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Effect of resin and photoinitiator on color, translucency and color stability of conventional and low-shrinkage model composites

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ABSTRACT

Objective. To study the effect of a low-shrinkage methacrylate monomer and monoacylphosphine oxide photoinitiator on color, translucency, and color stability of model resin-based composites (RBCs).

Methods. Four micro-hybrid RBCs were prepared containing barium-glass fillers in bisphenol A-glycidyl-methacrylate (BisGMA) and triethyleneglycol-dimethacrylate (TEGDMA) or urethane-based low-shrinkage monomer FIT-852 (FIT; Esstech Inc.) and TEGDMA matrix. Camphorquinone (CQ)/amine or Lucirin TPO were used as photoinitiators. Commercial low-shrinkage RBCs (Charisma Diamond, Heraeus Kulzer and N'Durance, Septodont) and conventional RBCs (Tetric EvoCeram, Ivoclar Vivadent and Filtek Z250, 3M ESPE) were used as controls. Color and translucency were measured using Thermo Scientific Evolution (Thermo Fisher Scientific) and SpectroShade™ Micro (MHT Optic Research) spectrophotometers. Color stability was evaluated after immersion in black tea (pure, with milk or lemon) and distilled water. Data were analyzed using analyses of variance with Tukey's post-test ($\alpha = 0.05$). **Results.** Photoinitiators had no significant effect on baseline color. Initially whiter FIT-based RBCs showed greater staining in all staining solutions than BisGMA-based RBCs. TPO-containing RBCs showed better color stability than CQ-containing RBCs irrespective of the base monomer. Tea and tea with lemon induced greatest color changes. Adding milk to tea significantly reduced material staining.

Significance. Urethane-based low-shrinkage monomer FIT and conventional BisGMA affected color, translucency and color stability of their respective RBCs. Despite being used in posterior teeth, low-shrinkage RBCs are expected to have favorable optical and esthetic properties. Manufacturers are urged to provide information on optical properties of monomers and monomer mixtures in their low-shrinkage RBCs to allow understanding of interaction with fillers and photoinitiators.

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1. Introduction

Optical properties such as color, translucency and fluorescence are important characteristics of resin-based composites (RBCs) for initial color match with natural teeth. Ideally, RBCs should mimic the esthetic characteristics of natural teeth and possess color stability throughout the functional life-time of the restoration. However, RBCs are prone to discoloration when exposed to saliva, food and beverages [1–3]. One major reason for restoration replacement is the color mismatch between the tooth and restoration [4].

The initial color of a dental composite is dependent on monomer composition, filler and photoinitiator content [5–7]. Color stability is not only determined by material composition and restoration finishing and polishing, but is also affected by patient's dietary habits, including the time the restorations are exposed to colored food and beverages [1,8–10]. Previous studies have analyzed effects of the type, size and loading of fillers on optical properties of RBCs [11–15]. Less work has been done on the influence of monomers [16] and photoinitiators [7,17] on the initial color and translucency of RBCs.

The most frequently used monomers in commercial RBCs are bisphenol A glycidyl dimethacrylate (BisGMA), urethane dimethacrylate (UDMA) and triethylene glycol dimethacrylate (TEGDMA). Low-shrinkage RBCs, such as Filtek Silorane (3M ESPE), Kalore (GC), Venus Diamond (Heraeus Kulzer) and N'Durance (Septodont), were introduced on the market with the aim to reduce polymerization shrinkage. Although low volumetric contraction seems unlikely to affect color and despite the fact that low-shrinkage RBCs are used in posterior teeth, they are also expected to have favorable optical and esthetic properties and not just low shrinkage and bond durability. Arocha et al. [18] demonstrated better color stability of the BisGMA-free Venus Diamond (Heraeus Kulzer) than some conventional RBCs. The same composite showed similar or smaller color changes as compared to two conventional RBCs [19].

