2017

Measurement of Impact Forces on Teeth and Jaw when Wearing Sports Mouth Guards

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MNE 507 | **Team members:** Alghamdi Abdullah, Alnaser Mobarak, Quiroz Ingrid, Serrate Ciro Alcoba, Veizaga Rodrigo | **Faculty adviser:** Dr. Laleh Golshahi PhD | **Sponsor:** VCU School of Dentistry | **Sponsor adviser:** Dr. Heloisa Terra D.D.S., Dr. Peter Moon MS PhD Professor Emeritus

Abstract

The objective of this project is to accurately measure the forces the teeth and jaw experience when subjected to impact. For this purpose piezoelectric technology (PVDF) **,** which converts force into voltage and vise versa can be used to measure forces applied to teeth. A PVDF cable is calibrated and used for measuring force along with a control measuring device (PCB Piezotronics). The cable allows for adequate fit between mouth guard and denture. Two masses, a baseball and 2 lbs - 3D printed projectile was dropped from a height of 1 m onto the denture with and without mouth guard. Results showed a significant force absorption by the mouth guard (more than 50% of initial impact force). FEA Analysis was also used to show the regional stress and strain along the denture.

Introduction and Background

The purpose of this project is to find accurate measurements of impulse inflicted upon teeth and jaw. For this project, the team is specifically finding the force absorption by wearing a mouth guard. In the United States, around 15 million Americans suffer dental injuries, and 5 million teeth are lost (Academy of General Dentistry).The range of injuries varies; from chipped teeth to fracture of mandible (**Figures 1-2)** Estimating the actual impact on the teeth may prevent serious injuries by improving the mouth guards with the information known.

Figure 1. 3D printed chipped jaw

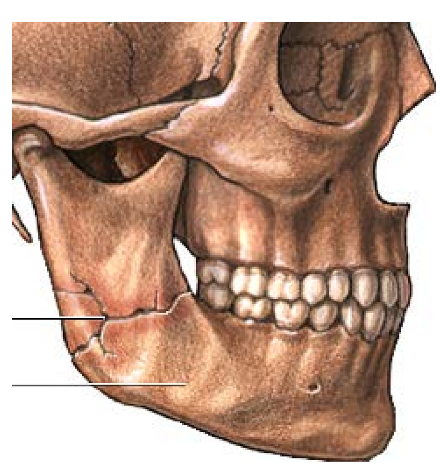


Figure 2. Fractured mandible

Methods

Piezoelectric cable is a more adequate device for measuring dynamic forces than strain gauge (HBM Test and Measurement), which from previous studies had ranked better than load cells, and accelerometer.
The testing setup, included a free fall column, 3-D printed projectile (adjustable masses), baseball, and an in house 3-D printed jaw and teeth model (**Figure 3 a-d**).

