# *VETMED:* 3D PRINTED-PATIENT SPECIFIC INCLINE PLANE FOR MANAGEMENT OF CLASS II MALOCCLUSION IN DOGS


Benjamin Smith, Lily Gallagher, Giovanni Militello, Daniel Konon, Tony Pribnow, Owen Kolnik

University of Wisconsin- Madison, (Client) Dr. Graham Thatcher, Department of Veterinary Medicine; (Advisor) Dr. John Puccinelli, Department of Biomedical Engineering


## Abstract


Class II malocclusion is a common genetic skeletal deformity among dogs that affects the dental interlock between teeth. The mandibular (lower) jaw is shorter in length than the maxillary (upper) jaw, causing the lower canines to puncture and damage the upper gum palette. The current treatment works to safely correct the malocclusion through tipping orthodontics. However, this process is both expensive and timely, making it an inaccessible procedure for most pet owners. With an improved workflow and simplified design, this procedure can be available for all pet owners and affected animals. The final design is made to be patient specific, needing three measured variables; bridge length, ellipse dimensions, and the inclined plane angle, which would cut down the workflow for the orthodontist as well as making it user friendly for the orthodontist to change. Upon the designs simplicity, 3D printing in titanium (Ti64) allows for the device to withstand a canines biting force. Solidworks stress analysis showed little to no deformation as well as low von Mises stress values with a 1400 N force. The future goal is to be able to print and use the design to treat patients.


## Background and Motivation

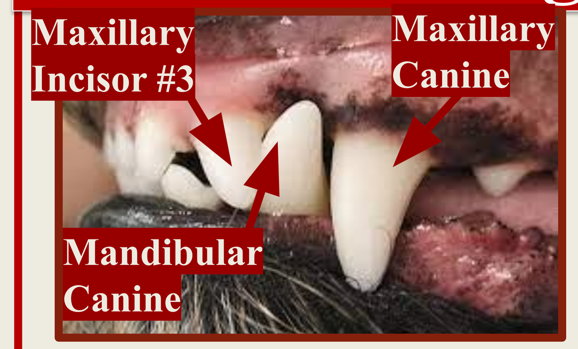


**Figure 1: A Normal Occlusion [1]**

The mandibular canine fits in between the maxillary incisor and canine [1]. The crown of the lower canine points outward and the jaw closes correctly.

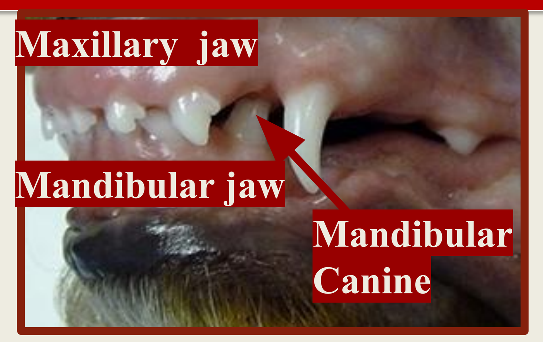


**Figure 2: Class II Malocclusion [2]**

The upper jaw is shorter than the upper jaw[1]. The lower canine crown is pointing inward and the jaw does not close correctly. Autosomal Recessive Mutation (Affect 10% of purebreds[3])

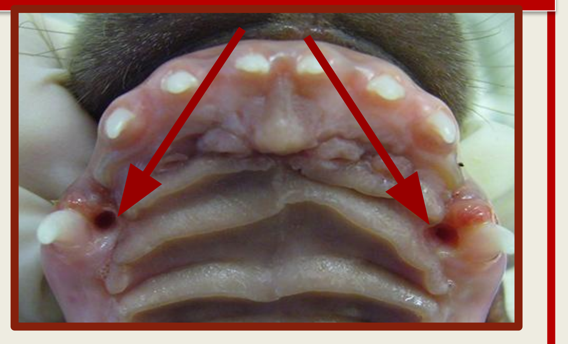

**Figure 3: Puncture Wounds [2]**

The lower canines puncture damage the gum palate and tissue of the upper jaw.

