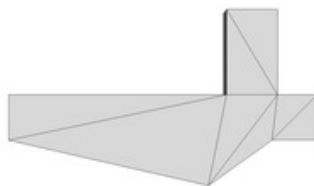
**Content:**

A simplified jaw was made in solidworks. See attached picture.

**Conclusions/action items:**

With a simplified jaw we can begin to do stress analysis.

• LAURA RICHMOND • Dec 08, 2019 @04:18 PM CST



SimpleJaw.png(8 KB) - [download](#)



## 11/11/2019 - Importing Files Mesh Software

• LAURA RICHMOND • Dec 08, 2019 @04:22 PM CST

**Title:** Importing files into SolidWorks

**Date:** 11/11/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To use a mesh software to simplify the jaw and implant STLs and import them into solidworks

**Content:**

Using meshlab (see attached) the complicated STLs were saved as a dxf file and imported into solidworks as a solid. However, doing this caused the program to crash.

**Conclusions/action items:**

Given that the program crashes when trying to import the files in this way, this is not a valid way to import the files. However, the dxf files were used to make visuals for the final report and poster.

• LAURA RICHMOND • Dec 08, 2019 @04:29 PM CST



MESHLAB.JPG(10.3 KB) - [download](#)



## 11/12/2019 - Trying to simplify STLs for solidworks

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• LAURA RICHMOND • Dec 08, 2019 @04:29 PM CST

**Title:** Simplification of STLs

**Date:** 11/12/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond, Will Wightman, Professor Wille

**Goals:** To get STL files to for finite element analysis.

**Content:**

The files were able to be imported into SolidWorks however they failed to mesh when trying to use the SolidWorks Finite element analysis testing wizard. Professor Wille reached out to a lab member for tips on getting the solid to mesh. However, despite using the solidworks meshing tool, the implant continued to fail.

**Conclusions/action items:**

Given the complications when importing the files into Solidworks and attempting to do finite element analysis, it was decided that simplified models should be made by hand.





## 11/20/2019 - Solidworks simplifications

• LAURA RICHMOND • Dec 08, 2019 @04:39 PM CST

**Title:** Simplified Models in solidworks

**Date:** 11/20/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To create simplified models of the jaw and implant to test in FEBio and SolidWorks

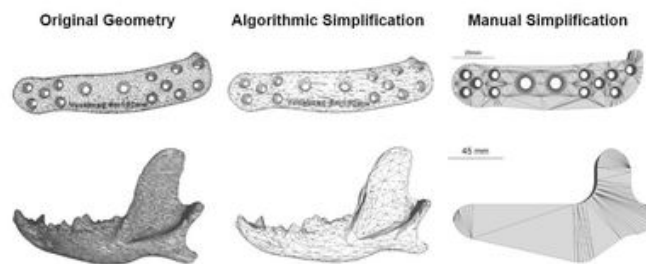
**Content:**

The purpose of created a manual simplification is to have a model that will be able to mesh for finite element analysis. This model will be used to test whether FEBio and Solidworks get the same result for stress distributions.

**Conclusions/action items:**

With a simplified model, we can begin testing whether FEBio is a valid software to use for finite element analysis.

• LAURA RICHMOND • Dec 08, 2019 @04:39 PM CST



Makinghem.JPG(61.2 KB) - [download](#)



## 12/2/2019 - Created a variety of simplified models

• LAURA RICHMOND • Dec 08, 2019 @04:48 PM CST

**Title:** Creating models of varying simplicity

**Date:** 12/2/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To create several models with varying complexity

**Content:**

The difficulties of importing files into FEBio and Solidworks led the team to believe that our client should create a simple model of their desired implant and test that. For this to occur, two things had to be confirmed:

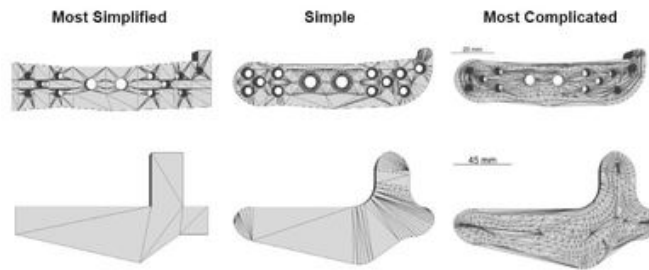
1. FEBio was a reasonable substitute for Solidworks
2. Making simplifications would not change the stress analysis

To confirm these two things, additional models were made in SolidWorks for finite element analysis. The most simple model was created with straight lines and had 90 degree angles. The simple model used a filleting technique to curve the corners of the implant and remove the 90 degree angles. The complex model added topography to the simple model.

**Conclusions/action items:**

With these three models, finite element analysis could be done on them to determine if they were statistically different. This would determine whether our clients are able to create simplified models of their desired implant and optimize it manually.

• LAURA RICHMOND • Dec 08, 2019 @04:48 PM CST



stuff.JPG(54.8 KB) - [download](#)



# 12/2/2019 - Finite Element Analysis

• LAURA RICHMOND • Dec 08, 2019 @04:55 PM CST

**Title:** Finite Element Analysis

**Date:** 12/2/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To perform finite element analysis in SolidWorks.

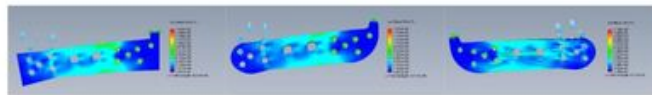
**Content:**

Using the simulation wizard, finite element analysis was performed on the most simple, simple, and complex models of the implant and jaw. Pictures are attached.

**Conclusions/action items:**

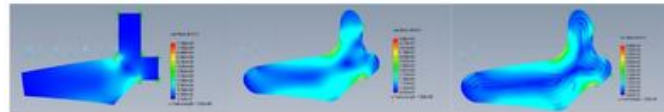
With the finite element testing analysis done, the simplifications can be determined to be statistically different or whether simplifications are likely to be accurate representatives of the actual model.

• LAURA RICHMOND • Dec 08, 2019 @04:56 PM CST



rainbow.JPG(25.7 KB) - [download](#)

• LAURA RICHMOND • Dec 08, 2019 @04:56 PM CST



rainbow2.JPG(26.8 KB) - [download](#)



# 12/02/2019 - Statistical Analysis of Finite Element Analysis

• LAURA RICHMOND • Dec 08, 2019 @05:12 PM CST

**Title:** One sample t tests

**Date:** 12/02/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To determine whether making simplifications to the jaw and implant changes the stress distribution

**Content:**

Shown below is a summary of the results of the one sample t tests. Attached is the work for the calculations.

	Avg Rank of Stress	P-Value
Implant	26.33	0.045
Mandible	19.67	0.029

**Conclusions/action items:**

An alpha value of 0.03 was chosen because a larger confidence interval was desired because simplifications of the implant will decrease accuracy. With than alpha value, the mandible was determined to be statistically different but the implant was not.

• LAURA RICHMOND • Dec 08, 2019 @05:13 PM CST

Data  
Monday, December 2, 2019 1:08 PM

Chomp Chomp Texas

- 2 red
- 3 orange
- 3 yellow
- 2 green

red = 4  
 orange = 3  
 yellow = 2  
 green = 1

$$2(4) + 3(3) + 3(2) + 2(1)$$

$$8 + 9 + 6 + 2$$

25

Chomp Chomp Final

- 1 red
- 2 orange
- 2 yellow

[data\\_results.pdf\(9.8 MB\) - download](#)



# 09/20/2019 - My design idea

LAURA RICHMOND • Oct 07, 2019 @11:50 PM CDT

**Title:** My first design idea

**Date:** 09/20/2019

**Content by:** Laura Richmond

**Present:** Laura Richmond

**Goals:** To come up with a preliminary design idea.

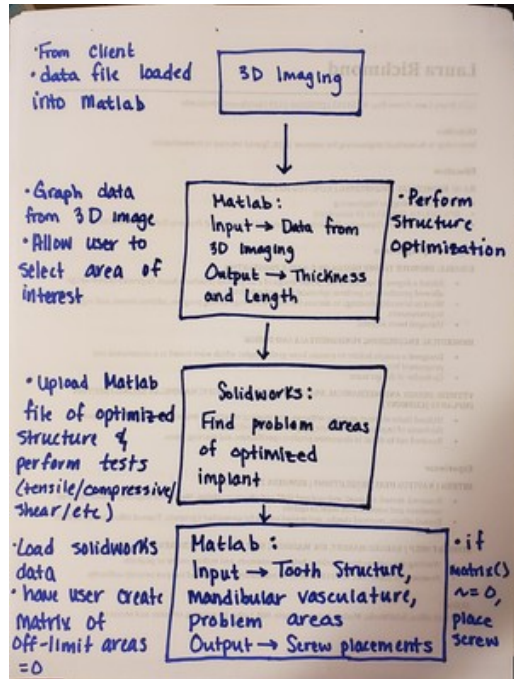
**Content:**

See attached

**Conclusions/action items:**

With this preliminary design, we will be able to discuss the team's ideas at the team meeting and make a design matrix of the best ideas or a combination of the team's ideas,

LAURA RICHMOND • Oct 07, 2019 @11:49 PM CDT



idea.jpg(832.8 KB) - download



## 09/23/2019 - Team's designs

• LAURA RICHMOND • Oct 08, 2019 @12:10 AM CDT

**Title:** Summary of Team's Designs for the design matrix

**Date:** 09/23/2019

**Content by:** Laura Richmond

**Present:** Team

**Goals:** To summarize the four designs the team came up with after reviewing individual designs.

**Content:**

**The Tiered:**

The Tiered is a process split between Matlab and Solidworks. It begins with Matlab. The client would put the inputs into matlab which would optimize the dimensions and screw placement. It would then be put into solidworks for finite element analysis. If the implant failed it was then put into matlab again and repeated until a successful implant was created. This would be the easiest to program as our team's experience lies mostly in Matlab. However, this design requires the Matlab license as well as the Solidworks license which are not available to the vet school and also expensive. It also has a large user time as it requires switching between two different programs to perform different tasks.

**The Monolith:**

The monolith uses ImageJ which is an open source that is very easy to use. Although ImageJ has large libraries of plug-ins available, a finite element analysis plug-in does not exist and so it will be made from scratch using a simplified analysis. ImageJ uses Java which is fairly easy to pick up, especially with some coding background and also part of our team's experience. The plug-in that we create will be able to be activated and then a 3D image of the area of interest could be loaded in. The vet would select the region of interest in the file and the program will perform the analysis and spit out the optimized implant.

**The Iterator:**

The Iterator is a Generative design. The computer performs the optimization thousands of times until it has created an implant it cannot improve upon. The pros of this design were the easy interface. The inputs were put into the program and the program ran until it came up with a satisfactory output. The cons of this were its difficulty to program. We wouldn't be able to code something this sophisticated and although there are programs such as this one out there, they aren't free and not within the budget.

**The Square One:**

The Square One is similar to the Monolith. Its an independent application that would be developed from scratch. The application would begin with the user inputting the parameters and it would run the code and spit out the implant. The cons of this design is that it would be prone to bugs as we wouldn't be using any existing libraries and everything would have to be written and debugged. It would be very time consuming and there is no benefit in creating everything ourselves.

**Conclusions/action items:**

After coming up with these four designs, the team put them in a design matrix and the Monolith won. It was the most cost effective and easiest to work with design. The Monolith is the design we have chosen. Now that we have our final design, we will be able to begin coding and prototyping.



# 10/08/2019 - Green Pass Certification

LAURA RICHMOND • Oct 08, 2019 @12:12 AM CDT

**Title:** Green Pass Certification

**Date:** 10/08/2019

**Content by:** Laura Richmond

**Present by:** Laura Richmond

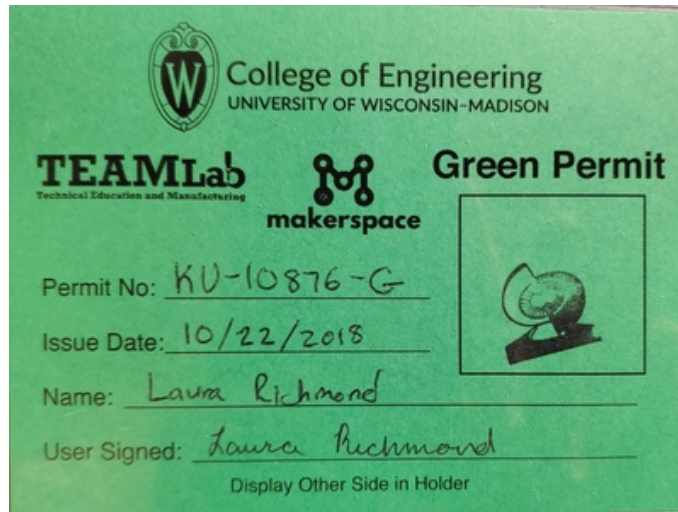
**Goals:** To gain my green pass in order to use the lathe and mill in the COE TEAM Lab.

**Content:** Please see picture attachment for certification.

**Conclusions/action items:**

This certification allows me to work in the COE TEAM Lab using the mills and lathes.

LAURA RICHMOND • Oct 08, 2019 @12:14 AM CDT



Front.jpg(1.1 MB) - [download](#)

LAURA RICHMOND • Oct 08, 2019 @12:14 AM CDT



Back.jpg(100.9 KB) - [download](#)



## 10/08/2019 - Matlab Onramp Course Certification

LAURA RICHMOND • Oct 08, 2019 @12:14 AM CDT

**Title:** Matlab Onramp Certification

**Date:** 10/08/2019

**Content by:** Laura Richmond

**Present by:** Laura Richmond

**Goals:** To participate in Matlab training

**Content:** Please see picture attachment for certification.

**Conclusions/action items:**

This certification shows that I have prior coding experience.

LAURA RICHMOND • Oct 08, 2019 @12:16 AM CDT



Sect301\_Richmond\_hmwk01.pdf(91.7 KB) - [download](#)





# Lab: SolidWorks I

## *Background*

## Pre-Lab

Read through the entire pre-lab section and complete the following tasks. All pre-lab work, including pre-lab quizzes, must be completed and turned in prior to the start of lab.

## Overview

SolidWorks is a software package that can help with design, analysis, and prototyping. It is also one of the main modeling programs that is used in industry. Being proficient at a modeling software package, such as SolidWorks, gives an engineering student an advantage over those who are not when applying for jobs or internships. The best way to hone in your modeling skills is to complete the provided tutorials and practice modeling your own designs. When creating a part in SolidWorks, it is important to plan out the design and layout of the part before starting to model it. In order to do this properly, you must think and sketch in 2D and then extrude or revolve your part into 3D. This will become more apparent throughout this lab. Listed below are the goals of this lab.

- Get a feel for the user interface and layout of SolidWorks.
- Understand how to plan the layout of a part and how to properly model it.
- Understand how to use SimulationXpress Analysis Wizard in SolidWorks to test part failure.

## Getting Started with SolidWorks

Complete the Introduction tutorial in SolidWorks. Open SolidWorks (it can be found on any CAE computer and can be tethered). After it loads, click "Accept", then click the bubble "Do not show me dynamic help" and click Okay. At the top of the program hover over the word SolidWorks until the menu shows up. Under Help, select SolidWorks Tutorials, it shows up as the second drop down icon. Under Tutorials by Category, select Getting Started. Select Introduction to SolidWorks. Follow the instructions and complete the tutorial up to the point of creating the part. Once you get to the instruction page that says MY FIRST DRAWING, you are finished and do not need to go any further. Save the part as a JPEG and post it in your notebook.

# Lab: SolidWorks I

## Lab Protocol

### Lab Exercise: Solid Modeling, Assemblies, Drawings, and Stress Testing

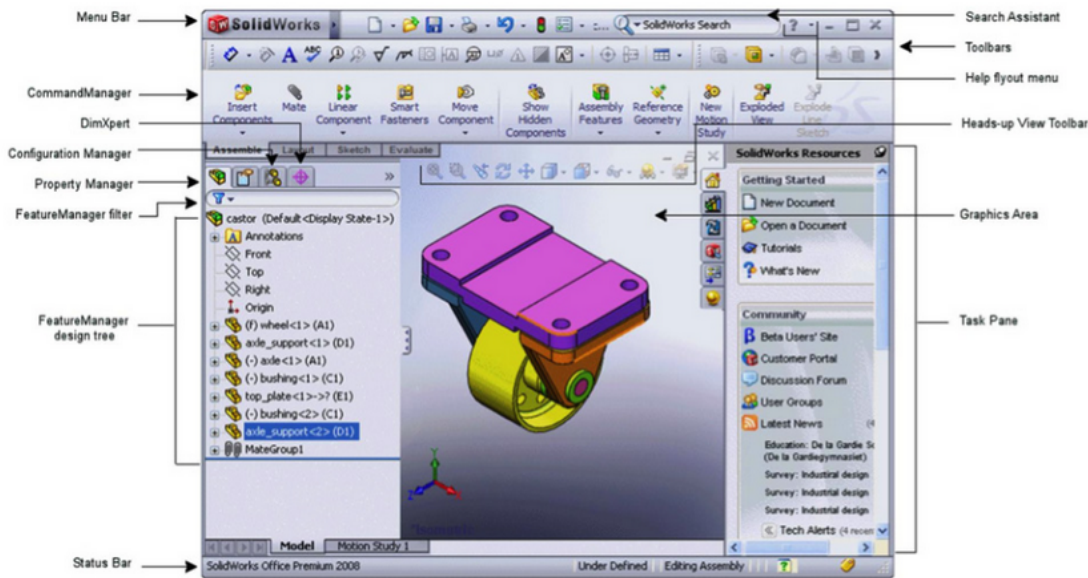


Figure 1: User interface for SolidWorks

## Creating a Part

Use the drawing in Figure 2 (see attachment) to reconstruct the SolidWorks part. If you do not use the provided dimensions for the part, the assembly will not work.

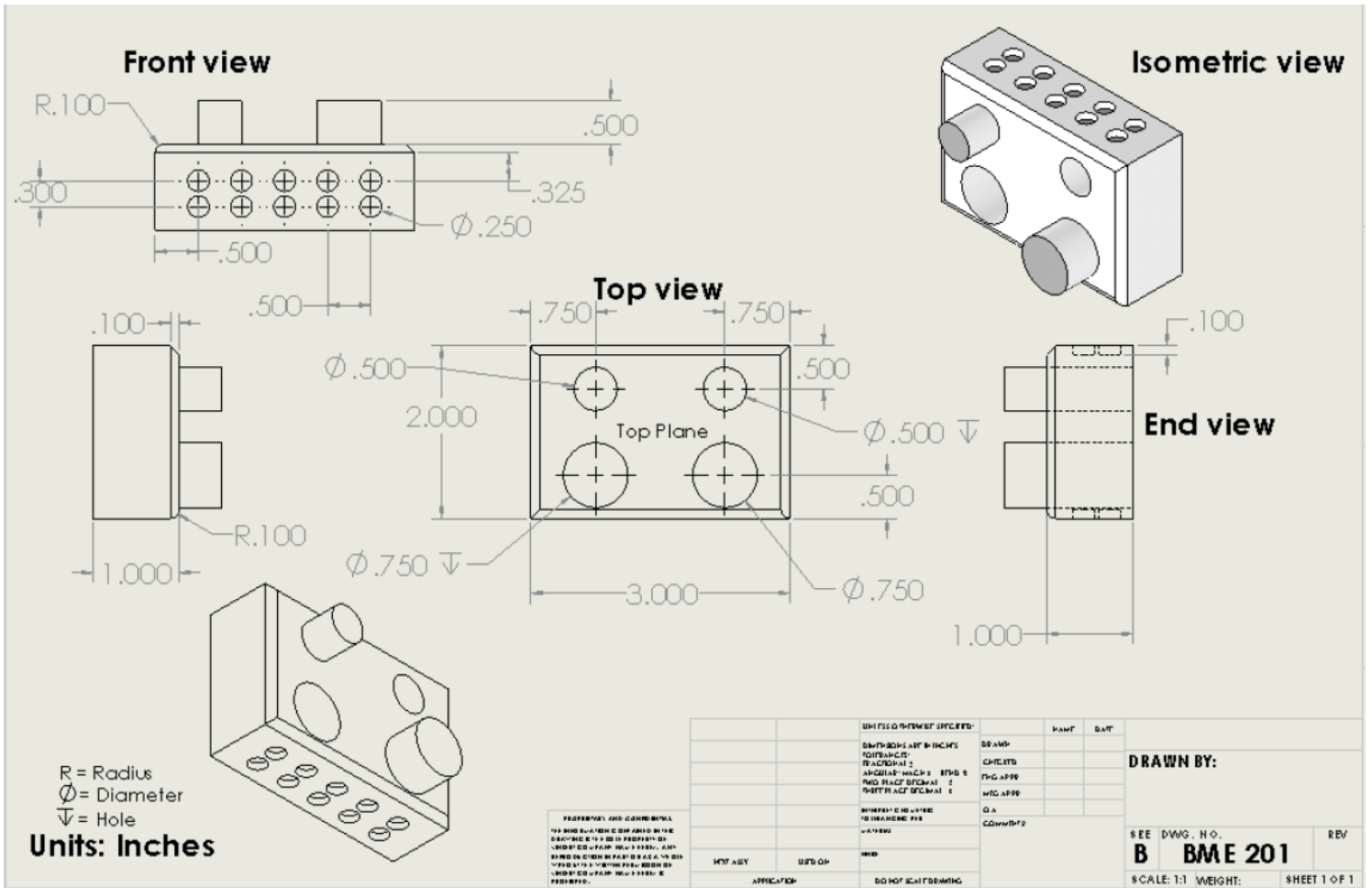


Figure 2: Part Drawing

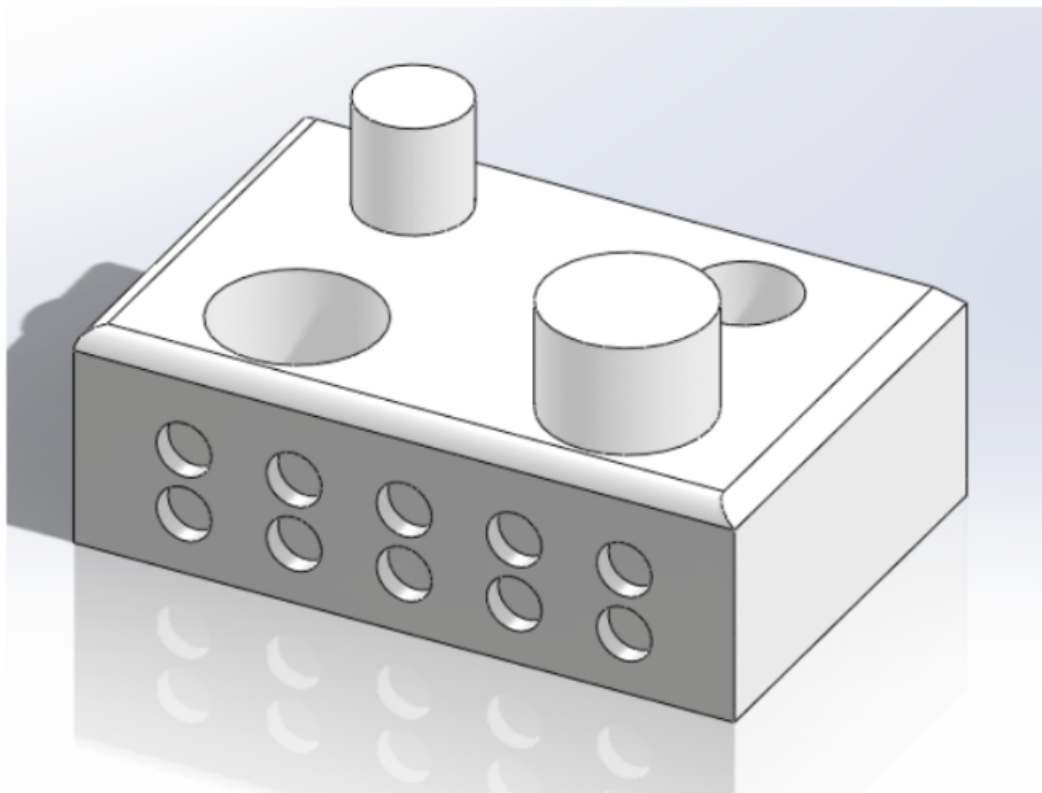



Figure 3: Isometric View of a part



## Creating the Base

### 1. Open "New Document"

- Click the **Part** square
- Click **OK** button
- Check Units:  Options icon at the top of the page > Document Properties > Units > IPS > **OK**

### 2. Extrude Boss/Base

- Click **Extrude Boss/Base**
- Select the **TOP** plane

- Draw rectangle  making sure you start at the origin and the coincident icon appears  and drag North East


#### d. Click on **Smart Dimension**

- Note the color of the rectangle
- Click on the top of the rectangle
- Drag dimension to desired location
- v. Assign the appropriate dimension
- Repeat for the right side of the rectangle
- Double click on an existing dimension to edit it
- To delete a dimension, exit Smart Dimension by clicking on the Smart Dimension icon, right click on the dimension, delete
- Notice the rectangle is now black instead of blue; this means the sketch is fully defined

#### e. Click **Exit Sketch**

#### f. Extrude

- Assign the proper thickness

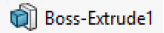
- If necessary, switch directions with  found under Direction 1. Consider this carefully; you just sketched in the Top Plane of your part.


