BME Design-Fall 2019 - Will Wightman
Complete Notebook

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Team contact Information

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

Last Name	First Name	Role	E-mail	Phone	Office Room/Building
Thatcher	Dr. Graham	Client	graham.thatcher@wisc.edu	(608) 471-3300	
Skala	Melissa	Advisor	mcskala@wisc.edu	(608) 316-4108	
Wightman	Will	Leader	wwightman@wisc.edu	(414) 204-7811	
Laura	Richmond	Communicator	larichmond@wisc.edu	(920) 530-2123	
Kim	Young	BSAC	yjkim25@wisc.edu	(414) 739-3387	
Van Horn	Cade	BWIG	cavanhorn@wisc.edu	(612) 850-0583	
Gaspar	Kylie	BPAG	kgaspar@wisc.edu	(630) 745-8030	

Project description

▪ 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 osteogenisis 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:

▪ Will Wightman ▪ Oct 08, 2019 @10:39 PM CDT

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

> Acording 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 scafold-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

▪ 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 prefered
  - Thinking about computational time and complexity for each software
  - We can take budget out of PDS

Conclusions/action items:

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 determne what parts of the project we want to take part in.

2019/09/23 - Team Meeting - Design Matrix

▪ 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 Blendr 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 Blendr
- 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 blendr 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

▪ 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

▪ 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

▪ 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.

2019/10/08 - 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 though 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 maester 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 bit 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

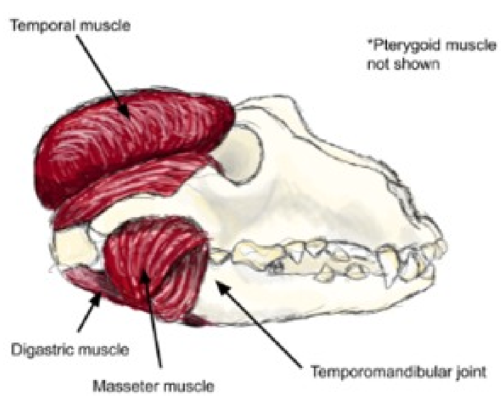


Figure I: This figure demonstrates the basic musculature of a canine skull in reference to the mandible. Pterygoid muscles not show, but located between the roof of the canine's mouth and the posterior-medial edge of the mandible.

LabeledMuscles.PNG(91.1 KB) - download Attached is Figure I demonstrating the musculature and anatomy of the Dog's Jaw

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

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].

2019/09/11 - 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 osteogenisis 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 [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.

2019/09/19 - 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

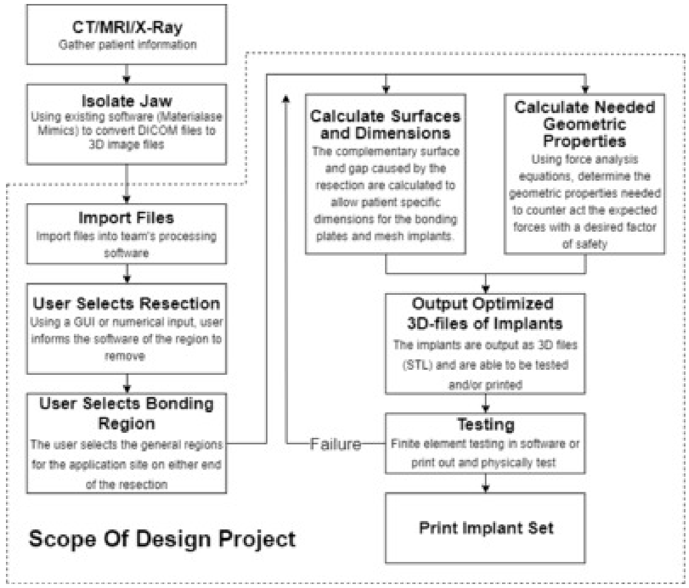
Given this project is not a typical BME project in which one standard device is generated and optimized for the client, it is important to clearly layout and define the process. This will insure the entire team is working toward the same goal.

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.

▪ Will Wightman ▪ Sep 21, 2019 @01:06 PM CDT



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.

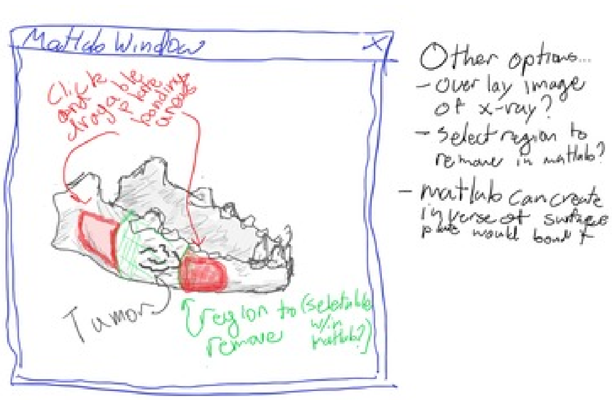
General Description:

- 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 an 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 to 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://danbscott.ghost.io/writing-an-stl-file-from-scratch/

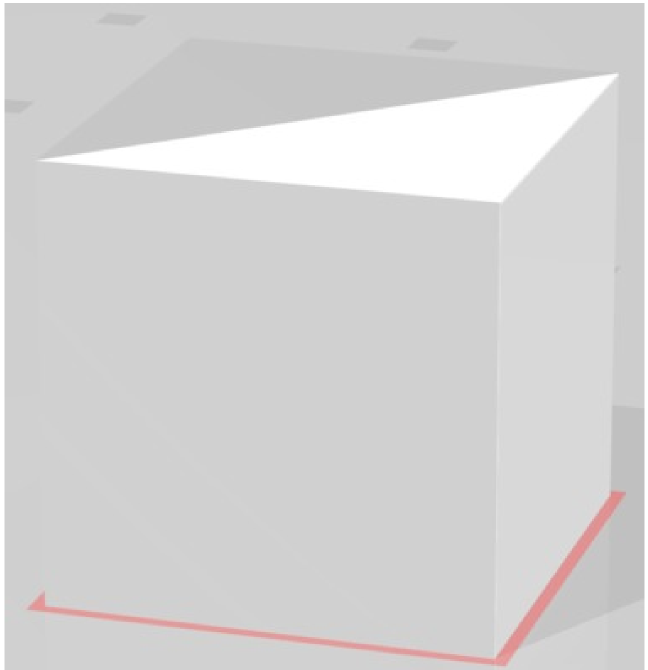
[2] - http://www.fabbers.com/tech/STL_Format#Sct_binary

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.