### Current Treatment: Incline Plane

- Timely and Expensive.
  - ~1 week
  - CT Scan ~$100-500 [4].
  - Anesthesia ~$90-200 [5].
- Process repeats with each specific patient.
- 2020 project material (Dental LT resin) broke after 2 weeks of treatment.

**Figure 4:** The skull mold created from the CT scan with the hand-carved incline plane attached.

## Design Criteria

- 3D Printable patient specific Incline Plane Device.
- Improve workflow and user friendly.
  - Reduces measurement and manipulation time to 1 hour.
  - Final product be produced under 1 week.
- Produce device by orthodontist.
- Must fit average maxillary canine width of 11 mm [6].
- Withstand 6-8 weeks of use.
- Material to withstand up to 1400 N of Bite Force [6].
- Reduce current costs:
  - CT Scan ~$100-500 [4].
  - Anesthesia ~$90-200 [5].

## Final Design

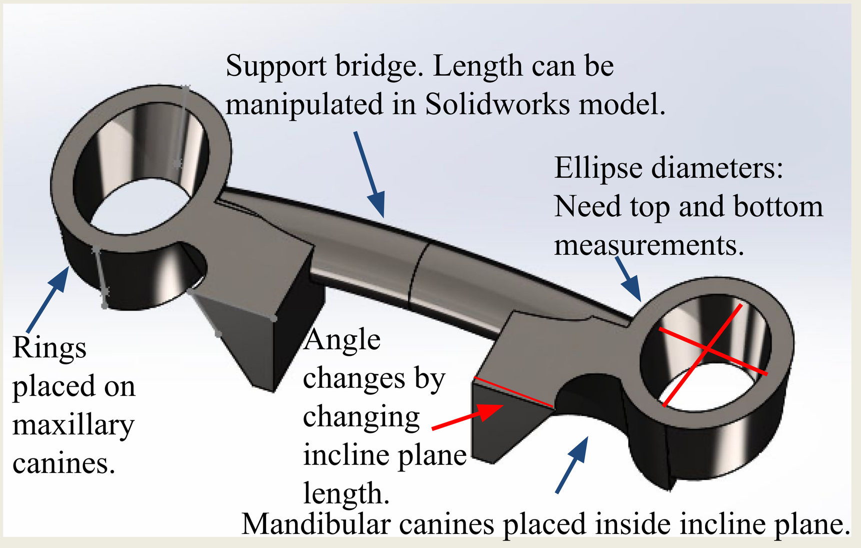


**Figure 5:** Final SolidWorks Design.

**Figure 6:** Final Design in 3D printed model canine.

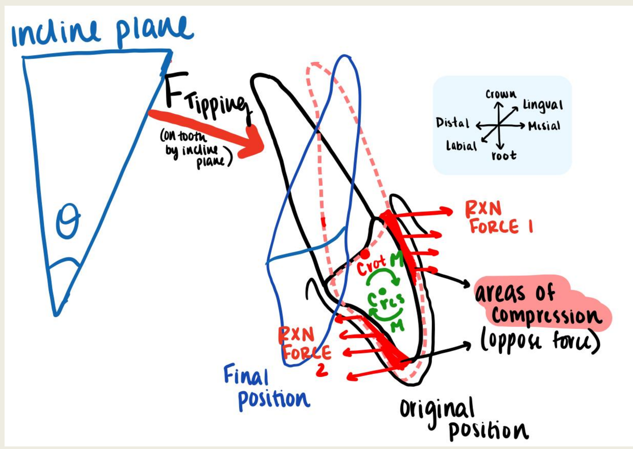


**Figure 7: Uncontrolled tipping**

The root and crown of the tooth are moving in opposite directions. The center of rotation is near the center of resistance, where the moment force is M = F x d.

