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

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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. Compression testing showed no deformation when tested with a force of 926 N. In the future, the device will be tested on patients with class II malocclusions.

Background and Motivation

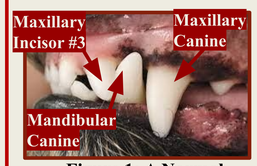

Figure 1: A Normal Occlusion [1]
The mandibular canine fits in between the maxillary incisor and canine [1]. The crown of the lower canine points outward and the jaw closes correctly.

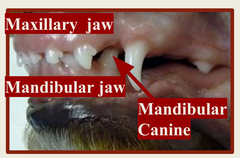

Figure 2: Class II Malocclusion [2]
The upper jaw is shorter than the upper jaw[1]. The lower canine crown is pointing inward and the jaw does not close correctly. Autosomal Recessive Mutation (Affect 10% of purebreds[3])

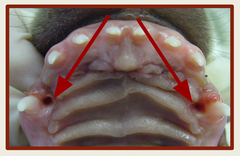

Figure 3: Puncture Wounds [2]
The lower canines puncture damage the gum palate and tissue of the upper jaw.

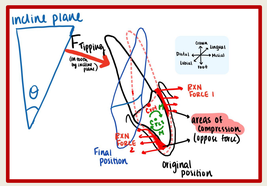

Figure 4: Uncontrolled Tipping:
The root and crown of the tooth are moving in opposite directions. The center of rotation is near the center of resistance, where the moment force is M = F x d.

Current Treatment: *Incline Plane*

- Timely and Expensive.
  - ~2/3 week
  - CT Scan ~$100-500 [4].
  - Anesthesia ~$90-200 [5].
  - Total Cost: $2500-$3000
- Process repeats with each specific patient.
- 2020 project material (Dental LT resin) broke after 2 weeks of treatment.

Design Criteria

- 3D Printable patient specific Incline Plane Device.
- Improve workflow and user friendly.
  - Reduces measurement and manipulation time to 1 hour.
  - Final product ready to 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 926 N of Canine Bite Force [6].
- Reduce current cost of production to under $200

Final Design

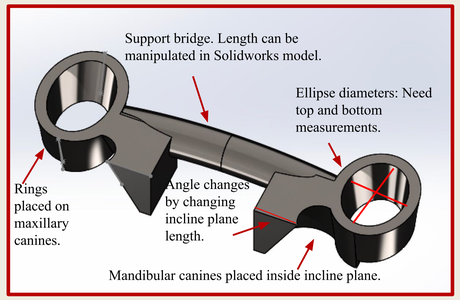

Figure 5: Final SolidWorks Design.

Figure 6: Final Design 3D printed in Ti-64.

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: ~$120 for Ti64 [8]
  - Time: 30 minutes to design, ~2/3 weeks to print in Ti64 [8]

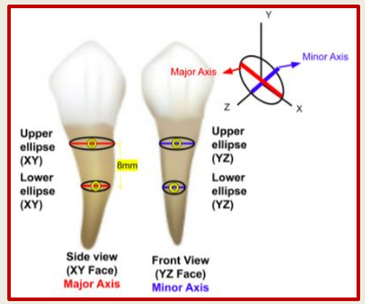

Figure 7: Measurements taken to create the incline plane ring supports

MTS Machine Compression Test and Results

Testing Protocol

- Compression testing with an MTS machine to verify the part could withstand the max bite force experienced by mandibular canines.
- 3 cycles providing up to 989.5 N of force, with a strain rate of 0.001 s^{-1}, to mimic the environment the plane will experience in a patient.

Testing Apparatus

- Fabricated compression plates out of aluminum and used two bolts to fasten the incline plane to the lower plate.
- Two bolts to act as maxillary canines on the upper plate that will apply the force onto the incline plane.

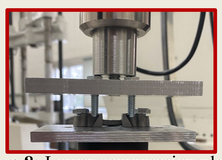

Figure 8: Lower compression platen fastening incline plane in place.

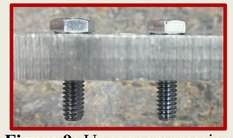

Figure 9: Upper compression platen with bolts as maxillary canines.

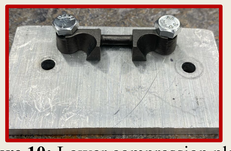

Figure 10: Lower compression platen fastening incline plane in place.

Results

- Initial distance from each point of contact between the bolts and the incline plane to be 23.76mm before testing and 23.76mm after.
- Device withstood maximum bite force with no deformation
- No visible damage or scratches on the part itself.

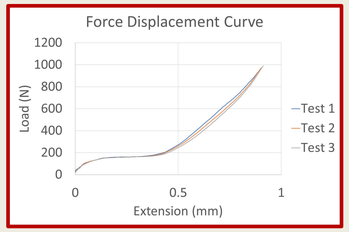

Figure 11: Load (N) vs. Extension (mm) graph for each compression test run on the incline plane.

Workflow

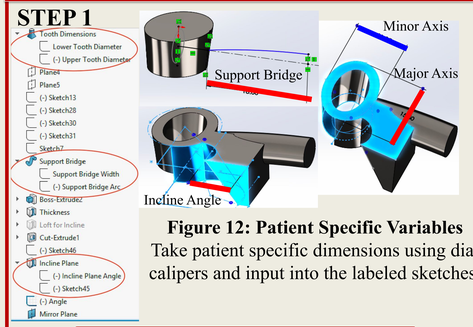

Figure 12: Patient Specific Variables
Take patient specific dimensions using dial calipers and input into the labeled sketches.

STEP 2

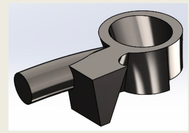

Figure 13: Mirrored Piece
Create a mirrored model of the design.

STEP 3

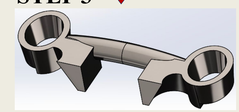

Figure 14: Assembly of parts
Assemble the two pieces together.

- 3D print the assembly in Ti64Al4V.
- Repeat process for the next patient.
- Cost: ~$120 for Ti64 [8]
- Time: 30 minutes to design, ~2-3 weeks to print in Ti64 [8]

Future Work

- Testing
  - Test workflow using measurements and dimensions from additional subjects
  - Create video walking user through workflow
  - Have veterinarian take measurements and test device on a canine
  - Observe individuals with limited SolidWorks knowledge attempt to use the workflow
- Marketing
  - Continue intellectual property process with WARF
  - Potentially create a company (Canines Corrected) to be intermediaries between veterinarians and clients
    - Affects 10% of purebred dogs in the US, which is around 4 million dogs [9]
    - ~$120 cost for production, could charge veterinarian $300 for 150% profitability

Acknowledgements

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