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Evaluation of polymerization characteristics and penetration into enamel caries lesions of experimental infiltrants

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ABSTRACT

Objectives: To evaluate the properties of experimental infiltrant blends by comparing them with the commercial infiltrant Icon® and penetration homogeneity into enamel caries lesions.

Methods: Groups were set up as follows: G1 (TEGDMA 100%); G2 (TEGDMA 80%, Ethanol 20%); G3 (TEGDMA 80%, HEMA 20%); G4 (TEGDMA 75%, BisEMA 25%); G5 (TEGDMA 60%, BisEMA 20%, Ethanol 20%); G6 (TEGDMA 60%, BisEMA 20%, HEMA 20%); G7 (TEGDMA 75%, UDMA 25%); G8 (TEGDMA 60%, UDMA 20%, Ethanol 20%); G9 (TEGDMA 60%, UDMA 20%, HEMA 20%) and Icon®. Ten specimens were comprised by each group for the following tests ($n = 10$): degree of conversion (DC), elastic modulus (EM), Knoop hardness (KH), and softening ratio (SR). Infiltrant penetration was evaluated using confocal microscopy (CLSM). Data were subjected to two-way ANOVA and a Tukey's test (5%). Data comparing experimental materials and Icon® were analysed using ANOVA and Dunnett's test (5%).

Results: The highest DC values were found in G1, G7, G8, and G9. The lowest DC values were found in G2, G4, G5, and G6. EM and KHN were significantly lower in HEMA and with ethanol addition for all blends, except for G9. There was no significant difference among the groups regarding SR, and it was not possible to take KHN readings of G2, G5, and G8 after storage. There was no significant difference among groups for infiltrant penetration into enamel lesions.

Conclusions: The addition of hydrophobic monomers and solvents into TEGDMA blends affected DC, EM, and KHN. UDMA added to TEGDMA resulted in an increase in DC, EM, and KHN. Overall, solvents added to monomer blends resulted in decreased properties. The addition of hydrophobic monomers and solvents into TEGDMA blends does not improve the penetration depth of the infiltrants.

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1. Introduction

Minimum intervention dentistry (MID) is the modern medical approach to the management of caries lesions. It has been shown that it is a good approach, since over time, sealing of carious dentine results in lower levels of infection[1] and can allow higher dental tissue preservation than traditional dentine caries removal.[2] MID is based on caries risk assessment and focusing on the early prevention and interception of disease.[3–5] The remineralization of an early enamel lesion could be achieved by an improvement in the patient's oral hygiene and by local fluoridation.[6] However, remineralizing conditions are difficult to reach and depend on good oral hygiene.[7]

While healthy enamel microstructure reveals regular periodicity of prisms of hydroxyapatite[8,9] a promising approach to arrest early caries lesions might be the infiltration of enamel subsurface lesions with low-viscosity light-curing resins.[10] The ability of resins to penetrate into porous enamel lesions was firstly described more than 30 years ago.[11]

Regarding lesion progression, there are some clinical studies in the literature.[12–15] The evaluation of the progression of the lesion is performed in patients with high, medium and low caries risk, comparing control and experimental (sealed lesions) and showed that infiltrated/sealed groups have increased therapeutic effect when compared to nonsealed/noninfiltrated lesions.[12,13] However, it is known that in low caries risk patients, many of these lesions will remain in enamel for at least twelve months and do not require treatment.[9] In addition, studies have shown that in low caries risk patients receiving regular topical fluoride therapy, progression could take forty months.[16] Consequently, the time for evaluating caries progression plays an important role in clinical studies comparing techniques or therapeutics.

Studies conducted by some authors[12,13] showed a range from 25% to 37.8% on therapeutic effect of infiltration technique, depending on the age group and material (infiltrant or adhesive system). It should be considered that the therapeutic effect can be directly related with the material physic-chemical and mechanical properties. In order to increase the therapeutic effect, materials properties should be improved, since ideally, an infiltrant should present low viscosity, low surface tension, and acceptable mechanical properties that support dental abrasion and oral degradation.[10]

TEGDMA-based materials show appropriate characteristics for an infiltrant material, including low viscosity and high degree of conversion. However, this monomer is highly hydrophilic and may undergo degradation in an oral environment, reducing the clinical performance.[17] Thus, the addition of UDMA or BisEMA, which are considered more hydrophobic monomers with low viscosity than TEGDMA (BisEMA – 0.03 Pa s; UDMA – 1.23 Pa s),[18] could be interesting.

Although studies[19] using confocal microscopy show that TEGDMA neat monomer blends demonstrate satisfactory penetration, TEGDMA reduction and adding BisEMA or UDMA in blends could result in satisfactory curing properties. On the other hand, a high penetration coefficient, which describes the penetration of liquids into porous solids driven by capillary forces[20] can also be achieved through the addition of diluents. Paris et al.[21] found that mixtures containing HEMA and ethanol showed the highest penetration coefficient; however, in some cases, the polymerization was deficient, and the final material was rubbery or even liquid. Therefore, the addition of a solvent such as ethanol increases the penetration coefficient, but it could jeopardize the mechanical properties, such as degree of conversion, flexural strength, elastic modulus, hardness and cross-link density. Nevertheless, although the DC is an important factor, it does not provide a complete characterization of the network structure. Cross-linking density test indicate pendant double bonds that are tied into the polymer network. Cross-linking density is an important factor for good network formation and physical properties.[22] Cross-linking density has been indirectly assessed by polymer softening after exposure to ethanol.[23]

The first aim of this study was to evaluate the effect of hydrophobic monomers and solvents on properties (degree of conversion, Knoop hardness, softening ratio, elastic modulus) of experimental infiltrant blends and comparing them to a commercially available infiltrant, Icon® (DMG, Germany). The second aim was to evaluate the penetration depth of the materials as well as their homogeneity into enamel caries lesions.

2. Materials and methods

2.1. *Infiltrant preparation*

The following monomers were used in different combinations, as described in Table 1: triethyleneglycol dimethacrylate (TEGDMA) (Sigma–Aldrich Inc., St. Louis, MO, USA, Batch #01612M), ethoxylated bisphenol A glycidyl dimethacrylate (BisEMA) (Sigma–Aldrich, Inc., St. Louis, MO, USA, Batch #03514HF), diurethane dimethacrylate (UDMA) (Sigma–Aldrich, Inc., St. Louis, MO, USA, Batch #09405BJ), 2-hydroxy-etilmetacrylate (HEMA) (Sigma–Aldrich, Inc., St. Louis, MO, USA, Batch #MKBF2452V), and ethanol (Sigma–Aldrich, Inc., St. Louis, MO, USA, Batch #51496AM). The light-curing initiator system selected for photoinitiation was camphorquinone (CQ) (Sigma–Aldrich, Inc., St. Louis, MO, USA, Batch #532604), and dimethyl aminoethyl methacrylate (DMAEMA)

Table 1 – Infiltrant blends composition.

Infiltrant icon	Composition Methacrylate-based resin matrix
G1	TEGDMA 100%
G2	TEGDMA 80%, Ethanol 20%
G3	TEGDMA 80%, HEMA 20%
G4	TEGDMA 75%, BisEMA 25%
G5	TEGDMA 60%, BisEMA 20%, Ethanol 20%
G6	TEGDMA 60%, BisEMA 20%, HEMA 20%
G7	TEGDMA 75%, UDMA 25%
G8	TEGDMA 60%, UDMA 20%, Ethanol 20%
G9	TEGDMA 60%, UDMA 20%, HEMA 20%