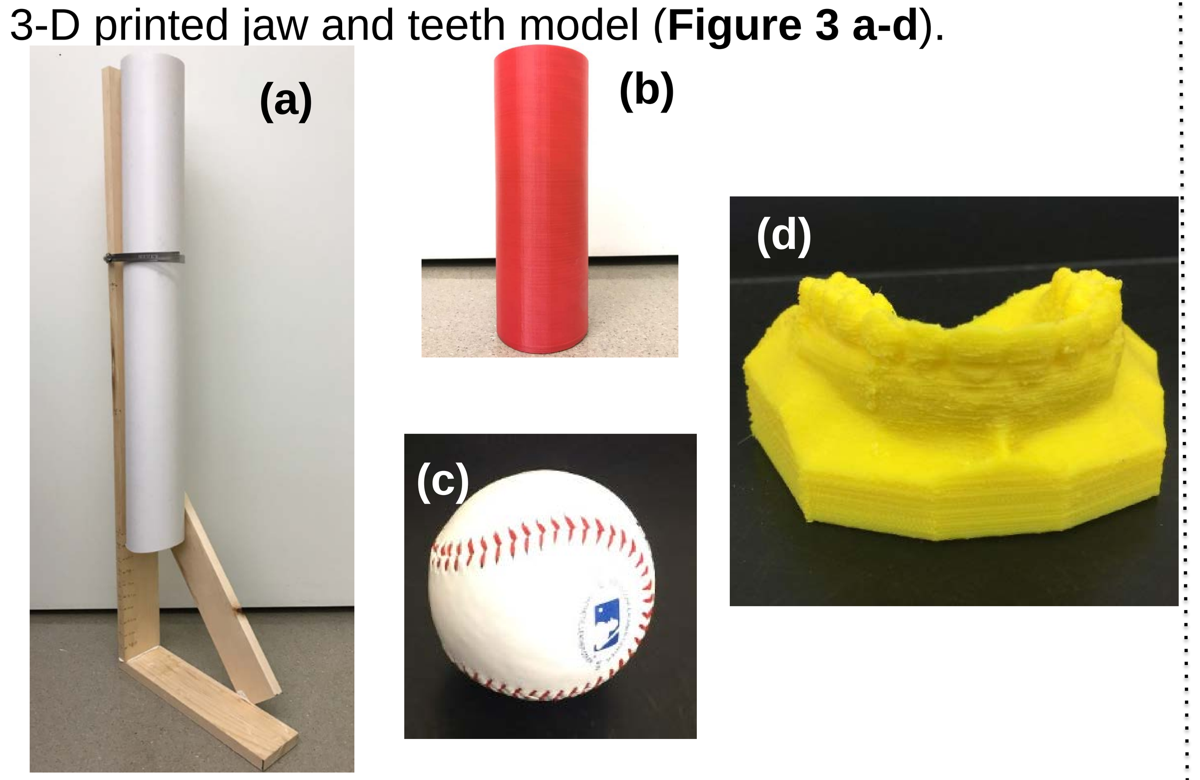


Figure 3. The elements of the experimental setup (a) free fall column (b) 2lb mass cylinder (c) baseball, and (d) 3-D printed jaw model.

With the aid of PCB Piezotronics sensor (**Figure 4a**), which was calibrated to a sensitivity of 0.9677 mV/lbf as the control group, it was proceeded with the calibration of the piezoelectric cable (**Figure 4b**). Voltage and Force are proportional and therefore their ratio, piezo-constant was found. For accuracy, several trials (n=10) were carried out. Another method used was through FEA analysis, by modeling the denture, and a sphere of different masses (0.142 and 0.91 kg).

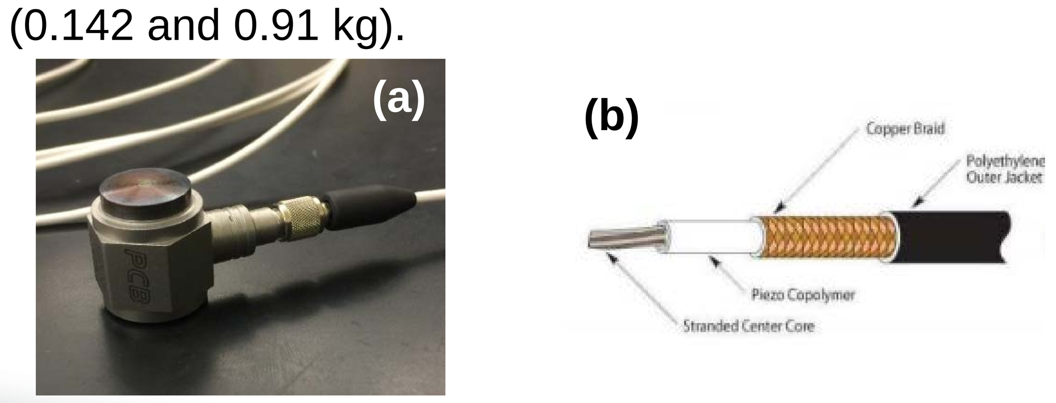


Figure 4. (a) PCB Piezotronics sensor for calibration, and (b) PVDF cable used in the tests.

Results and Discussion

Using a drop test tower shown **in Figure 3a** the mass elements used were:

Baseball	m = 0.142 kg
Projectile	m = 0.91 kg

*Projectile was filled with salt which has a density of 2160 kg/m^3 to reach target mass.

