TEMPOROMANDIBULAR JOINT DYSFUNCTION

Christopher Barnes, Jorge Pumachagua, Elias Saliba
Department of Mechanical Engineering, Embry-Riddle Aeronautical University

BACKGROUND

Temporomandibular Joint Dysfunction (TMJD) is a disorder where there is an anterior displacement of the articular disk with reference to the condyle. TMJD is a common disorder that affects nearly 10 million Americans [1]. The abnormal jaw mechanics causes major symptoms of umcomfortability and pain. These symptoms are clicking, pain in the jaw, difficulty chewing and severe bruxism. Bruxism is a condition where teeth grind or clench involuntarily at any time of the day, especially during sleep time. Bruxism engages the Masseter, Temporalis, Medial and Lateral Pterygoid muscles to be under involuntary movement which leads to the exhaustion of the muscles and jaw joints. Along with, the Temporomandibular Joint (TMJ) is nearly connected with the ear muscles where a misalignment of the articular disk can set excess pressure on the branches of the trigeminal nerve and therefore cause aching pain around the ear; exhibiting how delicate TMJD can be to the human health.The ideal solution in the current market to treat TMJD remains unknown in the biomedical community. Within the past twenty years, treatment options to help relieve TMJD involved a series of stages and processes, like physical therapy to help alleviate TMJ pain by avoiding extreme jaw movements and using prescribed medications. One such treatment option is dental splints: plastic mouthpieces that fit on the upper and lower teeth. Although this helps with teeth alignment and reduce the effect of bruxism on the excessive wear and damage of the teeth, they do not prevent bruxism, grinding/clenching of the teeth [3].

ENGINEERING APPROACH

The approach taken to understand TMJD is based on the fundamentals of levers. The mandible is classified as a class 3 lever. The fulcrum being the mandibular condyle as seen in figure 1. The effort is applied by the four mastication muscles, the medial pterygoid, lateral pterygoid, temporalis and masseter as seen in figure 2. Therefore, the load is at the end of the lever. Positioning of the fulcrum and effort is crucial since if one of the two are out of alignment, a higher effort is required for the load resulting in a stronger tension on the mastication muscles and mandibular condyle.

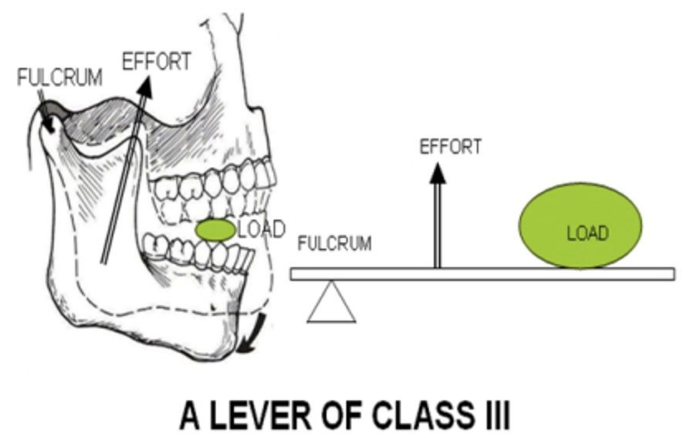

Figure 1: Mandible as class III lever [6]

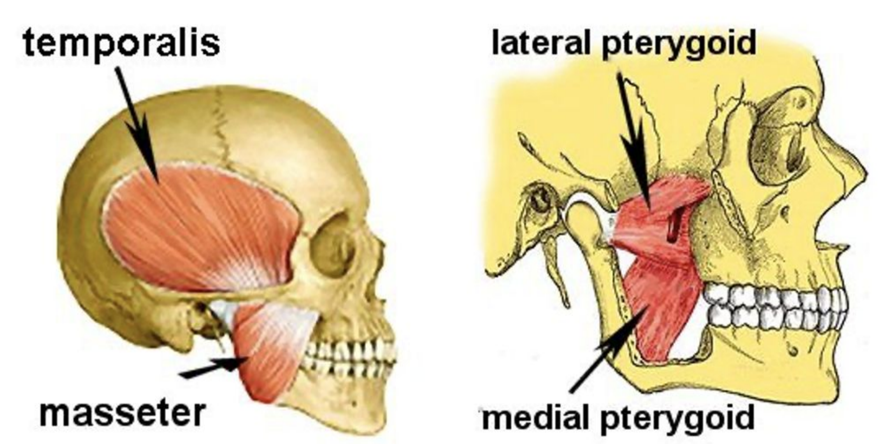

Figure 2: Muscles of Mastication [4]

