

In Vivo Testing of Hydroxyapatite Particles for Bonding of Strain Gauges

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INTRODUCTION: The forces on bone are dynamic, regulating bone remodeling and fracture healing. Strain gauges have been used to measure bone the bone deformations that regulate these processes, but adhesives rapidly degrade limiting the utility of this technique *in vivo*. Previous studies in our lab have shown that strain gauges coated in a calcium phosphate ceramic (CPC) powder allow for permanent bone bonding to strain gauges to facilitate accurate long-term *in vivo* bone strain measurements. Due to difficulties in producing large quantities of previously used CPCs, the goal of this project was to test bone bonding to strain gauges coated using commercially available hydroxyapatite (HA) particles.

METHODS: 20 three-month-old male Sprague-Dawley rats were utilized in this IACUC approved study. A total of 4 types of HA particles were tested: HA 2 (Acicular 40R), HA 6 (Fibrous 10Wx500L), HA 7 (Spherical 200R), and HA 9 (Microspheres 15-60R). Uniaxial strain gauges were coated with the HA particles using medical grade epoxy. Each rat had one strain gauge implanted on the right femur. The rats were injected with a calcium-binding fluorochrome and weighed weekly. Rats were maintained for 9 weeks. 3 days after the final fluorescence injection, the rats were euthanized, and the bilateral femora were explanted. A strain gauge coated with the same HA particles as the implanted gauge was glued to the control femur in the same anatomical position for mechanical testing. Mechanical testing was performed using cantilever bending to compare strain transfer in implanted and glued strain gauges. Strain transfer was calculated as (Experimental Femur Strain at 0.6N Newtons ÷ Control Femur Strain at 0.6N Newtons) * 100%. All data was analyzed with SPSS using ANOVA with a Tukey HSD post-hoc test.

RESULTS: Throughout the 2-month *in vivo* period, all groups gained weight with no differences in weight between each group ($p>0.05$)(Graph 1). Following 2 months *in vivo*, all the strain gauges were securely attached to bone after explantation. Mechanical test results for tension tests are shown in Graph 1, which demonstrates similar strain transfer between the HA 6 ($160 \pm 27\%$) and HA 9 ($125 \pm 51\%$) strain gauge groups. HA 2 ($193 \pm 78\%$) showed the highest strain transfer and HA 7 showing the lowest ($55 \pm 36\%$)($p<0.05$).

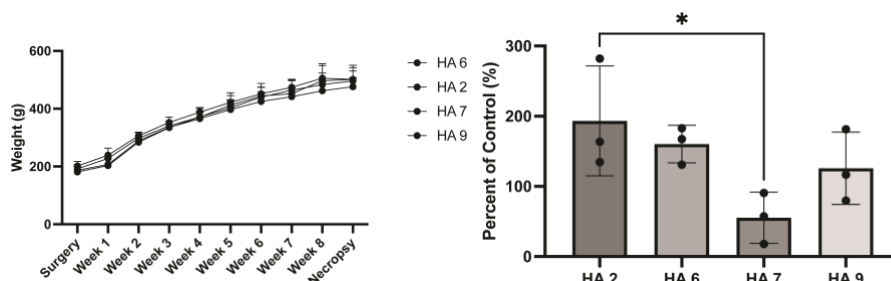
DISCUSSION: This study demonstrates that HA 2 group has the highest strain transfer, and HA 7 had the lowest strain transfer ($p<0.05$). The gauges coated in HA 6 showed the least variability and HA 9 showed the most similar strain transfer compared to glued control gauges. Further analysis with quantitative histology, histomorphometry and high-resolution computed tomography are needed to understand how new bone formation could have affected bone strain during mechanical testing and the mechanical coupling of the bone to the strain gauge.

SIGNIFICANCE/CLINICAL RELEVANCE: This *in vivo* rat study has shown that three of the four HA particles provide a suitable coating for strain gauges to allow for long term *in vivo* measurement collection. Further characterization of bone growth is needed to confirm the relationship between bone bonding and mechanical coupling of the sensors to the bone. These results demonstrate that additional preclinical studies using a large animal model are warranted to determine which formation may work best in clinical trials.

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IMAGES AND TABLES:



Graph 1 (left): Weekly averages of the rats weights throughout the 2 month *in vivo* period.

Graph 2 (right): Tension testing results between the 4 different CPC particle groups.