Page 19 / WISEST Special Issue / Volume 2 / DOI: 10.29173/aar55

Changes in the mechanical response of dental stone to submersion in saline

Joanne Cai[1], Dan Romanyk, Kathryn Houg

[1]Department of Mechanical Engineering, University of Alberta

Abstract

Previously, dental stone has been utilized in mechanical testing of the periodontal ligament, which connects the tooth to the alveolar bone. This was achieved by casting swine mandibles in dental stone for displacement controlled testing. The stone was used as a riding base to hold the mandible in place. However, this was done in dry, ex vivo conditions, failing to simulate the natural presence of vascular fluid in the periodontal ligament. While this can be simulated with submersion in saline, the mechanical response of dental stone to saline is currently unknown, and thus cannot yet be used to secure the mandible in saline. To identify differences in the strength of dental stone after submersion in saline, Coecal Type III Dental Stone samples were cast in a 3D printed mold, then submerged in 0.9% NaCl solution for varying time periods: 0 hours, 0.5 hours, 1 hour, 4 hours, and 24 hours. Samples were then removed from the solutions, patted dry, and placed in an Instron ElectroPuls E3000 for compression tests. The Instron preloaded samples to 3 N, displaced them to 0.1 mm at 0.025 mm/s, held them for 10 s, then offloaded at 0.025 mm/s. This cycle was repeated five times per test, with each sample undergoing two tests. Results showed that the last three cycles of each test were most consistent, and were the only ones considered in further analysis of results. The average peak force and average force during the 10 s hold of each test were compared across submersion times, and, considering standard deviation, showed no consistent differences. A linear regression was completed to determine statistical differences between the force values. The p-values of the average peak force and average force were 0.624 and 0.892 respectively, approaching the required value of 1, and therefore failed to reject the null hypothesis, representing no significant difference in the average force across submersion times. As a result, it can be assumed that submersion in saline has no effect on the strength of dental stone. These results can be applied to further research on the periodontal ligament, involving submersion of the swine mandible in saline solutions.

Key words:
dental stone, saline, mechanical response, dental stone strength, submersion

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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.

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.

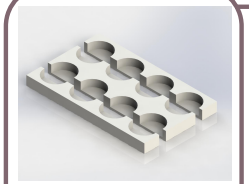
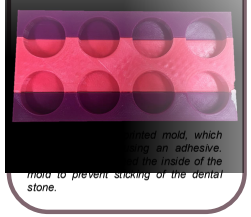


Figure 1: A 3D rendering of the mold created on SOLIDWORKS. It was designed in three separate parts as dental stone expands when dried and cannot be removed from a connected mold.



printed mold, which ing an adhesive. the inside of the mold to prevent sticking of the dental stone.

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

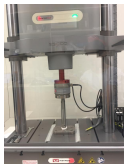


Figure 3: Instron ElectroPuls E3000, used to apply a load to the dental stone.

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.

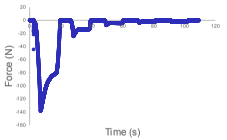


Figure 4: Example of the force output from the control sample 2, test 1.

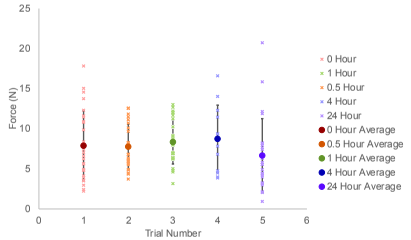


Figure 5: Average peak force across each trial type during compression tests. (Absolute values are shown)

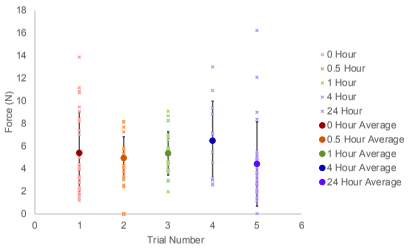


Figure 6: Average force across each trial type during compression tests. (Absolute values are shown)

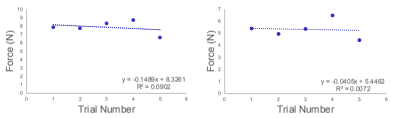


Figure 7: The slope of the average peak force (left) and average force (right).

- 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

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