#### g. Click the **Green Check** icon in the *FeatureManager*


### 3. Save Part

- Click **Save** icon in the Menu Bar
- Select a folder to save the part in
- Name your project
- Click **Save** button
- Always save your part after you create or edit a feature

### 4. Editing a Feature or a Feature Sketch (for future reference)

- To edit a feature (thickness of extrusion), right click on the feature in the Feature Manager Design Tree,  select in the upper left

corner icon .

- To edit a feature sketch (dimensions), right click on the feature in the Feature Manager Design Tree, select  in the upper left corner.

- To delete a feature, right click on the feature in the Feature Manager Design Tree, Select Delete.

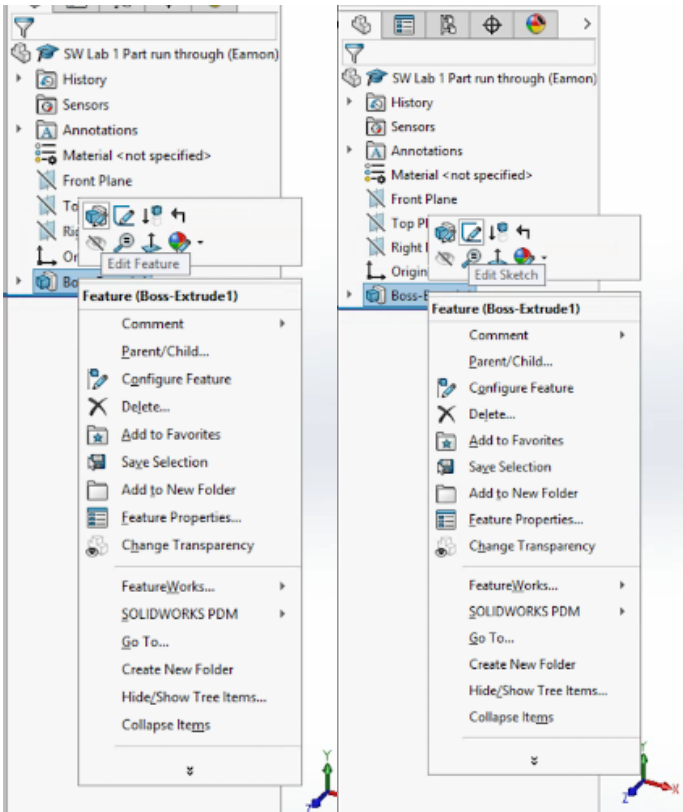


Figure 4: Editing features and feature sketches

5. Change views or orientation

- a. Use the scroll wheel to zoom in and out, it will zoom to where your cursor is located
- b. Click and hold the scroll wheel, move the mouse to rotate the part
- c. Zoom out a ways, press F on the key board to return to screen fitted view
- d. Select the View Orientation button at the top of the Graphics Area to choose isometric and other views. Refer to Figure 1 to determine where the Graphics Area is located

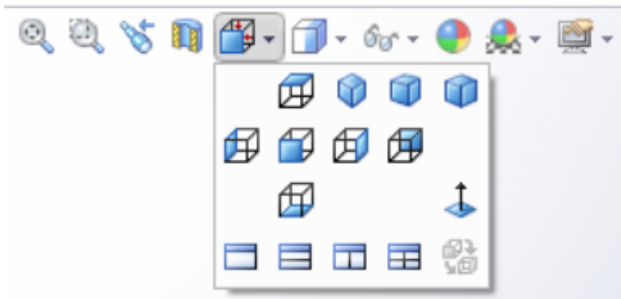



Figure 5: View orientation button

## Creating Extrusion Cuts

1. Extrude Cut(s)

- a. Select the appropriate plane to sketch on to cut the two large holes through the part.
  - i. When sketching, it is of utmost importance to be normal to the sketching plane. Use the View Orientation button to select the Top Plane, or highlight the top plane of the part by clicking it, then click View Orientation button and select the Normal To button. A third option is to right click on the Top Plane of the part, select the  Normal To button from the pop button. This button is great for non-traditional planes. If you ever accidentally move the view away from normal, use this button to return to the proper view while sketching. Try all methods before continuing. Make sure you are normal to the Top Plane before continuing.
- b. Click **Extruded Cut**
- c. Select the Top Plane, it should already be in normal to view
- d. Draw 2 circles
  - i. Revisit Figure 2 to make sure you know where the holes are located on the Top Plane

- ii. Click once at the approximate center point of the circle
- iii. Click again to set the radius of circle (rough estimate)
- iv. Notice at the bottom *FeatureManager* there is a *Parameters* box. This tells you where the circle is located and how big its radius is. Changing these does not define the circle's size or position. In order to define entities in a sketch, you need to use **Smart Dimension**
- e. Dimension the circle's diameters appropriately according to Figure 2 using **Smart Dimension**
- f. Position Circles
  - i. Click on Smart Dimension
  - ii. Click on center of circle
  - iii. Click on edge of base
  - iv. Assign the rest of the Dimensions appropriately
  - v. Make sure all the dimensions are defined. If the circle is blue, it is not fully defined. If it is still blue, you should be able to click on the circle's center point and drag it around in space. If the sketch is fully defined, it should appear black and not be movable by clicking and dragging.
  - vi. Click Exit Sketch
- g. Extrude Cut
  - i. Click and hold scroll wheel to rotate the part to an appropriate view of the extruded cut preview
  - ii. Assign the depth of the extrusion and set to **Through All**
  - h. Click **Green Check** icon in the *FeatureManager* Area

## 2. Save Part

## Extruding Posts


### 1. Extrude Posts

- a. Click **Extrude Boss/Base**
- b. Make Sketch
  - i. Select the appropriate plane
  - ii. Draw 2 circles
  - iii. Dimension circles
  - iv. Position Circles
  - v. Click **Exit Sketch**
- c. Extrude
  - i. Assign thickness
- d. Click the **Green Check** icon in the *FeatureManager*

### 2. Save Part

## Fillets and Chamfers

### 1. Create Fillets

- a. Click the **Features** tab
- b. Click **Fillets** 
- c. Notice the blue highlighted box in the *FeatureManager* asking you to select edges. Select edges to Fillet. The Front and End views in Figure 2 show which edges have a fillet and which do not.
- d. Set radius
- e. Select **Full Preview** icon
- f. Click **Green Check** icon

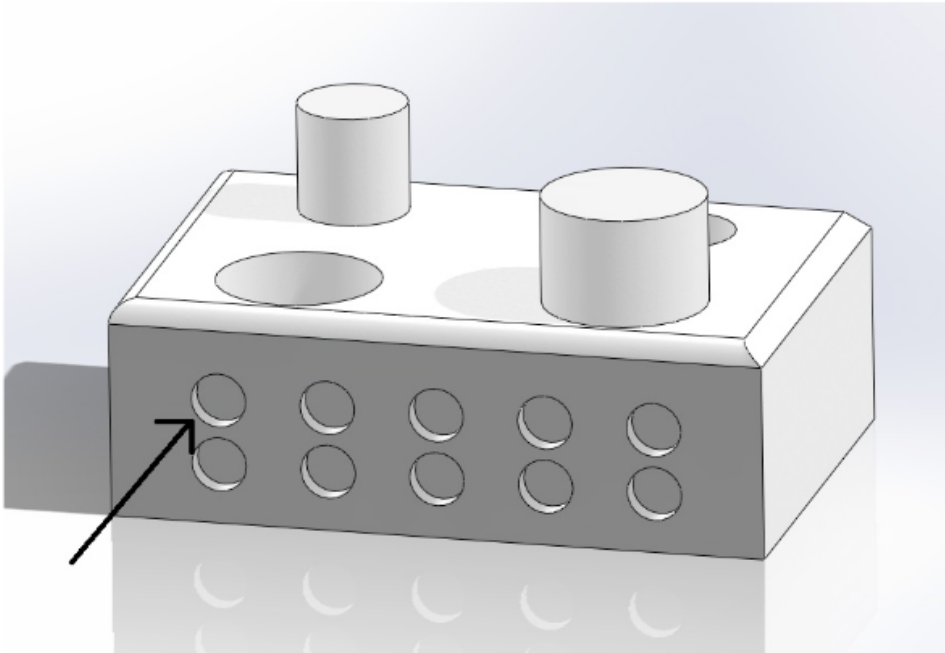
### 2. Create Chamfers

- a. Click on small arrow on **Fillet** button
- b. Select edges to Chamfer
- c. Set depth of the chamfer to 0.1"
- d. Select "Full Preview" button. Notice that the chamfer follows the fillet and continues down the edges. This is not desired.
- e. Unselect "Tangent Propagation" button
- f. Click the **Green Check** icon in the *FeatureManager*

### 3. Save Part

## Linear Patterns

To quickly create many same features in a grid, a linear pattern is used. In this lab, we will pattern the feature shown in Figure 6. Which plane is this feature located on? View Figure 2 to determine this. Hint: Reference the post features.




**Figure 6:** Single feature to pattern

1. Create Feature to Pattern

- a. Click **Extruded Cut**
- b. Select appropriate plane. Make sure you are in proper view orientation of that plane before starting to sketch.
- c. Make Sketch
  - i. Draw 1 circle (draw the circle that the arrow in Figure 6 is pointing to)
  - ii. Dimension circle
  - iii. Position circle by assigning correct dimensions

2. Click **Linear Pattern**  Linear Sketch Pattern

- a. Highlight "Entities to Pattern" box in the lower left of the Feature Manager by clicking in the box below "Entities to Pattern"
  - i. Select circle drawing
- b. In "Direction 1"
  - i. Set *D1* for the spacing between features
  - ii. Set # of Features
- c. In "Direction 2"
  - i. Set # of Features
  - ii. Set *D2*
    - iii. Switch directions if necessary 
- d. Click the **Green Check** icon in the *FeatureManager*
- e. Click **Exit Sketch**

3. Extrude Cut

- a. Select blind under "Direction 1"
- b. Set *D1*
- c. Click the **Green Check** icon in the *FeatureManager*


4. Save Part

## Mirrors and Adding Planes

In this step we will mirror the linear pattern we just did to the opposite side of the part instead of repeating the process of Linear Patterns.

1. Create a plane to mirror off of



- a. In the Features tab, select , then select plane
- b. While "First Reference" is highlighted, expand the pop out Feature Manager Design Tree, then select Front Plane
- c. Set Offset Distance to 1.00 inch. Click "Flip offset" to place the plane in the center of the part (use scroll wheel to rotate part to get a good view)
- d. Click the **Green Check** icon in the *FeatureManager*

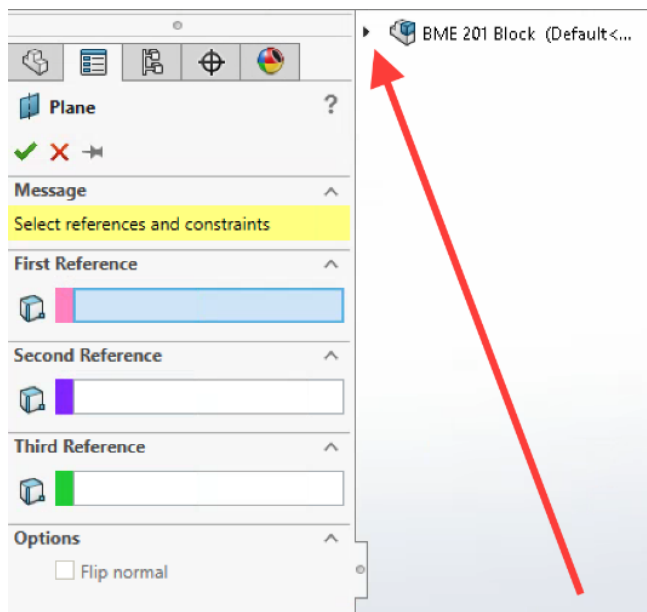




Figure 7: Pop out feature manage design tree

## 2. Mirror Cut-Extrude2



- a. Select **Mirror** 
- b. Under Mirror Face/Plane, Select the plane you just created.
- c. Expand the pop out Feature Manager Design Tree (Figure 7)
- d. Select Cut-Extrude 2
- e. Rotate part to see if it worked
- f. Click the **Green Check** icon in the *FeatureManager*
- g. Right click on Plane 1, Select hide 

## 3. Save Part

# Section Views and Display Style

Section views and the Display Style are helpful when trying to view features on the inside the part or the cross section of a part.

## 1. Create a section view of the part


- a. Select the Section View icon  from the top of the Graphics Area
- b. Under "Section 1" make sure Front Plane is selected
- c. Set  $D$  to -0.5
- d. Under "Section 2" select the Right plane by clicking on it
- e. Set  $D$  to 0.75
- f. Click the Flip icon 
- g. Click the **Green Check** icon in the *FeatureManager*
- h. This allows you to see the cross section of the part at this point

## 2. Undo Section View


- a. Click the Section View icon 

## 3. Change the Display Style of the part to *Hidden Lines Visible*






- a. Select the Display Style icon  from the top of the Graphics Area
  - b. Select the *Hidden Lines Visible* option from the dropdown menu.
  - c. Rotate the part to view the different internal features as hidden lines
4. Undo Display Style
- a. Click the Display Style icon and select *Shaded With Edges*





## Editing Material

1. Right click the Material icon  Material <not specified> in the Feature Manager Design Tree
  - a. Select Edit Material
  - b. Expand the Plastics tab
  - c. Select PS Medium/High Flow
  - d. Click Apply, then close
  - e. Note how the part's color changes and how the Material tab is now labeled. If you zoom in close, texture can also be seen with some materials.
2. You can check part properties by clicking on the **Evaluate** Tab, then by clicking on **Mass Properties**
3. Save part

## Edit Appearance

1. Select the Appearance icon  at the top of the Graphics Area (not the icon to the right of the Graphics Area)
  - a. Set color under the Color tab
  - b. If only certain planes are to be colored, clear the Section Geometry blue highlighted box.
  - c. Select the Select Faces icon
  - d. Click on the desired part faces 
  - e. To remove all colors and appearances, select the *Remove Appearance* button. If the *Remove Appearance* button is not an option, right click in the *Selected Geometry* box and *Clear Selections*. You may need to edit the Material again to get the default material appearance to show again.
  - f. Click the **Green Check** icon in the *FeatureManager*
2. Selecting a Texture instead of a color
  - a. Click the Appearances, Scenes, and Decals icon  at the right of the Graphics area
  - b. Browse through the textures and select one
  - c. To remove a texture, do 1.e
  - d. Before moving on to Assemblies and saving the part, make sure the part material is specified as PS Medium/High Flow
3. Save Part

## Adding a Decal


1. Step 1: Change the *FeatureManager* to the *DisplayManager* and open the decal library
  - a. At the top of the *FeatureManager* there are five different tabs click on the *DisplayManager* icon 
  - b. Click the View Decals icon  at the top of the *DisplayManager*
  - c. Click Open Decal Library
2. Apply and edit a decal
  - a. Bring the bottom of the part normal to the viewing plane using the *View Orientation* icon  at the top of the Graphics Area
  - b. Click on the Warning decal found in the decal library and drag it onto the bottom of the part
  - c. Notice how the *DisplayManager* has automatically been switched to the *PropertyManager*
  - d. Adjust the size of the decal until it fits on the part without being cut off by the holes
  - e. In the *PropertyManager*, under *Mask Image*, select *Selective color mask*
  - f. Click on the *Pick Color* icon 

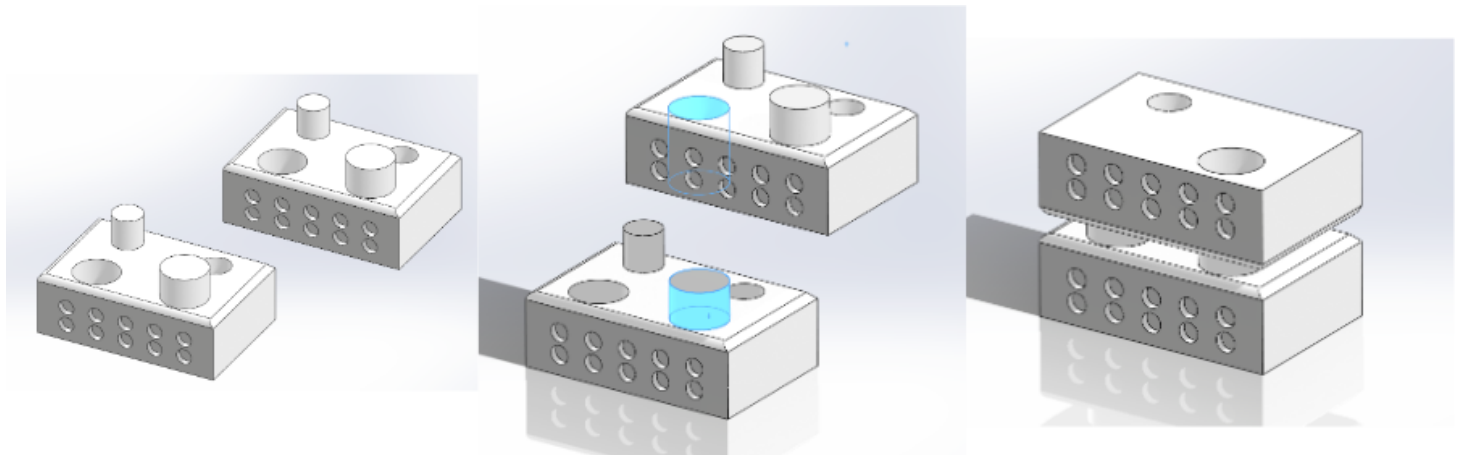
- g. In the *Decal Preview* window in the *PropertyManager* click on the white portion of the decal and the yellow portion of the decal. Notice how it gets rid of these colors of the decal on the part
- h. If custom decals are desired in future projects, they can be loaded by using the *Browse* button in the *Decal Preview* window of the *PropertyManager*. Pictures can also be used as decals in SolidWorks
- i. Click the **Green Check** icon in the *PropertyManager*

## Assemblies

When creating assemblies, it is important to determine which part everything is referenced from. For example, when building a car, everything is built around the car frame. When building a swing set, everything is built around the swing frame. The first part placed in the graphics area in SolidWorks is the part everything revolves around and is considered fixed. If we were to build a swing set in SolidWorks, and we placed the swings in the graphics area before we placed the frame, the frame would rotate about the swings. This would be incorrect modeling. This is good to keep in mind for future projects, but will not affect the assembly done in this lab.