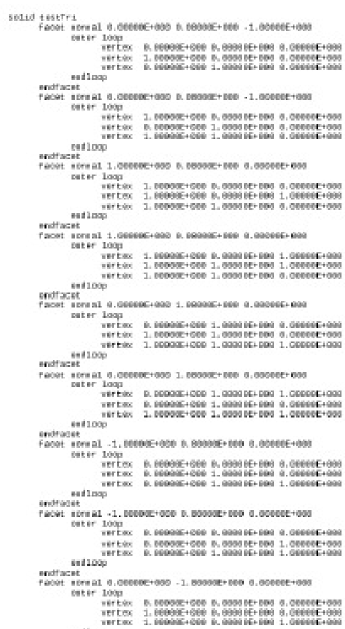
More research is needed into STL readers, writers, and editors, particularly those that can handle STLs

▪ 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 veiwer.

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



```
solid testTri
	facet normal 0.00000E+000 0.00000E+000 -1.00000E+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 -1.00000E+000
		outer loop
			vertex  1.00000E+000 0.00000E+000 0.00000E+000
			vertex  0.00000E+000 1.00000E+000 0.00000E+000
			vertex  1.00000E+000 1.00000E+000 0.00000E+000
		endloop
	endfacet
	facet normal 1.00000E+000 0.00000E+000 0.00000E+000
		outer loop
			vertex  1.00000E+000 0.00000E+000 0.00000E+000
			vertex  1.00000E+000 0.00000E+000 1.00000E+000
			vertex  1.00000E+000 1.00000E+000 0.00000E+000
		endloop
	endfacet
	facet normal 1.00000E+000 0.00000E+000 0.00000E+000
		outer loop
			vertex  1.00000E+000 0.00000E+000 1.00000E+000
			vertex  1.00000E+000 1.00000E+000 1.00000E+000
			vertex  1.00000E+000 1.00000E+000 0.00000E+000
		endloop
	endfacet
	facet normal 0.00000E+000 1.00000E+000 0.00000E+000
		outer loop
			vertex  0.00000E+000 1.00000E+000 0.00000E+000
			vertex  1.00000E+000 1.00000E+000 0.00000E+000
			vertex  1.00000E+000 1.00000E+000 1.00000E+000
		endloop
	endfacet
	facet normal 0.00000E+000 1.00000E+000 0.00000E+000
		outer loop
			vertex  0.00000E+000 1.00000E+000 1.00000E+000
			vertex  0.00000E+000 1.00000E+000 0.00000E+000
			vertex  1.00000E+000 1.00000E+000 1.00000E+000
		endloop
	endfacet
	facet normal -1.00000E+000 0.00000E+000 0.00000E+000
		outer loop
			vertex  0.00000E+000 0.00000E+000 0.00000E+000
			vertex  0.00000E+000 1.00000E+000 0.00000E+000
			vertex  0.00000E+000 1.00000E+000 1.00000E+000
		endloop
	endfacet
	facet normal -1.00000E+000 0.00000E+000 0.00000E+000
		outer loop
			vertex  0.00000E+000 0.00000E+000 0.00000E+000
			vertex  0.00000E+000 0.00000E+000 1.00000E+000
			vertex  0.00000E+000 1.00000E+000 1.00000E+000
		endloop
	endfacet
	facet normal 0.00000E+000 -1.00000E+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  1.00000E+000 0.00000E+000 1.00000E+000
		endloop
```

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

▪ Will Wightman ▪ Sep 30, 2019 @06:11 PM CDT

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

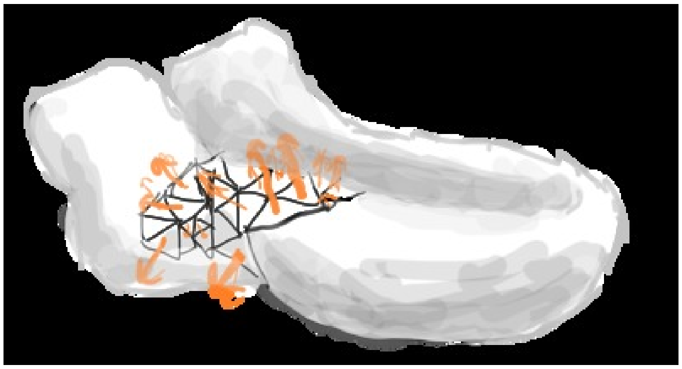
Conclusions/action items:

This approach will offer the team a starting point for finding an 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.

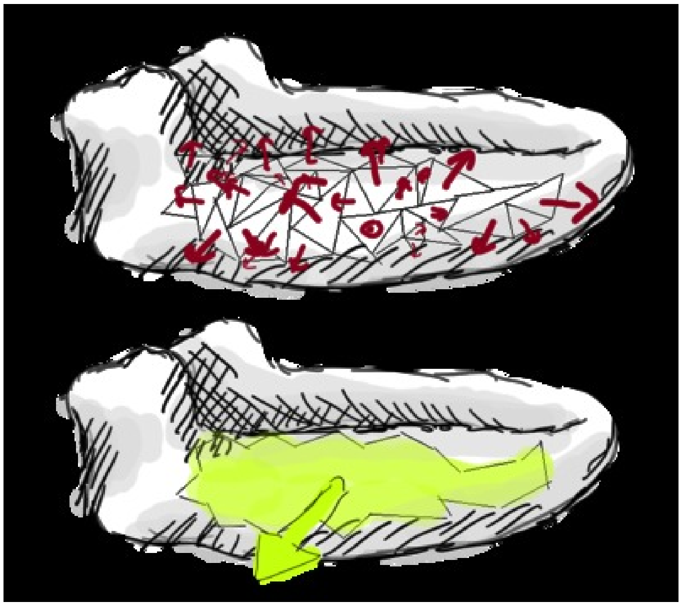
More research into Java's 3D viewing/processing library is necessary before beginning to build an entire package. Specifically, the way STL files are represented in the existing frameworks.