METHODS

The current market dental guards do not prevent protrusion, protraction, retraction, nor lateral or medial excursion. This is a current issue as the individual is exerting forces on their jaw with the grinding movement causes the articular disk to slip. Subsequently current dental guards do not relieve the jaw muscle average bite force of 700 N on the molars and about 350 N on the incisors [5]. To counter this, the design has an upper guard custom fit made out of PMMA filament.. The front of the upper guard will be thicker than the back portion to prevent the 1st and 2nd molars from touching. This should relieve the 700N at the back of the mouth. In addition to the top guard, there is a bottom guard made of a 50A resin material. The bottom guard will only cover both premolars on both sides. This will help relieve the force on the incisors. This combination will allow for friction to be present between the dental guards under biting force preventing grinding. To test the previous concept, a prototype 3D skull model was found on GrabCad [2]. Two dental guards were designed for the upper and lower teeth with respect to the skull model. The skull model and dental guards were 3D printed for testing. The skull was printed in PLA filament due to the skull being a harder material.

ABSTRACT

The goal of this senior design project is to produce an alternative to the current market of dental guards available that non-invasively treat Temporomandibular joint dysfunction (TMJD). TMJD occurs when there's an anterior dislocation of the articular disk in reference to the condyle. The focus of the design is to prevent patients that have been rehabilitated by a specialist from regressing due to bruxism. Bruxism is a condition where teeth grind, gnash, or clench involuntarily at any time of the day, especially during sleep time. Bruxism engages the Masseter, Temporalis, Medial Pterygoid, and Lateral Pterygoid muscles to continuously be under involuntary movement which leads to the exhaustion of the muscles and jaw joints and therefore can provoke rehabilitated patient's symptoms to worsen. The current market provides numerous types of dental guards that reduce the effect of bruxism on the excessive wear and damage of the teeth. Nonetheless, these dental guards do not prevent protrusion, protraction, retraction, or lateral or medial excursion. This is a current issue as the individual is exerting forces on their jaw with the grinding movement causes the articular disk to slip. The design aims to produce a dental guard that can relieve the temporomandibular joint (TMJ) from pressure while it's under bruxism, preventing the patient's symptoms from augmenting. The design process consists of 3D printing a two-piece dental guard out of Polymethyl methacrylate (PMMA) filament and elastic 50A resin. As for the early testing stage, the product will initially be tested on a skull model made of Polylactic acid (PLA) filament. Depending on the testing results, it could progressively lead to the phase of being approved by the Institutional Review Board (IRB) to test on an experimental group.

