Blends From *In Situ* Photopolymerization of Poly(ethylene glycol) Dimethacrylate – Polylactide Mixtures*

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Introduction: Poly(ethylene glycol) dimethacrylates (PEGDMAs) have been used as a resin component in dental applications and have been polymerized to form hydrogels for soft tissue engineering.[1,2] Polylactide (PLA), an α-polyester that is biodegradable and biocompatible, has also been extensively studied for drug delivery and tissue engineering.[3]

Blending polymers is a cost-effective method to engineer materials with unique properties.[4] On the other hand, photopolymerization of monomer mixtures is also widely used to prepare dental materials.[1] This study was designed to investigate structure-property relationships of crosslinked-PEGDMA/PLA blends as a prototype model system for a series of novel biomaterials that have potential applications in areas such as tissue engineering, drug delivery, and tissue sealants. Mixtures of PEGDMA and PLA were photopolymerized to yield blends of crosslinked-PEGDMA with PLA. The effects of PLA content and molecular mass on the PEGDMA degree of vinyl conversion (DC), the blends' miscibility, mechanical properties, swelling behavior and *in vitro* cellular responses of the blends were studied.

Materials and Methods†: The PEGDMA oligomer (number average molecular mass: 875 g/mol), camphorquinone (CQ) and ethyl 4-N,N-dimethylaminobenzoate (4E) were from Aldrich Corp. PLA-2K (Resomer104, 2096 g/mol) was from Boehringer Ingelheim Inc.; PLA-63K (Medisorb, 63000 g/mol) was from Alkermes Inc.

Blends were prepared using two different approaches depending on the PLA molecular mass. In both cases, the PEGDMA was first activated for photo-polymerization with an initiator system consist of 0.2 % CQ and 0.8 % 4E by mass fraction. Resin mixtures were formulated directly from PLA-2K with photo-activated PEGDMA. Solvent (dichloromethane) addition was needed to prepare the PEGDMA/PLA-63K mixtures, followed by solvent removal. Disk specimens (thickness ≈ 1 mm and diameter ≈ 10 mm) of crosslinked-PEGDMA and its blends were prepared by visible light irradiation (wavelength = 470 nm) for 1 min per side in a dental curing unit (Triad 2000 from Dentsply Inc.). DC, miscibility, mechanical properties, *in vitro* swelling behavior, and cellular response of the blends were investigated using the methods previously reported.[5]

Results and Discussion: The average DC after 1 min of irradiation (determined using Fourier transform infrared spectrometry, calculated using the area under the C=C absorption peak at 1637 cm^{-1}, utilizing the methacrylate carbonyl as an internal standard) of the PEGDMA and the 10 % and 50 % PLA-2K blends (by mass fraction) were 83 %, 81 %, and 84 %, respectively. It appeared that the addition of the low molecular mass PLA-2K up to 50 % by mass fraction did not interfere with the reaction kinetics of PEGDMA photo-polymerization as the DC was comparable for the pure PEGDMA network and crosslinked-PEGDMA/PLA-2K blends. However, the addition of the high molecular mass PLA-63K significantly decreased the DC of PEGDMA over the same irradiation time. The average DC for the 10 % and 50 % PLA-63K blends (by mass fraction) were 61 % and 32 %, respectively, suggesting that the reaction kinetics had been reduced with the incorporation of high molecular mass PLA. The DC of PLA-63K blends can be greatly enhanced through longer curing times and/or post-curing periods. For example, 24 h after photo-polymerization for 1 min per side, the DC of 50 % PLA-63K blends was found to be 83 %, comparable to that of the crosslinked PEGDMA. The results from differential scanning calorimetry (DSC) studies (two heating-cooling cycles from 100 °C to -80 °C at a ramp rate of 5 °C/min under nitrogen) revealed that PLA-2K was miscible with crosslinked PEGDMA over the entire blend composition. The single glass transition (T_g) of the blends was compositionally dependent and agreed with the calculations using the Fox and Gordon-Taylor equations. PLA-63K was only partially miscible with crosslinked PEGDMA as two T_g were observed for all blend compositions.

For mechanical testing, dog-bone shape specimens (length = 60 mm and width = 10 mm) were measured using a universal testing machine (Instron-5500R) with a load cell of 100 N and a cross-head speed of 1 mm/min. Figure 1 shows the representative tensile stress-strain curves of crosslinked PEGDMA, 50 % PLA-2K, and 30 % PLA-63K blends. PLA-63K blends have the best mechanical properties in terms of stiffness, toughness, and strength.

Crosslinked PEGDMA, PLA-2K blends and PLA-63K blends swelled approximately 10 % by volume during soaking in PBS for 2 weeks. Phase contrast microscopy was used to study samples after 1 d of culture with MC3T3-E1 osteoblast-like cells. Cells appeared to be rounded and clumped on PEGDMA surfaces (Figure 2A), indicating that the cells did not adhere well on the PEGDMA specimens. However, the degree of cell adhesion and spreading on 50 % PLA-63K blends is comparable to that for the negative control, tissue culture polystyrene (TCPS), after one day (Figure 2B, data not shown)

Summary: Miscible or partially miscible blends of crosslinked-PEGDMA and PLA were prepared using a unique combination of mixing and photo-polymerization processes. Through careful selection of components and the control of processing conditions, the properties of the blends, such as DC, mechanical properties, and cell adhesion, can be modified and enhanced compared to crosslinked-PEGDMA alone.
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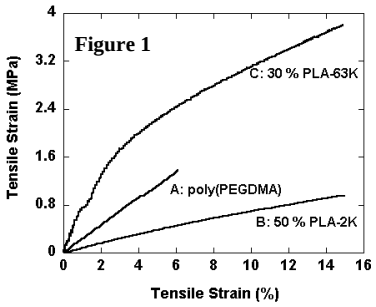

Figure 1. Representative tensile stress-strain curves of (A) crosslinked-PEGDMA, (B) 50 % PLA-2K blends and (C) 50 % PLA-63K blends.

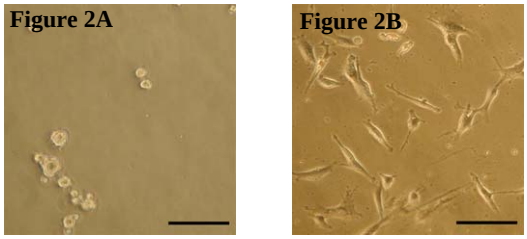

Figure 2. Phase contrast microscopy images of (A) crosslinked-PEGDMA and (B) 50 % PLA-63K blends after cell culture for 1 d. Scale bar: 100 μm.

References

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† *Certain commercial materials and equipment are identified in this paper in order to specify adequately the experimental procedure. In no case does such identification imply recommendation by the National Institute of Standards and Technology nor does it imply that the material or equipment identified is necessarily the best available for this purpose.*

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