▪ Will Wightman ▪ Oct 07, 2019 @11:08 PM CDT



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

▪ Will Wightman ▪ Oct 07, 2019 @11:40 PM CDT



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:

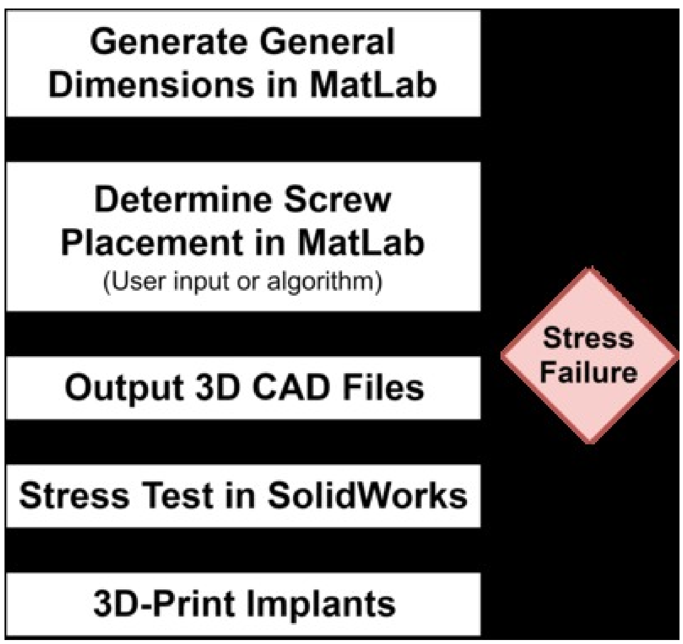
See attached images for the Tiered, Monolithic, Iterator, and Square One designs.

Conclusions/action items:

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

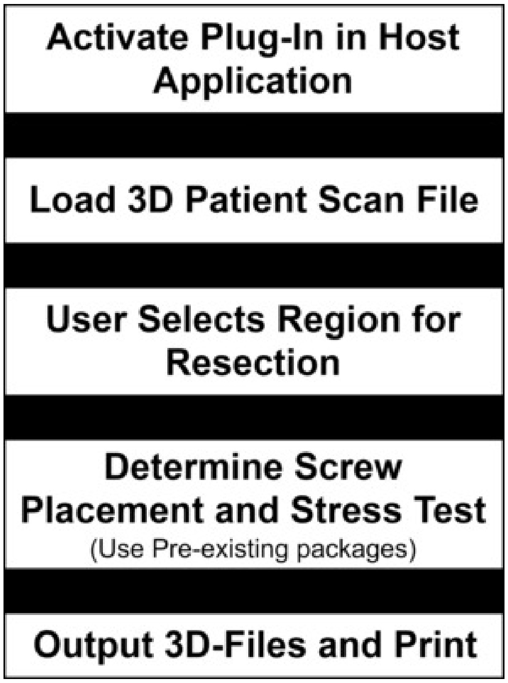
Hopefully, these diagrams will convey the concepts well enough to prompt good questions and feedback.

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



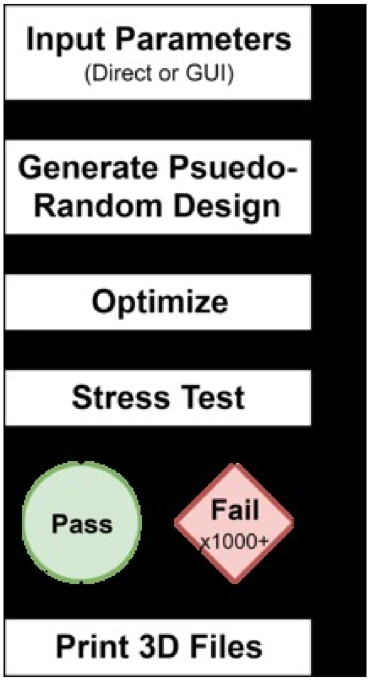
TheTiered_20190930.png(351.7 KB) - download The Tiered Approach - The tiered approach uses a modular approach to complete the general algorithm. Dimensions and screw placement are calculated in MatLab and stress testing is done in SolidWorks. (Image is transparent - If over black background, arrows flow down from Generate General to 3D-print implants with a "negative feedback" loop between stress testing and determine screw placement)

▪ Will Wightman ▪ Oct 08, 2019 @12:17 AM CDT



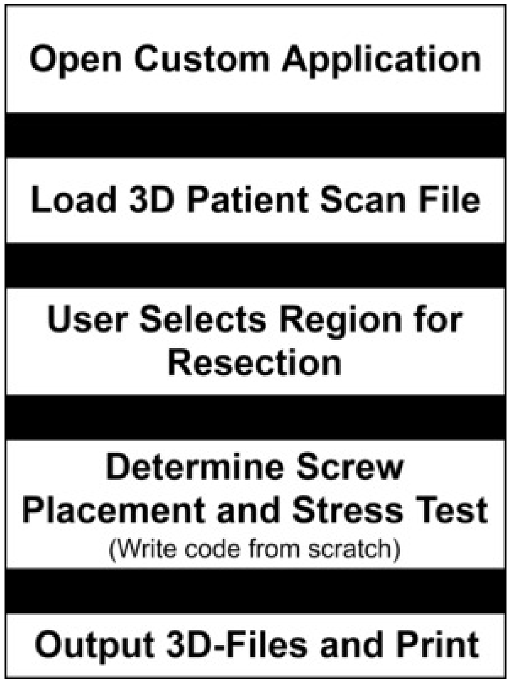
TheMonolithic_20190930.png(311.2 KB) - download The Monolithic Approach - This approach is built as an plug-in for ImageJ, making use of existing packages for ImageJ and Java. (Image is transparent - If over black background, arrows flow from the top of the diagram to the bottom)

▪ Will Wightman ▪ Oct 08, 2019 @12:22 AM CDT



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")

▪ Will Wightman ▪ Oct 08, 2019 @12:25 AM CDT



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

[redacted]

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	

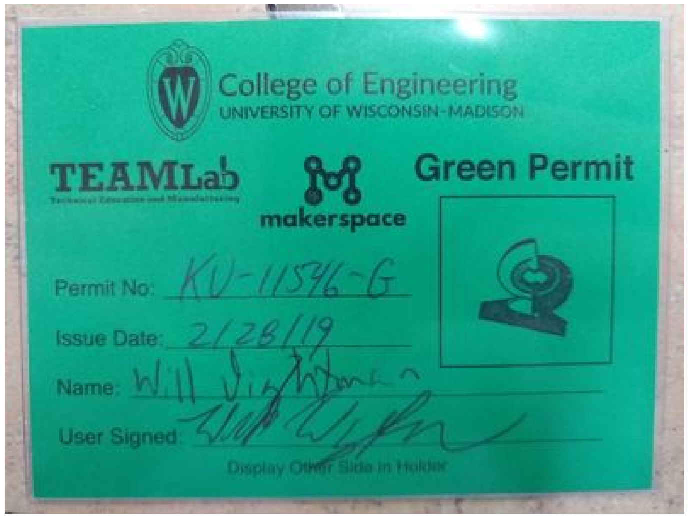
Data Effective: Mon Oct 8 23:37:24 2018
Report Generated: Tue Oct 9 00:13:00 2018

[redacted]

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

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.

