Cyclic Fatigue Testing of Calcium Phosphate Cements

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Statement of Purpose: This study was conducted to compare the mechanical performance of calcium phosphate cement (CPC) and fiber loaded calcium phosphate cement (FCPC) in a model of cyclic loading. The model employed three cortex screws completely embedded in the cements which were then subjected to cyclic compression testing.

Methods: Calcium phosphate powder (CPC) was made by blending α-tricalcium phosphate, calcium carbonate, and monocalcium phosphate monohydrate. The fiber loaded calcium phosphate (FCPC) was made by blending the 82/18 poly (L-lactide co-glycolide) polymer fibers into the CPC powder. Both the CPC and FCPC were packed into pouches and then mixed with a dilute sodium phosphate solution to create a CPC or FCPC paste. The FCPC solution has a small quantity of sodium hyaluronate incorporated into the solution.

To prepare the samples, polyethylene (PE) molds were prewarmed to 37°C. For the CPC samples, a stainless steel plate was secured to one of the molds with 5.0mm locking screws and then the 4.5mm cortex screws were place into the plate. The CPC was then mixed and injected around the screws. The construct was placed in 37°C phosphate buffered saline (PBS) for overnight curing. For the FCPC samples, the stainless steel plate was secured to one of the molds with locking screws. The FCPC was then mixed and injected into the voids. The FCPC loaded mold was placed in 37°C PBS for 10 minutes. After setting, a 3.2mm drill was inserted through the FCPC, and then a 4.5mm cortex screw was inserted into the FCPC. The final construct was placed into 37°C PBS for overnight curing.

Figure 1: Construct used for the testing

Results/Discussion: In the first experiment, cured FCPC constructs were subjected to loads as high as 700N completed the 10,000 cycle test without failure. At higher loads, 750N and 950N, the cyclic loading pulled the FCPC plug out of the void.
In the second experiment, the PE molds were tapped to assure the FCPC would remain in the mold during the cyclic loading. The FCPC construct was able to reach 10,000 cycles at loads up to 800N without failure. In the final sample of the group, the construct was loaded at 800N until failure, which occurred after 21,866 cycles when the stainless steel plate bent and cracked. In the third group the CPC was evaluated. At 500N and 950N the CPC results were similar to the FCPC results. However, at 750N and 850N the construct failed due to cracking of the CPC and pull-out of the screws, and not failure of the stainless steel plate. In both cases, the end result was that the plate separated from the PE blocks. In the final group the number of cycles applied to FCPC was varied at a constant load of 800N. The construct failed at 19,000 cycles when the plate bent and cracked.

Figure 2: Example of pullout – Exp #1

Figure 3: Example of plate failure – Exp #2

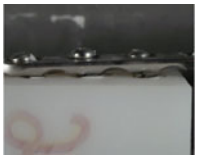

Figure 4: Example of CPC failure – Exp #3

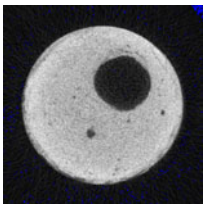

Figure 5: FCPC microCT after 2,500 cycles

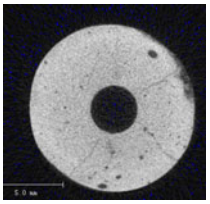

Figure 6: FCPC microCT after 19,000 cycles

Conclusions: Testing clearly demonstrates that under the same cyclic loading conditions CPC fails due to screw pull-out and cement fragmentation and FCPC samples ultimately experience failure of the plate with the screws remaining firmly attached to the PE blocks and the FCPC remains intact

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