VetMed: Optimization of Mandibular Implants

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Abstract

- Implants used in canine patients post mandibulectomy are currently designed with limited considerations of patient specific parameters.
- This project attempts to design an open source computational package that will optimize the implant to each patient.
- The package will include a coding component to generate an individualized implant and a stress testing component to determine its efficacy.

Problem Definition

Motivation

- Common injuries or cancers in dogs result in the necessary removal of the injured section of jaw.
- Vets need a simple method to print a patient specific implant that will function properly while avoiding certain areas of the mandible, such as nerves and tooth roots, while the lost bone regrows.

Background

- Mainly lateral movement
- Temporomandibular joint
- Bite force comes from jaw adductor muscles
- The forces on a jaw can be replicated in software such as SolidWorks and FEBio.
- From the testing software a model of the implant can be made with optimized locations of screw placement on the patient's' jaw.

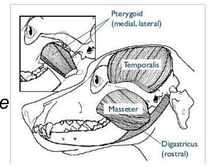

Figure 2: *Main muscles of a canine mandible* [1]

Design Specifications

- Streamline a process to import patient data from a CT scan in a usable format.
- Maintain an accurate representation of the anatomy while reducing complexity and file size.
- Develop a protocol to generate an optimized implant for the patient.
- The program should be user friendly and widely accessible for veterinarians.

STL Files and Computer Aided Simplification

Figure 2: *STL files of titanium implant*

- The STL format represents 3D surfaces with triangles
- In order to use Finite Element Analysis (FEA), the STL surface must be converted to a 3D mesh.
- The higher the triangle count, the more complicated the mesh, and the more complicated the analysis
- Make use of simplified and recursive algorithms to simplify models.

$$\vec{r}_{Centroid} = \sum_{n=1}^{N} \frac{\vec{x}_i}{N} \qquad \vec{A}_{Total\ Area} = \sum_{n=1}^{N} a_i \hat{n}_i$$

Figure 3: *Equations used in STL file simplification*

Simplified Models

- Simplifications were made first in mesh programs which allowed STLs to be imported into SolidWorks, however they were still too complicated for FEA.
- Models of the jaw and implant were manually developed with a range of triangle counts and complexities for FEA.
- SolidWorks FEA was used to determine the implications of simplification by testing the models varying in complexity and comparing the stress distributions.
- SolidWorks FEA was then compared to FEBio to determine the validity of the open source software.

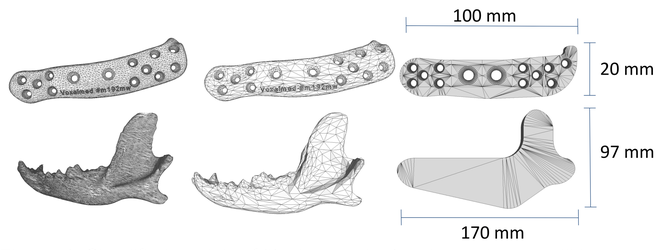

Figure 4: *Simplified models of titanium implant and a canine mandible. Most detailed on the left to the most simplified model on the right. Dimensions are consistent across each model.*

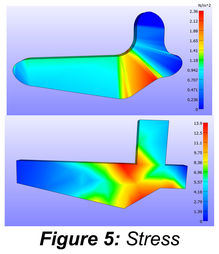

Figure 5: *Stress testing of simplified mandibles models in FEBIO [3]*

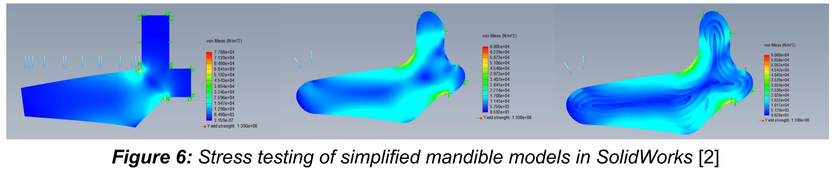

Figure 6: *Stress testing of simplified mandible models in SolidWorks* [2]

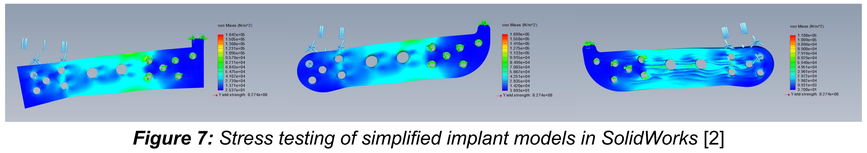

Figure 7: *Stress testing of simplified implant models in SolidWorks* [2]

References

[1] Melmed, C., Shelton, Bergman, R. and Barton, C. (2019). *VetFolio*. [online] Vetfolio.com. Available at: https://www.vetfolio.com/learn/article/masticatory-muscle-myositis-pathogenesis-diagnosis-and-treatment [Accessed 3 Dec. 2019].

[2] Hirschtick, J. (2019). *SolidWorks*. Concord, Massachusetts: Dassault Systèmes.

[3] Weiss, J. (2007). *FEBio*. Musculoskeletal Research Laboratories: University of Utah.

Results of Finite Element Analysis

One Sample T-Test analysing homogeneity across simplified models

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

- T-Test performed to determine if simplified models were significantly different
- At **α** = 0.03, only the mandible was significantly different

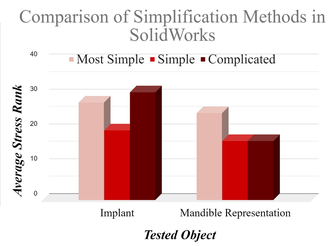

Figure 8: *Bar Graph comparing simplified models and their numbers of stress points*

- The moderately simplified model showed the lowest amount of stress points on both the mandle representation and the titanium implant.
- The jaw had similar stress counts for both the simple and most simple models.
- From the t-tests, we can conclude that all models of the implant will yield statistically similar results.
- Simplified models result in smaller file sizes which can be easily exported by veterinarians.

Future Project Development

- Development of a cohesive program
- Improve process of simplifying the jaw
- Convert from Java to C++
- Run process with multiple variations
- Update to include screw placement
- Combine all functions into a single open source program

Figure 9: *Placement of screws in a canine mandibular implant*

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