DENTAL MATERIALS 28 (2012) e15–e18

Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/dema

Viscoelastic stability of resin-composites under static and dynamic loading

Muhammad Kaleem[a,b,*], Konstantinos Masouras[a], Julian D. Satterthwaite[a], Nick Silikas[a], David C. Watts[a]

[a] Biomaterials Research Group, School of Dentistry, University of Manchester, Manchester, UK
[b] Army Medical College, National University of Science and Technology, Rawalpindi, Pakistan

ARTICLE INFO

Article history:
Received 14 June 2009
Accepted 29 November 2011

Keywords:
Resin composite
Static creep
Dynamic creep
Viscoelastic stability
Cyclic loading
Mechanical properties

ABSTRACT

Objectives. To compare the viscoelastic behavior (creep) of dental resin-composites under both static and cyclic loading in compression.
Methods. Ten cylindrical specimens (4 mm × 6 mm), divided into two subgroups ($n = 5$) were prepared from each of four commercial resin-composites, using a divisible stainless steel mold. They were thoroughly cured from all sides. Groups 1 and 2 were loaded statically and dynamically respectively after 1 d of fabrication and dry storage. Group 1 was loaded with a constant static load of 35 MPa and it was applied for 2 h followed by 2 h of strain recovery to obtain the static creep (%) and permanent set (%) respectively. To Group 2 a cyclic load between 1 MPa and 50 MPa was applied at a frequency of 0.25 Hz for 30 min to obtain the "dynamic" creep strain (%). Regression and correlation analysis ($\alpha = 0.05$) was performed to examine possible correlations between static and "dynamic" creep.
Results. For the resin-composite investigated, a good correlation was found between "dynamic" creep strain (%) and maximum static creep strain (%) ($r = 0.92$) and a strong correlation was also found between "dynamic" creep strain (%) and permanent set (%) ($r = 0.97$), Significance: Maximum static creep was significantly higher than "dynamic" creep. A direct numerical equivalence was not expected between static and "dynamic" creep values, as in the case of "dynamic" creep, loading was cyclic and was applied for a shorter overall period. Nevertheless a strong correlation was found between the static and dynamic creep measurement.

1. Introduction

The use of resin-composite materials as a substitute for dental amalgam in posterior tooth restorations is increasing, partly due to improved esthetics, biocompatibility and mechanical properties [1,2]. These restorations are subjected to high loading forces during chewing. The loads in local contact areas on the occlusal surface have been reported to reach 66 N, and under extremely high bite forces contact loads can reach up to 90 N [3]. The relatively high forces indicate that high stresses develop in occlusally located restorations during the chewing process which may result in the failure of the restorations. Thus it is essential to understand the viscoelastic behavior (creep-strain, Permanent set) of these materials.

Several studies have been carried out to understand the viscoelastic stability of resin-composite restorations, which is

* *Corresponding author at:* Department of Science of Dental Materials, Army Medical College, National University of Science and Technology, Rawal Pindi, Pakistan. Mobile: 0092 03225138862.
E-mail addresses: dr_kaleem78@hotmail.com, mkaleem-amc@nust.edu.pk (M. Kaleem).
0109-5641/$ – see front matter
doi:10.1016/j.dental.2011.11.026

quite a complex phenomenon and depends on matrix composition, environmental and load conditions. In most of the studies, a static compressive load was applied to determine the creep behavior [4–9], but in a few studies torsion and tensile creep modes were used [10,11].

The restoration loading force during chewing is low and repeated. The estimated number of chewing stress cycles imposed intra-orally on a dental restoration is more than 3×10^5 per year [12]. Under such conditions, there is the possibility of strain recovery during the unloading phases. So it is useful to investigate the material deformation behavior under both cyclic and static loading and examine the relationship between these two modes.

A strong correlation between static and "dynamic" creep was reported by Oden et al. [9]. They found that, during dynamic loading, the creep deformation at the end of the test period was comparable to the static creep deformation and that by increasing the applied load and number of cycles, the dynamic creep recovery decreased.

The aim of this study was to examine the viscoelastic behavior (creep) of dental resin-composites under two different loading conditions (static and cyclic). The null Hypotheses for this study were: (i) there is no difference between the creep behavior of resin-composites under static and dynamic loading; and (ii) there is no difference in creep behavior between materials.