PROTOTYPE DESIGN

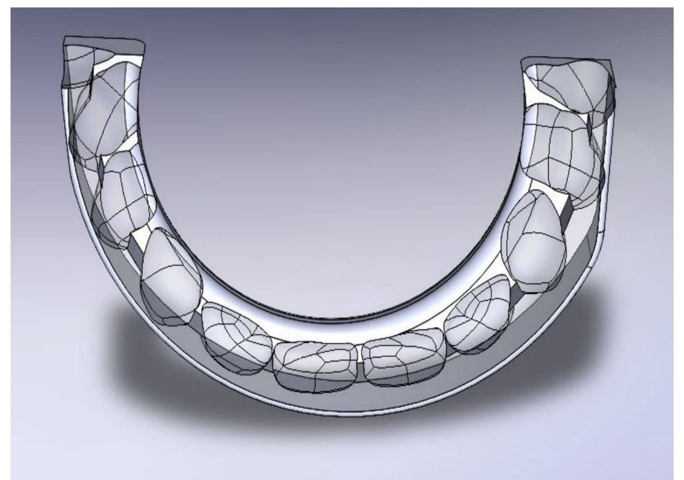

Figure 3: Top dental guard CAD model

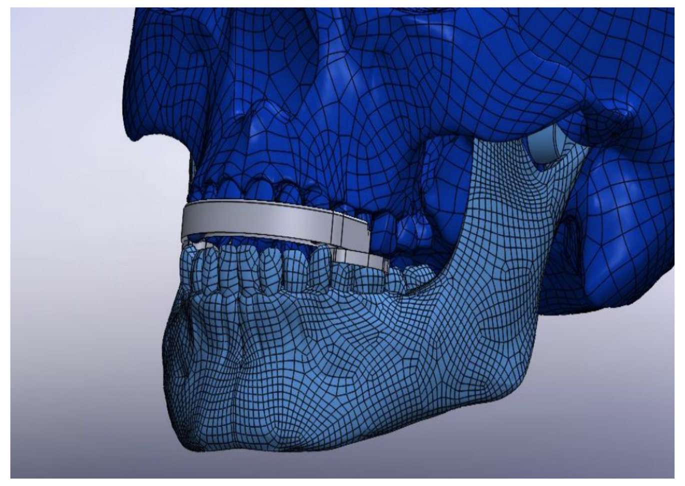

Figure 4: CAD model dental guard fit

Figure 5: TPU dental guard

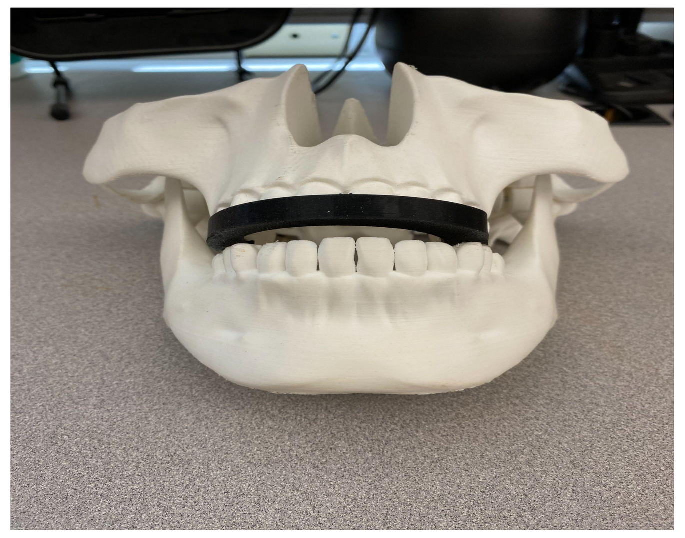

Figure 6: PLA skull model with dental guards on

RESULTS

As the prototype is prepared for testing, the dental guard will initially be tested with the 3D printed skull model. In order to record data, load cell sensors were connected to a microcontroller that will be used to analyze the bite force of the jaw with the dental guard connected to observe if the bite force reduces to the threshold where the pressure is reduced. With a rig installed to position, the skull model with the dental guard, the testing phase will commence with multiple weights to simulate bite force.

