Magnetite-doped organic-inorganic nanocomposite scaffolds stimulate bone cell functions

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Statement of Purpose: For bone tissue engineering, organic-inorganic nanocomposite scaffolds are of great interest as they have mechanical and biological properties favorable for bone regeneration.[1] Here, sol-gel processed nanocomposite scaffolds doped with magnetite nanoparticles (MNs) at small quantities were produced and the mechanical and biological properties were in-depth examined.

Methods: $FeCl_2 \cdot 4H_2O$ and $FeCl_3 \cdot 6H_2O$ in 1 M HCl were mixed and added into 200 mL of 1.5 M NaOH. The resulting precipitated MNs were then isolated by applying a magnetic field. MNs dispersed in water were added into gelatin solution. After homogenous dispersion, APTES and TMOS were added to produce the sol. 1M HCl were added to the slurry to be used for the sol-gel reaction. FT-IR, SEM, TEM, water contact angle measurement, dynamic mechanical analysis, and SQUID were used to characterize the scaffolds. For bone bioactivity measurements, treatments with 1.5 x simulated body fluid (SBF) were performed and mineral induction was checked by SEM and XRD. Cell growth of rat mesenchymal stem cells (MSCs) on the scaffolds was carried out by SEM. Cell differentiation on the scaffolds was demonstrated by the measurements of alkaline phosphatase (ALP) and alizarin red staining (ARS).

Results: SEM and TEM images showed porous and homogeneous nanoparticles (~10 nm), respectively. XRD and FTIR analyses showed the characteristic peaks of MN with their incorporation. Compared to the pure scaffolds, the MNs scaffolds showed a rapid increase in magnetization with little energy loss. The saturation magnetization of the magnetic scaffolds increased with increasing MN content, from 0.24 emu/g for 1% MN to 0.64 emu/g for 3% MN. The storage modulus (E') significantly increased as the MN content increased; from 100 kPa (0% MN) to 450 kPa (3% MN). The loss modulus was also significantly higher with increasing MN content; from 60 kPa for 0% MNs to 150 kPa for 3% MN. The tan delta (E"/E') decreased with increasing MN content. The water uptake capacity increased with increasing MN content. In SBF test, the highest mineralization was shown for 2%MN scaffold. Cell proliferation increased in the order; 2% MN > 3% MN > 1% MN > 0% MN. The cells on MN scaffolds were more elongated, with a number of highly extended filopodia processes, compared to pure scaffold. Cellular mineralization and ALP expression levels were significantly higher in MN scaffolds.

Conclusions: The MN-incorporated sol-gel processed scaffolds exhibited excellent magnetic properties, preserving the superparamagnetic behavior of native MN. The MN scaffolds showed significantly improved mechanical properties, effective for bone tissue engineering. The MN incorporation increased water uptake and swelling of the scaffolds. The MN addition preserved the excellent apatite-forming ability of the scaffold in SBF. The MSCs cultured on the magnetic scaffolds were significantly promoted in proliferation and osteogenic differentiation, implying usefulness for bone tissue engineering.

References: Perez RA. Adv Drug Del Rev. 2013;**65:**471-496.