Thiol-based Photopolymerizable Coating Enabling the Fabrication of Soft, Transparent, Patient-Specific Vascular Models with SLA 3D-Printing

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Abstract

Simulating endovascular procedures and studying hemodynamics with vascular phantoms aid in endograft selection and surgical planning. Ideally, a vascular phantom should be anatomically accurate, made in a soft material with properties as close as possible to vascular tissue, and sufficiently transparent for ease of visualization. However, achieving the convergence of these properties has proven challenging. Furthermore, no reports were found in the literature on post-processing treatments to improve the final finish of elastomeric SLA 3D-printed objects in general, let alone when complex hollow geometries are required. Here, we report the fabrication of real-sized patient-specific vascular phantoms with high anatomical fidelity and optical transparency, as well as mechanical properties closer to those of vascular tissue. These final properties were achieved by 3D-printing patient-specific vascular models with commercial elastomeric acrylic-based resins before coating with thiol-based photopolymerizable resins. Ternary thiol-ene-acrylate chemistry was found to be optimal. A PETMP/allyl glycerol ether (AGE)/polyethylene glycol diacrylate (PEGDA) coating with a 30/70% (PETMP-AGE)/PEGDA ratio applied on a flexible resin yielded elastic modulus, UTS, and elongation of 3.41 MPa, 1.76 MPa, and 63.2%, respectively, within the range of the human aortic wall. The PETMP/AGE/PEGDA coating doubled the optical transmission from 40% to 80%, approaching the 88% of the benchmark silicone-based elastomer. Higher transparency correlates with a decrease in surface roughness from 2000 to 90 nm after coating. Coated 3D-printed anatomical replicas are showcased for pre-procedural planning and medical training with good radio-opacity and echogenicity. Our overarching goal is to introduce the use of thiol-click chemistry for coating 3D-printed objects as a straightforward solution to some of the inherent limitations of photopolymer-based additive manufacturing, as exemplified in the case of the fabrication of unparalleled vascular phantoms.