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Temperature-dependence of creep behaviour of dental resin-composites

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ABSTRACT

Objectives: To determine the effect of temperature, over a clinically relevant range, on the creep behaviour of a set of conventional and flowable resin-composites including two subgroups having the same resin matrix and varied filler loading.

Methods: Eight dental resin-composites: four flowable and four conventional were investigated. Stainless steel split moulds (4 mm × 6 mm) were used to prepare cylindrical specimens for creep examination. Specimens were irradiated in the moulds in layers of 2 mm thickness (40 s each), as well as from the radial direction after removal from the moulds, using a light-curing unit with irradiance of 650 mW/cm^2. A total of 15 specimens from each material were prepared and divided into three groups (n = 5) according to the temperature; Group I: (23 °C), Group II: (37 °C) and Group III: (45 °C). Each specimen was loaded (20 MPa) for 2 h and unloaded for 2 h. Creep was measured continuously over the loading and unloading periods.

Results: At higher temperatures greater creep and permanent set were recorded. The lowest mean creep occurred with GS and GH resin-composites. Percentage of creep recovery decreased at higher temperatures. At 23 °C, the materials exhibited comparable creep. At 37 °C and 45 °C, however, there was a greater variation between materials. For all resin-composites, there was a strong linear correlation with temperature for both creep and permanent set.

Conclusions: Creep parameters of resin-composites are sensitive to temperature increase from 23 to 45 °C, as can occur intra-orally. For a given resin matrix, creep decreased with higher filler loading.

1. Introduction

Laboratory research and clinical trials are considered as the main tools to characterise and evaluate the performance of resin-based restorative materials. An essential part of the critical evaluation of these materials is to examine their behaviour under stress. One method to study the normal deformation response of polymer materials is to measure the strain as a result of an applied stress during a selected time period. This deformation is known as creep. Subsequently, the relaxation response after stress removal can be observed and is known as recovery.[1]

Creep behaviour may be classified as static or dynamic. The time-dependent deformation produced in a solid as a result of constant stress is known as static creep. Dynamic creep refers

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to the similar phenomenon when the applied stress is cyclical, such as that in a fatigue test.[2] As noted by Oden et al.[2] and Watts,[3] static creep is relevant clinically and is a useful method for studying the viscoelastic behaviour of dental restorative materials.

The distinctiveness of this type of examination compared with strength properties is that the technique, in addition to its usefulness in showing the material's ability to resist stresses without failure, illustrates how the stresses are accommodated by compliant behaviour through viscoelastic and viscous flow under constant stress and the ability of the material to relax towards its original condition on removal of stresses.[1] Changes in the occlusal surface anatomy of resin-composite restorations result from two main factors: loss of material by wear processes and also creep deformation that may contribute to the observed loss of height.[2]

The content, nature, distribution, and size of inorganic filler particles determine the magnitude of the viscoelastic creep in resin-based materials.[1,4] In addition, creep deformation of dental resin-composites is affected by the choice of monomer type and diluent concentration in the matrix formulation. Resin-composites with rigid monomers, such as Bis-GMA, and low concentration of diluents, such as TEGDMA, exhibit lower creep than do other resin-composites with higher diluent concentrations.[5]

Resistance of dental restorative materials to degradation and distortion in the oral environment largely determines their durability and clinical performance.[6] Mechanical properties of resin-composites are influenced not only by their chemical composition, but also by the environment to which they are exposed.[2] The extent of viscoelastic deformation is dependent on several factors, including stress level, temperature, and moisture.[4,7,8] When temperature is increased, this can result in higher creep via increased thermal motion of the polymer backbones.[9,10] Plastics and rubbers show extensive changes in properties with temperature because temperature-dependence of polymer properties is a general phenomenon.[11]

The interaction between the thermal environment and moisture can have a detrimental effect on polymer-based restorative materials. Voids and microscopic cracks in the material surface may open as temperature is increased, with the result that more fluid is adsorbed into the openings. Trapped fluid can cause flaw growth when temperature is reduced suddenly and repetition of this process may lead to failure of resin-composite restorations.[12]

The aim of this study was to determine the creep and recovery for a set of flowable and conventional resin-composites including two subgroups having the same resin matrix and varied filler loading in relation to temperature. The specific objectives were to measure, at three different temperatures within a clinically relevant range, the following parameters: (a) maximum creep; (b) maximum creep recovery; (c) percentage of creep recovery; and (d) permanent set. The test hypotheses were: (i) creep will increase at higher temperatures; (ii) for a given resin matrix, creep will decrease with higher filler loading; and (iii) there will be a correlation between temperature and both creep and permanent set.

2. Materials and methods

Eight dental resin-composites were investigated: three of these materials (GF, GH and GS) are based on a resin matrix made up of Bis-GMA, Bis-EMA and TEGDMA but increasing filler loading (80–89, w/w). Another two resin-composites (VD and VP) are based on the resin matrix formulation of TCD, di-HEA and UDMA but different filler loading (81 and 76, w/w, respectively). Materials and manufacturers' information are listed in Table 1. Fig. 1 shows the chemical structure of two monomers used in some of these materials.

Specimens were prepared using stainless steel split moulds (4 mm diameter × 6 mm length). Glass microscope slides, covered with transparent polystyrene matrix film, were positioned at the upper and lower surfaces of the cylindrical

Table 1 – Resin-composites investigated: codes, lot numbers, filler loadings, resin systems and manufacturers' information.

Product	Code	Type	Manufacturer	Lot no.	Resin system	Filler wt%
GrandioSo Flow	GF	Flowable	Voco, Cuxhaven, Germany	1104372	Bis-GMA, Bis-EMA, TEGDMA	80
GrandioSo Heavy Flow	GH	Flowable	Voco, Cuxhaven, Germany	1051279	Bis-GMA, Bis-EMA, TEGDMA	83
GrandioSo	GS	Conventional	Voco, Cuxhaven, Germany	1048014	Bis-GMA, Bis-EMA, TEGDMA	89
Estelite Flow Quick	ES	Flowable	Tokuyama Dental Corporation, Japan	E646B	Bis-MPEPP, TEGDMA, UDMA	71
G-aenial Universal Flo	GU	Flowable	GC Corporation, Tokyo, Japan	1011091	UDMA, Bis-MEPP, TEGDMA	69
GC Kalore	KA	Conventional	GC Corporation, Tokyo, Japan	1006171	DX-511, UDMA, Dimethacrylate co-monomers	82
Venus Diamond	VD	Conventional	Heraeus Kulzer GmbH, Hanau, Germany	010037	TCD, di-HEA, UDMA	81
Venus Pearl	VP	Conventional	Heraeus Kulzer GmbH, Hanau, Germany	VP301110	TCD, di-HEA, UDMA	76