### Inserting Assembly Components


1. Open "New Document"
  - a. Click the **Assembly** square
  - b. Click **OK** button
2. Selecting parts to include
  - a. Click on the **Keep Visible** at the top of the Begin Assembly Feature Manager . This will allow you to continually insert parts into the graphics area without the Begin Assembly Feature Manager disappearing. If you do not select it, you will have to click on **Insert Components** tab each time you want to add a single part
  - b. Your saved part should appear in the *Part/Assembly to Insert* box. Items will appear here if they were worked on and saved during the current SolidWorks session. If they were created in a past session and the SolidWorks program has been closed since then, you will need to click the **Browse** button and find them where they are saved
3. Insert Parts
  - a. Click to highlight the part in the *Part/Assembly to Insert* box
  - b. Place 2 parts in the graphics area by moving your mouse to the graphics area. The first one placed will be the fixed part that everything is referenced off of. To place the part click once. Place the second part to the North East of the first or fixed part as shown in Figure 8 (next page). This will make assembling the two pieces down the road much easier
  - c. Once you have two parts inserted, Click the **Green Check** icon in the *FeatureManager* Area
  - d. If too many parts are inserted, right click on the extra part and select delete, select yes when the confirm delete box appears
  - e. Click down on the first part you inserted and try to drag it around, it should not be able to move since it is fixed. Try to drag the other part, it is floating so it should be moveable. On other projects, you may need to change which part is fixed and which parts float. Or, if you delete the object that was fixed, you might now want to fix another part instead. To do this, right click on the fixed part and click *Float*. To fix a floating part, do the same but this time select *Fix*. After you have done this make sure the floating part is to the North East of the fix part as described in b



**Figure 8:** Left: Layout of assembly pieces, fixed piece is in the lower left. Middle: Mate #1. Right: Mate #3 final layout

### Mating Components


## 1. Mate Parts

a. Click the **Mate** icon  in the **Assembly** tab (do not click **Mates** in the *FeatureManager*)

b. Mate #1

i. Click the side of the Large Post on Part #1 (fixed part in South East)

ii. Click the inside of the Large Hole on Part #2 (floating piece) – the parts should align automatically

iii. Click the Flip **Mate Alignment** Icon  from the pop up tool bar

iv. Click the **Green Check** icon on **pop-up** toolbar.

**NOTE:** Click on Part #2 and move it up and away from Part #1, noticing how the post and the hole are now mated and will not become unaligned. Also notice how you can move Part #2 but if you try to drag Part #1, i.e. the fixed part, it will not move.

c. Mate #2

i. Click the side of the Small Post on Part #1

ii. Click the inside of the Small Hole on Part #2 – the parts should align automatically

iii. Click the **Green Check** icon on pop-up toolbar.


d. Mate #3

i. Click on the Top plane of Part #1

ii. Click on Top plane of Part #2

iii. The parts should move together

iv. If the parts to be mated are not supposed to be in contact and a certain gap between them is desired, the gap distance can be set by clicking

on the **Distance** button  in the pop up menu, or clicking adjusting the distance in the *FeatureManager* next to the **Distance** button. Try putting a gap of 0.25".

v. Click the **Green Check** icon on pop-up toolbar.

e. Click the **Green Check** icon in the *FeatureManager*

**NOTE:** Parts should line up without any errors. Linear patterns should line up. If errors appeared and did not let you do certain mates, you dimensioned your part incorrectly while creating it.

## Error Checking, Measuring, and Editing Mates

### 1. Checking for Errors by Measuring

a. Click on the **Evaluate** tab

b. Click **Measure**

c. Use this tool to check to see if you dimensioned features incorrectly. If your part mated correctly you do not need to find incorrect dimensions, but continue so you learn how to use the measure tool. To check the location of a circular hole center or shaft, first click on the perimeter of the feature and then click the side you want to measure from. Check the measurements with those in Figure 2 and see which hole/pole is dimensioned wrong in location or size. To un-highlight a plane or feature, click somewhere off the part in the Graphics Area.

d. Close the *Measure* popup box to exit the measure feature

### 2. Editing Mates

a. In the Feature Manager Design Tree expand Mates (located at the bottom of the Feature Manager Design Tree)

b. By hovering the mouse over each listed mate, a preview of the mate will appear on the part

c. To edit a mate, right click on the mate and select the **Edit Feature** tab. This is helpful for editing distance mates

d. Mates can be deleted by right clicking and selecting Delete

### 3. Save Assembly

a. Click **Save** icon in the Menu Bar

b. Select folder to save part in

c. Name your project

d. Click **Save** button

## Exploded Views

### 1. Create an exploded view of the assembly

a. Display the assembly in the trimetric orientation under the **View Orientation**  button at the top of the Graphics Area. To do this you will have to select the dropdown menu from the isometric icon

- b. Click the **Assembly** tab
  - c. Click the **Exploded View** icon
  - d. While the *Settings* box is highlighted blue, click the upper most part to signify which part is going to move away from the assembly
  - e. On the axis on the part select the Y axis, the one pointing upwards, by clicking the arrow
  - f. Set *D1* to 2 inches
  - g. Click Apply
  - h. The top part should move upwards away from the bottom part
  - i. Click the **Green Check** icon in the *FeatureManager*
  - j. To collapse the exploded view, right click on one of the blocks, select collapse
2. Save Assembly

## Manipulation of Part Orientation

When we mated components, we simply changed the part orientation by using the Mate settings. If a part needs to be reoriented without being mated, below is an easy method to accomplish this.

1. Insert a third block into the assembly file by clicking on the **Insert Components** icon in the *Assembly* tab
  - a. Right click on the new part
  - b. Select *Move with Triad*
  - c. Click and drag a specific axis arrows to translate the part in the respective direction
  - d. Click and drag the rings to rotate the part
2. Delete the extra part
3. Save Assembly

## Drawings

Drawings are very important when obtaining price quotes from machinists, explaining a part to a colleague, or creating the part yourself in the machine shop. Drawings should be descriptive and include dimensions for everything needed to recreate the part. We are going to recreate the drawing shown in Figure 2.

### Setting up the Drawing

1. Open "New Document"
  - a. Click the **Drawing** square
  - b. Click **OK** button
  - c. Select **B-Landscape** from the scroll down menu in the *Sheet Format/Size* pop-up box
  - d. Click the **OK** button

### Inserting Views

1. Choose part/assembly
  - a. Select the part to be drawn in the Part/Assembly Insert box in the *PropertyManager* on the left side of the screen
  - b. Click the blue **Next Arrow** found at the top right corner of the *PropertyManager*
2. Choose views to show
  - a. Select **Preview** found at the bottom of the Orientation box in the *PropertyManager* to display a preview in the Graphics Area
  - b. Select **Top View** icon from the *Standard Views* box
  - c. Move mouse cursor into the *Graphics Area* and place the Top View in middle of the Graphics Area by left clicking once
3. Inserting projected views
  - a. Move the mouse cursor to the right and click to display the **Right End View**
  - b. Move the mouse cursor to the left and click to display the **Left End View**
  - c. Move the mouse cursor downwards and click to display the **Front View** (this will be moved later)
  - d. Move the mouse cursor down and left to display the **Isometric View**, do the same for the upper right corner isometric view.
  - e. Click the **Green Check** icon in the *FeatureManager*
  - f. If too many views were accidentally placed, right click on the extra view and delete it

- g. If a view was missed, highlight the **Top View** left clicking on it
- h. Under the **View Layout** tab, click **Projected View** and place the missing view on the drawing
- i. Views can be relocated by clicking on and dragging them

#### 4. Place the **Front View**

- a. Due to limited space for dimensions, the **Front View** is going to be located on the left side of the sheet
- b. If you try to drag the front view to the left, it will not go because it is aligned with the **Top View**
- c. To break the alignment, right click on the **Front View**, highlight *Alignment*, select *Break Alignment*
- d. Place the **Front View** in the upper left hand corner
- e. Your drawing should now have the almost the same view placement as Figure 2, with a difference in the front view

#### 5. Save Drawing

## ***Inserting View Labels and Altering the Display Style***

#### 1. Inserting a label for the Top View

- a. Select the **Annotation** tab
- b. Click on **Note**
- c. Place the note above the **Top View**
- d. Change the font size to 26
- e. Select Bold for the font style
- f. Type **Top View**
- g. Click the **Green Check** icon in the *FeatureManager*
- h. Reposition the label if need be by dragging it

#### 2. Create labels for all other views

- a. Left click on the **Top View** label so that it is highlighted blue
- b. Use "control+c" to copy the note
- c. Use "control+v" to paste the note
- d. Place the note where necessary, double click on the note and type in the correct view label
- e. Repeat so that all necessary views are labeled as they are in Figure 2. Include a units label.

#### 3. Change the display style for the top isometric view and the right end view

- a. Click and highlight the top isometric view
- b. Under the *Display Style* in the *FeatureManager* select *Shaded With Edges*
- c. Click and highlight the right end view
- d. Under the *Display Style* in the *FeatureManager* select *Hidden Lines Visible*

#### 4. Label the **Top Plane**


- a. Copy the Top View label and paste it
- b. Double click on the pasted label and change it to a non-bolded font with a size of 16 displaying Top Plane
- c. Place it accordingly on the top plane of the part as shown in Figure 2

#### 5. Save Drawing

## ***Inserting Dimensions***

When inserting dimensions in a SolidWorks drawing, it is the same thing as labeling. The Dimensions are already set in the part file and will automatically show up in correct value when you ask it to be displayed.

#### 1. Set up dimension font size

- a. Click on Options icon  at the top of the page > Document Properties
- b. Click on **Dimensions** (Not just expanding it, but click on **Dimensions**)
- c. Click on **Font**
- d. Fill in Points bubble
- e. Select 24 for a value
- f. Click **OK**

#### 2. Insert Dimensions according to Figure 2

- a. Select the **Annotation** tab
- b. Click on **Smart Dimension**
- c. Label part dimensions in the same fashion as setting dimensions while making the part

## Editing Title Block

### 1. Edit the Title Block

- Right click the **Sheet Format1** text under Sheet1 in the *FeatureManager*
- Click **Edit Sheet Format**
- Zoom in to the lower right corner
- Double Click on TITLE: and replace with DRAWN BY: JOHN SMITH (but insert your own name instead)
- Bold the text and make it big enough to fill in the entire box, your name might be split into two lines
- Add any other information desired
- Editing the Drawing Number

If you saved your part with a really long title, chances are it is not fitting in the DWG. NO. box. You can now edit this by double clicking on it and renaming it or giving it a part number so that it fits in the box. You can decrease the font size to help it fit, but be careful that it is large enough to be comfortably readable when it is in an 8"x11" print out form.

- Right click the **Sheet Format1** text under Sheet1 in the *FeatureManager*
- Click **Edit Sheet**

### 3. Save the drawing

## Adding Detailed and Section Views

### 1. Create a new drawing

- Use the instructions found in Setting up the Drawing and Inserting Views to create a new drawing with *only the front view* in the center of the page.

### 2. Insert detailed view of the lower right corner of the front view

- Click the **View Layout** tab
- Click **Detailed View**
- Click **High Quality**
- Use the cursor to draw a circle around the lower right corner as shown in Figure 9, be sure to include two of the holes
- Place the detailed view appropriately by dragging the circle by perimeter and center point
- Play with the detail view settings. Change the style and scale

### 3. Save the drawing

### 4. Insert a section view of the part

- Click the **View Layout** tab
- Click **Section View**
- Place the section view centered on the left post as shown in Figure 9
- Drag the section view and place it to the left of the part. Notice how the part is where the arrows of the section view are pointing, this is done for conventional reasons. The hash marks on the section view indicate where the a cut was made in the solid material

### 5. Save the drawing

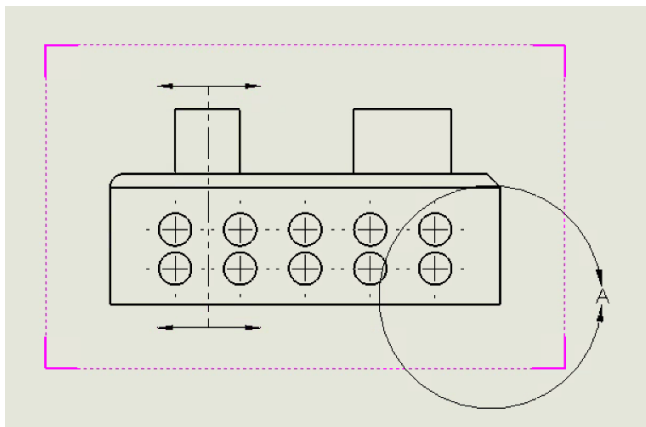


Figure 9: Centerline for the section view


## Printing and Sending Drawings

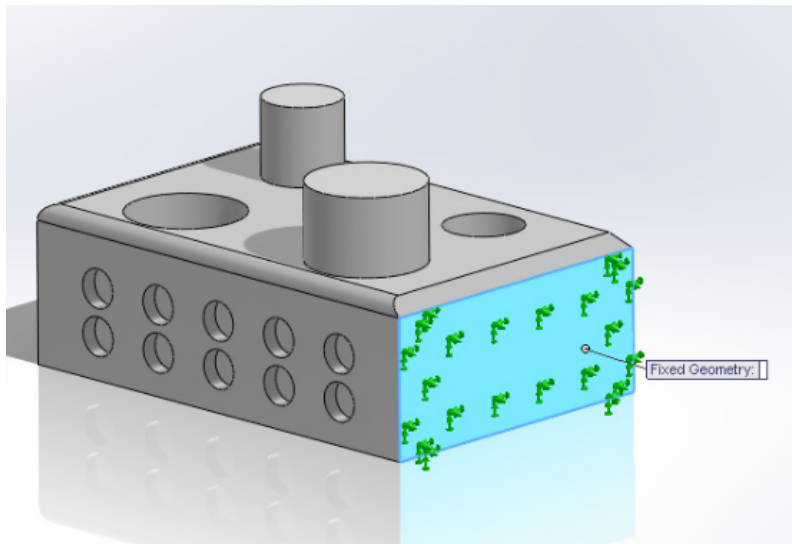
Printing a SW drawing or emailing one to a colleague can be frustrating. To print a drawing directly from SolidWorks, highlight the File dropdown menu. Select Page Setup. Under the Resolution and Scale section, highlight the bubble Scale to Fit. This will provide a full print out of the drawing. It is important to note that it is a good idea to save the drawing as a JPEG if you plan on opening the drawing on a computer that does not have SW installed on it as it will be save as a

SW file if not specified. When sending a SW file to a professor or advisor, send them a JPEG version of the drawing so they can easily open it up on their office computer. To do this with the best quality image, make maximize SW on your monitor, then press the F key on the keyboard to zoom in. Next, click save as, and save it as a JPEG.

## SimulationXpress Analysis Wizard

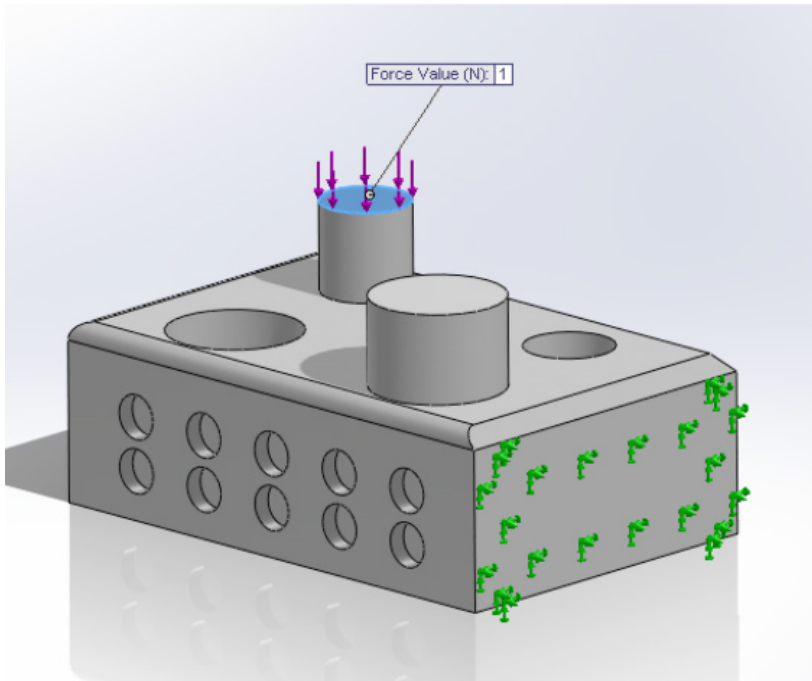
The SimulationXpress Analysis Wizard allows you to do stress analysis on a part. It will give you an idea on what types of loads a part can withstand before failure as well as the factor of safety. If you plan to use this tool for a project, it is important to make sure SolidWorks has the material properties of the material you plan on using stored in its data bank.

1. Use the control + TAB short cut to riffle through open files in SolidWorks
  - a. Hold down the CONTROL keyboard key
  - b. Press the TAB keyboard key once while still holding CONTROL
  - c. Press TAB again to highlight different files
  - d. Once the part file is highlighted, let go of CONTROL and it will maximize the part file window
  - e. To switch back and forward between two files, simply press CONTROL + TAB and let go of both. This allows you to quickly go back and forward between two files such as a part and its drawing
  - f. Make sure the part file is maximized before going on
2. Open the Simulation Wizard
  - a. Click the **Evaluate** tab
  - b. Click on the **SimulationXpress Analysis Wizard** icon , add-ins, deselect it, try clicking **SimulationXpress Analysis Wizard**
3. Apply a fixture to the part
  - a. Read the text in the *SimulationManager* popup now and for each of the follow steps
  - b. Click the **Green Next** arrow in the *SimulationManager* popup
  - c. Click *Add a fixture*
  - d. Orient the part so that it is in shown in Trimetric form
  - e. Select the face as shown in Figure 10 while the *Standard (Fixed Geometry)* box is highlighted in the *FeatureManager*
  - f. Click the **Green Check** icon in the *FeatureManager*
  - g. Click the **Green Next** arrow in the *SimulationManager* popup



**Figure 10:** Fixture face for the part

4. Apply a force to the part
  - a. Click *Add a force* in the *SimulationManager* popup
  - b. Select the top face of the small post as shown in Figure 11
  - c. Make sure the units are English (IPS)
  - d. Set the force to 200 lbf
  - e. Click the **Green Check** icon in the *FeatureManager*
  - f. Click the **Green Next** arrow in the *SimulationManager* popup



**Figure 11:** Force face for the part

5. Apply a material to the part
  - a. The material was specified when you made the part as PS Medium/High Flow
  - b. Click on *Change material*
  - c. For a material to be testable in this simulator, each of the properties highlighted in red must be available. Not all materials in SolidWorks have these properties available. Due to this, plan accordingly when making projects if you wish to use this analysis feature. Choose *Nylon 101* from the *Plastics* folder
  - d. Click *Apply*
  - e. Click *Close*
  - f. The material should now read *Nylon 101* in the *SimulationManager*
  - g. Click the **Green Next** arrow in the *SimulationManager* popup
6. Run the Simulation
  - a. Click *Run Simulation*
  - b. If the part does not behave how you expect it to in future projects, this is where you would edit the constraints. Click *Yes, continue*.
7. View the results
  - a. Click each of the green arrows to view the different results
  - b. Click *Play animation* to view how the part deflects
  - c. Click *Stop animation*
  - d. Notice below *Show where factor of safety (FOS) is below: 1* it signifies that the lowest FOS is ~3.4 based on the parameters. A general guideline to follow is to have the FOS of your part be somewhere from 2 to 3. For parts that are involved in safety mechanisms, a higher FOS would be desired
8. Edit the FOS settings
  - a. Under *Show where factor of safety (FOS) is below*: change the number to 5
  - b. Click *Show where factor of safety (FOS) is below*:
  - c. Notice the portions of the part that turn red. These are the failure points of the part
9. Change the Mesh Settings: The mesh settings of the part also affects the accuracy of the analysis. The simulation is preset to run at a "medium" mesh. If we change the mesh to "fine" it will create smaller triangle size and create a more accurate force analysis.
  - a. Hit the *Back* button at the bottom right twice until you are on the Run page. Select *Change Settings*
  - b. Select *Change Mesh Density*, select *okay*
  - c. Check the *Mesh Parameters* box to see the metrics of the mesh triangles
  - d. Change Mesh density to *Fine*
  - e. Select *Next*
  - f. *Run the simulation*, select *Yes, continue*
  - g. What has the lowest FOS changed to now that we refined it to a higher quality mesh? Why is this the case?
10. Edit the load parameter
  - a. At the bottom of the *FeatureManager* locate the *External Loads* folder.
  - b. Right click on *Force-1*
  - c. Click *Edit Definition*



- d. Change the force to 600 lbf
- e. Click the **Green Check** icon in the *FeatureManager*
- f. Click *Rerun the study* in the *SimulationManager*
- g. Click *Yes, continue*
- h. Notice how the lowest FOS now changes to  $-0.95$  if the part is expected to experience a loading of 600 lbf

11. Create the report

- a. Click *Done viewing results*
- b. Click *Generate report*
- c. Click *Generate* in the popup window
- d. Save the report
- e. Show the report to an SA to show that you completed the tutorial.
- f. Click *Generate eDrawings file* play around with the different features in the file. Show the eDrawings to an SA to show you completed the tutorial.



# Lab: SolidWorks I

## Assessment Questions

### Directions:

- The following questions correlate with the lab exercises and should be answered in **Canvas** SolidWorks I assessment to receive credit. Feel free to take any notes here, but your work here in the notebook will not be graded.

**1. What is the factor of safety?**

- The ratio of how many people are wearing their seatbelt to how many are not.
- The ratio of the yield stress of the material to the calculated minimum stress when in use
- The ratio of the breaking stress of the structure to the calculated maximum stress when in use

**2. What is an example of why FOS should be considered during design? A structure can be built much stronger than necessary in case of...**

- An emergency situation
- An unexpected load
- Misuse
- Degradation
- All the above.

**3.** In order to create this piece from a block of plastic, it is necessary to use an end mill to first cut the stock material to the proper size on the \_\_\_\_\_. While still on the \_\_\_\_\_, it is possible to use a(an) \_\_\_\_\_ to make the smaller hole and a(an) \_\_\_\_\_ to make the \_\_\_\_\_. Next, it is possible to make the \_\_\_\_\_ using the CNC capabilities of the \_\_\_\_\_. Finally, the linear pattern of holes can be made using a(an) \_\_\_\_\_ and can be done by hand or with the CNC function on the \_\_\_\_\_. Fill in the blanks using the following options, enter only the number associated with the answer choices below:

- 0.5" drill bit
- mill
- smaller hole
- 0.75" drill bit
- larger hole
- fillets, posts, chamfers
- posts and fillets
- chamfers and posts
- 0.25" end mill
- lathe



# Lab: SolidWorks I

*Lab Report: 3D Modeling and Finite Element Analysis Report*

***DUE: at the Beginning of Lab in two weeks***

## Directions:

- The **Team Leader** should **submit** the responses in a **PDF format to the Canvas** to receive credit.
- **All members should include a copy in their notebook.** List the names of the members who worked on the lab report in the entry. Do your best to divide the work amongst group members evenly.
- This section of your report should answer the following questions in paragraph form, and include (IEEE) citations where necessary.
- There are 2 key parts to this report:
  - 1. Designing a sample holder to be used in the bioreactor
  - 2. Conducting initial testing on a bone graft sample in SolidWorks

For your final project, you will need to design a 'holder' for the bioreactor. It will suspend the biomaterial in the environment. Refer to the design specifications and develop a 3D model of your design ideas.