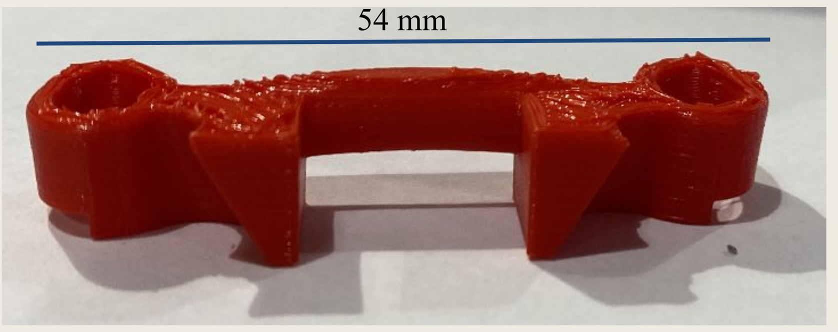


**Figure 8:** Final Design 3D printed in PLA Material.

### Unique Features

- Three variables to manipulate: support bridge length, ellipse dimensions, and inclined plane angle.
- Reduces time to make patient specific under 1 hour.
- Ti64Al4V (Ti64) Material.
  - Elastic Modulus: 113.8 GPa [7]
  - Yield Strength: 880 MPa [7]
  - Cost: ~$100 for Ti64 [8]
  - Time: < 1 hour to design, ~3-4 weeks to print in Ti64 [8]

## 1400 N Solidworks SimulationXpress Analysis Wizard Test

### Final Design Under Stress Testing

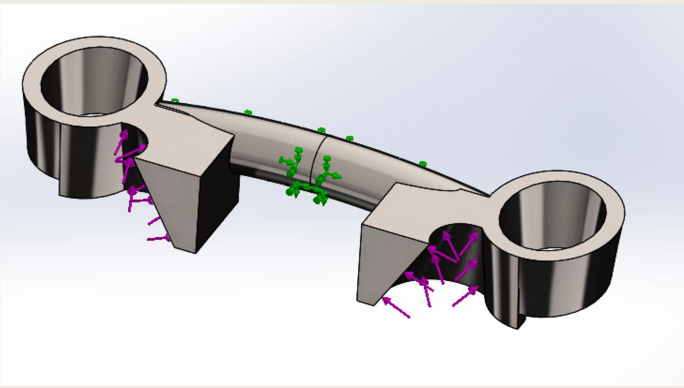

**Figure 9:** Stress analysis of the final design.

- Mandibular canine forces applied to incline plane.
- Support bridge fixed into position.

### Von Mises Stress From Direct Contact

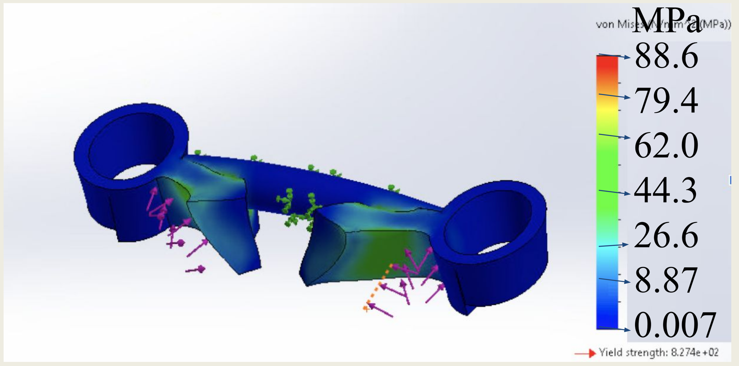


**Figure 11:** Von Mises stress throughout the final design.

- Stress values ranged from 0.007 MPa from blue regions to 44.3 MPa in green regions.
- Lowest FOS of 9.33.

