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Mechanical Properties and Antibiotic Release Characteristics of Poly(methyl methacrylate)-based Bone Cement Formulated with Mesoporous Silica Nanoparticles

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Abstract : Postoperative implant-associated infections in soft tissues and bones remain a serious complication in orthopaedic surgery, which leads to impaired healing, re-implantation, prolong hospital stay and increase cost. Drug-loaded implants with sustained release of antibiotics at the local site are current research interest to reduce the risk of post-operative infections and osteomyelitis, thus, minimize the need for follow-up care and increase patient comfort. However, the improved drug release of the drug-loaded bone cements is usually accompanied by a loss in mechanical strength, which is critical for weight-bearing bone cement. Recently, more attempts have been undertaken to develop techniques to enhance the antibiotic elution as well as preserve the mechanical properties of the bone cements. The present study investigates the potential influence of addition of mesoporous silica nanoparticles (MSN) on the in vitro drug release kinetics of gentamicin (GTMC), along with the mechanical properties of bone cements. Simplex P was formulated with MSN and loaded with GTMC by direct impregnation. Meanwhile, Simplex P with water soluble poragen (xylitol) and high loading of GTMC as well as commercial bone cement CMW Smartset GHV were used as controls. MSN-formulated bone cements are able to increase the drug release of GTMC by 3-fold with a cumulative release of more than 46% as compared with other control groups. Furthermore, a sustained release could be achieved for two months. The loaded nano-sized MSN with uniform pore channels significantly build up an effective nano-network path in the bone cement facilitates the diffusion and extended release of GTMC. Compared with formulations using xylitol and high GTMC loading, incorporation of MSN shows no detrimental effect on biomechanical properties of the bone cements as no significant changes in the mechanical properties as compared with original bone cement. After drug release for two months, the bending modulus of MSN-formulated bone cements is 4.49 ± 0.75 GPa and the compression strength is 92.7 ± 2.1 MPa (similar to the compression strength of Simplex-P: 93.0 ± 1.2 MPa). The unaffected mechanical properties of MSN-formulated bone cements was due to the unchanged microstructures of bone cement, whereby more than 98% of MSN remains in the matrix and supports the bone cement structures. In contrast, the large portions of extra voids can be observed for the formulations using xylitol and high drug loading after the drug release study, thus caused compressive strength below the ASTM F541 and ISO 5833 minimum of 70 MPa. These results demonstrate the potential applicability of MSN-functionalized poly(methyl methacrylate)-based bone cement as a highly efficient, sustained and local drug delivery system with good mechanical properties.

Keywords : antibiotics, biomechanical properties, bone cement, sustained release
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