- Please provide SolidWorks images of at least three (3) different design ideas for the sample holder of the bioreactor including dimensional drawings. **Note, that each team member should come up with and draw in SOLIDWORKS (at least one) of their own unique design(s). This should appear (as an image and SOLIDWORKS file attachment), with a detailed description, in your notebook as a design idea(s). Your notebook should also include any initial hand drawings of this design as well as the evolution of your design idea into the CAD drawing (not simply one image). You need not provide all design ideas from every team member in this report.**
- Provide explanations for the functionality of different aspects in each design. Create a design matrix comparing each of your designs and explain the relative weighting of the different qualities by which you choose to judge your designs. Indicate which of the possible designs scored the highest, and why it will be chosen over the other options.
- Consider the potential stock materials to be used for the sample holder (3D printing is not an acceptable approach).
- For an initial assessment of your bone graft, use SolidWorks simulation tools and materials manager to create a custom material or a predefined material with properties similar to the values you found for bone during your literature search. Experiment with different shapes and forces to simulate mechanical testing on the MTS machine. Remember that the client needs the samples to fail during compressive testing, and that the MTS is capable of applying a maximum load of 10kN. Include any references for force expectation data from literature research.



# Lab: SolidWorks I

## *Appendix*

If you are interested in learning more about SolidWorks applications and tools, check out the SolidWorks Resource Center: <http://www.solidworks.com/sw/resources.htm>. You will find demo videos, online help and tips, and tutorials.



# Lab: SolidWorks II

## Background and Pre-Lab

### Directions:

- The following questions correlate with the background material and should be answered in canvas to received credit. Feel free to take any notes here based on this section of the lab. Your notes for this section will not be graded.
- Read through the entire pre-lab section and complete the following tasks. All pre-lab work, including pre-lab quizzes, must be completed and turned in prior to the start of lab.

### Overview

This lab will build on the skills you learned in the previous lab. The goals for this lab are:

- Learn additional SolidWorks modeling features and techniques
- Understand how theoretical stress analysis and computer aided stress analysis is different

### Theoretical Stress Analysis

Two of the most important aspects of design are user safety and product strength. It is always good to keep in mind failure modes of the parts you are designing as well as how failures of that part affect the user and their safety. A good modeling package should be able to calculate different loads on a part for you, but is always good to understand how these calculations are made and know if the computer's results reasonable. By knowing the relationships of several of the part's material properties, as well as its dimensions, simple stress calculations can be made.

$$\text{Stress } \sigma = \frac{F}{A}$$

$$\text{Strain } \varepsilon = \frac{L_f - L_i}{L_i} = \frac{\Delta L}{L_i}$$

$$\sigma = \varepsilon * E$$

**Table 1:** Properties for ASTM A36 Steel

ASTM A36 Steel Properties	
Yield Stress $\sigma_y$	250 MPa
Ultimate Stress $\sigma_u$	400 MPa
Elastic Modulus $E$	200 GPa

A simple tensile test is run on a bar of ASTM A36 Steel with a diameter of 15mm and a gage length of 150mm. Use the material properties provided in Table 1 to answer the following quiz questions on the course website.

**1. If  $\sigma = 200$  MPa, what is the force applied?**

F =

**2. What is  $\epsilon$  for this test?**

$\epsilon =$

**3. If  $\epsilon = 0.002005$  mm/mm, what is  $\sigma$  ?**

$\sigma =$

**4. Will the bar fail under this stress?**

- a. yes
- b. no

**5. What is the force applied at  $\epsilon = 0.002005$  mm/mm?**

F =

**6. Watch the ASTM A36 Steel Tensile Test YouTube video that is linked on Canvas Courses. Where does the rod break?**

- a) Near the end
- b) Somewhere in the middle
- c) What Rod?

**7. What does the term “necking” mean in tensile testing?**

- a) non-uniform deformation of a ductile material in a tensile test
- b) melting of the metal at areas under large amounts of stress
- c) uniform deformation of a ridge material in a tensile test

# Lab: SolidWorks II

## Lab Protocol

### Solid Modeling, Assemblies, Drawings, and Stress Testing

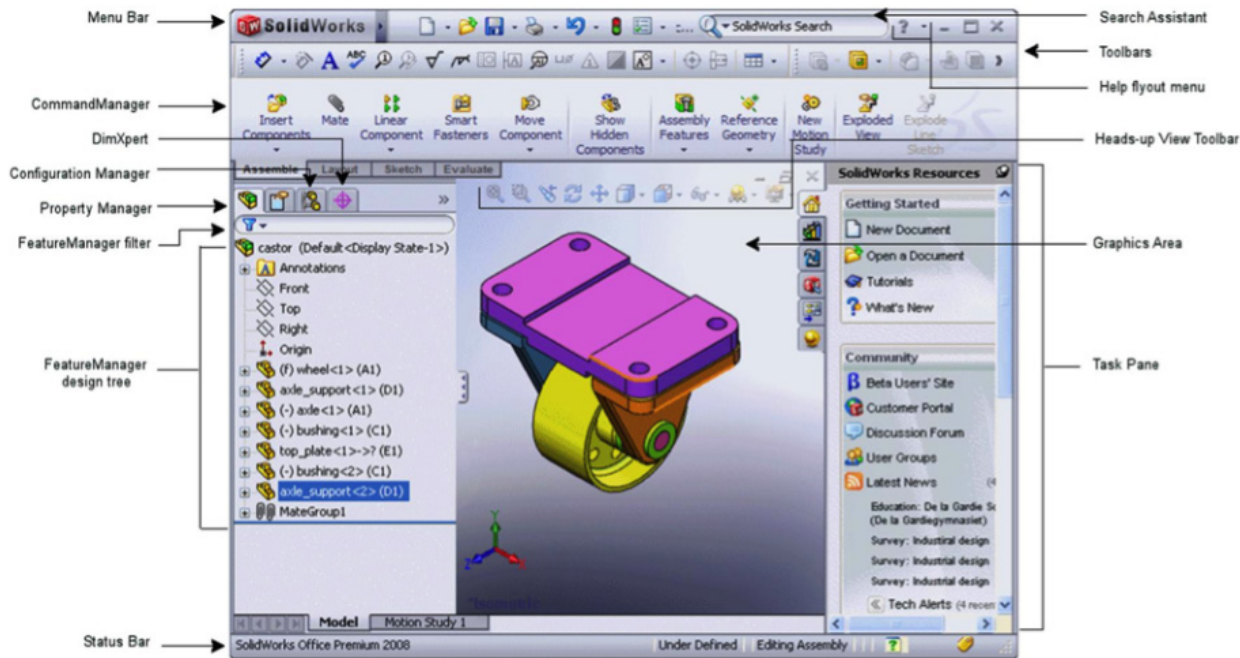



Figure 1: User interface for SolidWorks


## Revolved Boss/Base and Shelling

1. Open "New Document"

- a. Check Units:  Options icon at the top of the page > Document Properties > Units > IPS > **OK**

2. Revolved Boss/Base

- a. Click **Revolved Boss/Base**
- b. Select the **Right** Plane

c. Use lines and centerlines to create the sketch shown in the left side of Figure 2 (centerlines can be found from the line  dropdown menu in the sketch tab)

d. Dimension the sketch as shown in the right side of Figure 2 below

e. Note that the bottom line in Figure 2 is not a centerline

f. Click on the **Spline** icon 

g. Click the lower left endpoint of the solid line in the sketch




h. Work your way up the left endpoints of the centerlines by clicking on them as shown in the right side of Figure 3

i. Once you click the top endpoint, click on the **Spline** icon again to end the spline

- j. Draw a vertical centerline starting at the top endpoint, or the end of the spline as shown in the right side of Figure 3
- k. From the dropdown menu of the *Display/Delete Relations* icon in the *Sketch* tab, click *Add Relation*
- l. While the *Selected Entities* box is highlighted blue, select the spline sketch as well as the vertical centerline previously drawn.
- m. Click *Tangent* in the *Add Relations*
- n. Click the **Green Check** icon in the *FeatureManager*
- o. Add the two solid lines to complete the sketch as shown in Figure 4 and dimension them properly as shown
- p. Click **Exit Sketch** (If you accidentally exited the sketch prematurely at some point previously and had to go back in and edit it, you may have to highlight the sketch on the left in the feature tree by clicking on it, then select **Revolved Boss/Base** in the *Features* tab)
- q. While the *Axis of Revolution* is highlighted click on the .500 inch line drawn in step o.
- r. Click the **Green Check** icon in the *FeatureManager*

3. Save Part

4. Shell the part

- a. Click **Bottom** from the *View Orientation*  icon at the top of the Graphics Area
- b. Click on the **Shell** icon  in the *Features* tab
- c. Click on the bottom of the part while the box in the *FeatureManager* is highlighted
- d. Click the **Green Check** icon in the *FeatureManager*
- e. Click *Hidden Lines Visible* from the *View Orientation* icon 
- f. Inspect the internal cavity of the part created by the shell
- g. Return to *Shaded With Edges* from the *View Orientation* icon

5. Save Part

6. Create a Drawing of the Vase

- a. Include in the drawing a front view, a side view, and two isometric views above the part
- b. One of the isometric views should be *Shaded with Edges* and one should be *Hidden Lines Visible*
- c. Include a Section view of the end view by cutting the end view down the middle
- d. Do not include anything else (labels, dimensions, units, etc.)
- e. Show an SA the drawing before moving on

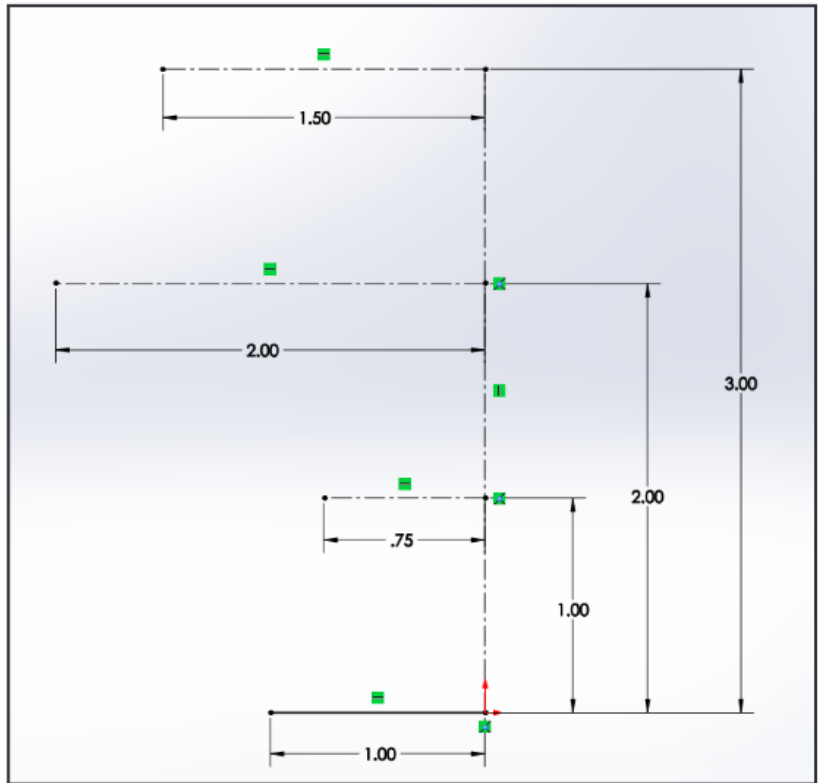
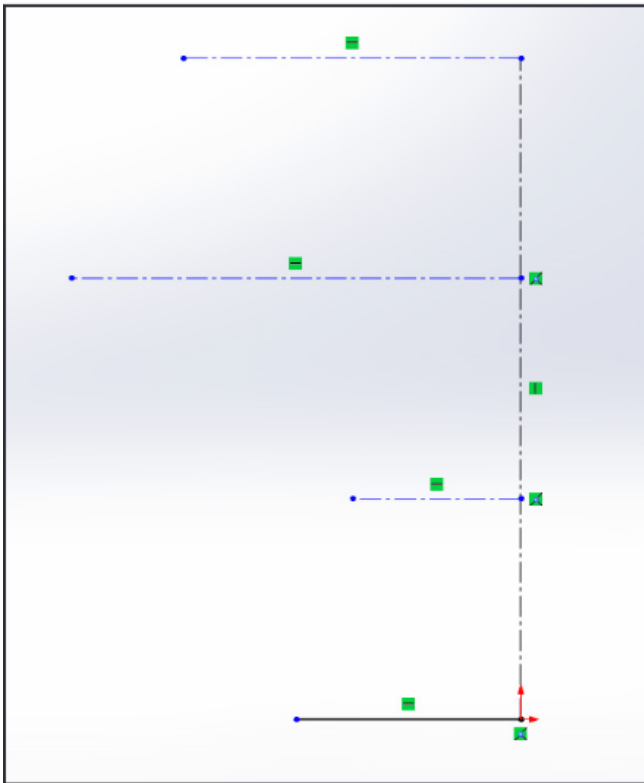


Figure 2: Left: Sketch layout. Right: Sketch with dimensions



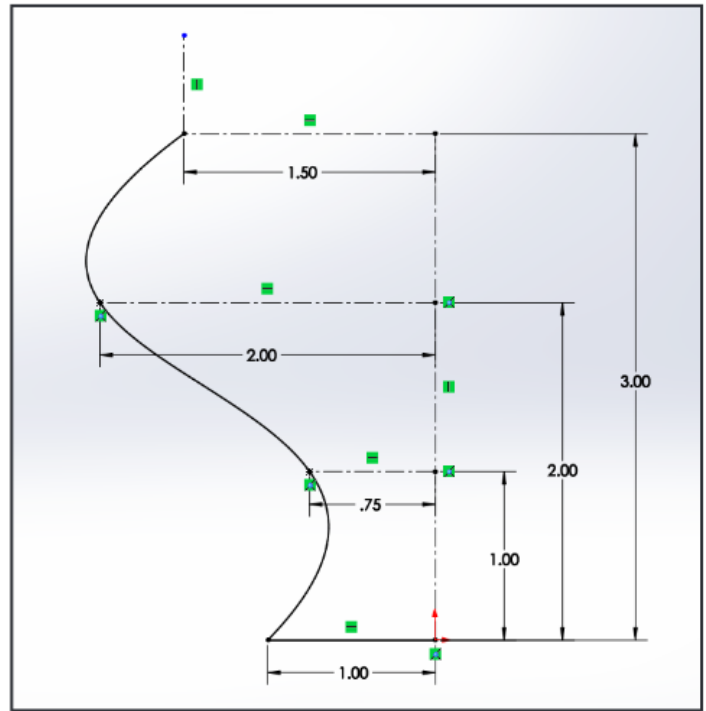
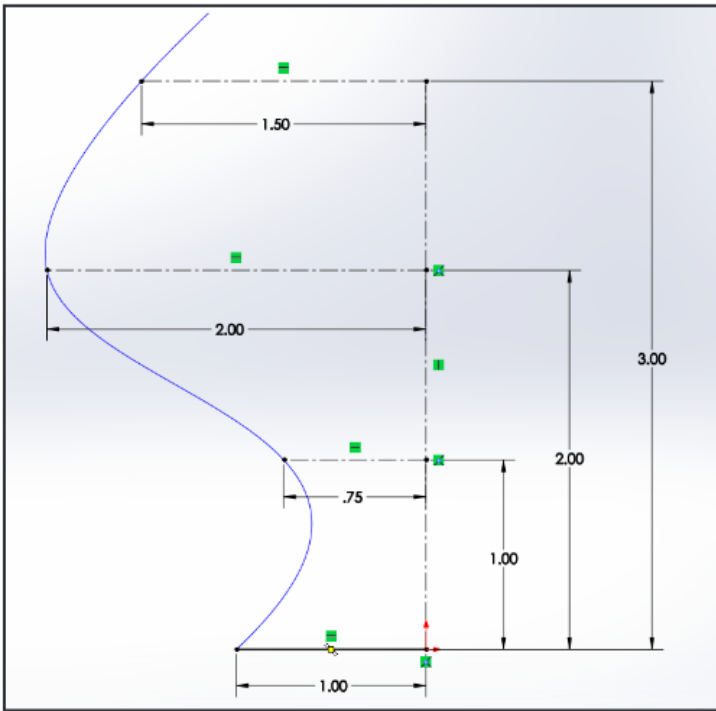


Figure 3: Left: Creating the Spline. Right: Adding a Centerline to the end of the spline.

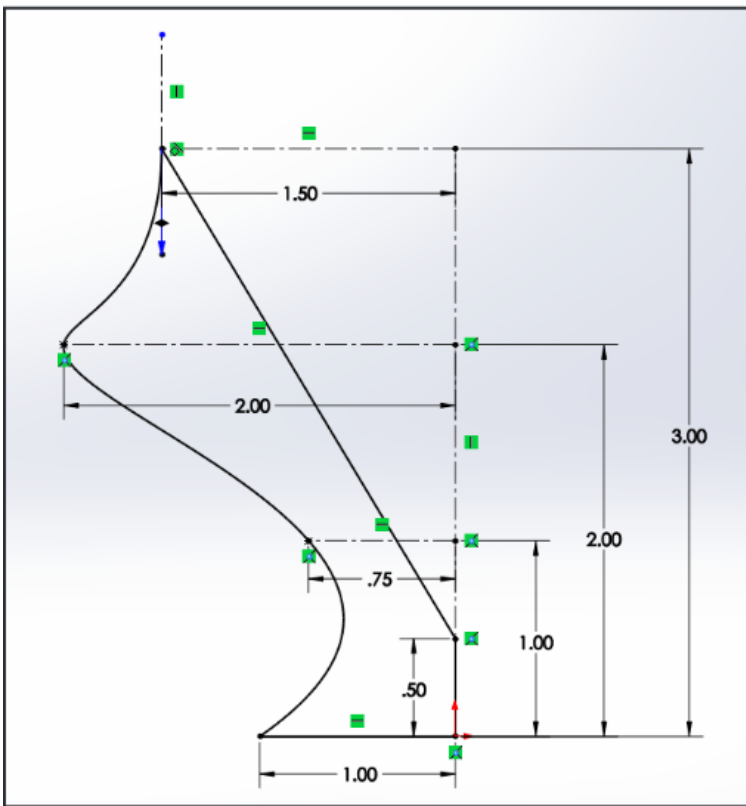



Figure 4: Addition of two final lines, one being dimensioned at .500 inches.

## Lofted Cuts


1. Open "New Document"

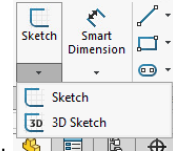
a. Check Units:  Options icon at the top of the page > Document Properties > Units > IPS > OK



2. Make a circular lofted cut through a rectangular prism

a. Extrude a 5"x5" rectangular sketch on the top plane to a depth of 3", Figure 5

b. Click **Right** from the *View Orientation*  icon at the top of the Graphics Area

- c. Create a sketch on the **Right** side of the prism using a centerline to find the center of the rectangle and center a 2.5" diameter hole as shown in Figure 6. Place a Point  at the right most edge of the circle as shown in Figure 6. Exit sketch.
- d. Now create the sketch a 1" diameter circle shown in the left image of Figure 7 on the **Front** side. Place a Point on the left most edge of the circle. Note, two center lines are used, one to find the center of the rectangle as done previously, and a second centerline to find the halfway point from the upper corner of the rectangle, to the center point as shown in the right image of Figure 7. Exit sketch.
- f. Create a reference plane using the edges highlighted in pink and purple as shown in Figure 8.
- g. Create a sketch on the reference plane of a 1" diameter circle shown in Figure 9 using the two centerline technique done previously. Place a Point on the left most edge of the circle. Exit sketch.



- h. Next create a 3D sketch. From the Sketch Tab, click the down arrow under the Sketch icon to select 3D Sketch.
- i. Click the spline icon and place a spline starting from the point placed on the 2.5" circle, then the point on the 1" circle inside the part, and finally the point on the 1" circle on the **Front** side as shown in Figure 10. Click the spline icon again to end the spline. Exit the 3D sketch by clicking on 3D Sketch the same way you started the 3D Sketch in the previous step.
- j. Next click on the Display Style icon  at the top of the screen and select Wireframe.
- k. In the Features tab, select  Lofted Cut
- l. In the Profiles box, select the 2.5" circle, the 1" circle inside the part, and then the 1" circle on the **Front** side of the part in that order. Select the spline as a Guide Curve as shown in Figure 11. Hit the green check mark to complete the lofted cut. Guide curves can be used to better define the path you wish the lofted cut to take, but in this case the preprogrammed curve without the guideline is close to the path our guide curve defines.
- m. Click on the Display Style icon and change it back to shaded with edges.
- n. Show an SA the part before moving on
- o. If you have time at the end of the lab, try editing the guide curve to force the path of the loft in a manner of your choosing.

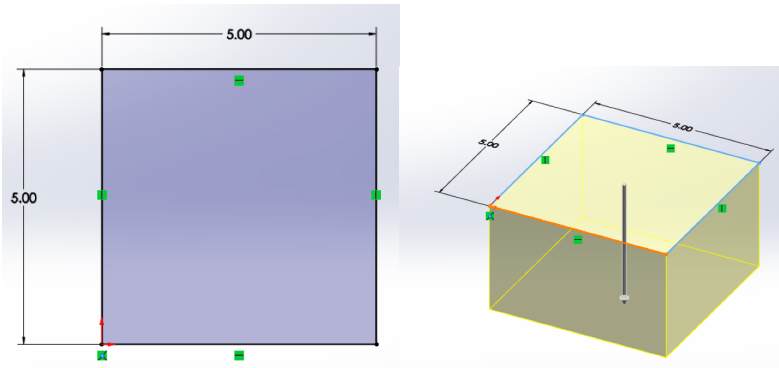


Figure 5: Extrude a 5"x5" sketch to a depth of 3".

