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Journal of Bone Research

Opinion Article

Calcium Sulfate/Hydroxyapatite (CaS/HA) Composite Uses in Orthopedic Applications

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DESCRIPTION

Biomaterials made of Calcium Sulphate and Hydroxyapatite (CaS/HA) have been looked into for usage in a number of orthopedic applications. However, it is still unclear how the CaS/HA composite would interact mechanically with bone at the microscopic level.

Every year, osteoporosis causes more than 8 million fractures in the world. Additionally, patients with low bone density are more likely to experience orthopedic implant failure during fixation. In procedures like femoroplasty and vertebroplasty, prophylactic augmentation of low-density bones with bone cement can lower the risk of low-energy fractures. By enhancing the primary and secondary stability of orthopedic implants, augmentation with bone cement can also be employed to enhance their fixation.

Due to its biphasic nature, Calcium Sulfate/Hydroxyapatite (CaS/HA) is a biomaterial that has attracted research during the past ten years. Within 6 to 8 weeks, the CaS phase resorbs, leaving the HA particles as a scaffold for bone ingrowth. The biomaterial has high osteoconductivity as a result. Additionally, controlled drug distribution of substances like antibiotics and bioactive compounds is possible using the CaS phase. CaS/HA is employed in clinical practice today, for instance, during wrist osteotomies, vertebroplasties, and tibial condyle fractures.

Despite having a wide range of uses, it is mainly unknown how the CaS/HA and bone composites would behave mechanically at the microscale. It may be possible to better comprehend the substance and, consequently, the development of clinical applications, by having a thorough understanding of how bone and CaS/HA deform and how damage builds up under stresses up to global failure. The mechanical behavior of bone and interactions between bone and biomaterials at the microscale may now be studied because of recent advancements in imaging techniques. A specimen can be *in situ* loaded while Synchrotron Radiation micro-Computed Tomography (SR-CT) is being used to examine the damage mechanisms of the specimen. In addition to visually identifying crack initiation and progression, Digital Volume Correlation (DVC) can be used to calculate strain fields in bone and provide internal displacements. DVC has been used in the past on artificial and animal bones that had been filled with acrylic bone cement. It was demonstrated that the bone, the bone-cement interface, and the pure cement could all be measured with similar accuracy and precision. It was demonstrated that damage under compression began outside of the cemented region on complete porcine vertebrae that had been injected with strong acrylic cement. The strain could typically be computed with accuracy and precision below 0.001 in a number of experiments on composite specimens that used a resolution of 252-2200 m. As trabeculae normally have a thickness of about 150 m in the femoral head, this resolution is insufficient for distinguishing strains inside individual trabeculae. It is possible to use DVC to analyze strains inside individual trabeculae in human trabecular bone specimens with an accuracy and precision of about 0.001 by lowering the resolution to below 40 m. The high radiation dose that the samples are subjected to during SR-CT is one of its drawbacks. This may harm the components of the samples, particularly the collagen, and may have an impact on their mechanical characteristics. However, one can avoid exceeding the thresholds that have been known to cause damage and have these adverse consequences by limiting total exposure (e.g., the number of photos and load stages, exposure time, etc.).

Shortly after injection, CaS/HA can improve the energy absorbed and fracture strength. This is in favour of using CaS/HA to strengthen bone during surgical procedures such as, for instance, vertebroplasty. The issue of stress shielding, which can occasionally occur when bone is enhanced with higher stiffness bone cements like Poly(Methyl Methacrylate) (PMMA) or collapse of nearby vertebrae in the case of vertebroplasty, may also be prevented by the comparatively low rise in Young's modulus. Due to the lower strains at which CaS/HA fractures (relative to bone tissue) are strained, more energy is absorbed before the bone is injured, which is advantageous. As a result, CaS/HA might be used to improve the incorporation of orthopedic hardware like nails and screws. When osteoporosis is advanced, the mechanical qualities of the bone around a fixation device are weakened. As a result, screws or nails may not initially provide adequate stability, resulting in failure and the need for reoperation in up to 10% to 25% of patients. Several months

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Received: 03-Aug-2022; Manuscript No. BMRJ-22-19256; **Editor assigned:** 05-Aug-2022; PreQC. No. BMRJ-22-19256 (PQ); **Reviewed:** 19-Aug-2022; QC. No. BMRJ-22-19256; **Revised:** 26-Aug-2022; Manuscript No. BMRJ-22-19256 (R); **Published:** 05-Sep-2022, DOI: 10.35248/2572-4916.22.S2.004.

Citation: Treglia G (2022) Calcium Sulfate/Hydroxyapatite (CaS/HA) Composite Uses in Orthopedic Applications. J Bone Res. S2.004.

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after a patient receives a CaS/HA injection, the CaS phase is expected to resorb, leaving the HA particles as a scaffold for bone ingrowth. As a result, the local structure will gradually alter, and the mechanical characteristics are anticipated to shift closer to those of natural bone. Because bone-active molecules can be combined with CaS/HA before injection or given systemically after surgery, it is possible to actively recruit osteoblasts, which will improve bone formation and bone strength.