2. Materials and methods

Four commercial resin-composite restorative materials Grandio, Charisma, Tetric Evoceram and P60 were used for this study (Table 1). Ten cylindrical specimens (4 mm × 6 mm), divided into two subgroups ($n = 5$) were prepared from each material, using a divisible stainless steel mold containing a cavity (4 mm diameter × 6 mm depth). Specimens were prepared by using a layering technique. Samples were thoroughly cured from both sides with 600 mW/cm^2 irradiance for 40 s (Demetron Optilux 500; Kerr, Orange, CA, USA). The samples were finished by carefully trimming any excess with a 600-grit silicon carbide paper under running water. Then they were further cured in a light cure oven (Visio® Beta Vario, ESPE, Germany) for 7 min, to ensure complete polymerization. Groups 1 and 2 were loaded statically and dynamically, respectively, after one-day of dry storage.

The static creep apparatus used in this study has been described previously by Baroudi et al. [8]. The basic principle of this method is the application of a constant load via of a loading pin. High stresses can be applied because of the use of a lever (Fig. 1). A constant static load of 35 MPa was applied for 2 h followed by 2 h of strain recovery to obtain the maximum static creep-strain (%) and permanent set (%), respectively.

A Universal Testing Machine (Z020, Zwick/Roell GmbH & Co. KG, Ulm, Germany) was used for the "dynamic" creep measurement. A loading cycle, of 4 s was used, which could be achieved repeatedly and reliably for the preset values of load and experiment duration. In each cycle, stress increased and then decreased between 1 MPa and 50 MPa at a constant rate. During the loading cycles, the force, displacement and time were recorded. Force was recorded in increments of 1 N.

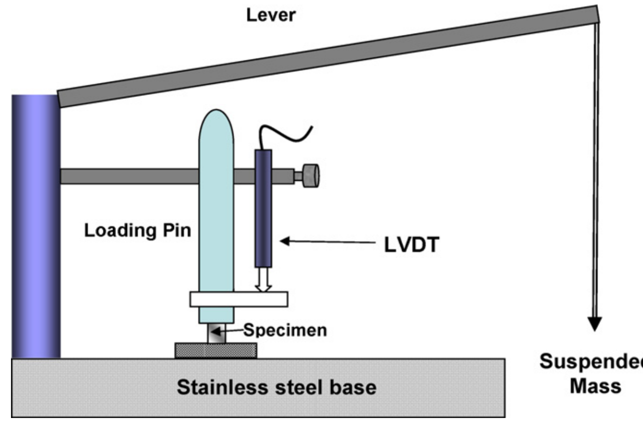

Fig. 1 – Apparatus used for the static creep measurement.

Increments of time were 0.01 s and of displacement 1 μm. Data were recorded during 450 cycles within 30 min. The force, displacement and time data were processed with Matlab R2007b software. From all stress values, only those between 35 and 36 MPa, recorded during the loading phase of each cycle, were separated and used in the plots, along with the corresponding values of strain and time. The stress variation between 35 and 36 MPa caused a respective creep variation. A quadratic regression analysis of the data points was employed to optimize each plot of creep versus time. Average creep values were calculated for each time moment from the different experimental runs.

Data were entered into statistical software (SPSS ver. 16, SPSS Inc., Illinois, USA) and analyzed separately with one way ANOVA for maximum static creep strain (%), permanent set (%) and "dynamic" creep strain (%). Homogeneity of variance was calculated by using Levene statistics. Bonferroni post hoc tests ($p < 0.05$) was used for materials. Regression and correlation analysis ($\alpha = 0.05$) was also performed to examine possible correlations between static and "dynamic" creep.

3. Results

The mean maximum static creep (%), permanent set (%) and dynamic creep strain (%), along with the standard deviations (SD) are presented in Table 2. "Dynamic" creep strain ranged from 0.72 to 1.01 (%). Maximum static creep strain and permanent set ranged from 1.59 to 3.45 (%) and 0.42 to 0.82 (%), respectively. The values were not statistically significant ($p = 0.05$).

A strong correlation was found between "dynamic" creep strain (%) and static permanent set (%) at 1 d ($r = 0.97$) (Fig. 2). In addition a strong correlation was found between "dynamic" creep strain (%) and maximum static creep strain (%) ($r = 0.92$) (Fig. 3).

4. Discussion

Resin-composites are widely used as posterior restorative materials. Yet they can fail due to bulk, cusp and marginal fractures under high and repeated oclussal forces [13]. Although creep measurement under dynamic loading appears to be