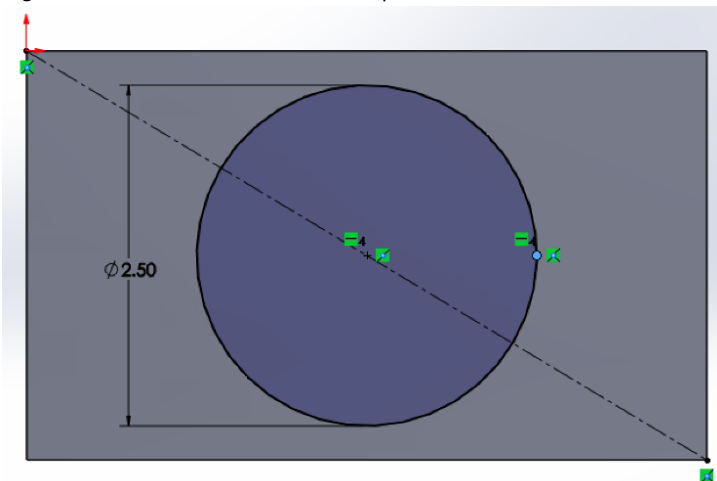
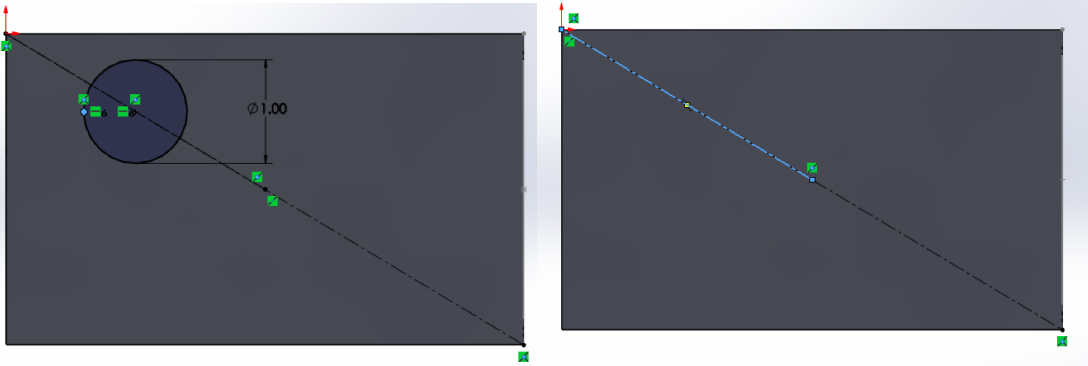
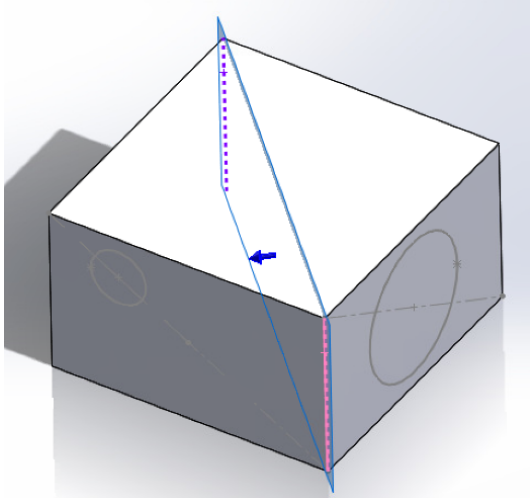


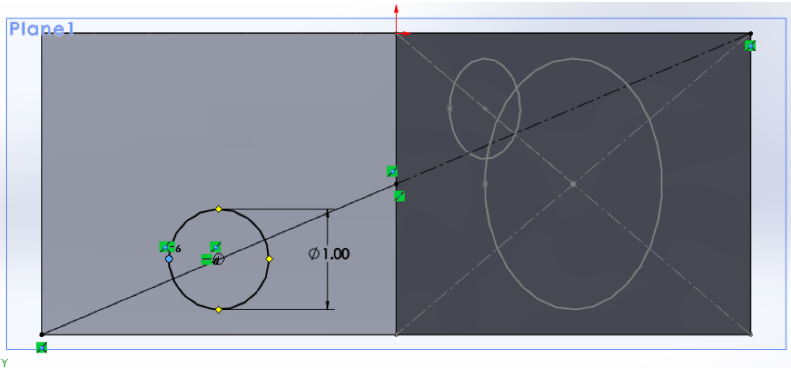
Figure 6: Sketch of a 2.5" diameter hole at the center of the **Right** side



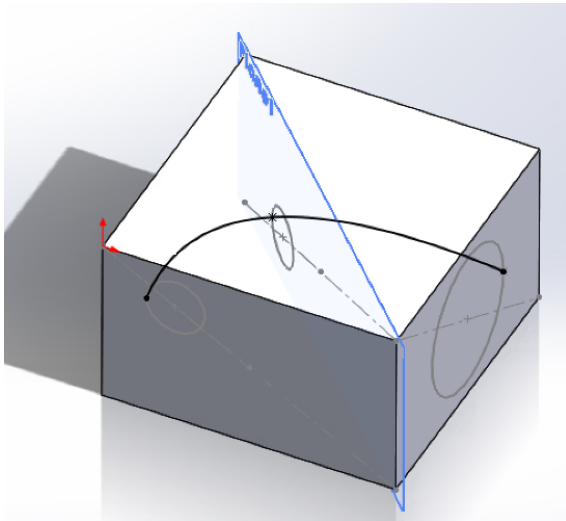
**Figure 7:** Left: Sketch a 1" diameter hole at the center of the upper left quadrant of the **Front** side. Place a Point on the left most edge of the circle. Right: Use two centerlines to find the center of the upper left quadrant. First draw a centerline from the bottom right corner to the top left corner. Next draw a second centerline from the top left corner to the midpoint of the first centerline.



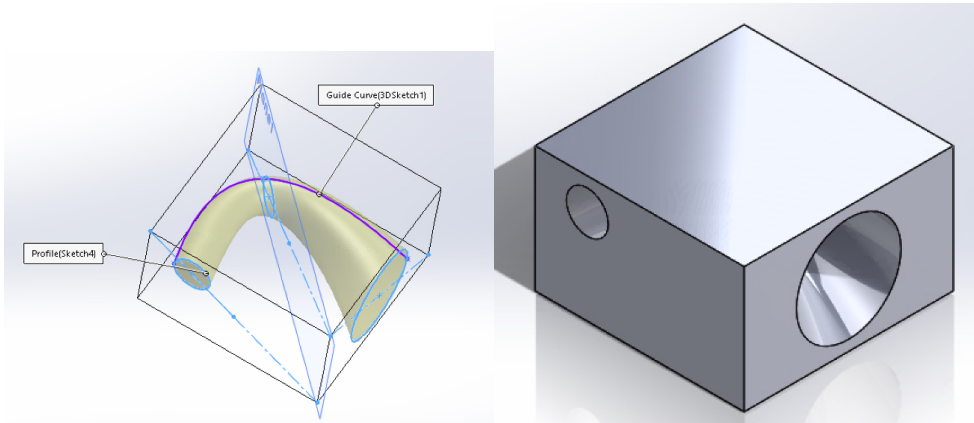
**Figure 8:** Create a reference plane using the two diagonal edges shown.



**Figure 9:** Create a sketch of a 1" diameter circle using the two centerline technique shown previously to place the circle at the center of the bottom left quadrant of the rectangle. Place a Point on the left most edge of the circle. Note, the gray sketches in the right half of the part are the sketches completed in the previous steps.



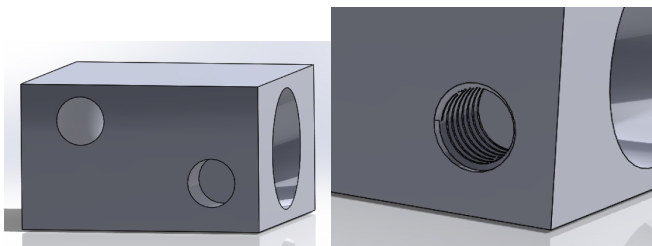
**Figure 10:** Create a spline connecting each of the circles using the point on each circle.



**Figure 11:** Creating the lofted cut.

## Threading Holes and Countersinks

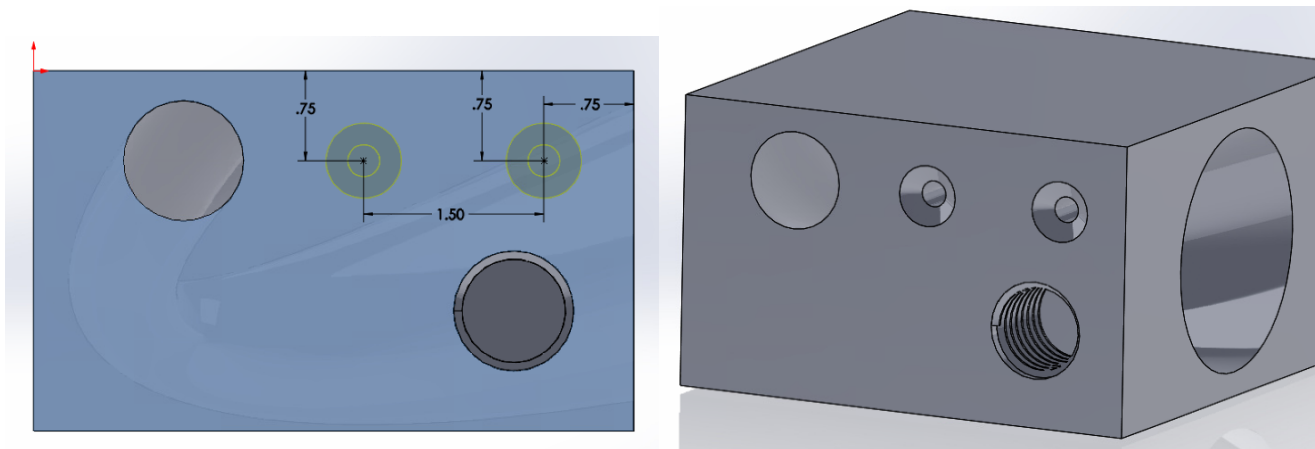
1. Use the same part created for the Lofted Cut.
2. On the Front face of the part, extrude cut a 1" diameter hole, 1" from both the right edge and 1" from the bottom, 1" deep as shown in the left of Figure 12.
3. Create threads in the hole
  - a. In the Features tab, click the down arrow in the Hole Wizard icon, select Thread. Select OK if a warning pops up.
  - b. Select the outside rim of the 1" hole while the Thread Location box is highlighted.
  - c. Select the bottom of the hole for the End Condition. Up To Selection should be selected.
  - d. Under Specifications: Type - Inch Die, Size - 1.0000-8, Thread method: Extrude Thread, Thread Options: Right-hand thread, trim with end face
  - e. Hit the green check mark. The threaded hole should appear as it does in the right of Figure 12.



**Figure 12:** Extrude a 1" hole 1" deep on the Front face and create threads.

4. Place several countersink holes next to the treaded hole.
  - a. In the Features tab, click the down arrow in the Hole Wizard icon, select Hole Wizard.
  - b. Select Countersink under Hole Type
  - c. Standard: ANSI Inch, Type: Flat Head Screw (100), Size 1/4, Fit: Normal, End Condition: Blind to 1.000in, Head clearance: 0.05 in.


- d. Select the Positions Tab, select the Front face
- e. Place two holes and use the Smart Dimension tool to place them as shown in Figure 13.
- f. Select the green check mark
- g. Show and SA before moving on.



**Figure 13:** Place two countersink holes at the locations shown.

## Creating an ASTM A36 Steel Tensile Test Specimen

1. Use the Revolved Boss/Base Feature to create the test specimen shown in Figure 14

- a. Change Units to metric:  Options icon at the top of the page > Document Properties > Units > MMGS> **OK**
- b. Use the **Right Plane** to sketch in
- c. Hint: do not sketch the full outline of the bar shown in the drawing to avoid revolve errors
- d. If you are prompted that your sketch is open, it means you didn't close it with lines and may have used center lines instead. Select no and edit your sketch appropriately.
- e. Apply the appropriate material

2. Save Part

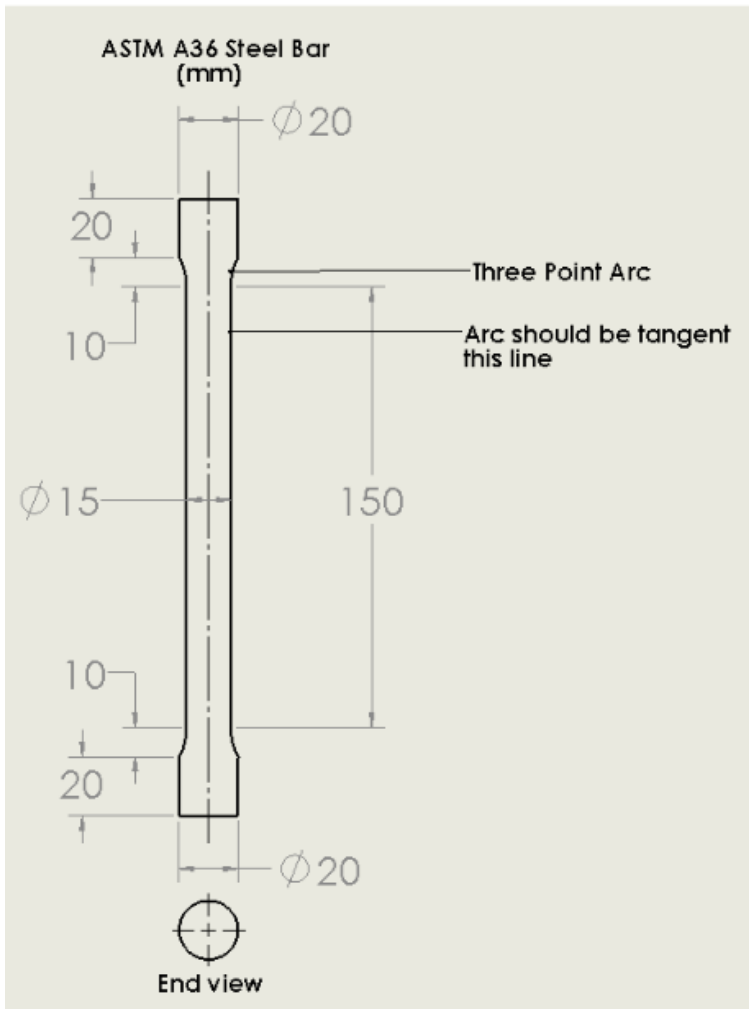


Figure 14: Drawing of ASTM A36 Steel Specimen

## Performing a Tensile Test With the SimulationXpress Analysis Wizard

1. Open *SimulationXpress Analysis Wizard* from the **Evaluate** tab (you may have to go to Tools > Add-Ins... > deselect SolidWorks Simulation then click *SimulationXpress Analysis Wizard* again)
2. Perform the tensile test
  - a. Fix the bottom of the part
  - b. Apply the force found in the PreLab to stress the bar to 200 MPa to the top of the part. Make sure it is in tension.
  - c. Apply the material
  - d. Run the simulation
  - e. Analyze the results and record the lowest FOS in this design with this loading.
  - f. When analyzing the results, be sure to find the initial failure point. Ask SimulationXpress to show where a FOS is just above the lowest FOS found in the design. This will show the initial point of failure. If you ask it to show where a FOS is greatly above the lowest FOS in the design, the entire part will show failure. Will the part ever experience such a load that will cause this type of failure?



# Lab: SolidWorks II

## Assessment Questions

### Directions:

- The following questions correlate with the lab exercises and should be answered in **CanvasSolidWorks II** assessment to receive credit. Feel free to take any notes here, but your work here in the notebook will not be graded.

**1. What is the lowest FOS for the part in Figure 5 at this load?**

- a) 10
- b) 5.6
- c) 1.15
- d) 18.6

**2. At what force will the part fail (assume a FOS of 1 is a failure)?**

- a) 19,550N
- b) 70,700N
- c) 71,400N
- d) 40,640N

**3. Based off of the FOS the part is almost at failure. Why does the part almost fail at a load close to the yielding stress if the ultimate stress is much higher? (Hint: what is the difference between part failure in engineering application and the actual breaking of a part)**

- a) If a part yields during normal loading, it will no longer deform until it breaks.
- b) If a part yields during normal loading, it will continue to yield as time goes on, eventually breaking.
- c) There is no difference between yielding stress and ultimate stress.

**4. Does the FOS increase if the part is tested in compression?**

- a. yes
- b. no

**5. Does this make sense compared to real data on compression of ductile materials? (assume specimen is not long enough to undergo buckling)**

- a. yes
- b. no, ductile materials are much stronger in tension than in compression if buckling does not occur.
- c. no, ductile materials are much stronger in compression than in tension if buckling does not occur.

**6. Does the part fail at the same point as the parts on YouTube? How so?**

- a. No, the part on YouTube failed on the edges, while the stress analysis in SolidWorks shows that part fails at the center of the gage.
- b. No, the parts on YouTube failed at the center of the gage length. The stress analysis in SolidWorks shows that the part fails at the ends of the gage.
- c. Yes, the parts fail at the same point in the center of the gage.
- d. Yes, the parts fail at the same point at the ends of the gage.

**7. Does the simulator take necking into account? How can you tell?**

- a. No, it can be seen that it undergoes uniform deformation.
- b. Yes, it can be seen that it undergoes uniform deformation.
- c. Yes, it can be seen that it undergoes non-uniform deformation.





## Lab Report

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- Christa Wille - Mar 03, 2019 @09:39 AM CST

# Lab: SolidWorks II

*Lab Report: 3D Modeling and Finite Element Analysis Report - See SolidWorks I*

***DUE: before lab next week***



# Lab: SolidWorks II

## *Appendix*

If you are interested in learning more about SolidWorks applications and tools, check out the SolidWorks Resource Center:  
<http://www.solidworks.com/sw/resources.htm>. You will find Demo videos, online help and tips, and tutorials.



## 9/11/19 Mandibular Reconstruction Research

- YOUNG KIM - Oct 05, 2019 @02:01 PM CDT

**Title:** Mandibular Reconstruction Research

**Date:** 9/11/2019

**Content by:** Young Kim

**Present:** Young Kim

**Goals:** Gain further knowledge regarding mandibular reconstruction.

**Content:**

Defining the problem:

After dogs experience an oral tumor or other mandibular trauma, segmental bone resection(mandibulectomy) is conducted to remove the aforementioned condition. However, the reconstruction of the mandible is often not performed. This leaves the dog with post-operational problems that severely decrease their quality of life.

Goal:

To combat the post-op issues that arise, a mandibular implant put into place. The challenge proposed to our team is to discover the optimal structural properties for an implant that would withstand the mastication forces of the dog.

Relevant Information:

This [article](#) describes the efficacy of titanium as a dental implant because of its biocompatibility, strength, corrosion and wear-resistant nature.

The implant should work to restore the dog's quality of life, and should be made of a material(ie titanium) that would last the entire lifetime of the dog throughout expected circumstances

3-D printing can be used to create the desired mandibular implant. This article describes its use in craniomaxillofacial implants and extrapolations can be made to apply this technology to the implant that will be used in the dog's mandible.

To ensure that the implant lasts the lifetime of the dog, it must be structurally tested to withstand the mandibular forces exerted from activities such as chewing. Within this [article](#), measurements of actual and artificially acquired bite forces were obtained. The highest actual force recorded was 1,394 N, while the highest artificially obtained force was 926 N for the canines and 3,417 N for the molars. Other elements of analysis were also employed, but no result surpasses 3,417(highest value is 1,949 N for the canines and 2,036 N for the molars).

The figures reported above should be taken with a grain of salt, as obtaining any reliable measurement of force regarding bite force from animals proves to be challenging because the task cannot be directed perfectly, either not representing the true bite force(in vivo test) or overestimating the true bite force(in vitro test)

**Conclusions/action items:**

In order to design a viable implant, several factors must be taken into account, such as the longevity and strength of the implant, the size of the dog and its predicted bite force, and the location in which the resection has taken place. Further follow up with both the advisor and client should be made to clarify the goal of this specific project, and details regarding the subject of this implant.



## 9/17/19 Lifetime and Size

• YOUNG KIM • Sep 23, 2019 @10:01 PM CDT

**Title:** PDS research

**Date:** 9/17/19

**Content by:** Young Kim

**Present:** Young Kim

**Goals:** Investigate the approximate lifetime and size the implant should be to assist in completing the preliminary product design specifications.

**Content:**

How long will the mandible implant stay attached?

There isn't an article describing the lifetime of implants regarding dogs/animals.

It is expected that the implant will stay in place until post-operational issues arise.

According to this [article](#), plate fractures most often occur between 6-9 months after the surgery takes place. Stress has been found to be localized on the inner curvature and is where the fractures commonly occur. Recorded rates of failure range from 0 to 18%.

What size should the mandible implant be?

The size of the implant will vary on a case to case basis.

For the best fit, the implant should be molded to the [actual shape](#) of the 3-d mandible.

Increasing the width of the implant alleviates certain areas of concentrated stress. However, this complicates the process of molding the implant to the 3-D shape of the mandible.

**Conclusions/action items:**

The implant can remain attached until defects occur, usually around 6-9 months after insertion. The ideal size of the mandible will change depending on the subject, but increasing the lateral width of the implant itself could prove useful in distributing concentrated stress.

With the preliminary product design specifications complete, more research should be done regarding the programs that we plan on using to completing our product.



## 10/25/19 Relevant Software

• YOUNG KIM • Dec 09, 2019 @05:50 PM CST

**Title:** Relevant Software Research

**Date:** 10/25/19

**Content by:** Young Kim

**Present:** Young Kim

**Goals:** Perform research to become familiar potential software to be utilized in upcoming development.

**Content:**

(Copy pasted from Google Docs)

Matlab:

- Powerful computational software
- Could serve as an additional software source for the processing of data from dog
- Can create smaller programs, alongside large complex applications
- Includes commands for 2-dimensional and 3-dimensional data visualization, possibly useful
- Use to generate dimensions of implant itself?
- Utilize matrices for screw placement?
- Utilize for the data analysis of final testing Data?

<https://cimss.ssec.wisc.edu/wxwise/class/aos340/spr00/whatismatlab.htm>

<https://www.mathworks.com/solutions/data-analysis.html>

SolidWorks:

- The baseline finite element analysis software
- Available for all members of the team, but possibly not for client/potential users(veterinarians)
- Many online resources and tutorials available

[https://www.youtube.com/watch?v=Y3LfOv5o8\\_M](https://www.youtube.com/watch?v=Y3LfOv5o8_M)

[Long Tutorial with various subsets of testing](#)

FEBio:

- FEA for biological systems
- Makes much more sense with the subject of our project, Canine mandibles could be tested
- Open source, available for any who wish to use it
- Learning curve for several members in the group, very limited knowledge
- Written in C++, code should be written accordingly

-Plugins can be developed, as seen in the first article below, a similar approach could be taken further down the road with this project

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6225080/>

[https://help.febio.org/FEBio/FEBio\\_um\\_2\\_8/index.html](https://help.febio.org/FEBio/FEBio_um_2_8/index.html)

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3705975/>

**Conclusions/action items:**

The final approach for current needs will be to use models within both FEBio and SolidWorks, and ensure the efficacy of FEBio in its results through a comparison with more reliable SolidWorks results. Matlab can be used later down in the development of the project, but use is currently limited.