In multi-component commercial RBCs, it is often difficult to assess how much certain components contribute to the actual material properties. Experimental RBCs differing in one component are a better model for this aim. However, it is often not possible to obtain raw materials due to patent protection. This is especially true for the abovementioned low-shrinkage RBCs i.e. urethane-based DuPont monomer DX-511 (Kalore, GC), tricyclodecane (TCD)-urethane (Venus Diamond, Heraeus Kulzer) and long-chain dimer acid-based monomer (N'Durance, Septodont).

FIT-852 (FIT; Esstech, Essington, PA, USA) is a novel low-shrinkage, non-linear bifunctional urethane-based methacrylate monomer with a molecular weight of 1100–1200. Based on manufacturer's data, the refractive index of FIT is 1.494, volumetric shrinkage is 2.0–2.5% and the degree of conversion is 65–85%. Literature data on FIT is scarce. A previous study by Johnston et al. [20] reported a higher degree of conversion (DC), lower shrinkage and improved flexural strength for the FIT-based than the BisGMA-based experimental RBCs. A higher degree of conversion and significantly lower shrinkage but also lower Vickers hardness, flexural strength and modulus were recently reported for FIT-based in relation to BisGMA-based

experimental RBCs [21]. Furthermore, spectroscopic characterization revealed no aromatic ring and confirmed the presence of >NH groups in FIT [21].

In this study, FIT was used as a model low-shrinkage monomer to compare its effect on color, translucency and color stability with that of conventional BisGMA-based RBCs. The rationale for using a urethane-based monomer as being generally representative of low-shrinkage monomers is the fact that most other low-shrinkage monomers in commercial RBCs are also urethane-based (DuPont in Kalore, TCD in Venus Diamond and dimer-acid monomer in N'Durance).

Alternative photoinitiators, such as phosphine oxides, were developed to overcome the yellowing effect of the most frequently used photoinitiator camphorquinone (CQ) [7,17], and also to maintain or even improve the polymerization efficiency in absence of a co-initiator [22]. The most promising photoinitiator seems 2,4,6-trimethylbenzoyldiphenylphosphine oxide (Lucirin TPO), which has already been used in some RBCs. Previous studies reported better results for TPO over CQ/amine in terms of polymerization efficiency [7,23,24] and color stability [7,25]. Albuquerque et al. [25] reported that TPO photoinitiator might improve the color stability of RBCs.

Color stability of RBCs is an important contributor to a longer life-span of dental composite restorations. It is commonly tested by staining in different solutions, most frequently in red wine, tea and coffee, where tea is the most popular drink world-wide and red wine was reported to induce the highest discoloration [1–3,8,18,26]. Though absorption spectra of tea and red wine differ across the 450–600 nm region, similarities in discoloration effects were observed using principal component analysis suggesting that fairly similar results may be expected in both staining solutions [27]. We selected tea for this study as pH of the staining solutions was reported to have an effect on the color stability apart from the discoloring agents [28,29]; however, it has not been clarified to what extent the pH alone affects staining. In this study, the influence of pH on the color stability was analyzed using black tea, this solely and with the addition of lemon.

The aim of this study was (a) to investigate the influence of a conventional (BisGMA) and a low-shrinkage (FIT) monomer, as well as of CQ/amine and TPO photoinitiator on the color and translucency of RBCs, and (b) to evaluate the color stability of RBCs after immersion in different staining solutions. The null hypotheses were: (1) there are no differences in color and translucency of the tested RBCs, and (2) the type of staining solution does not influence the color changes of RBCs.

2. Materials and methods

2.1. Preparation of resin-based composites (RBCs)

Four model micro-hybrid RBCs were tested in this study (Table 1). All ingredients were weighed on an analytical balance, accurate to 0.1 mg (ACCULAB ALC-110.4, Sartorius group, Goettingen, Germany), in plastic tubes wrapped in tin foil to prevent light exposure. Homogenization was done using a rotator at 20 rpm for 48 h. Filler was added sequentially in five portions by vortexing at 1000 rpm (Vortex, Velp

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