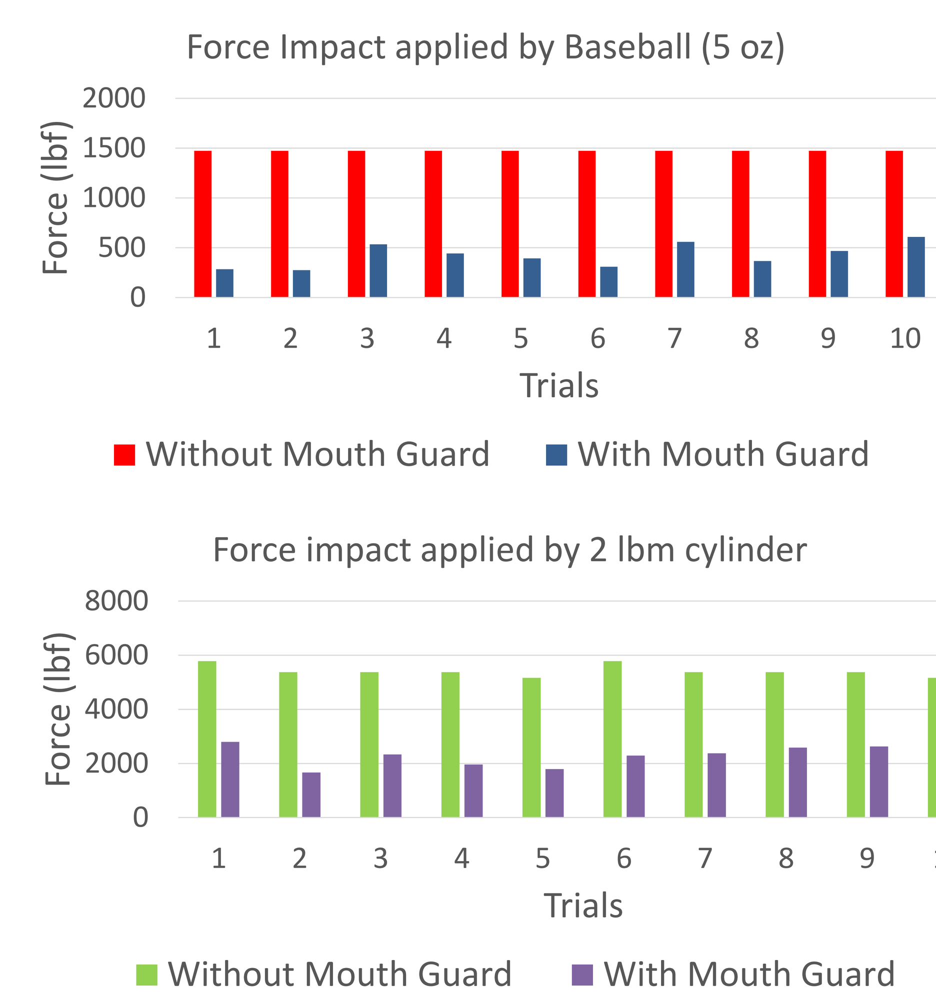


Figure 5. Shock absorption graphs

After 10 trials, we can observe that wearing a mouth guard may significantly reduce the magnitude of injury on teeth. Around 70% of the force was absorbed by the mouth guard with baseball, and 60% for the 2 lb mass. These results can be seen in **Figure 5**.

FEA Analysis:

Analysis with Solidworks shows a maximum Stress on the most red area shown below of 415 MPa. Maximum Displacement was 1.454 mm with a .06795 maximum strain for the baseball.

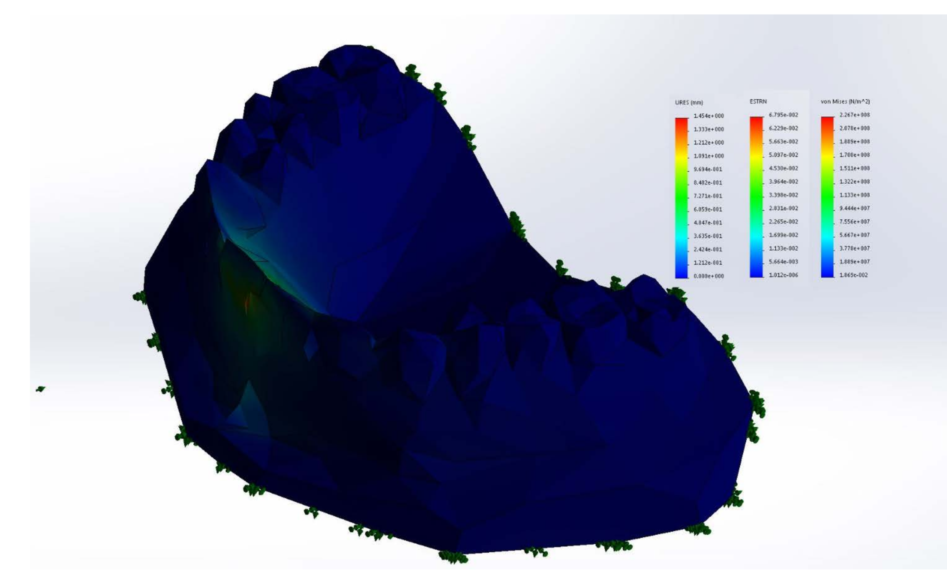
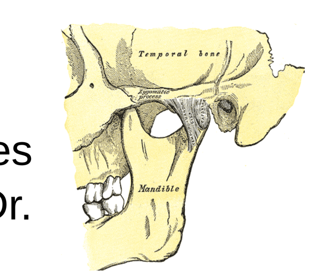


Figure 6. FEA analysis of jaw hit by baseball

Conclusion and Future Needs

The team concluded that significant forces, with the use of a drop test set provide enough momentum to break someone's denture. For this experiment we assumed that the cast is modeled after a perfect prototype; Normal Occlusion (molars not aligned) and therefore there is an even wear of the teeth. Braces are used in order to correct more than just aesthetics, because malocclusion, may mean that teeth will eventually shift out of their places and cause greater strain on the temporomandibular joint. For this reason, a study using other bites may yield different results regarding actual force required to dislocate the jaw, and therefore improve the mouth guards.



Acknowledgment Equipment and supplies provided by the School of Engineering and Dr. Hadimani are acknowledged.

Special Thanks to PCB PIEZOTRONICS MTS SYSTEMS CORPORATION

VCU School of Engineering