## 11/6/19 Possible Coding Languages

• YOUNG KIM • Dec 09, 2019 @05:51 PM CST

**Title:** Possible Coding Languages

**Date:** 11/6/19

**Content by:** Young Kim

**Present:** Young Kim

**Goals:** Investigate differences between potential coding languages.

**Content:**

(Copy pasted from GDocs)

Java:

-Use with Eclipse IDE, clean workspace

-Use in conjunction with GitHub

-Easy collaboration with group members and a safe "storage" space with previous revisions available for a possibly enhanced debugging process

-Primary language for development of our code, Most familiar/Universal

C++:

-More related to hardware than Java

-Small differences in semantics

-Primary language for use in FEBio

-Necessary conversion between Java and C++ must be made

<https://www.educba.com/c-plus-plus-vs-java/>

<https://www.guru99.com/cpp-vs-java.html>

**Conclusions/action items:**

First, code will be developed in the more familiar Java. However, for compatibility with FEBio, a conversion of the code must be made into C++.



## 11/16/19 Useful Comp Sci Info

• YOUNG KIM • Dec 09, 2019 @05:53 PM CST

**Title:** Useful Java Information

**Date:** 11/16/19

**Content by:** Young Kim

**Present:** Young Kim

**Goals:** Perform research to discover relevant functions within Java to compare the angles of normal vectors off of the mandible STL file.

**Content:**

(Copy pasted from Google Docs)

Useful knowledge to develop Angle Comparison method in Java:

-Vector representation in Java

-Will already took care of input of vectors into Java

-<https://www.geeksforgeeks.org/java-util-vector-class-java/>

-Dot and Cross Product

-Use to find angles of vectors?

-<https://www.geeksforgeeks.org/program-dot-product-cross-product-two-vector/>

-Sources comparing two angles of vectors:

-<https://stackoverflow.com/questions/2150050/finding-signed-angle-between-vectors>

-<https://stackoverflow.com/questions/40641401/how-to-calculate-the-angle-between-two-vectors>

**Conclusions/action items:**

Knowing this information, an important consideration to make is how the angles between the vectors are measured. The vectors are normal vectors of triangles off the mandible, an understanding of how they are represented in Java and how they can be compared must be had.





## 9/19/19 Design Idea

• YOUNG KIM • Sep 19, 2019 @10:30 PM CDT

**Title:** Initial Design Idea

**Date:** 9/19/19

**Content by:** Young Kim

**Present:** Young Kim

**Goals:** Develop a preliminary design idea to fulfill the needs proposed by the client.

### Content:

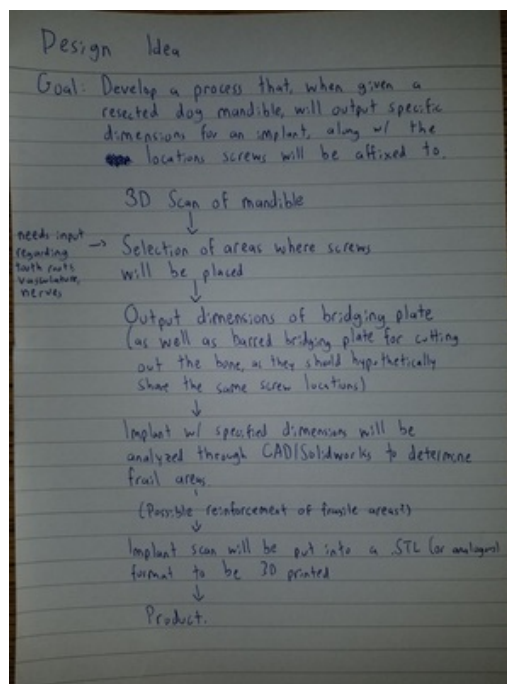
A possible resolution to the problem given by the client is to design a process that will streamline the process of designing an implant for distinct dogs. To begin this process, problem areas that should not be disturbed should first be highlighted and sectioned off. These problem areas could be places where tooth roots, blood vessels, nerves, or glands exist among other considerations. This knowledge can then be used to determine locations on the jaw which screws will be affixed. These areas will be analyzed by a program to determine the final dimensions of the 3D implant. Then, a structural analysis of the implant must be done. This will help determine possible problem areas which could fail under significant load (max 5000N?). Those areas could be reassessed and possibly reinforced. The 3D image of the implant can then be transferred to a file type supported by 3D printers to manufacture the final product.

Areas of concern within this work-flow mainly appear when problem areas occur on the implant. The specific method to reinforce these areas without making the implant significantly large and resource-consuming is not yet known, and the program itself that will determine the dimensions of the implant must be written by the group.

### Conclusions/action items:

More research should be done regarding the amount of space available so that the possible reinforcement of the mandible could occur. Methods of reinforcing the implant should also be investigated so that a cost/space effective method should be chosen if problems arise. A selection of programs must also be made. A 3D imaging program, 3D printing program, and design program to conduct structural analysis are necessary, but others should also be considered when writing the actual script that will determine the dimensions of the implant itself.

• YOUNG KIM • Sep 19, 2019 @10:19 PM CDT



dognew.jpg(3 MB) - [download](#)



## 9/27/19 File issues

- YOUNG KIM - Oct 03, 2019 @11:20 PM CDT

**Title:** File Issues

**Date:** 9/27/19

**Content by:** Young Kim

**Present:** Young Kim

**Goals:** Investigate issues that may arise regarding the file type and size we will encounter when using ImageJ and attempting to 3D print.

**Content:**

(copy pasted from Google Docs)

After conducting research, receiving input from our advisor and client, and determining the final outcome of the design matrix, we reached a conclusion on our desired process. We decided that utilizing ImageJ as the major platform for our project would be ideal. ImageJ is a free and open source software that would allow us to open the CT scan data, as the data type, DICOMs, is supported. Dr. Jason Bleedorn informed us of issues he encountered with a previous group who attempted to use solidworks and struggled to open DICOM files. He suggested that similar problems could arise with CAD as well. However, after reading the posts of other imageJ users, I found that exporting our implant as a file type supported by 3D printing might pose an issue. To combat this, I attempted to find ways to convert the common output type imageJ users utilized, .tiff, to a supported 3D file type (either .stl or .obj).

**File Type:**

A blogpost describes a process that we could employ to change the .tiff output to .stl. It works with a program called Fiji, an open source software that downloads ImageJ alongside many bundled plugins to fulfill a host of needs that users may have. This is a quick and free solution that we could utilize to convert our files. However, more research should still be done regarding the resolution of the implant and the possibility of losing data after conducting the conversion.

<http://talesofa3dprinter.blogspot.com/2014/02/converting-tiff-data-to-stl-file.html>

[https://imagejdocu.tudor.lu/faq/general/which\\_file\\_formats\\_are\\_supported\\_by\\_imagej](https://imagejdocu.tudor.lu/faq/general/which_file_formats_are_supported_by_imagej)

<https://fiji.sc>

<https://www.3dhubs.com/knowledge-base/3d-printing-stl-files-step-step-guide/#step-1>

A groupmate is currently in the process of developing a program that would format the data directly into a .stl file type, which would eliminate any need of converting between different file types. This would be the best solution if done successfully, as the data would be written entirely as a .stl file, but it must first be finalized and tested to check its functionality and viability for this project.

**Conclusions/action items:**

More research should still be conducted regarding the final resolution of the implant after conversion/using the program to output .stl directly. Trial runs could possibly be done with dummy 3D print files to check if the loss of data is a concern. I also plan on downloading and working with Fiji to test its benefits over ImageJ itself.



# 11/26/19 Green Pass

• YOUNG KIM • Dec 09, 2019 @05:43 PM CST

**Title:** Green Pass

**Date:** 11/26/10

**Content by:** Young Kim

**Present:** Young Kim

**Goals:** Complete necessary quizzes and training to make green part and receive Green Pass

**Content:**

Welcome, Young Kim  
 You are logged in to the  
 EMU Reservation System

TEAM Lab
Reserve a Machine
My Reservations
My Status

Materials Fee is paid through 2019-12-31. [See Receipt](#)

Pay Fee Through 2020-06-30

You may apply for the following upgrades:

Name
Welding 1
CNC Mill 1
Woodworking 1
Ironworker 1
Laser 1
Cold Saw 1

You have the following permits and upgrades:

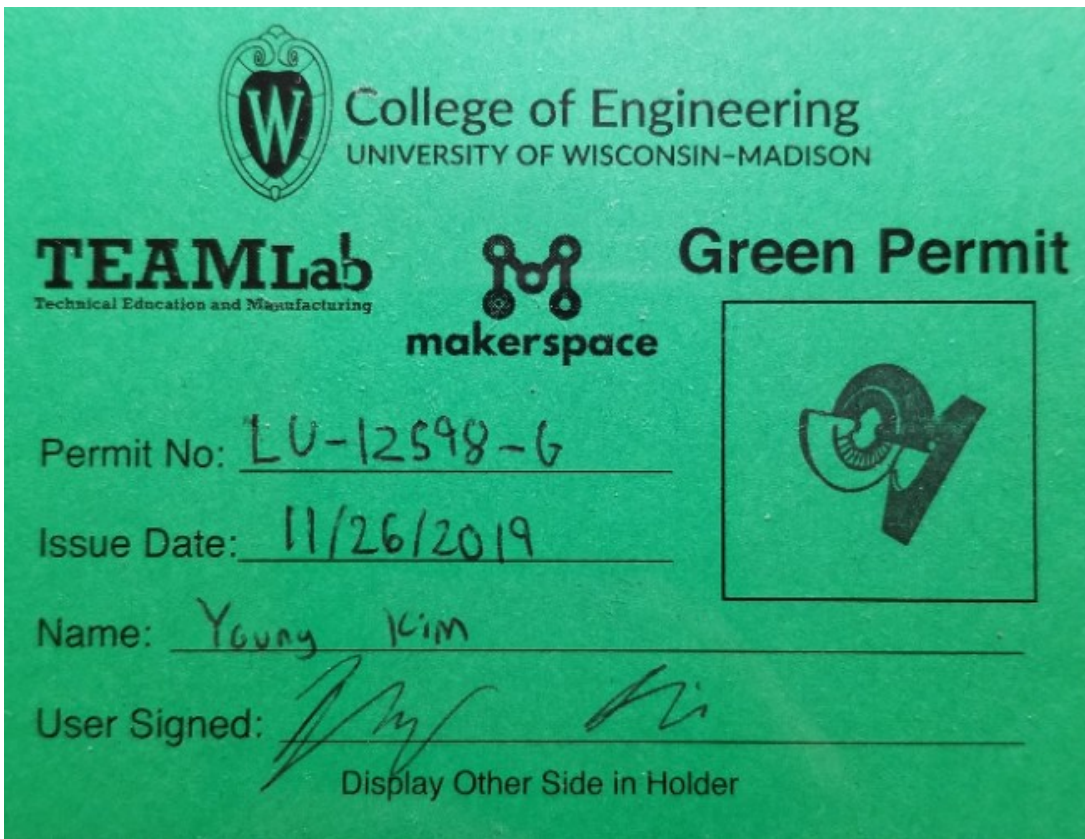
Name	Date
Green Permit	11/26/2019
Red Permit	02/12/2019

[View Upcoming Seminars](#)

You have used the following:

Type	Machine	Hours
Lathe	Eisen 11 Lathe	3.0
<b>Lathe Total</b>		<b>3.0</b>
Mill	Eisen 7 Mill	2.0
<b>Mill Total</b>		<b>2.0</b>
<b>Grand Total</b>		<b>5.0</b>

After completing the quizzes and attending the seminar, the green part was completed and Permit obtained.



**Conclusions/action items:**

Now, I have access to the mill and lathe in the MakerSpace. This step was completed preemptively for my enrollment in BME 201, and was recommended by several people to be done before break.



## 9/12/19 Client Meeting

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• YOUNG KIM • Sep 19, 2019 @09:37 PM CDT

**Title:** Client Meeting

**Date:** 9/12/19

**Content by:** Young Kim

**Present:** Whole Group

**Goals:** Gain a deeper insight into the problem itself with the Client

**Content:**

Currently, implants are simply ad hoc( "looks like it fits about right"). There isn't any methodical process used to fit each implant to the dog, the surgeon picks and chooses the location based on the size of the gap, presence of vasculature, or presence of tooth roots.

Within the implant lies a mesh scaffold included holding the bone graft. This permits the growth of new bone over the implant.

The overall goal of this project appears to be determining the ideal implant size/shape to ensure that the implant will not inhibit any daily actions the dog will partake in, promotes the steady regrowth of resected mandible, and will endure the daily masticating forces the dog will exert on the mandible.

A possible method of achieving this outcome is by designing a program that will receive input of the 3D structure of the specific mandible and outputs dimensions for the ideal bridge plate. This ideal bridge plate can then be further analyzed to ensure that it is placed in a location that avoids vasculature, tooth roots, or nerves.

**Conclusions/action items:**

Now that possible outcomes for this project are known, I can pursue further research in any of the varying fields. Specifically, more information should be sought regarding the creation of a program that will receive a 3D image of the resected mandible, and output dimensions.



# 10/1/19 Presentation Script

- YOUNG KIM - Oct 05, 2019 @02:06 PM CDT

**Title:** Presentation Script

**Date:** 10/1/19

**Content by:** Young Kim

**Present:** Young Kim

**Goals:** Prepare a script for the upcoming presentation to effectively communicate both peers and advisors

**Content:**

Thanks Laura,

1)

One problem we anticipate to encounter is the compatibility of files between programs. Converting the output from ImageJ into a suitable file type for 3D printing could pose issues. However, we have already begun investigating methods of file conversion and even started developing code for our process that would directly output a supported file type.

We plan on facing difficulties when writing our code, as only certain members of our group have in depth computer science knowledge, and debugging is often a lengthy process, even for experienced programmers.

We also discovered that there was no existing package for finite element testing on imageJ. This means that we need to develop our own method of stress testing our implant, which would be done using simplified force analysis methods. We run the risk of not accurately representing the true force distribution, but we plan to implement a large factor of safety to combat this.

2)

Our next steps will be to begin developing the Monolithic using Java and ImageJ

We will run the process with a variety of jaws with different dimensions and resection areas, and then

3D print an initial prototype and address any potential issues we find with the implant.

We also plan on Consulting with other professionals to receive more input on our process

And of course, continue to revise our process as necessary

3)

We would like to thank our clients, Dr. Graham Thatcher and Dr. Jason Bleedorn for proposing this project and providing constructive input on our different ideas.

Our advisor, Dr. Melissa Skala for guiding us through the preliminary design process and offering experienced insight regarding imaging techniques

And the BME department for providing us with the opportunity and resources to work on this project

**Conclusions/action items:**

After writing this script, I should remember to continue to revise and practice, to ensure that the presentation process runs smoothly. I should also ask other members of the team with greater knowledge of the process to look over my script and see if they find any mistakes with the statements that I plan to make.



## 12/04/19 Poster Presentation Script

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• YOUNG KIM • Dec 09, 2019 @10:38 AM CST

**Title:** Poster Presentation Script

**Date:** 12/04/19

**Content by:** Young Kim

**Present:** Young Kim

**Goals:** Create a script for the final poster presentation to help me effectively communicate the Design Specifications of the project.

**Content:**

(Copy Pasted from Google Docs)

Design specifications were determined according to the initial requirements of the coding and stress testing components of the final, cohesive product.

Firstly, patient data must be adequately formatted. The CT scan of the patient's mandible should be converted into a suitable file type for both the creation of an individualized implant and finite element testing.

The generated file must then be simplified to ensure compatibility with stress testing software and reduce computational time, while retaining salient details of patient anatomy. This will ensure the optimized implant's reliability in its installment and usage.

A protocol to develop such an implant must be designed to match the specific geometry of the patient's mandible, avoid screw placement in problem areas, and withstand forces exerted during the patient's daily usage.

The final product should implement the previous specifications into a cohesive, user friendly, and easily accessible software package for veterinarians to utilize.

**Conclusions/action items:**

The following script addresses each bullet point written on the poster and gives an idea of the desired outcomes the team was looking for throughout the semester.

Future work includes possible input from William/Laura and practice with the script in preparation for Poster Presentation day.





## 9/11/19 Mandibular Reconstruction Research

- CADE VAN HORN - Oct 06, 2019 @09:32 AM CDT

### Title: Mandibular Reconstruction Research Notes

**Date:** 9/11/19

**Content by:** Cade Van Horn

**Present:** Cade Van Horn

**Goals:** The goal of this research is to gain a better understanding of mandibular reconstruction, including the reasons reconstruction is performed, and the different types of surgeries that may be performed.

### Content:

Goals of Mandibular Reconstruction:

- The goal of this surgery, mandibular reconstruction, is to restore the shape and form of the jaw, as well as the function of the entire mandibular apparatus.
- The goal is also to allow motion of the jaw that does not cause pain and allows the patient to speak and eat.

Treatment options:

- Options for treating mandible defects include Mandibular Reconstruction Plates, or MRP, that may or may not include soft tissue flaps.
- Another treatment option is bone grafts.
- The way the jaw is reconstructed depends on the properties of the defects, such as the size and location and any skin damage surrounding the defect.
- Now that microsurgical techniques are available, reconstructive surgery can be performed immediately without risk of other disease diagnoses.
- One of the simplest techniques to solve a defect does not include surgery or reconstruction. It involves collapsing the defect and wound closure. However, this technique is rarely used and not recommended

3D Printing Technologies:

- Reconstruction is often performed using fibular osteocutaneous free flaps
- 3D technology can provide more precise models and fixation guides
- 3D printed titanium fixation plates and implants may become useful in the future as technology develops

Maxillo-Mandibular Amputations and Implants Rehabilitation:

- Conventional reconstruction is usually placed in the lower part of the jaw, which results in a low position for the grafted bone.
- Implants are usually placed with an axis created by the maximum bone height possible

More important things to consider in a severely deficient mandible:

- bone bulk to give strength to the mandible and protection for the neurovascular bundle
- a broad convex ridge
- ideal ridge relationships
- fixed tissue over the denture and implant support areas
- sufficient depth of the facial and lingual vestibules
- the emergence of osseointegrated implants has been revolutionary in the rehabilitation of atrophic mandibles and has helped with mandibular reconstruction.
- implants can be tailored to each individual, providing better stability, retention, and comfort

J. K. Potter, "Mandible Reconstruction," *ScienceDirect*, 2012. [Online]. Available: <https://www.sciencedirect.com/topics/medicine-and-dentistry/mandible-reconstruction>. [Accessed: 11-Sep-2019].

### Conclusions/action items:

This site provided a lot of information on the goal of mandibular reconstruction and some of the basic methods. This gave me a great starting point of understanding the subject. Now going forward I can apply this knowledge and research more about specifically canine mandibular reconstruction rather than in humans.



## 9/16/19 Canine Mandibular Reconstruction Research Notes

• CADE VAN HORN • Sep 18, 2019 @12:16 PM CDT

**Title:** Canine Mandibular Reconstruction Research

**Date:** 9/16/19

**Content by:** Cade Van Horn

**Present:** N/A

**Goals:** The goals of this research are to learn more about the reasons mandibular reconstruction is performed and how it is assessed for canine patients.

**Content:**

Oral cancer affects human and canine patients, and treatment of this cancer often includes surgery on the tissues of the face and oral cavity to remove any cancerous tumors. Radiotherapy is also used, and these two strategies can lead to damaged bone structure and difficulties with bone regeneration. Benign cancerous tumors often lead to needing to remove a segment of the mandible in order to prevent the disease from coming back. Segments of the mandible may need surgery for other reasons such as trauma and blast injuries. Reconstruction of the mandible after a segment of the jaw is removed is a tricky procedure, involving bone, teeth, and gingiva (the gums).

The goal of mandibular reconstruction is to re-establish the normal physiology and structure of the mouth and jaw, as well as restore facial aesthetics. It should allow for speech in humans, and in canines and humans, it should create a permanent and useful restoration of the arrangement of the teeth (dentition), allow for proper alignment of the teeth, (maxillo-mandibular occlusion), allow for normal chewing and jaw dynamics (mastication), allow for normal swallowing (deglutition), and allow for sensibility of the mucosa (a mucous gland in the mouth) and lips. Reconstruction should also provide the desired aesthetics of the patient. Surgeons should do their best to prevent any complications such as infections or fistulas (abnormal connections of two parts of the body).

The current and popular method of mandibular reconstruction involves a bone plate, and this can be done with or without bone grafts. Reconstruction with bone grafting can create better definition of the jaw. Primary reconstruction takes place at the time of tumor removal so that there is one operation. Secondary reconstruction takes place after a healing period.

Non-vascularized bone grafts (NVBG) can be used successfully but are not advised for primary reconstruction because of a high rate of failure. For secondary reconstruction, NVBG can be slightly more successful for smaller defects, but the failure rate for larger defects is high and this type of bone graft comes with risks such as serious bleeding or injury to the mucosa.

Vascularized bone grafts (VBG) have become standard, especially for primary reconstruction. It is particularly useful when the defect is larger (greater than 9cm), or when radiotherapy or soft tissue reconstruction are needed. vascularized osseomyocutaneous flaps have been designed which provide better results and better full-mouth restoration. However, VBG also has high risks. The technique requires a highly skilled surgical team, and each flap design can only be used for specific defects. In addition, the donor site often does not recover well.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2811127/>

[1] Elsalanty, M., Zakhary, I., Akeel, S., Benson, B., Mulone, T., Triplett, G. and Opperman, L. (2019). *Reconstruction of Canine Mandibular Bone Defects Using a Bone Transport Reconstruction Plate*. [online] NCBI. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2811127/> [Accessed 16 Sep. 2019].

**Conclusions/action items:**

Continue to research and begin the product design specifications.



## 9/18/19 Materials, Aesthetics, and Accuracy - PDS research

- CADE VAN HORN - Oct 06, 2019 @09:52 AM CDT

**Title:** Materials, Aesthetics, and Accuracy - Research for the Product Design Specifications

**Date:** 9/18/19

**Content by:** Cade Van Horn

**Present:** N/A

**Goals:** The goals are to learn more about the intended materials or our project, the appearance and aesthetics of the final outcome, as well as the accuracy and repeatability of our product. All of these are important for filling out the PDS.

