Changes in the Mechanical Response of Dental Stone to Submersion in Saline

Joanne Cai, Dan Romanyk, Kathryn Houg
Department of Mechanical Engineering, University of Alberta

Introduction

- Dental stone has been used in testing the mechanical properties of the periodontal ligament, which connects teeth to the alveolar bone (*Romanyk et al, 2017*).
- Previously, a swine mandible was used, and was secured with dental stone so displacement controlled tests could be done on the premolars in dry, ex vivo conditions. This was done by casting the base of the mandible in Coecal Type III Dental Stone.
- In an ex vivo state, the natural conditions of the periodontal ligament cannot be simulated. Fluid in the ligament comes from vascularity in the tissue, but is pushed out during testing and not replenished. A more natural state can be simulated through submersion in saline.
- However, the effect of saline on dental stone strength in regards to this experiment is currently unknown.
- This study examines the mechanical response of dental stone samples to a 0.9% NaCl solution after varying submersion times.

Methods

A 3D printed mold was created on SOLIDWORKS and printed (Figure 1, Figure 2) to create identical samples of dental stone.

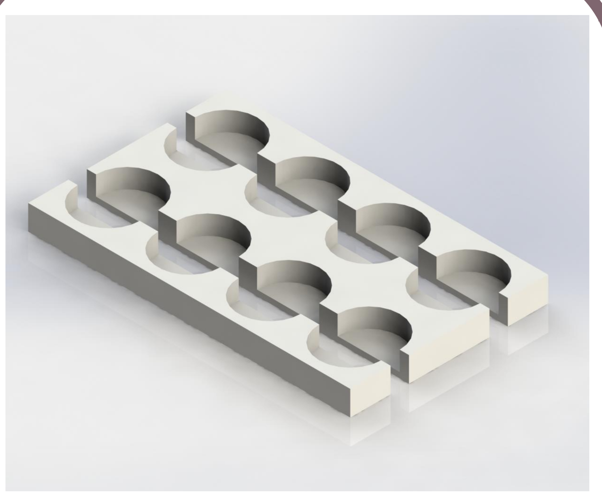

Figure 1: A 3D rendering of the mold created on SOLIDWORKS. It was designed in three separate parts as dental stone expands when dried and cannot be removed from a connected mold.

Figure 2: The 3D printed mold, which was put together using an adhesive. Polyethylene film lined the inside of the mold to prevent sticking of the dental stone.

150 mL of Coecal Type III Dental Stone was mixed with 50 mL of water for 1 minute and dried in molds for 1 hour. This was repeated 3 times.

Samples were submerged in 0.9% NaCl solution for 0.5 hours (trial 2), 1 hour (trial 3), 4 hours (trial 4), and 24 hours (trial 5), with four samples per submersion time. Four samples were tested without submersion, as controls (trial 1). Afterwards, samples were removed from the solution and patted dry.

An Instron ElectroPuls E3000 preloaded samples to 3 N, then displaced them to 0.1 mm at 0.025 mm/s. This was held for 10 s before offloading at 0.025 mm/s. This cycle was repeated 5 times per test, with 2 tests per sample.

- After testing, the Instron ElectroPuls E3000 (Figure 3) recorded the displacement and force applied to the samples.

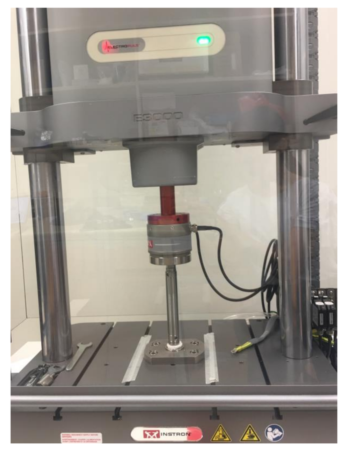

Figure 3: Instron ElectroPuls E3000, used to apply a load to the dental stone.

Results

- The force applied during the last three cycles of each sample were the most consistent (Figure 4) and were the only ones considered going forward.
- The peak force was averaged for each test and compared between submersion times (Figure 5).
- The average force during the 10 s hold for each test was averaged and compared between submersion times (Figure 6).
- The standard deviation was also considered and graphed.