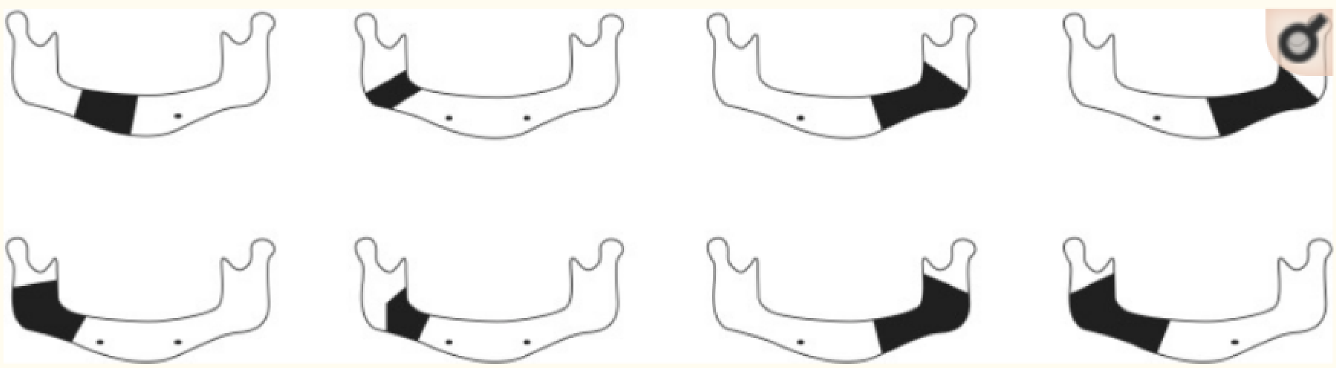


Fig. 6

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 fractions 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 my 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 bit 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 a 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 four 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.

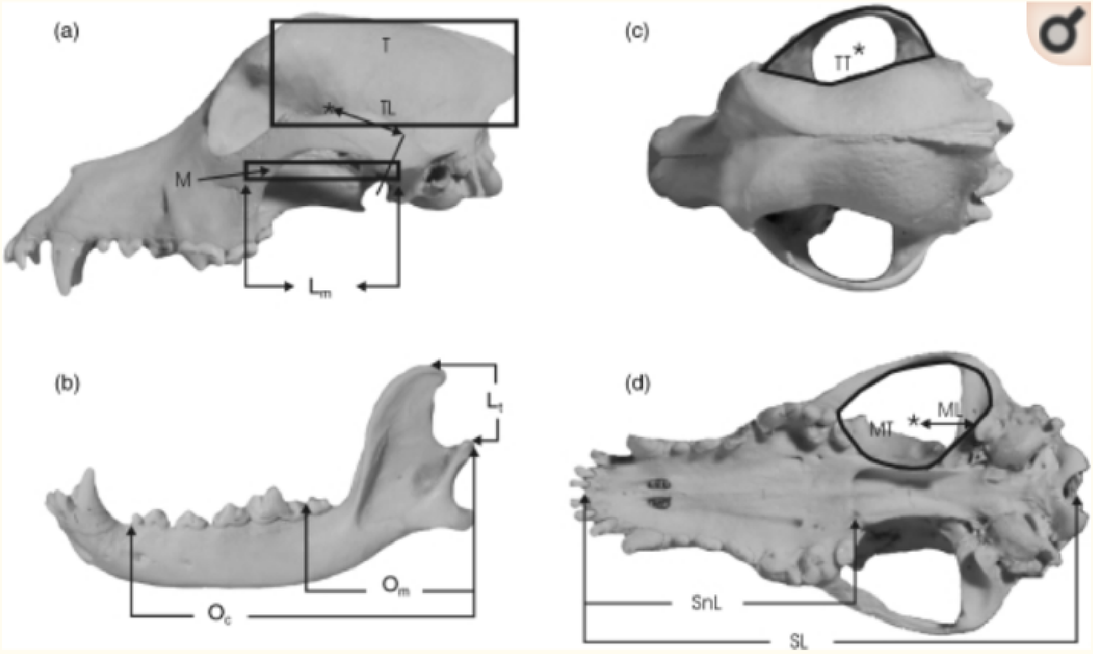
Table of Dog Database sorted by skull shape and size

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	Cairn 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

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

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

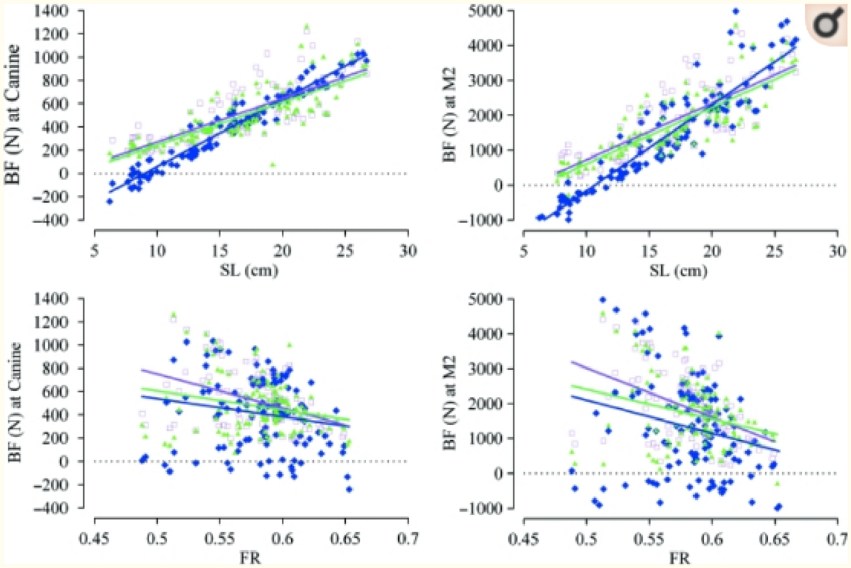


Fig. 2

Predicted bite force (BF) at the molar (right) or canine (left), for the regression model (blue closed diamonds), lever model 2 (pink open squares) and lever model 1 (green closed triangles) vs. skull length (SL, cm) (top) or facial ratio (FR) (bottom).