**Content:**

*Accuracy and Reliability: Establish limits for precision (repeatability) and accuracy (how close to the "true" value) and the range over which this is true of the device.*

1. The bone plate needs to be secured with three to four screws on each end that must have accurate placement so as not to disrupt the roots of the remaining teeth, the gums, or the mucosa gland [Cade\_Source\_1].
2. The process of determining where these screws are placed, potentially through software that can take a scan of a specific patient's anatomy and personalize the plate to the patient, should present accurate placement of screws such that the plate can be held firmly in place under different types of forces and not cause any further damage to the oral cavity.
3. The process for placing these screws should demonstrate precision and be repeatable for patients with different anatomies and mandibular gap defect sizes.

*Materials: Establish restrictions if certain materials should be used and if certain materials should NOT be used (for example ferrous materials in MRI machine).*

1. Titanium may be used for 3D printing, and other materials such as plastic or carbon fiber may be used in the place of titanium in the instance of 3D printing prototypes. The 3D printed materials will be used to create a bone plate, cut guide, and mesh to promote osseogenesis. Titanium is a useful material for creating three dimensional, dynamic plates that will conform to the jaw and not pose any post-operative problems. Plastics that may be used for prototypes will not be used in actual surgeries, but will instead serve as a model [Cade\_Source\_2].
2. Different types of computer software may be used, including MRI scanning software to depict the anatomy of the canine, solidWorks to create a three-dimensional representation of the bone plate that can be processed and 3D printed, and Matlab to create a program that could optimize the process of placing the screws.

*Aesthetics, Appearance, and Finish: Color, shape, form, texture of finish should be specified where possible (get opinions from as many sources as possible).*

1. The final software should be easy to use for doctors and should be able to design a plate that is functional and provides an aesthetic outcome for the patient. This means it should be able to accurately represent the anatomy of the patient in order to fit specialized bone plates that restore the normal structure and appearance of the canine's mandible.
2. The final bone plate that results from the more efficiently designed process should give the patient a correctly aligned and aesthetically pleasing jaw [Cade\_Souce\_3].

[Cade\_Source\_1] J. K. Potter, "Mandible Reconstruction," *ScienceDirect*, 2012. [Online]. Available: <https://www.sciencedirect.com/topics/medicine-and-dentistry/mandible-reconstruction>. [Accessed: 11-Sep-2019].

[Cade\_Source\_2] S. A. Paul, A. K. Karthik, R. Chacko, and W. Karunya, "Audit on titanium reconstruction of mandibular defects for jaw lesions," *Journal of pharmacy & bioallied sciences*, Jul-2014. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4157278/>. [Accessed: 18-Sep-2019].

[Cade\_Source\_3] Elsalanty, M., Zakhary, I., Akeel, S., Benson, B., Mulone, T., Triplett, G. and Opperman, L. (2019). *Reconstruction of Canine Mandibular Bone Defects Using a Bone Transport Reconstruction Plate*. [online] NCBI. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2811127/> [Accessed 16 Sep. 2019].

#### **Conclusions/action items:**

We need to continue to research, brainstorm design ideas, and write our product design specifications draft.



## 9/20/19 Bridging Plate Development Research

- CADE VAN HORN - Oct 01, 2019 @10:21 AM CDT

**Title:** Bridging Plate Development Research

**Date:** 9/20/19

**Content by:** Cade Van Horn

**Present:** N/A

**Goals:** The goals of this research are to better understand the development of bridging plates for canine mandibular defects.

**Content:**

(from research I initially documented in Google Drive):

- Bone defects in dogs can be caused by many things, trauma, impact, disease, tumors, etc
- Bone continuity and jaw functionality is an important goal when reconstructing the mandible
- The most common alloplastic implant for reconstruction uses bone plates and screws. This is rigid and used for stability.
- A different design is the locking reconstruction plate where the screws lock to the plate for extra stability
- One study was performed to develop a bridging plate with monocortical screws that would create minimal damage
- the plates should be able to resist force concentrations and would be tested using finite element methods
- Computed tomography images of dogs were used to develop the prototype
- Materialize software was used to create 3D images
- Physical models of the jaws were created from the 3D images
- The length of the screws was determined by measuring the midway buccal cortical bone of the mandibular body in the transversal cuts of the 3D image
- Solid works was used to design the bridging plates and locking screws.
- Stereolithography (STL) files of the mandibles were imported into the software to create a model
- Stress testing was performed using FEM (finite element methods)
- More testing was performed using a mechanical, universal testing machine
- All data were tested for normality using the Kolmogorov-Smirnov test
- All statistical analyses were made using GraphPad Prism software
- The screws were arranged unequally to help in the tension distribution
- 

**Conclusions/action items:**

The bridging plates designed in this study with differentiated geometry and locking screws showed mechanical resistance to support simulated induced bone model defects and were able to support at least 5 times the value of the bite force for each evaluated dog.

**References:**

[file:///C:/Users/Owner/Downloads/bridging%20plate%20devo%20for%20treatment%20of%20segmentals%20\(1\).pdf](file:///C:/Users/Owner/Downloads/bridging%20plate%20devo%20for%20treatment%20of%20segmentals%20(1).pdf)



## 10/02/19 Existing Designs Research

• CADE VAN HORN • Oct 06, 2019 @09:26 AM CDT

**Title:** Research on existing designs of mandibular implants

**Date:** 10/02/19

**Content by:** Cade Van Horn

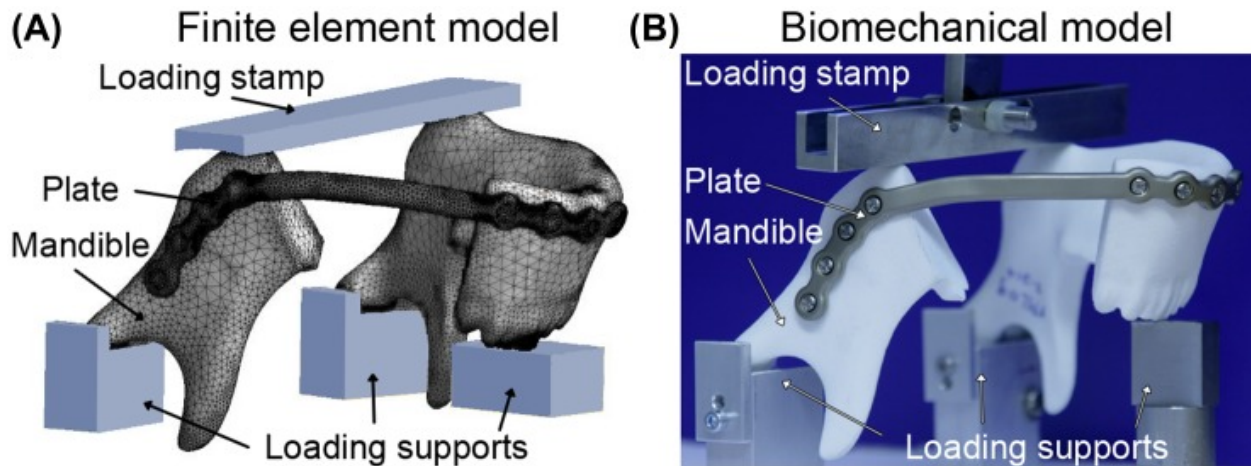
**Present:** N/A

**Goals:** The goal of this research is to find out if there are any processes that exist to make better implants for mandibular reconstruction and how these processes work.

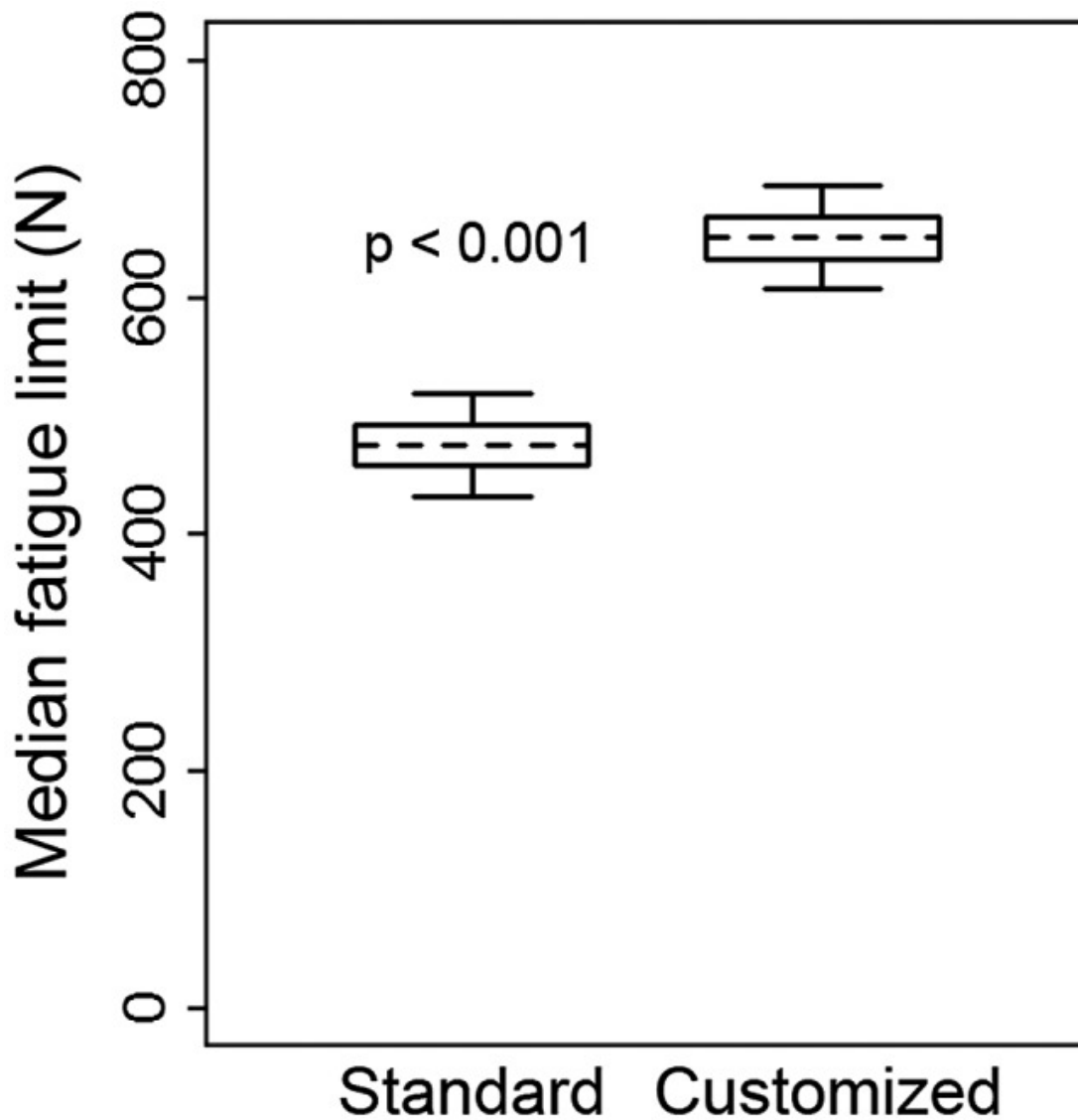
**Content:**

A study was done to analyze the function of more customized implants. The goal of the study was to make better-customized implants. Since rigid material is harder to contour to the patient's anatomy, and too much malleability is a safety concern, they wanted to find the right balance that would create a good implant that would conform to the jaw. They used finite element analysis to get important information on shape optimization. They also did sensitivity analysis to assess the strength of the implant.

- They used CADFEM to conduct finite element and sensitivity analyses
- A 3D mesh of a typical file was made using PTC Creo Parametric
- They used simplified screws, modeled as cylinders
- The model consisted of one million elements
- they assigned the materials with a Poisson's ratio of 0.3 and a Young's modulus of 10 gpa for bone
- They tested multiple forces on the jaw
- Below is the model from the study of their finite element testing:



- They determined the maximum stress at each bar, as well as the reaction forces of screws
- The median fatigue limit (MFL) can be used to describe their fatigue testing
- The MFL is the load at which half of the samples will fail and half will pass the test (carry the load without breaking)
- They used a mechanical testing machine to find the MFL
- They found that the MFL was much higher for the customized plates on the right than the standard plates on the left



R. Gutwald, R. Jaeger, and F. M. Lambers, "Customized mandibular reconstruction plates improve mechanical performance in a mandibular reconstruction model," *National Center for Biotechnology Information*, Mar-2017. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5359746/>. [Accessed: 06-Oct-2019].

**Conclusions/action items:**

This provided a lot of good information about finite element analysis and stress testing, however, they were in methods we might not be able to recreate, and the study did not talk about the process of making the customizable plate, just about the effectiveness of customizable plates versus standard plates.



## 9/23/19 Matlab Research

- CADE VAN HORN - Oct 01, 2019 @10:20 AM CDT

**Title:** Research on Matlab

**Date:** 9/23/19

**Content by:** Cade Van Horn

**Present:** N/A

**Goals:** The goals of this research are to gain a better understanding of Matlab and how it works to determine if we could potentially use it in any of our designs.

**Content:**

MatLab:

- integrates computation, visualization, and programming
- easy to use
- problems and solutions are expressed in familiar mathematical notation
- used for:
  - Math and computation
  - algorithm development
  - modeling, simulation, and prototyping
  - data analysis
  - scientific and engineering graphics
  - application development
- basic data element is an array that does not require dimensioning
- solve many technical computing problems, especially those with matrix and vector formulations
- System includes 5 main parts:
  - Matlab language
  - matlab working environment
  - handle graphics
  - mathematical function library
  - Application program interface (API)

<https://cimss.ssec.wisc.edu/wxwise/class/aos340/spr00/whatismatlab.htm>

**Conclusions/action items:**

Matlab has a pretty easy interface. It uses a matrix and can be used to input the images we will receive from our client of CT scans of dogs. This means we could potentially use it for some aspect of our project.





## 9/23/19 Java Research

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- CADE VAN HORN - Oct 01, 2019 @10:40 AM CDT

**Title:** Research on Java Programming Language

**Date:** 9/23/19

**Content by:** Cade Van Horn

**Present:** N/A

**Goals:** The goal of this research is to better understand how we could apply Java to our project

**Content:**

- java is a general-purpose, web-based computer programming language
- it is concurrent, object based, and class based
- compiled Java code can run on all platforms that support Java without the need for recompilation.
- This means that if we write code in java, it could easily be translated to other platforms and make our project more universal to our client and other potential users
- uses intermediate language called bytecode
- runs on Java Virtual Machine
- uses garbage collection to not take up too much storage, which would be good for our project since we don't want to use too much storage/memory

<https://howtodoinjava.com/java/basics/what-is-java-programming-language/>

**Conclusions/action items:**

Java is a multipurpose tool that we could easily use in our project. From my minimal experience with it, it is fairly easy to use and learn and could be applied to our project.



## 9/25/19 Research on Solidworks

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- CADE VAN HORN - Oct 06, 2019 @08:41 AM CDT

**Title:** Video Research on Solidworks

**Date:** 9/25/19

**Content by:** Cade Van Horn

**Present:** N/A

**Goals:** The goal of this research is to watch a video tutorial on Solidworks to gain a better understanding of the program and how we could potentially use it in our project, or discover its constraints if any.

**Content:**

I watched a couple of Solidworks tutorials and discovered that, though it is pretty easy to use, there is sometimes problems with file conversion when uploading STL files, like our client uses. However, it is very good for testing forces, so it could be very useful to us when we get to the testing phase of the project.

**Conclusions/action items:**

We need to continue to do research into what programs or programming languages we want to use to build our program, and determine which one would be the best for our client as well.



## 9/13/19 Brainstorming Initial Design Ideas

• CADE VAN HORN • Oct 06, 2019 @08:35 AM CDT

**Title:** Brainstorming Initial Design Ideas

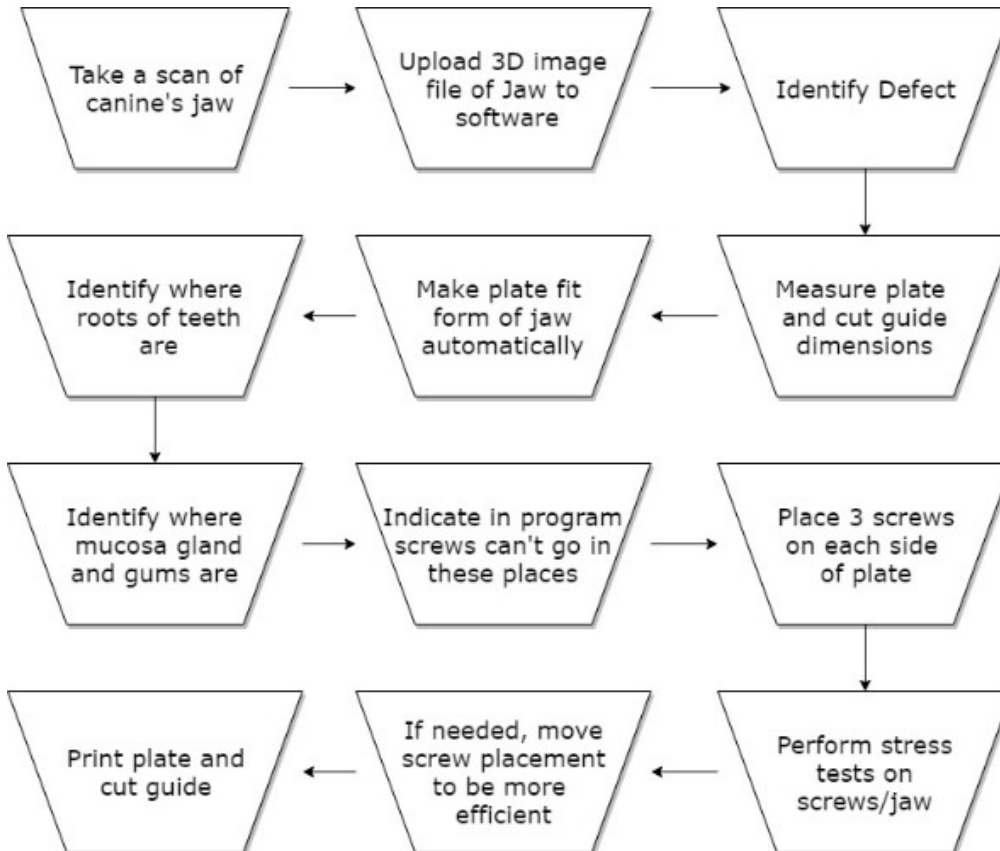
**Date:** 9/13/19

**Content by:** Cade Van Horn

**Present:** N/A

**Goals:** The goal of this brainstorming session is to create at least one cohesive design idea that can be shared with the group.

**Content:**



This flowchart is one of my ideas I came up with for the process that Dr. Thatcher could take to optimize the way he creates and designs the implants for his patients. He would use software like Matlab and Solidworks to plot out where problem areas are and identify to the computer that screws cannot go in these places. The computer would then decide where to place the screws for him, so he doesn't have to guess.

**Conclusions/action items:**

I have a cohesive design idea for the process we will design and optimize with this project, so now the group needs to meet and present all our design ideas to each other and decide which ones we want to consider.



## 2019/11/25 - Green Permit

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• CADE VAN HORN • Dec 05, 2019 @05:48 PM CST

**Title:** Green Permit Training

**Date:** 2019/11/25

**Content by:** Cade Van Horn

**Present:** Cade Van Horn

**Goals:** To complete all the training to get my green permit.

**Content:**

I took all the online tests and attended the green permit seminar, then I spent time in the TEAM lab working on the lathe and mill to build my test part. At the end of this process, I got my green permit.

**Conclusions/action items:** None.



## 10/31 - 11/07 - Github

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• CADE VAN HORN • Dec 05, 2019 @06:06 PM CST

**Title:** Github and initial coding

**Date:** 2019/10/31 - 2019/11/07

**Content by:** Cade Van Horn

**Present:** Cade Van Horn

**Goals:** This week we wanted to create a Github with all of the initial code for our program.

**Content:**

-Team meeting

-Practice with Github and understanding the STL optimization program

-Research on Java and creating programs

**Conclusions/action items:**

Now that we created a Github, we need to start refining the code to make it simplify the jaw.



## 11/07 - 11/14 - Coding

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• CADE VAN HORN • Dec 05, 2019 @06:02 PM CST

**Title:** Working on Coding for Prototype

**Date:** 2019/11/07 - 2019/11/14

**Content by:** Cade Van Horn

**Present:** Cade Van Horn

**Goals:** The goals of this week are to work on coding for the prototype

**Content:**

-Read through code

-Brainstormed ideas for simplifying jaw

-Tried different ways of working with triangles in Eclipse

**Conclusions/action items:**

There is a lot more that needs to be done with the prototype as far as getting it to work and testing it.



## 11/14 - 11/21 - Green Permit Work

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• CADE VAN HORN • Dec 05, 2019 @05:58 PM CST

**Title:** Green Permit Work

**Date:** 2019/11/14 - 2019/11/21

**Content by:** Cade Van Horn

**Present:** Cade Van Horn

**Goals:** The goals of this week are to continue working on the code with Will and to get my green permit.

**Content:**

This week I spent several hours in the Teamlab attending the green permit seminar and making my test piece. At the end of the process I got my green permit.

**Conclusions/action items:**

This coming week we need to finish what we can on the prototype.



## 11/22-12/5 - Final week

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• CADE VAN HORN • Dec 05, 2019 @05:54 PM CST

**Title:** Final Week

**Date:** 11/22/2019 - 12/5/2019

**Content by:** Cade Van Horn

**Present:** Cade Van Horn

**Goals:** This last week we need to finish the poster, and final report, and give our final poster presentation.

**Content:**

-Worked on final report, alone and with team

-Worked on poster with team

-Practiced for poster presentation with team

-Helped finish final report, practiced presentation one last time before the actual presentation

**Conclusions/action items:**

Give the final presentation and turn in deliverables.





## 2019/09/09- Mandibular Reconstruction Research

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- KYLIE GASPAR - Sep 11, 2019 @07:23 PM CDT

**Title:** Mandibular Reconstruction Research

**Date:** 9/9/2019

**Content by:** Kylie Gaspar

**Present:** Kylie Gaspar

**Goals:** Define unknowns in the project description and create a basic understanding of what mandibular reconstruction in dogs is, and what the process is.

