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# In vitro degradation of a biodegradable polylactic acid/magnesium composite as potential bone augmentation material in the presence of titanium and PEEK dental implants

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ABSTRACT

*Objective.* The aim of this study was to assess the degradation behavior by measuring the $H_2$ release of a biodegradable composite consisting of a polylactic acid matrix reinforced with 30% wt. spherical magnesium microparticles (PLA/Mg) as potential bone augmentation material in combination with dental implants of either titanium or polyetheretherketone (PEEK) in order to evaluate the potential influence of the titanium dental implants on the corrosion behavior of the Mg particles within the PLA matrix.

*Methods.* Three PEEK dental implants and three titanium dental implants were put into a central perforation of six PLA/Mg-discs. These samples were incubated at 37 °C for 30 days in McCoy's 5A modified medium and the $H_2$ release was evaluated.

*Results.* Between day 7 and day 16 the average $H_2$ release per $cm^2$ of the surface of the PLA/Mg-samples in combination with the titanium implants was significantly higher than that of the sample group combined with the implants of PEEK ($3.1 \pm 0.4$ ml vs. $2.8 \pm 0.4$ ml). This significant difference disappeared afterwards, whereas the $H_2$ release was highest at day 30 and amounted $3.5 \pm 0.7$ ml/$cm^2$ for the group with the titanium implants and $3.2 \pm 0.8$ ml/$cm^2$ for the group with the PEEK implants.

*Significance.* Regarding the similar values of the degradation depending $H_2$ release of the two implant material groups, the co-implantation of a PLA/Mg composite is not only possible

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with new metal-free implant materials such as PEEK, but also with conventional implants of titanium.



## 1. Introduction

Dental implants serve as artificial roots for the fixation of dental prostheses. By restoring the masticatory function through dental implants, the quality of life and nutritional status of the affected patients can be markedly improved [1,2]. A precondition for inserting dental implants is sufficient available bone volume at the jawbone region in consideration. The majority of bone volume reduction takes part in the first six months after tooth loss [3]. To compensate for this bone loss, a bone augmentation can be necessary, which is defined as an enlargement of the bone volume by addition of material or tissue [4]. For the augmentation of well-advanced bone volume loss the transplantation of a cortical-cancellous bone block prior to implant insertion has been proposed [5]. In most cases of vertical bone defects, these autogenous bone grafts have remained the procedure of choice [6]. In order to reduce overall treatment time and to facilitate the secondary surgical intervention, the bone ring technique has been described [6]. This single-stage technique of bone augmentation entails the stabilization of a dental implant with a ring-shaped autogenous bone graft simultaneous to implant insertion. Autogenous bone grafts suffer from the disadvantage of increased morbidity associated with the harvesting of the transplant at the secondary surgical site. Numerous alloplastic materials have been proposed as alternative in order to avoid this parallel intervention [7]. In this respect a synthetic material would be desirable that is readily available and that is over time completely replaced by natural bone without loss of volume.

A biodegradable composite based on polylactic acid reinforced with spherical magnesium particles could represent such a material. This composite was originally conceived for the manufacturing of degradable osteosynthesis plates [8]. In the form of bone rings it could potentially be used advantageously for single-stage vertical bone augmentations. Magnesium is the fourth most abundant cation in the human body [9]. More than half of the total physiological magnesium is stored in the skeletal bones [10,11]. Apart from being biologically compatible, magnesium based implants induce a beneficial increase of osteoblastic response [12–14]. The periosteal reaction that is induced by the released magnesium ions has been shown to increase bone development in the peripheral cortex of the cortical bone [15]. This is assumed to be partly due to the up-regulation of the expression of calcitonin gene-related peptide (CGRP) through the stimulating effect of the magnesium ions on the dorsal root ganglia (DRG) [16]. In an aqueous environment, magnesium transforms to $Mg(OH)_2$ according to the following equation:

$$Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$$

In moderation, the hydrogen gas formed in the course of the degradation reaction acts as a mechanical stress that seems to be capable of stimulating osteocyte-moderated bone remodeling [17]. In the presence of chloride ions, which are abundant in bodily fluids, $Mg(OH)_2$ further corrodes according to the following equation [18]:

$$Mg(OH)_2 + 2Cl^- \rightarrow MgCl_2 + 2OH^-$$

The hereby produced hydroxyl ions raise the pH value locally, an effect which is possibly counteracted to a certain degree by the degradation of the PLA matrix to lactate. A complete neutralization does not seem to occur, as evidenced by a pH increase in pure water [8]. In a buffered solution such as phosphate buffered saline (PBS), the pH value seems to stabilize at a moderate 7.2–7.4 [8]. Furthermore, the PLA matrix could possibly have a certain protective effect with respect to the magnesium corrosion [8]. This is especially noteworthy when considering the co-implantation of magnesium with dental implants made of titanium, because magnesium corrodes considerably faster in the presence of titanium due to galvanic coupling [19].

Therefore, the aim of the present study was the evaluation and comparison of the degradation behavior of a PLA/Mg composite in the presence of dental implants made of titanium and PEEK (polyetheretherketone), simulating a single-stage co-implantation of the augmentation material with both of these implant types using the bone ring technique.

## 2. Materials and methods

As base material for the manufacturing of the test specimens, granules of a biodegradable polylactic acid/magnesium (PLA/Mg) composite were prepared as described elsewhere [20]. In brief, the powder consisted of 30 wt.% micro-scale spherical Mg particles embedded in PLA (PLA 2003D, NatureWorks LLC, Minnetonka, USA) by mixing surface modified Mg particles and PLA solution in Tetrahydrofuran (THF), and then drying the homogenized suspension. The appearance of the PLA/30Mg granules was documented using scanning electron microscopy (SEM-FEG, Hitachi S-4800, Hitachi corporation, Tokyo, Japan) (Fig. 1).

Using a pellet press (Atlas Manual Hydraulic Press, Specac Limited, Kent, United Kingdom), six portions of about 0.26 g of PLA/30Mg powder were cold fused into six identical discs of PLA/30Mg composite using a pressure of 10 tons (Fig. 2). The resulting discs had a mean diameter of 13 mm and a mean height of 1.51 mm. A bore of 3.6 mm in diameter was drilled in the center of each PLA/30Mg composite disc in order to receive an implant body of corresponding diameter.

Half (n = 3) of the discs were fitted with custom-designed implants [21] made of unfilled PEEK (VESTAKEEP® i4 R, Evonik Industries, Essen, Germany), referred to as “PEEK”. The other half (n = 3) were fitted with implants made of machined titanium (grade IV) of the same size and design, referred to as “Ti”.

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