### Deformation of Final Design

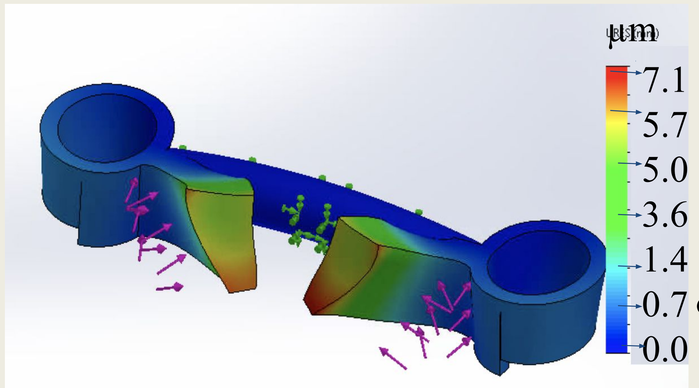


**Figure 10:** Deformation of device.

- Max deformation of 7.12 µm occurs at the 2 mm end of the incline plane in the red region.
- Closer to ring and support bridge deformation decreases.

### Von Mises Stress at Support Points

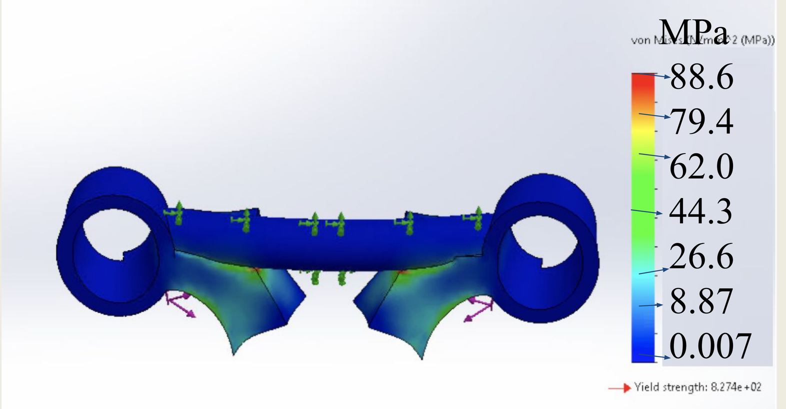


**Figure 12:** Von Mises stress throughout the final design.

- Stress values highest at contact of incline plane and support bridge in red at 88.6 MPa.

## Workflow

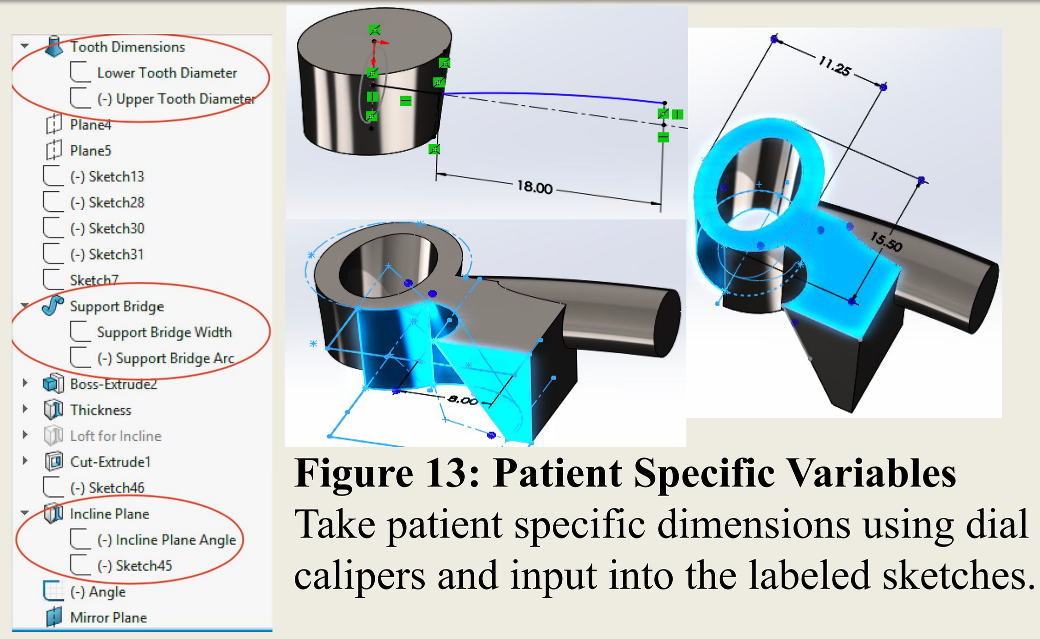

**Figure 13: Patient Specific Variables**

Take patient specific dimensions using dial calipers and input into the labeled sketches.