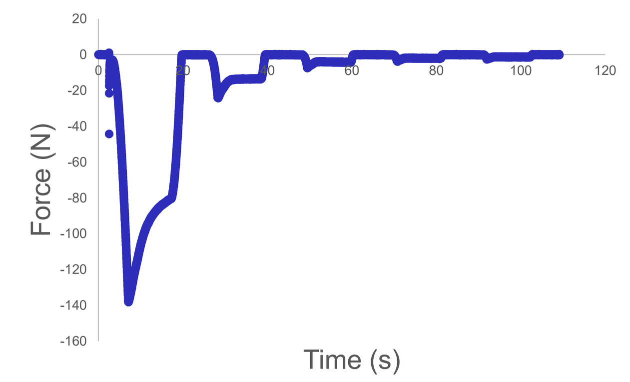

Figure 4: Example of the force output from the control sample 2, test 1.

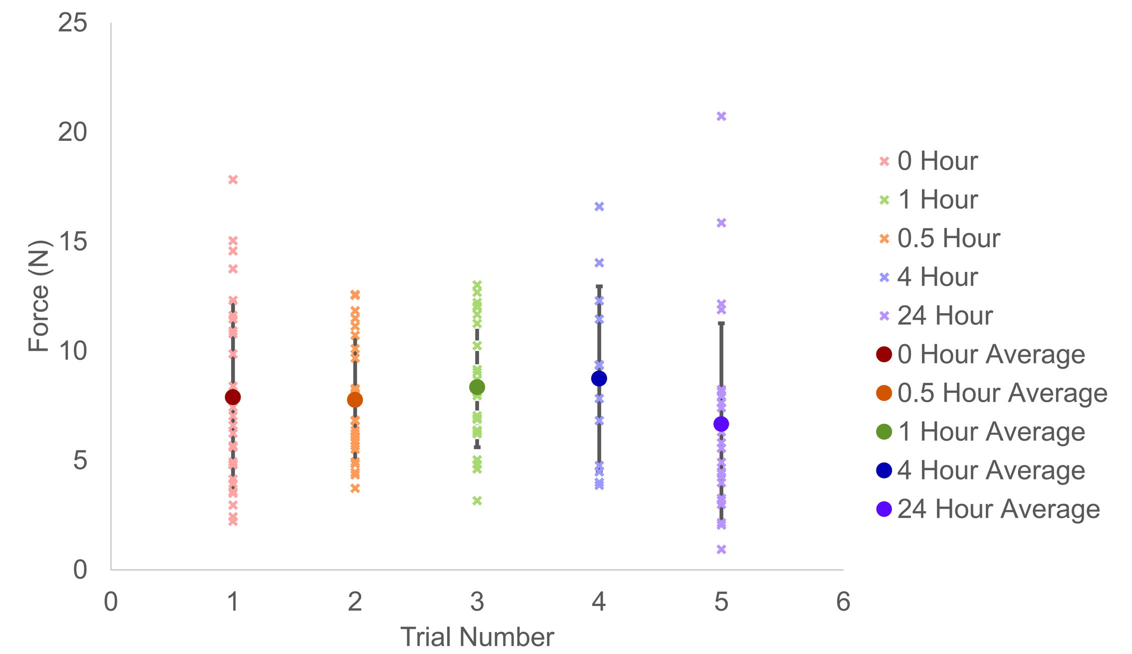

Figure 5: Average peak force across each trial type during compression tests. (Absolute values are shown)