**Content:**

### Defining unknowns

Temporomandibular joint- The joint that connects the jawbone and the skull. This is important to define in order to avoid causing stress to this joint when making our design. Stress on this joint can be caused by misalignment or injury of the teeth or jaw.

<https://www.mypetsdentist.com/pet-mandibulectomy.pml>

### Notes

Mandibulectomies relieve pain from oral tumors. After surgery many patients have increased salvation, and have to learn to retract their tongue to a new normal position. They may have problems chewing as the jaw disaligns and their top and bottom teeth bump into each other in a non productive way.

Pain in the TMJ can result in pain when opening or closing the mouth, and this decrease the range of motion of the jaw.

### Preliminary Goals

Avoid stress on any parts of the patient, including the temporomandibular joint.

Obtain appropriate contact between teeth, including the upper and lower teeth.

Remember to take into consideration the force that will be exerted on the device, and the jaw of the patient.

### **Conclusions/action items:**

Our goal is to make a complete replacement of the removed jaw section so that dogs have no pain, stress, or incorrectly shaped jaws.

To continue, we need to know if the client wants us to continue to work with the plate and screw design of the studies and tests already done for mandibular reconstruction.



## 2019/10/01-Canine Cranial Anatomy

• KYLIE GASPAR • Oct 08, 2019 @01:18 PM CDT

**Title:** Canine Cranial Anatomy

**Date:** 2019/10/01

**Content by:** Kylie Gaspar

**Present:** NA

**Goals:** To specify and research important canine anatomy in regards to our mandibular implant. After all research important to our design and testing is done, I must narrow down what is important to include for our Preliminary Presentation

**Content:**

Important Anatomy

nerves

Bite Force

Generated by craniomandibular structures

-Jaw adductor muscles(masticatory muscles)-These close the mouth, determine movement, and control bite force

Main role consist of

-temporal

-masseter

-medial and lateral pterygoid muscles

-Temporomandibular joints

-synovial condylar joint

-Movement is scissor movement-ie up and down

-lateral motion is limited

-affects shape of skull

-works with masticatory muscles

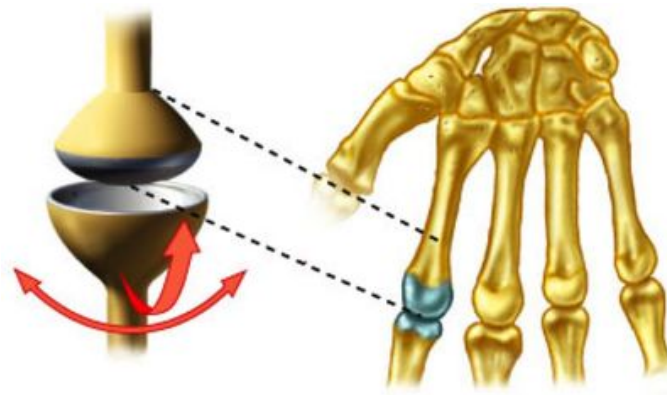
-Teeth

Force goes from masticatory muscles to the teeth

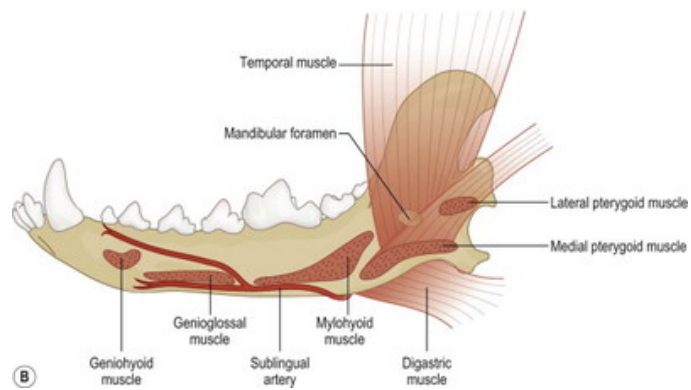
Unknown words

synovial condylar joint (Shown in Figure 1)-Synovial- two bones w cartilage linked cavity to connect them - Condylar = one bone has an ovalular head and another has an elliptical cavity to hold it.

**Conclusions/action items:**



**condyloid\_joint.jpg(65.7 KB) - download** (Figure 1) This shows a condyloid joint, specifically a synovial condylar joint working in a human hand. This is same type of joint is the type of joint that allows movement of the canine mandible.



**Canine\_Mandible.jpg(37.6 KB) - download** (Figure 2)



## 2019/10/04-Mid-semester Report Research-Motivation

• KYLIE GASPAR • Oct 07, 2019 @07:53 PM CDT

**Title:** Mid-semester Report Research: Motivation

**Date:** 2019/10/04

**Content by:** Kylie Gaspar

**Present:** NA

**Goals:** Motivation/Global and/or societal impact. Why is your device necessary? What are the demographics and context of the problem/unmet need? This should go beyond the needs of the client – use the literature to support the need. What your client wants may not be the best solution to the problem\*

**Content:** Mandibulectomy

Mandibulectomies in dogs are semi frequent and common procedures, a vet will go in and remove a tumorous portion of the canine's mandible and then let the dog recover. It is not common to replace the portion of the bone that is taken out, this commonly results in impaired dental occlusion and weaker jaw function (WagWalking, 2019).

**Conclusions/action items: What to put in report**

Mandibulectomies in dogs are semi frequent and common procedures, a vet will go in and remove a tumorous portion of the canine's mandible and then let the dog recover. It is not common to replace the portion of the bone that is taken out, this commonly results in impaired dental occlusion and weaker jaw function (WagWalking, 2019). A few companies, like Vetmed, have started researching options for implants to maintain more normal jaw function, but these devices still need improvements to ease patient stress as well as proper dental occlusion and usage. Our role is to optimize veterinarians time by making the process of making an individualized implant quick with minimal labor. We also are aiming to save resources by using exactly the correct amount of materials, not too much titanium or too many screws. Most importantly our role is to determine how to reduce stress on the patient's jaw with optimal screw placement and implant size.

Bibliography

WagWalking. (2019). *Partial Mandibulectomy in Dogs - Procedure, Efficacy, Recovery, Prevention, Cost*. [online] Available at: <https://wagwalking.com/treatment/partial-mandibulectomy> [Accessed 6 Oct. 2019].



## 2019/10/04-Mid-semester Report Research-Bio&Phys

• KYLIE GASPAR • Oct 08, 2019 @01:18 PM CDT

**Title:** Mid-semester Report Research: Biology and Physiology

**Date:** 2019/10/04

**Content by:** Kylie Gaspar

**Present:** NA

**Goals:**

**Content:**

**Conclusions/action items: What to put in report**

A canine's mandible moves mostly up and down with the help of the temporomandibular joint, the jaw adductor muscles generate the force which is distributed through the teeth. The temporomandibular joint is a synovial condylar joint that connects the lower mandible to the skull. Lateral movement of a canine's lower jaw is extremely limited, so for all intents and purposes it can be assumed the jaw moves only up and down.

The bite force, which determines stress on the mandible and our implant, comes from the jaw adductor muscles. These muscles are the temporal muscles, which move the mandible up, its opposite is the masseter muscle. The digastric muscles move the jaw forward and backward. The pterygoid muscle moves the jaw forward. The strength of all these muscles is dependent on the size of the canine.

Kim, S., Arzi, B., Garcia, T. and Verstraete, F. (2018). Bite Forces and Their Measurement in Dogs and Cats. *Frontiers in Veterinary Science*, 5.



## 2019/10/04-Mid-semester Report Research-Materials

• KYLIE GASPAR • Oct 07, 2019 @08:22 PM CDT

**Title:** Mid-semester Report Research: Materials

**Date:** 2019/10/04

**Content by:** Kylie Gaspar

**Present:** NA

**Goals:** To create a concise description of all materials and rationale for use-Include detailed list of materials and budget in an appendix

**Content:**

Titanium-"Titanium is the most biocompatible and corrosion-resistant metal its elasticity modulus corresponds to the elasticity modulus of the bone more than any other metal does"

"Titanium shows very low toxicity both in its ionic and also in its particle form" (1)

monocortical screws-(source) Cortical screws are used for surgeries---avoid harm to tooth and roots

"Miniscrews are variations of surgical screws used for rigid fixation in oral and maxillofacial surgery and are available in various diameters and lengths. Compared with traditional endosseous implants, miniscrews have some distinct advantages, including smaller size, greater flexibility in site placement, ease of placement, and reduced cost. It has been suggested that miniscrews do not osseointegrate and that their anchorage stability results from mechanical interlock. This eliminates the need for a waiting period before force application and permits easy removal."

Prototype-

-Plastic-\$0.1725-.3450 per mL(3)

-Carbon Fiber

### Conclusions/action items:-What to put in document

Titanium is used for all parts of the implant as it is the most biocompatible and corrosion resistant metal. It closely matches the physical properties of bone while remaining free of toxins to the body, which makes it extremely functional and safe for the patient (Neumann and Kevenhoerster, 2011). (cost). Monocortical screws are used to attach the implant to the patient's jaw. These screws are durable and reduce stress on the patient's jaw compared to other surgical screws. Plastic or carbon fiber will be used if a 3D printed prototype of the implant design is needed. Plastic is a good material to use for a prototype as it holds its form well and is a cheap way to accurately model the design. 3D printing from the makerspace is valued from \$0.1725-\$0.3450 per mL based on the type of plastic we choose. (Brettin et al., 2019) (AllThat3D, 2019)(Making.engr.wisc.edu, 2019)

### Bibliography

- (1) Neumann, A. and Kevenhoerster, K. (2011). Biomaterials for craniofacial reconstruction. *GMS current topics in otorhinolaryngology, head and neck surgery*, [online] 8. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3199817/> [Accessed 6 Oct. 2019].
- (2)AllThat3D. (2019). *17 Type 3D Printer Filament Comparasion | Buyer's Guide & Review 2019*. [online] Available at: <https://www.allthat3d.com/3d-printer-filament/> [Accessed 7 Oct. 2019].
- (3)Making.engr.wisc.edu. (2019). *3D Printers – UW Makerspace – UW–Madison*. [online] Available at: <https://making.engr.wisc.edu/3d-printers/> [Accessed 7 Oct. 2019].
- (4)Brettin, B., Grosland, N., Qian, F., Southard, K., Stuntz, T., Morgan, T., Marshall, S. and Southard, T. (2019). *Bicortical vs monocortical orthodontic skeletal anchorage*. [online] Available at: [https://www.ajodo.org/article/S0889-5406\(08\)00746-4/pdf](https://www.ajodo.org/article/S0889-5406(08)00746-4/pdf) [Accessed 7 Oct. 2019].



2019/10/22

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• KYLIE GASPAR • Oct 23, 2019 @09:20 PM CDT

**Title:** Research and comparison of Image J and FE Bio

**Date:** 2019/10/22

**Content by:** Kylie Gaspar

**Present:** Kylie Gaspar

**Goals:** Create a basic understanding of the pros and cons of different softwares we are considering with our project.

**Content:**

FEBio

Uses Finite Element Model- Which uses simple equations to be assembled into a larger system of equations

([https://en.wikipedia.org/wiki/Finite\\_element\\_method](https://en.wikipedia.org/wiki/Finite_element_method))

**Conclusions/action items:**

[https://serc.carleton.edu/eyesinthesky2/week2/intro\\_imagej.html#intro](https://serc.carleton.edu/eyesinthesky2/week2/intro_imagej.html#intro)



## 2019/10/28-Meeting rundown

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• KYLIE GASPAR • Oct 28, 2019 @08:17 PM CDT

**Title:** Important software info

**Date:** 2019/10/28

**Content by:** Kylie Gaspar

**Present:** All

**Goals:** Take notes from Will

**Content:**

Slicer - CT scans-legacy,editor

Blender

MeshMixer-scan of skull,

FEBio- preview-move around a model and put into testing

post view=results

what works best with febio-smaller file, which sections of jaw, etc

Solidworks- turn off addins to access addin we need

Forces on Jaw----Solidworks

**Conclusions/action items:**





## 2019/11/04-Solid works tutorial Notes

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• KYLIE GASPAR • Dec 08, 2019 @03:59 PM CST

**Title:** SolidWorks Tutorial Notes

**Date:** 2019/11/04

**Content by:** Kylie Gaspar

**Present:**

**Goals:**

- Get a feel for the user interface and layout of SolidWorks.
- Understand how to plan the layout of a part and how to properly model it.
- Understand how to use SimulationXpress Analysis Wizard in SolidWorks to test part failure.

**Content:**

Plan and sketch in 2D before starting work on SolidWorks.-need a design process first

**Conclusions/action items:**



## 2019/11/17-Final Report

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• KYLIE GASPAR • Dec 08, 2019 @04:15 PM CST

**Title:** Notes on Final Report for Team

**Date:** 2019/11/17

**Content by:** Kylie Gaspar

**Present:** NA

**Goals:** To go over the Final report while my team continues to do other work. After going over the report I will have notes for the team of what needs to be done. This is to make it less work for them to complete the report.

**Content:**

Most of the report can be left alone. We need to overall start incorporating the work on FEBio and current coding process. Also numbers and formulas need to be added.

**Conclusions/action items:**

Write sections of report designated "needs updating"

Reference: Google doc - <https://docs.google.com/document/d/1pqTqETCHVHVILvcFqSbn8T4qCGlxdQ4dtCBZolGgBnQ/edit?usp=sharing>



## 2019/12/02-Testing Results

• KYLIE GASPAR • Dec 08, 2019 @04:26 PM CST

### Title: Testing Results

**Date:** 2019/12/02

**Content by:** Kylie Gaspar

**Present:** All

**Goals:** Make a visual representation of our testing results and then a verbal conclusion of what these numbers mean in context of our project

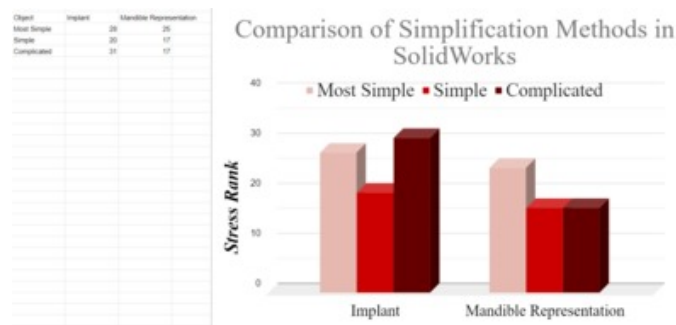
### Content:

Figure 1 shows the different levels of simplification that were stress tested in SolidWorks.

### Conclusions/action items:

Use this for our final report and know these facts for our final presentation. Put graph on final poster.

• KYLIE GASPAR • Dec 08, 2019 @04:21 PM CST



numbers\_pic.PNG(67.4 KB) - [download](#) Figure 1: Graphical Summary of testing results in SolidWorks by different simplification models



## 2019/09/17-PDS Select Areas

• KYLIE GASPAR • Oct 08, 2019 @01:17 PM CDT

**Title:** PDS Select Areas-Operating Environment, Performance Requirements, and Target Product Cost

**Date:** 9/17/2019

**Content by:** Kylie Gaspar

**Present:** Kylie Gaspar

**Goals:** To specify the above areas of the Preliminary Product Design Specification, specifically the following in respect to the three areas above:

"Establish the conditions that the device could be exposed to during operation (or at any other time, such as storage or idle time), including temperature range, pressure range, humidity, shock loading, dirt or dust, corrosion from fluids, noise levels, insects, vibration, persons who will use or handle, any unforeseen hazards, etc."

"The performance demanded or likely to be demanded should be fully defined. Examples of items to be considered include: how often the device will be used; likely loading patterns; etc."

"manufacturing costs; costs as compared to existing or like products"

**Content:**

Operating Environment- The device is placed during surgery of the jaw, so it is partially exposed to the oral cavity of the patient, which can lead to contamination.

Performance Requirements-Over all the design should maintain appropriate dental occlusion, this is done in the following

Bridging Plate- must exactly match screw hole placement on titanium plate, must outline and fit necessary incision size of patient. Screws should not be placed where a tooth root is.

Mesh should most importantly help supplement bone growth and structure, be immune to bacteria and viruses that may lead to it needing replacement, and hold the titanium implant and any subsequent implants after the first.

Titanium plate should support forces exerted on a typical mandible, it should also not induce too much stress on the patient.

Target Product Cost

Materials- Titanium

At least 4-6 cortical screws

**Conclusions/action items:**



## 2019/09/18-Previous Design Research

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- KYLIE GASPAR - Sep 18, 2019 @08:28 PM CDT

**Title:** Previous Design Research

**Date:** 9/18/2019

**Content by:** Kylie Gaspar

**Present:** Kylie Gaspar

**Goals:** To understand the goals, concerns, and results of previous projects and reports done on mandibular reconstruction in order to outline what is necessary to test our client's design.

**Content:**

"Each method has its advantages and disadvantages, but three biomechanical factors should be considered in the choice, namely, the masticatory muscles, the direction of the fracture line, and the forces involved on the repair of the fracture.10"-finite element pdf

"Due to the forces acting on the mandibular fractures, the implants should be positioned at the tension surface, that is at the alveolar border of the mandible.4,6,7 However, to avoid damage to the tooth roots associated with screw insertion, the plates must be placed on the lateral or aboral surface of the mandible.4,7 According to some authors, the biomechanical disadvantage of this plate location may eventually be overcome by orienting the plate according to the bending forces"-finite element pdf, also remember sheer forces

"The canine mandible is considered elastically isotropic and this property was used in"-Finite element pdf

play with angled cuts on jaw????

**Conclusions/action items:**



## 2019/09/19-Individual Design Ideas

• KYLIE GASPAR • Oct 02, 2019 @05:37 PM CDT

**Title:** Individual Design Ideas

**Date:** 2019/09/19

**Content by:** Kylie Gaspar

**Present:** NA

**Goals:** Make an outline of proposed design process to introduce to my team at the team meeting.

**Content:**

Figure 1- There are two different design processes on this page. First there is a design to test where the stress on a patients jaw is with the removed section of the mandible with solid works using data from known bite forces on canine mandibles from our research of previous articles and studies on this topic along with general physics including torque, two force members, etc. After determining that stress with Solid Works we will know where the optimal placement for screws are (where the jaw functions as it needs to and the stress on the patient is minimized). Then we will transfer that data to Matlab to create a matrix that incorporates the tooth roots into the data. Where there is a tooth root there cannot be a screw, this step will make sure we have screw placement for the implant where is can actually go without ruining patient occlusion. From there we will create a bridging plate/mesh scaffolding/titanium plate specific to the patient with the screw holes in place and the correct size of metal accounted for.

The second of the two design processes firsts tests stress on a typical canine mandible. Then we remove the specific section of the mandible needed for the patient and asses any new stress points this creates on the patient. During this step we will simultaneously be researching the physical properties of titanium, and more specifically, the properties of the plate our client currently uses. After these two steps we will determine where the screws must be placed on a predetermined shape of solid titanium, where the screws need to be placed we will add holes big enough to fit the screws. Then we will test that this implant works as a typical jaw (in our first step) does. After we determine the shape of the plate is good to go, we will then create a bridging plate and mesh scaffolding to go along with the surgery.

Figure 2-Figure 2 is less about design ideas and more about what the client wants out of our research. The clients needs start with a patient who needs mandibular reconstruction. Then they determine the necessary amount that needs to be removed, then they take scans of the patients mandible, then ideally they would want a specific implant and go to surgery. In between the third to last and second to last steps are where our design process is needed. The vertical flow chart shows my idea of what would be easiest for the client to get from the scan of the patient mandible to surgery.

**Conclusions/action items:**

I will present this to my team and we will collaborate on what our final testing process will be tomorrow at our team meeting.





## 2019/11/06-SolidWorks First Attempt

• KYLIE GASPAR • Dec 08, 2019 @04:10 PM CST

**Title:** First SolidWorks Attempt

**Date:** 2019/11/06

**Content by:**

**Present:** Kylie Gaspar

**Goals:** Learn basic functions in SolidWorks in order to create a model of a canine mandible.

**Content:**

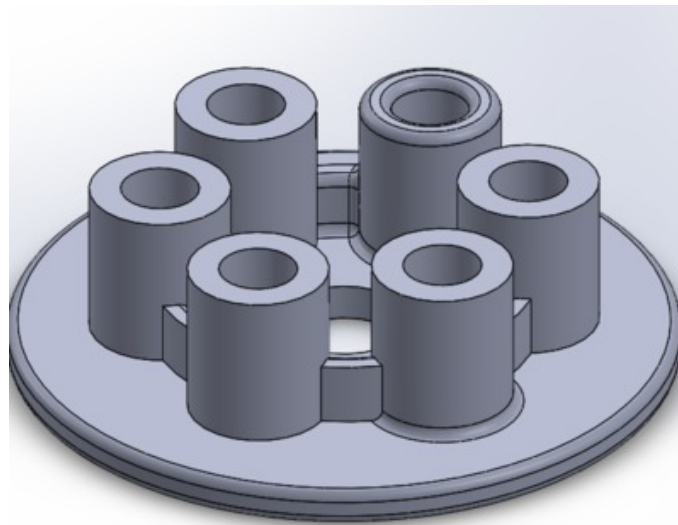
Making rounded edges is easy, it is important to know dimensions for every aspect of the design and then you can make anything.

**Conclusions/action items:**

Use this knowledge to create a canine mandible representation for the team.

Reference: Solidworks.com. (2019). *3D CAD Design Software*. [online] Available at: <https://www.solidworks.com/> [Accessed 8 Nov. 2019].

• KYLIE GASPAR • Dec 08, 2019 @04:05 PM CST



Solidworks\_attempt.PNG(132.3 KB) - [download](#) Figure 1: Design completed by following the first SolidWorks tutorial





## 2014/11/03-Entry guidelines

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• John Puccinelli • Sep 05, 2016 @01:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

**Title:** Descriptive title (i.e. Client Meeting)

**Date:** 9/5/2016

**Content by:** The one person who wrote the content

**Present:** Names of those present if more than just you (not necessary for individual work)

**Goals:** Establish clear goals for all text entries (meetings, individual work, etc.).

**Content:**

Contains clear and organized notes (also includes any references used)

**Conclusions/action items:**

Recap only the most significant findings and/or action items resulting from the entry.



**Title:**

**Date:**

**Content by:**

**Present:**

**Goals:**

**Content:**

**Conclusions/action items:**