Tree Inspired Magnesium Hybrid Column for Treating Steroid-associated Osteonecrosis in Weight-bearing Bipedal Emus

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INTRODUCTION: Biodegradable magnesium (Mg)-based materials show promise in managing musculoskeletal diseases, possessing proper mechanical strength and triggering self-regenerative process via spatiotemporal degradation. However, to achieve long-term steady state of local biomechanical environment, it is essential to coupling device degeneration and neo-tissue ingrowth without scarifying local mechanical integrity. Steroid-associated osteonecrosis (SAON) poses a unique and formidable clinical challenge in providing strong mechanical support to the major weight-bearing hip joint while also reversing its pathological progression. Tree-inspired column is one time-honored architectural concept, which employs a solitary central pillar and its cantilever structures as compression elements to uphold load-bearing facades[1]. It effectively transfers the distributed surface loads through the pillar to a focal point on the foundation.

METHODS: We incorporated a tree-inspired Mg hybrid column implanted into the weight-bearing region of femoral head. Our tree inspired Mg hybrid column consisted of a perforated outer layer crafted from a cannulated magnesium metal stent with strategically positioned holes along the stent wall. The inner canal and outlet holes were designed to facilitate the permeation grouting of injectable magnesium-based bone cement, promoting targeted infiltration into the surrounding bony cavity, specifically within the subchondral region. We conducted a 6-month large animal study using a clinically relevant bipedal emu model to examine the biodegradability and functionality of the tree inspired Mg hybrid column (Mg+BC) compared to core decompression (CD) and stand-alone treatment either pure Mg stent (Mg) or injectable Mg-containing bone cement (BC).

RESULTS SECTION: Mg+BC exhibited a more comprehensive load distribution across the bone-implant assembly in FEA analysis, leading to a decreased proportion of relatively high load-bearing region within the bone and a shift in loading predominance from subchondral trabeculae to subchondral bone plate (Figure 1). Compared to standalone Mg stent group, Mg+BC exhibited a more stable rate of degradation and an increased level of bone-implant contact in Micro-CT scanning, indicating a superior alignment between material degeneration and tissue regeneration (Figure 2).

DISCUSSION: The degradation products of Mg are well known, including Mg^{2+}, OH^{-} and H_2, as they may offer a promising therapeutic avenue for addressing the degenerative effects of SAON due to their crucial involvement in osteoimmunomodulation, biomineralization and selective antioxidant against ischemia-reperfusion[2]. Results from this study illustrate that, the tree-inspired Mg hybrid column achieved a moderate product-releasing rate through a virtuous dynamic pattern of degradation and re-deposition, while optimizing the stress distribution between implant and host bone tissue, thereby efficiently prevent the collapse induced by steroid in weight-bearing skeletal regions, particularly at the hip joint (Figure 3).

SIGNIFICANCE/CLINICAL RELEVANCE: We believe that this strategy of tree-inspired hybrid column holds immense potential for advancing Mg-based biomaterials towards human trials in the clinical scenario where both biodegradability and mechanical stability are of critical considerations.

REFERENCES: **[1]**. Md Rian I, Sassone M. Tree-inspired dendriforms and fractal-like branching structures in architecture: A brief historical overview. Frontiers of Architectural Research 2014; 3(3): 298-323. **[2]**. Kim J, Pan H. Effects of magnesium alloy corrosion on biological response – Perspectives of metal-cell interaction. Progress in Materials Science 2023; 133: 101039.

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IMAGES AND TABLES:

Figure 1

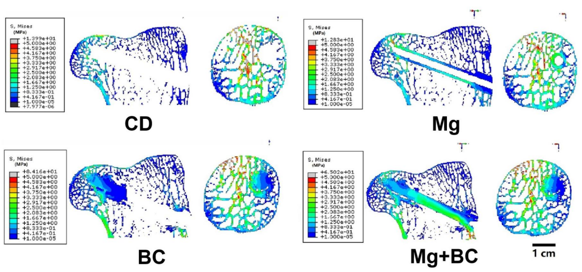

Figure 2

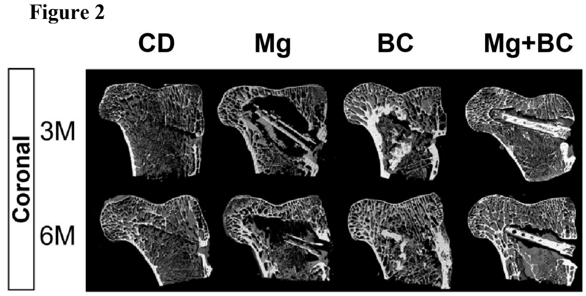

Figure 3