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:

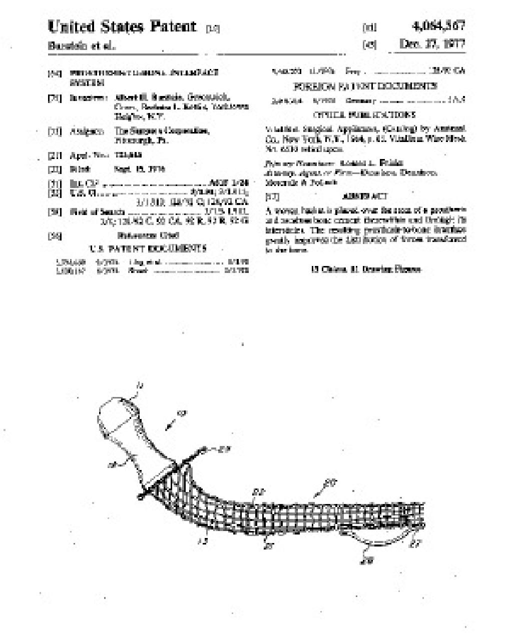
This particular patent is similar to the lattice described to us by the client. It consists of a woven basket that incorporates bone cement which is basically a PMMA polymer that encourages bone growth. This is very similar to the lattice that is incorporated in our current project. Our lattice is inserted 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 [19] [11] 4,064,567
Burstein et al. [45] Dec. 27, 1977

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:

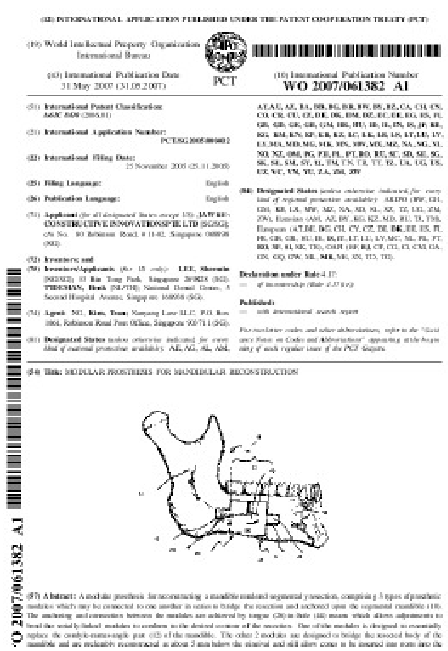
This particular design uses a series of prosthetic modules that are connected to each other. Something unique about this particular model is that is allows bending adjustments to conform to the contour of the jaw's shape. There are specific segments for different parts of the jaw. This design is similar to ours in that is 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 desire 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



WO2007061382A1.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:

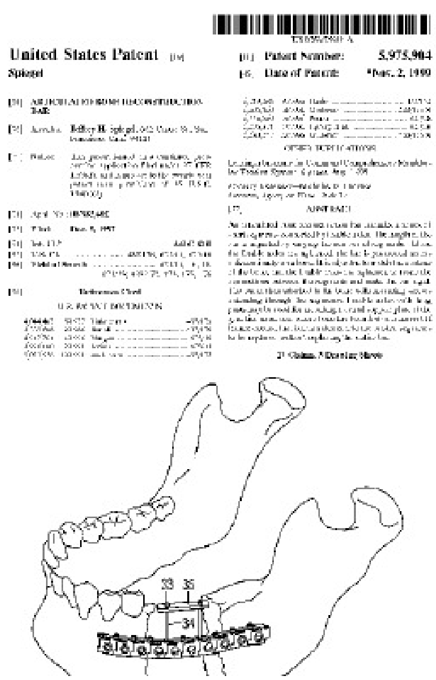
This design also uses a segmental approach. It has an adjustable length. This is achieved by varying the number of segments. This means you would have to consider the optimization of the size of the segments and the range of motion you wish to occur. The bar is also adjusted to fit the contour of the 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


United States Patent

Spiegel

Patent Number: 5,975,904

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:

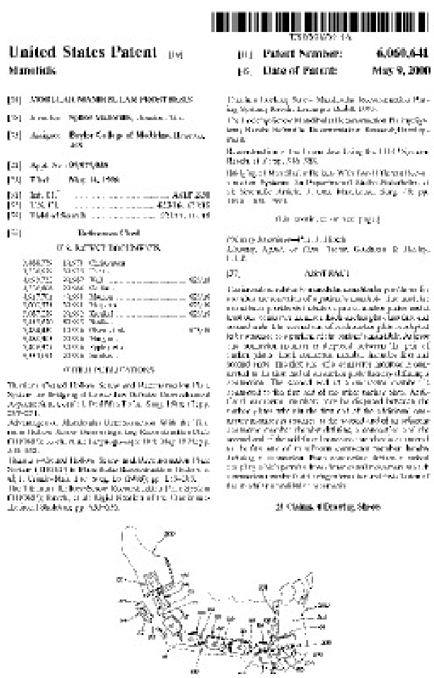
This design specifically includes two components. An anchor plate and connector members. The anchor plate attaches to the mandible and at least one connector is connected between two anchor plates. Addition connectors can be used. A unique thing about this design is the utilization of swivel coupling 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 [19]
Manolidis
[11] Patent Number: 6,060,641
[45] Date of Patent: May 9, 2000

US6060641.pdf(1.2 MB) - download

9/18/2019-Current Designs

▪ LAURA RICHMOND ▪ Oct 05, 2019 @06:06 PM CDT

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.

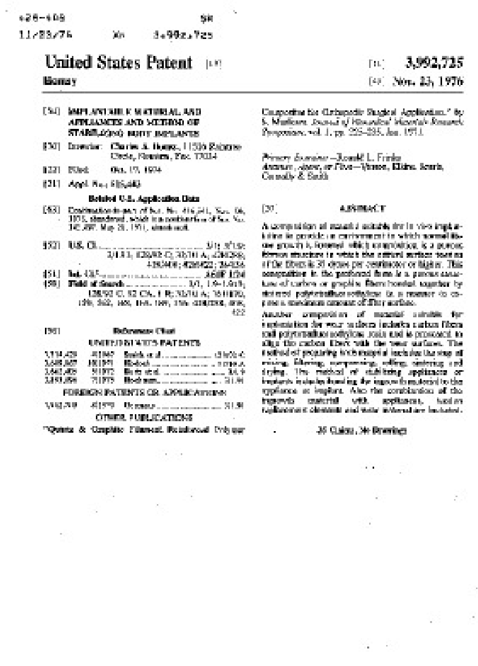
This design also considers another material that could be suitable for in vivo implantation. It includes carbon fibers and polytetrafluroethylene resin. It is processed in a way where alignment of carbon fibers and wear surfaces occurs.

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].