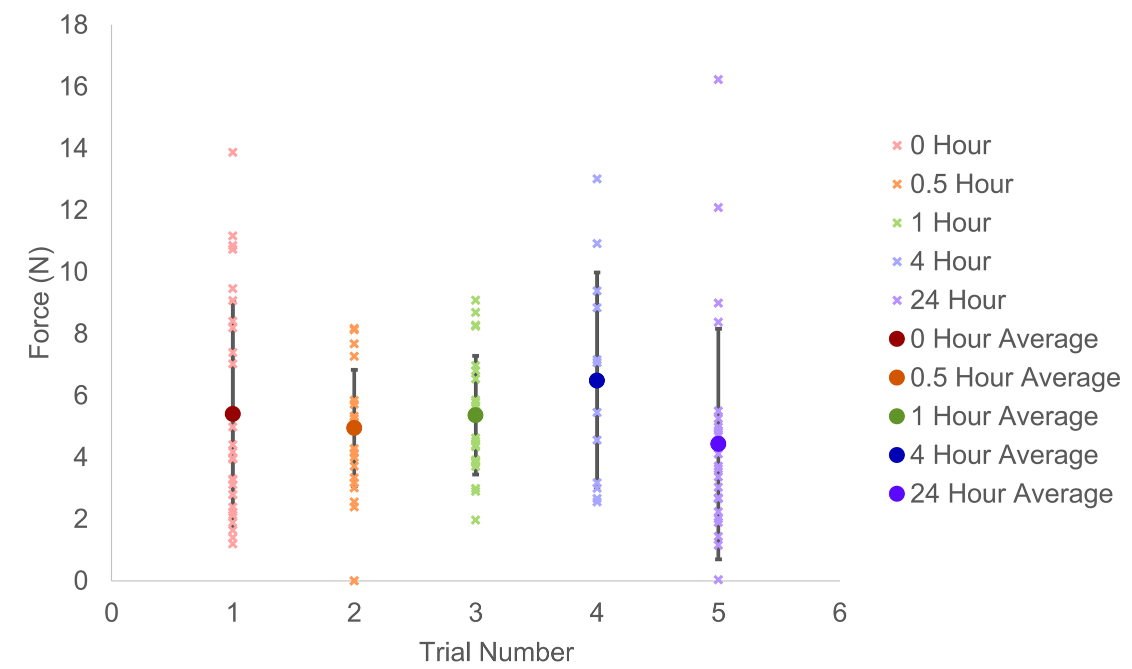

Figure 6: Average force across each trial type during compression tests. (Absolute values are shown)

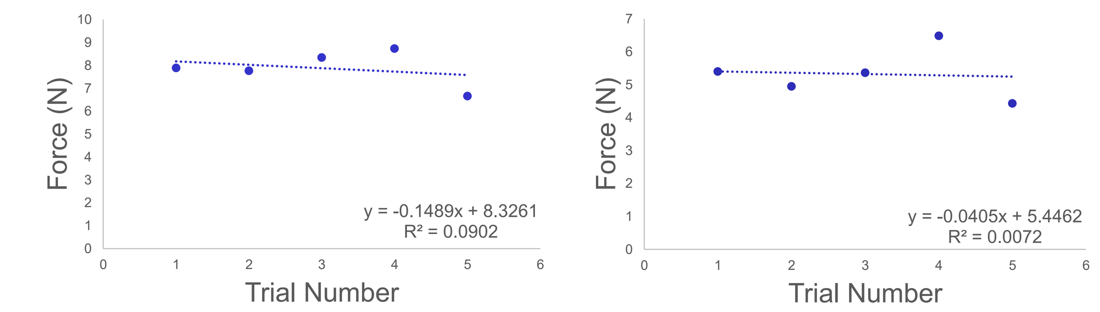

Figure 7: The slope of the average peak force (left) and average force (right).

- To determine a statistical difference between force values across different submersion cases, a linear regression was completed. A null hypothesis was made: H_0 : m=0. A failure to reject the null hypothesis will suggest there is no significant difference between the submersion cases. This requires that $R^2 \rightarrow 0$, and *p-value* $\rightarrow 1$. (Table 1)

Table 1: The R^2 value and p-value for the slopes of both the average peak force and average force graphs in Figure 7.

	Average Peak Force	Average Force
R^2	0.090	0.007
p-value	0.624	0.892

Conclusions

- The R^2 and *p-value* were found to approach the values specified above, failing to reject H_0. Consequently, m=0 is not rejected, and there is not a significant difference in the average force required to displace dental stone among the trial types.
- Therefore, there is no effect on the strength of dental stone when submerged in saline for any given time period.
- Limitations in this study include the varying curvature at the bottom of the dental stone samples, inconsistencies in the ratio used to create the dental stone mixture, and the length of time between removal of samples from saline and compression tests.
- These results can be used in further research on the periodontal ligaments of swine, demonstrating dental stone as a suitable material to hold a swine mandible in a saline solution.
- Future work on the mechanical properties of dental stone when submerged in saline could include water sorption testing.

Literature Cited

D. L. Romanyk, R. Guan, P. W. Major, C. R. Dennison, “Repeatability of strain magnitude and strain rate measurements in the periodontal ligament using fibre Bragg gratings: An ex vivo study in a swine model,” *Journal of Biomechanics,* 2017

Acknowledgements

Thank you to Dan Romanyk, Kate Houg, and Raymond Guan for guiding me through my experimental processes, and to all the members of my lab. As well, I would like to thank the Carey lab and their WISEST students for being so welcoming and supportive. Thank you to my sponsors, the Edmonton Rotary Club and Canada Summer Jobs, without whom this would not be possible. Finally, thank you to WISEST for all that they do for women in STEM.