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Development of viscoelastic stability of resin-composites incorporating novel matrices

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ABSTRACT

Objectives. To study the effect of resin matrix and maturation time (1 and 24 h) on the creep deformation of resin-composites, two of which have matrix-forming monomers that are either bis-GMA free or have an ormocer structure between the C=C groups.

Methods. Five resin-composites: four commercial and one experimental were investigated. Six specimens were prepared for each material and were divided into two groups ($n = 3$) according to the maturation time and condition. Group A was stored dry at room temperature for 1 h and Group B was stored for 24 h in distilled water to allow post-curing at 37 °C. Each specimen was loaded (20 MPa) for 2 h and unloaded for 2 h. The strain deformation was recorded continuously for 4 h. Statistical analysis was performed using one-way ANOVA and the Bonferroni post hoc test at a significance level of $a = 0.05$.

Results. The maximum creep-strain % after 1 h ranged from 1.32% to 2.50% and was reduced after 24 h post-cure to between 0.66% and 1.47%. Also, the permanent set after 1 h ranged from 0.70% up to 1.27% (Group A) and after 24 h ranged from 0.53% up to 1.20% (Group B).

Significance. Creep deformation and maximum recovery for all resin-composites decreased with time, demonstrating improvement in viscoelastic stability. However, there was no significant difference between the permanent set at different times, except for Herculite XRV Ultra. Composites with novel matrices showed comparable properties to existing bis-GMA based materials.

1. Introduction

As supplied for dental use, resin-composites are pastes that require polymerization. During irradiation for 20–40 s the materials change to a strong solid. However, many studies have shown that properties such as hardness continue to increase over several weeks due to post-curing [1]. Thus, the material at 24 h post-cure may be different than the material at 1 h.

Resin-composites have been subject to improvements especially with respect to their mechanical properties which make them suitable to be placed in load-bearing areas in posterior teeth, where they experience masticatory forces ranging from 60 to 90 N [2]. These forces can lead to eventual failure of the composite restoration. The variations of

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different resin-composites in their clinical performance can be partly understood by considering their behaviour under applied stress [3]. If creep is appreciable this will lead clinically to a considerable reduction in the anatomic form of class I and class II occlusal restorations.

The creep and recovery of resin-composites have been studied under both static and dynamic conditions [3]. The time-dependent deformation produced in a solid as a result of constant stress is known as static creep, while in dynamic creep the applied stress is cyclical [4]. Several studies measured static compressive creep [4–9]. A good correlation has been reported [4,10] between static and dynamic creep measurements where, during the dynamic loading, the creep deformation at the end of the assessment period was equivalent to the static creep deformation. Many factors affect the viscoelastic behaviour (creep) of resin-composites, such as the filler load, size and distribution, resin matrix and concentration of the diluent monomer [3,6,11]. Creep decreases in resin-composites with high concentrations of highly viscous monomers such as bis-GMA, for a given filler loading [12].

Bis-GMA is a dimethacrylate monomer widely used in the majority of current commercial resin-composites. However, studies on the safety of this monomer have considered the possible release of Bisphenol-A (BPA) from the matrix and its adverse effects [13–15]. BPA has the ability to stimulate some cytotoxic mechanisms [16]. Moreover, the high viscosity of bis-GMA necessitates the use of diluent molecules such as TEGDMA [17], which have greater cytotoxic potential. Recently, some bis-GMA free composites have been investigated [18,19]. UDMA has been proposed as a substitute for bis-GMA in orthodontic adhesives with comparable viscosities to bis-GMA monomer mixtures. Dimethacrylate composites have been used clinically for a considerable time with reasonable success. Alternative chemical matrices should be able to emulate that success (if not surpass it) and also offer less cytotoxicity.

In the last decade, new organic matrices have been developed as alternatives to conventional dimethacrylate networks. The main drive behind this research has been to introduce matrices with lower shrinkage and/or less toxicity. Examples of such networks are *Organically Modified Ceramics* (Ormocers) [20]. Some of these Ormocer composites do not contain any free dimethacrylate monomers and such materials have either no or minimal cytotoxicity issues compared to conventional resin-composites. Nevertheless, these Ormocer oligomers are terminated by methacrylate C=C groups.

The aim of this study was to examine viscoelastic creep and recovery of different dental resin-composites under compressive loading conditions. The null hypotheses for this study were: (i) there is no difference between the creep behaviour of resin-composites with different matrices, under compressive loading and (ii) there is no difference between creep behaviour of the same resin-composite at different maturation times.

2. Materials and methods

Five resin-composites: four commercial and one experimental were investigated (Table 1). Six specimens were prepared for each material in a split stainless steel mould with a cylindrical cavity (4 mm diameter × 6 mm depth). The samples were prepared using the layering technique and were light cured for multiple 40 s exposures from upper and lower surfaces and also from the sides, after removal of the specimens from the mould (Elipar S10/3M ESPE with average tip irradiance of 1200 mW/cm^2). A 600-grit silicon carbide paper was used to finish and trim any excess under running water. The specimens were divided into two groups ($n = 3$) according to the maturation time and condition. Group A was loaded statically after 1 h of dry storage at room temperature 23 °C and the second group after 24 h of wet storage in 37 °C. The static creep apparatus was described previously [9]. A constant stress of 20 MPa was applied on the specimen in compression via a holding pin for 2 h followed by 2 h of strain recovery to record the maximum static creep-strain (%) and permanent set (%), respectively, via continuous real time measurement with a LVDT transducer system [8,9].

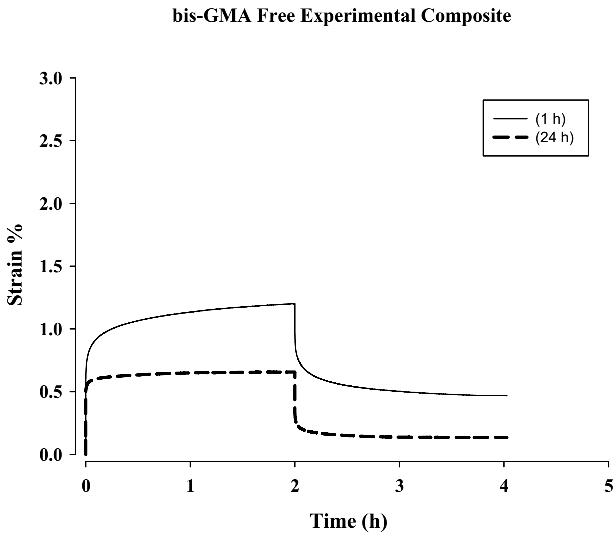

Fig. 1 – Creep and recovery at two maturation times of bis-GMA free experimental composite.

Data were entered into statistical software (SPSS ver. 16, SPSS Inc., Illinois, USA) and analysed using one-way ANOVA for maximum static creep-strain (%), maximum creep recovery and permanent set (%). Homogeneity of variance was calculated by using Levene statistics. Bonferroni *post hoc* tests ($p < 0.05$) were used for comparisons between the materials.

3. Results

The results are presented in Table 2 and Figs. 1–7. The maximum creep-strain ranged from 1.32% to 2.50% for Group A (1 h) and from 0.66% to 1.47% for Group B (24 h). Also, the maximum creep recovery ranged from 0.59% to 1.28% for Group A and from 0.12% to 0.27% for Group B. The permanent set ranged from 0.70% up to 1.27% for Group A and from 0.53% up to 1.20% for Group B (Table 2). Significant reductions were observed in the maximum creep for all materials after 24 h compared to 1 h. But there was no significant difference between permanent set at 1 and 24 h, except for Herculite XRV Ultra (Figs. 6 and 7).