▪ LAURA RICHMOND ▪ Oct 05, 2019 @06:06 PM CDT



United States Patent [19]

Homsy

[11] 3,992,725

[45] Nov. 23, 1976

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

Related U.S. Application Data

References Cited

UNITED STATES PATENTS

FOREIGN PATENTS OR APPLICATIONS

OTHER PUBLICATIONS

[57] ABSTRACT

US3992725.pdf(1.2 MB) - download

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:

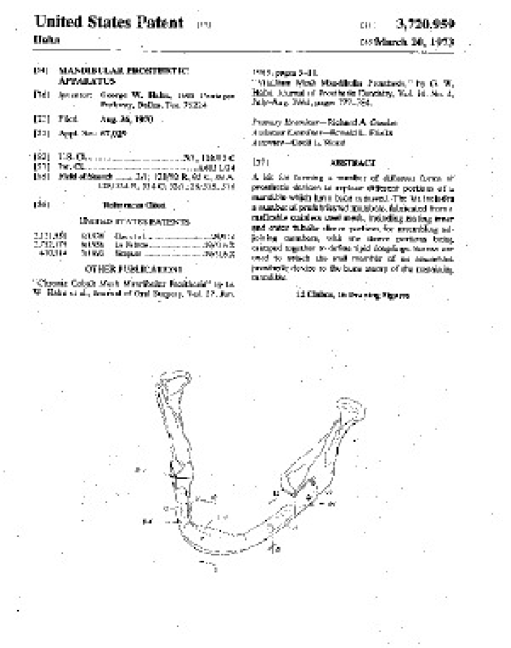
This design was unique in that instead of a single design, it is a kit that can form a number of different kinds of prosthetic devices that could be utilized to replace different components of the mandible includes prefabricated members, fabricated from a malleable stainless steel mesh, including mating 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


United States Patent
Hahn
3,720,959
March 20, 1973
MANDIBULAR PROSTHETIC APPARATUS
ABSTRACT
OTHER PUBLICATIONS

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/

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.

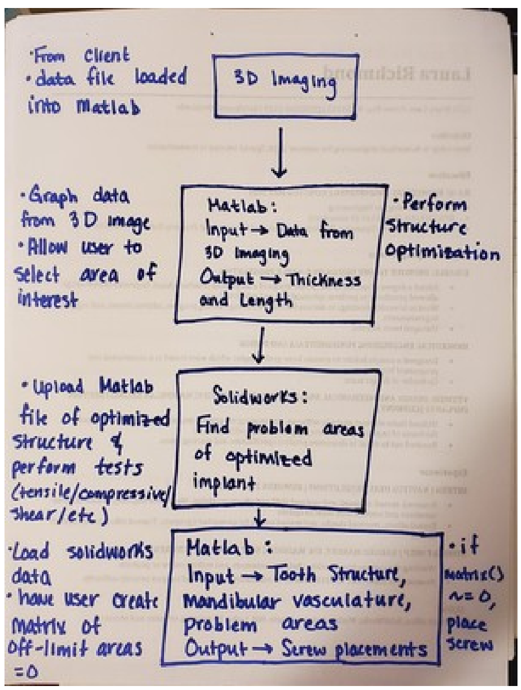
Content:

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

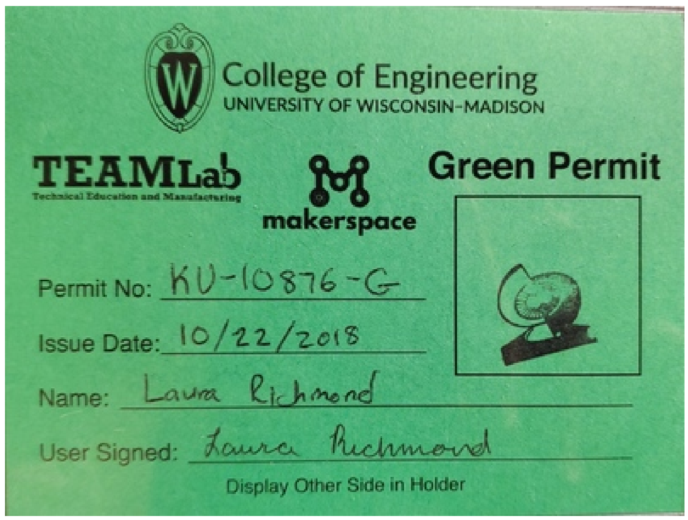
Goals: To gain my green pass in order to use the lathe and mill in the COE TEAM Lab.

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

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.

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:

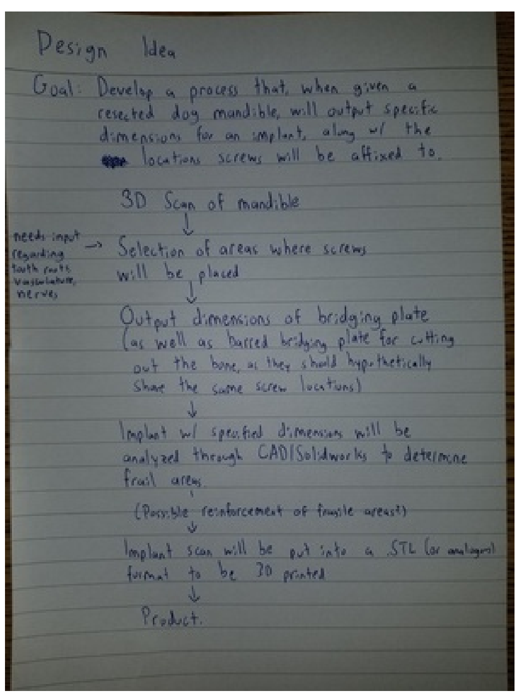
A possible resolution to the problem given by the client is to design a process that will streamline the process of designing an implant for distinct dogs. To begin this process, problem areas that should not be disturbed should first be highlighted and sectioned off. These problem areas could be places 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 and 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://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.

9/12/19 Client Meeting

▪ 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 procees 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.

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%20threatment%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

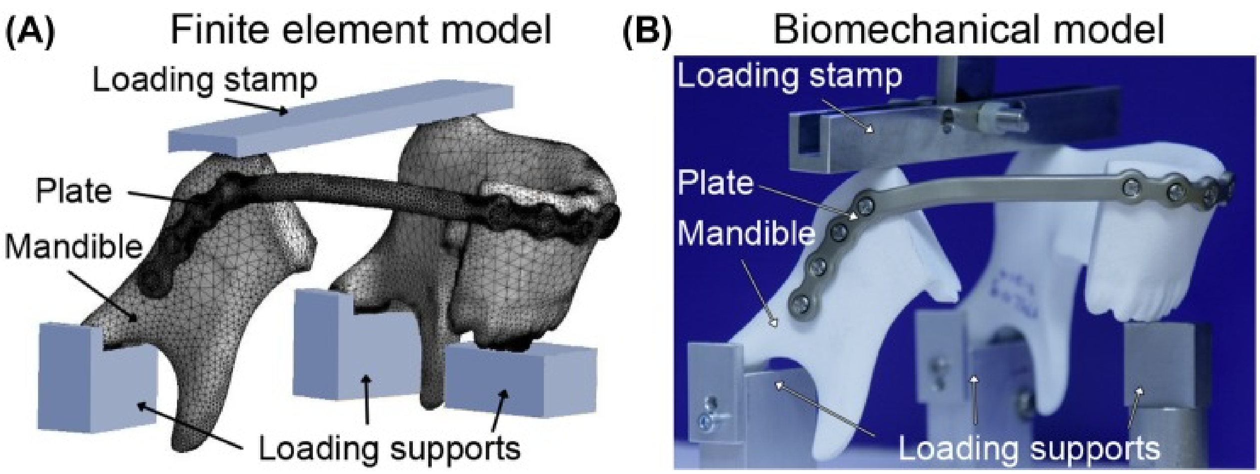
Present: N/A

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.