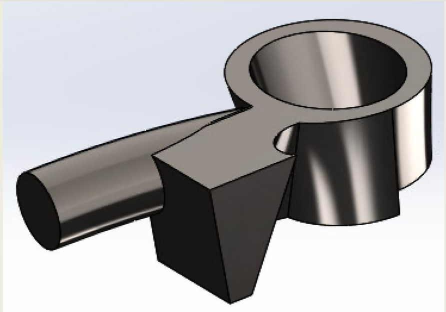

**Figure 14: Mirrored Piece**

Create a mirrored model of the design.

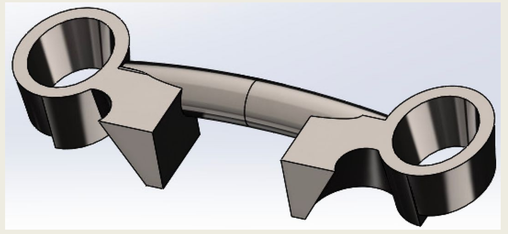

**Figure 15: Assembly of parts**

Assemble the two pieces together.

- 3D print the assembly inTi64Al4V.
- Repeat process for the next patient.
- Cost: ~$100 for Ti64 [8]
- Time: < 1 hour to design, ~3-4 weeks to print in Ti64 [8]

## Future Work

- Optimize Design:
  - Fillet the incline plane and the inside of the ring.
  - Further simplify Solidworks design while making the device more adaptable to increase ease of creating patient specific models.
  - Eliminate measurement error from 3D-Printing.
- Print final model in the desired material, Ti6Al4V (Ti64).
- MTS testing of final model.
- Cut down on current 3D printing time.
- Work with our client and use the final model with a patient.

## Acknowledgements


We would like to thank our client, Dr. Graham Thatcher, our advisor, Dr. John Puccinelli, and Ben Hildebrandt for assisting us through the design process, providing valuable resources and advice, and overall creating a great design experience.


## References


[1] G. Thatcher, "Diagnosis and management of Class II malocclusion," Can Vet J, vol. 60, no. 7, pp. 791–795, Jul. 2019. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6563895/

[2] "Lingually Displaced Canines," *www.dentalvets.co.uk*. https://www.dentalvets.co.uk/common-cases/lingually-displaced-canines

[3] J. E. R. Naomi K. Hoyer, "Prevalence of malocclusion of deciduous dentition in dogs: An evaluation of 297 puppies - Naomi K. Hoyer, Jennifer E. Rawlinson, 2019," *SAGE Journals*.

[4] "3D dental scan - what is Cone Beam CT?," *Richmond Dental & Medical*, 23-Oct-2019. https://richmonddental.net/library/3d-dental-scan-what-is-cone-beam

[5] Wag, "General anesthesia in dogs," *Conditions Treated, Procedure, Efficacy, Recovery, Cost, Considerations, Prevention*, 09-Sep-2021 https://wagwalking.com/treatment/general-anesthesia. [

[6] S. E. Kim, B. Arzi, T. C. Garcia, and F. J. M. Verstraete, "Bite Forces and Their Measurement in Dogs and Cats," *Front Vet Sci*, vol. 5, p. 76, Apr. 2018, doi: 10.3389/fvets.2018.00076.

[7] "Titanium Ti-6Al-4V (Grade 5), Annealed," *ASM material data sheet*. [Online]. Available: http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=mtp641. [Accessed: 08-Dec-2021].

[8] I.materialise, "Your 3D Printing Service," *i.materialise*. [Online]. Available: https://i.materialise.com/en. [Accessed: 08-Dec-2021].