

Development of Multifunctional Materials (MFM): Bioabsorbable Osteoconductive Drug-Releasing Hard Tissue Fixation Screws.

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Introduction

Further to achievement of reliable biocompatible hard reliable tissue bioabsorbable fixation devices, development of next generation was envisaged. There has been also an extensive research in development of slow-releasing drug systems. These two technologies thus were brought together, to develop devices, e.g. with dual function, hence the name "multifunctional" devices. For additional function, to address the problem of replacement of the bioabsorbable screw tracks with fibrous tissue, osteoconductive agent was added.

Materials and methods

Bioabsorbable polymeric polymers (PLGA 80/20 or PLDLA 70/30) were used as the matrix material. Bioactive glass (BG) 93/13 was included to confer the osteoconductive function. In MFM-1, for infection-resistance function, ciprofloxacin (CF) was included in the implant. CF is bacteriocidal and it has a wide range of activity against osteomyelitis-causing bacteria, with good penetration to compact bone. In MFM-2, for the function of modification of tissue-reaction, agent-x1 was used. The composite was made into rods which were subsequently self-reinforced (SR), then machined into screws, and granules and sterilized using g-irradiation. Drug release, changes in molecular weight, *in vitro* degradation profiles, mechanical properties, and microstructure were evaluated. Effects of MFMs *in vitro* cell models were studied the effect of the devices (on S. epidermidis bacterial culture, attachment and biofilm formation; on chondrocytes, and on osteoblasts). *In vivo* models included the implantation in cranial bone of rabbits to assess tissue reactions, biodegradation and drug bone concentration. Biomechanical testing was also carried out using human cadaver bones (pull out tests). In an osteomyelitis model in rabbits, MFM granules were used.

Results

MFM-1:

CF was **released** from the studied screws after 44 weeks (P/L/DL)LA) and 23 weeks (PLGA) *in vitro*. During this time drug release remained in range of 0.06 – 8.7 µg/ml/d (for P(L/DL)LA) and 0.6 - 11.6 µg/ml/d (for PLGA) after the start burst peak. The maximum release occurred in the 15th week (for P(L/DL)LA) and 8th week (for PLGA). CF remained bioactive throughout the *in vitro* drug release study. Initial mechanical properties of the screws are high and their application is easy. Measured initial shear strengths of the studied ciprofloxacin-releasing screws were 152 MPa (P/L/DL)LA) and 172 MPa (PLGA). Studied screws retain their mechanical properties at least 12 weeks (P(L/DL)LA) and 9 weeks (PLGA) *in vitro* at the level that ensures their fixation properties.

Histology did not show much difference from the control plain PLGA screws except for some increased giant cells at some areas of the implantation site. **Pull-out tests** indicated that the early version of the MFM-1 type of screws have lower values as compared to controls. The inclusion of the bioactive glass leads to further drop in mechanical properties. Inhibition of bacterial growth,

attachment and biofilm formation was significantly different than controls. In rabbit osteomyelitis model, healing was observed using MFM-1 antibiotic releasing devices.

MFM-2:

Over 60 d, release The mode of the release curve followed close trend to that seen with MFM-1. A Peak was observed during the 1st 6h. SR has enhanced the release process as also didi g-sterilization further. SEM microstructure showed highly oriented SR structure and proper distribution of the drug agent. Study of mechanical properties is going on.

Comments

These are the first reliable MFM antibiotic-releasing screws in the world, that can add to surgeon's tools to combat against bone infection and its costly consequences. During degradation, MFM-1 screws progressively released the drug and retained sufficient mechanical properties over 2-3 months. For MFM-2, therapeutic levels were achieved and maintained for the time passed so far (61 d).

Conclusions

SR-P(L/DL)LA and SR-PLGA MF screws with appropriate drug release, structural, mechanical and biocompatibility properties can be produced. Clinical studies will be started in near future (MFM-1).