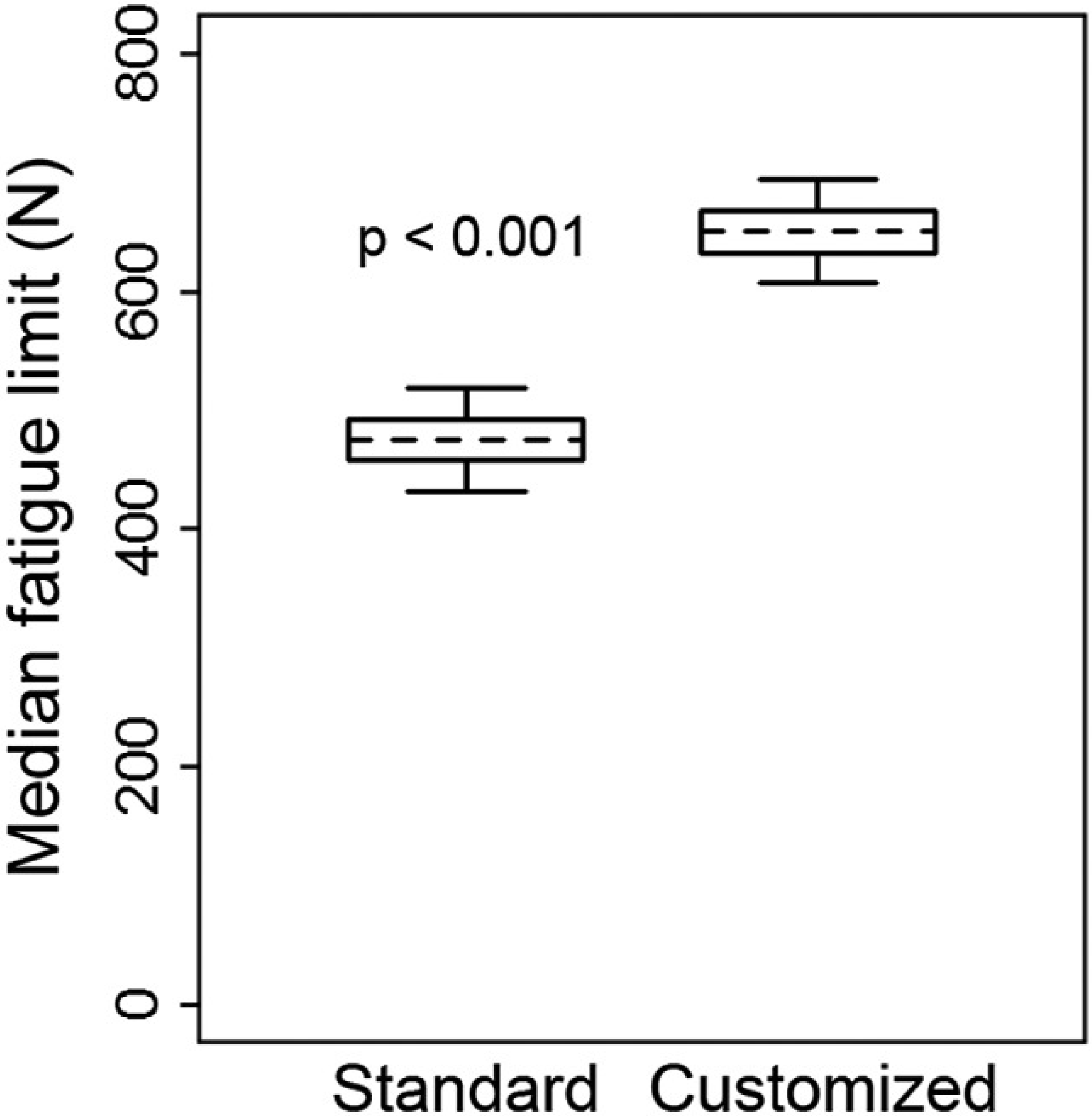
Content:

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 asses 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

▪ 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:

- ava 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

▪ 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

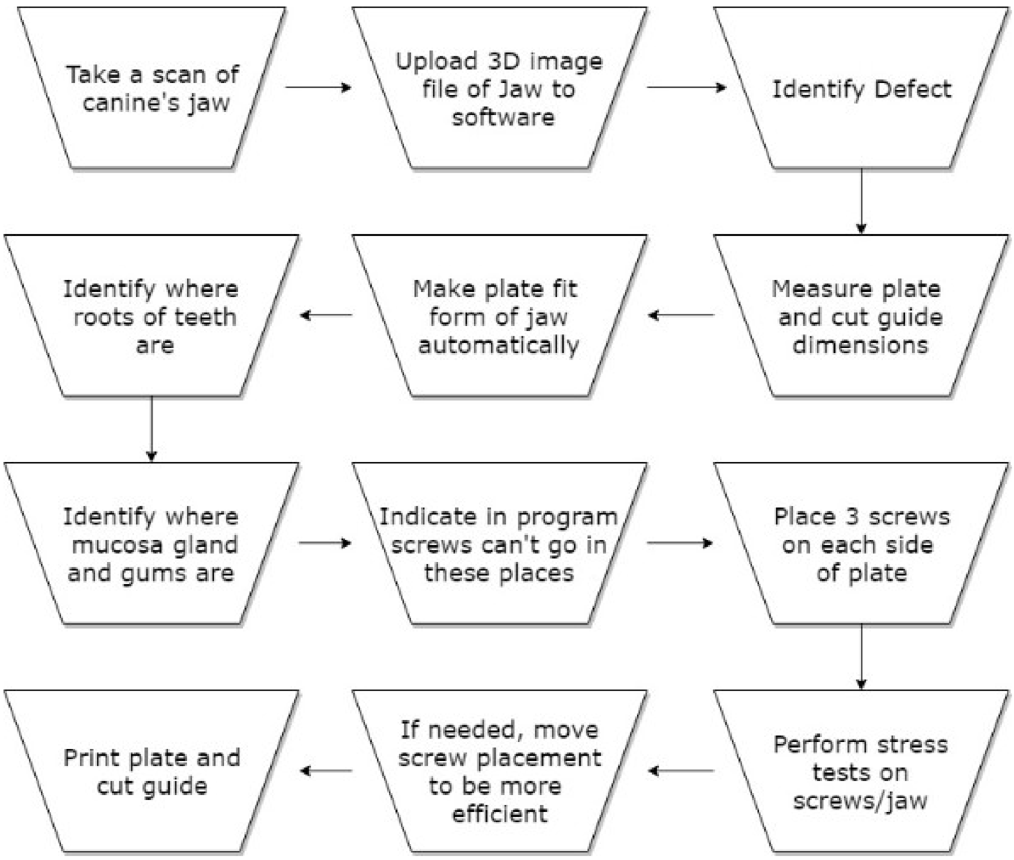
Date: 9/13/19

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.