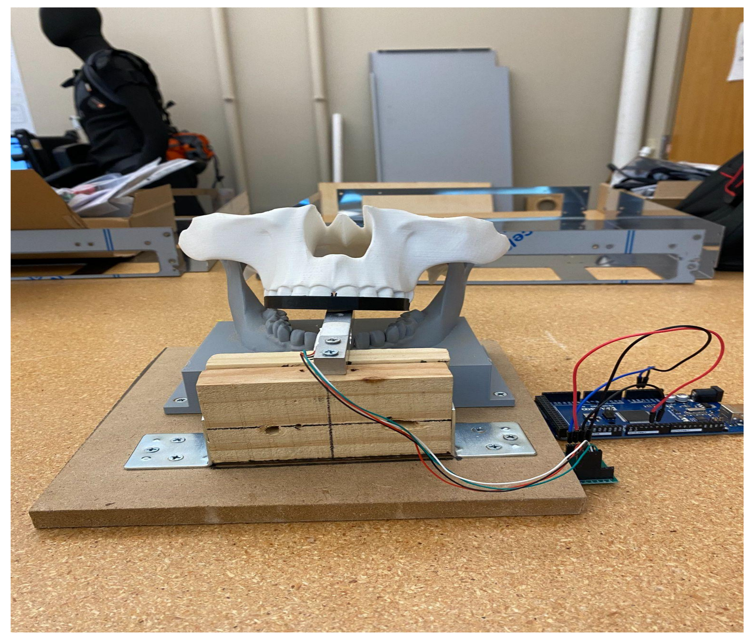

Figure 7: 3D skull model attached to testing rig

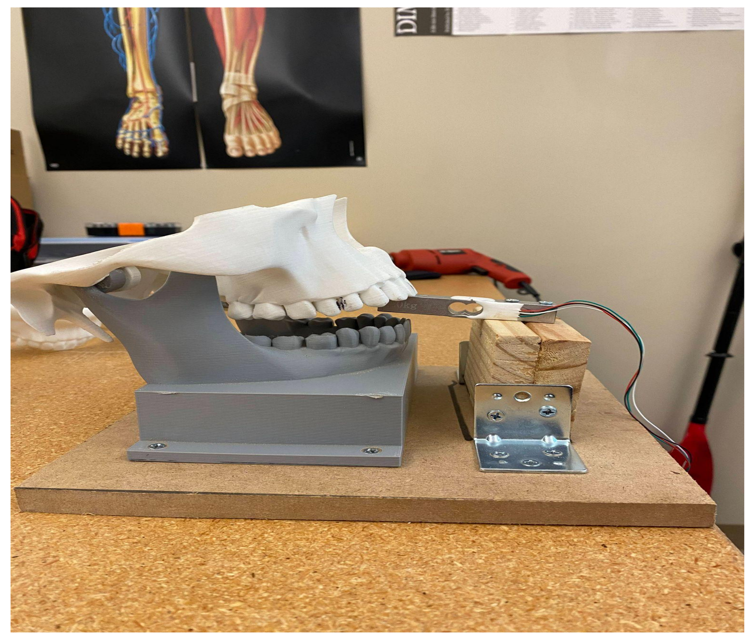

Figure 8: Testing rig side view

CONCLUSION

In the CAD design steps, the curvature of the teeth, taken from the 3D skull model, created difficulty for modeling the dental guard due to the misalignment of the upper front teeth on the skull model. The next steps to this project would include experimental testing, and interpret recorded data. The testing will include a series of increasing weights added to the top of the skull to simulate a bite force gradually up to 158 N [6].

REFERENCES

[1] Burke, D. (2019, March 13). *TMJ (temporomandibular joint) disorders*. Healthline. Retrieved from https://www.healthline.com/health/tmj-disorders#symptoms

[2] Free CAD designs, Files & 3D models: The grabcad community library. Free CAD Designs, Files & 3D Models | The GrabCAD Community Library. (n.d.). Retrieved from https://grabcad.com/library/3-parts-anatomical-skull-model

[3] Guaita, M., & Högl, B. (2016, February 20). *Current treatments of bruxism*. Current treatment options in neurology. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4761372/

[4] Hong, K. A. (2014, December 23). *The muscles of mastication*. Thousand Oaks Family Dentistry. Retrieved from https://www.thousandoaksfamilydentistry.com/blog/2014/12/22/the-muscles-of-mastication

[5] Bakke, M. (2016). Jaw Muscle. Jaw Muscle - an overview | ScienceDirect Topics. Retrieved from https://www.sciencedirect.com/topics/neuroscience/jaw-muscle#:~:text=The%20jaw%20muscles%20move%20the,(lateral%20pterygoid%20and%20digastric).

[6] Walia, M. S., Arora, S., Arora, N., & Rathee, M. (2014, January 1). *Temporomandibular Joint (TMJ): A weight bearing joint?* Research Gate. Retrieved from https://www.researchgate.net/publication/294428451_Temporomandibular_Joint_TMJ_A_Weight_Bearing_Joint

ACKNOWLEDGMENTS

Dr. Victor Huayamave, *Assistant Professor, Department of Mechanical Engineering*

Dr. Alesha Fleming, *Assistant Professor and Program Coordinator for B.S. in Aerospace Physiology*

EPPL Engineering Physics Propulsion Lab