2019/09/09- Mandibular Reconstruction Research

▪ 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

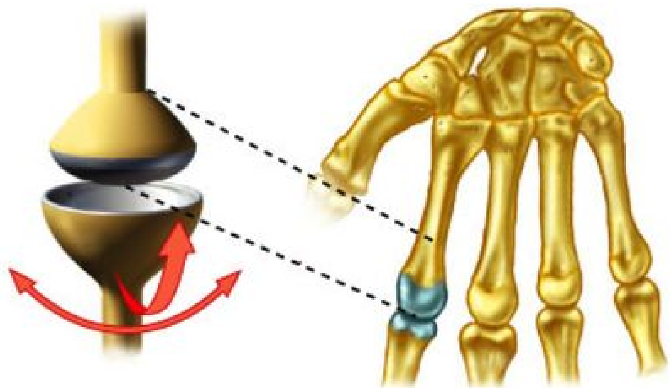
Force goes from masticatory muscles to the teeth

Unknown words

synovial condylar joint (Shown in Figure 1)-Synovial- two bones w cartilage linked cavity to connect them - Condylar = one bone has an ovallular head and another has an elliptical cavity to hold it.

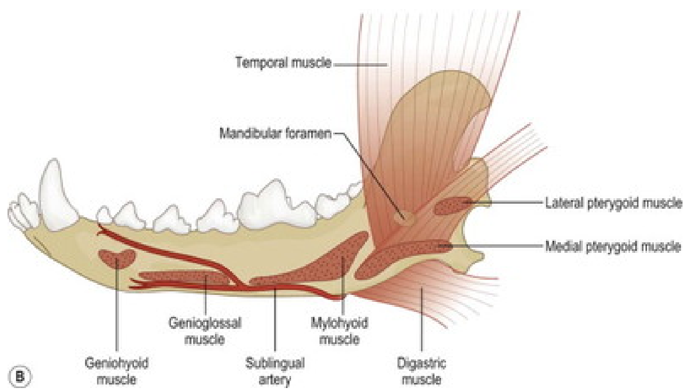
Conclusions/action items:

▪ KYLIE GASPAR ▪ Oct 02, 2019 @05:43 PM CDT



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.

▪ KYLIE GASPAR ▪ Oct 02, 2019 @05:49 PM CDT



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 assumes 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 maester 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 existent 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 [Accessed 7 Oct. 2019].

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

▪ 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"-fiinite element pdf, also remmeber 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 scafolding/titanium plate specific to the patient with the screw holes in place and the correct size of metal accounted for.

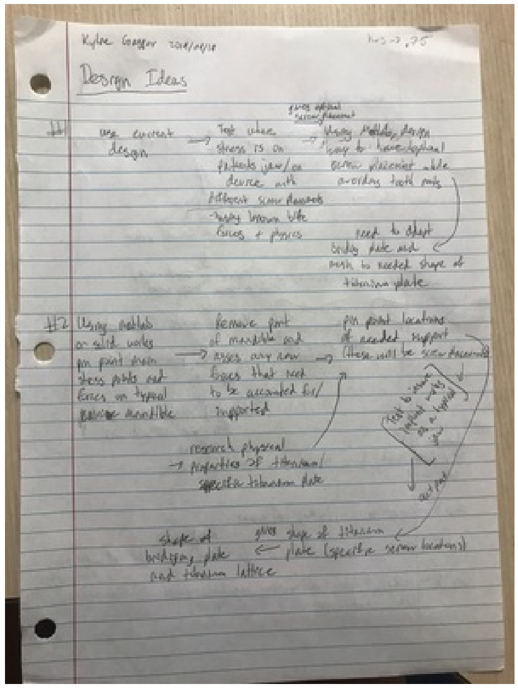
The second of the two design processes firsts tests stress on a typical canine mandible. Then we remove the specific section of the mandible needed for the patient and asses any new stress points this creates on the patient. During this step we will simultaneously be researching the physical properties 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 scafolding 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:

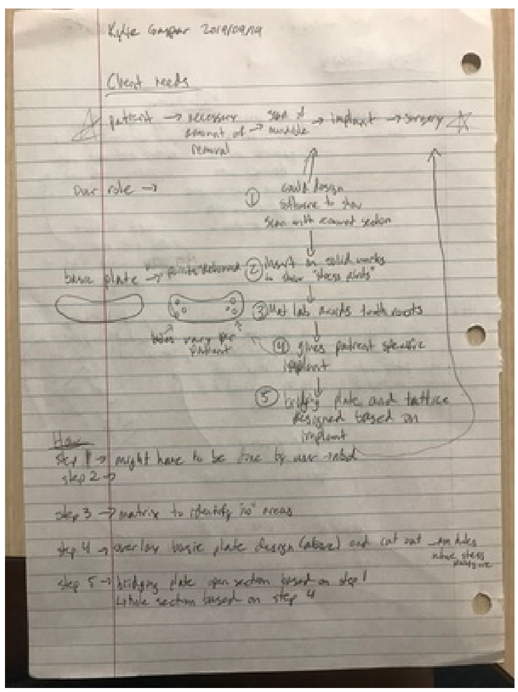
I will present this to my team and we will collaborate on what our final testing process will be tomorrow at our team meeting.

▪ KYLIE GASPAR ▪ Oct 01, 2019 @11:05 PM CDT



file.jpeg(2.5 MB) - download Figure 1

▪ KYLIE GASPAR ▪ Oct 01, 2019 @11:05 PM CDT



file1.jpeg(2.2 MB) - download Figure 2

2014/11/03-Entry guidelines

▪ 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.

2014/11/03-Template

▪ John Puccinelli ▪ Nov 03, 2014 @03:20 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: