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Stiffness of uncured resin-composites assessed via cavity-packing forces

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ABSTRACT

Objectives. To evaluate the stiffness and packability of unset resin-composites at different temperatures, taking into account the cavity wall effect.

Materials and Methods. Six representative commercial resin-composites were selected. Each material was placed in mould of different sizes for example ($\varphi = 7$, depth = 5 mm; or $\varphi = 3$, depth = 5 mm) held at 26 or 37 °C. Maximum packing force ($\mathbf{F_p}$) of the resin-composite was measured. A flat-ended stainless-steel probe with a diameter of either 6 mm or 3 mm was mechanically lowered onto and into the surface of each unset sample with a speed of 0.50 mm/s to a depth of 2 mm, which was held constant for 10 s. The compressive force produced on the probe by the unset resin-composites was plotted against time and the maximum value was identified ($\mathbf{F_p}$). Peak stress $\mathbf{S_p}$ was calculated by dividing the $\mathbf{F_p}$ by area of the probe used. Data were analyzed by univariate ANOVA and multiple pair wise comparisons were performed using a Tukey post-hoc test to establish homogenous subsets (at $p = 0.05$).

Results. $\mathbf{S_p}$ was taken as potential measure of stiffness. It ranged from 0.12 to 4.21 MPa and from 0.07 to 3.08 MPa at 26 and 37 °C, respectively. Univariate ANOVA showed significant influence of the plunger cavity ratios, temperature and materials on $\mathbf{S_p}$ ($p < 0.001$). A strong interaction was also found between plunger cavity ratios, temperature and materials for $\mathbf{S_p}$ ($p < 0.05$).

Conclusion. Peak stress $\mathbf{S_p}$ is a useful parameter for characterizing the stiffness of uncured resin-composite materials, additionally resin-composite formulation, temperature and wall effect did effect the packability of resin-composite.

1. Introduction

Resin-composites are now the preferred choice for direct posterior restorations, due to an increased demand of aesthetically acceptable restorations, and their improved mechanical strength and wear resistance [1,2]. In class I and II posterior cavities, it is important to obtain tight proximal contacts before curing and good post-cure mechanical properties to promote appropriate clinical service.

The vast majority of *in-vitro* research published in the past 25 years, is on post-cure properties of resin-composites [3–6].

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Table 1 – Resin composite restorative materials used for the investigation.

Materials	Code	Lot no	Filler wt%	Manufacturer
Clearfil Majesty Esthetic	CME	00001A	66%	Kuraray Medical, Germany
Clearfil Majesty posterior	CMP	00006A	82%	Kuraray Medical, Germany
Filtek Silorane	FS	7AR	76%	3M ESPE, St. Paul, USA
XRV Herculite ultra enamel	XRV	07-1032E/05-1263D	79%	Kerr, USA
Quixfil	Qu	0703002499	66%	Dentsply, Germany
Grandio	Gr	630877	87%	Voco, Cuxhaven Germany

Interestingly, there are very few studies that deal with the pre-cure handling properties [7–14], despite the interest of clinicians in this subject which includes stickiness, slumping, and sculpting of the occlusal anatomy of the restored teeth [7–9]. Handling behavior will ultimately affect the clinical selection of a material for a specific restoration. In consequence, there is increased demand for the development of restorative composites, which not only exhibit good post-cured mechanical properties, but also improved handling characteristics [3,14].

Resin-composites are viscoelastic materials exhibiting both viscous and elastic nature at the same time depending on their composition, which also affect their response to an external force, and afterward their stress relaxation [15,16]. Many rheological properties of restorative materials are related to their handling characteristics, such as viscosity, elasticity, flowability and adaptability to cavity walls [8,17].

However rheology properties of filled resin-composites are rare and difficult to produce consistent results [18]. Clinically a composite paste will be packed into a cavity or onto a shallow tooth surface. Particularly in a cavity, cavity dimension such as width will influence the packability. This influence of cavity-wall proximity may be termed the wall effect [16].

The aim of this paper is to present a methodology for characterizing the relative stiffness and packability of the composite paste. This method will take into account the wall effect and also temperature. The null hypotheses tested in this investigation were: (i) there was no wall effect apparent resulting from different cavity sizes; (ii) Force or stress required for packing composite paste into a standardized cavity did not vary with composite formulation; (iii) Force or stress required for packing composite paste into a standardized cavity did not vary with composite temperature.

2. Materials and methods

Five representative dimethacrylate and one silorane based resin-composites were selected for this investigation (Table 1). Maximum packing force of the resin-composite with and without wall-effect was measured using a sensitive stress strain instrument (TA.XT2i Stable Micro Systems, Godalming, Surrey, UK) [12,13]. The analyzer comprised a stainless-steel cylindrical probe of varying diameter ($\varphi = 2$ or 6 mm) connected to a force transducer to measure the force acting on the probe. Modifications to the analyzer were carried out as follows: a thermostatically controlled frame ($\varphi = 70$ mm) was constructed and fixed to the stainless steel stand, this frame contained a cylindrical mould cavity (Fig. 1), the dimensions of which could be altered ($\varphi = 7$, depth = 5 mm; or $\varphi = 3$, depth = 5 mm) and into which the composite sample to be tested was placed. The temperature of the mould cavity was regulated using an embedded thermostat and an adjustable power supply unit, with a thermocouple in close proximity to the sample: the temperature was set at either 26 °C (room temperature) or 37 °C (oral cavity temperature).

The modified apparatus was used to measure and analyze the maximum packing force (F_p, N) during bulk packing.

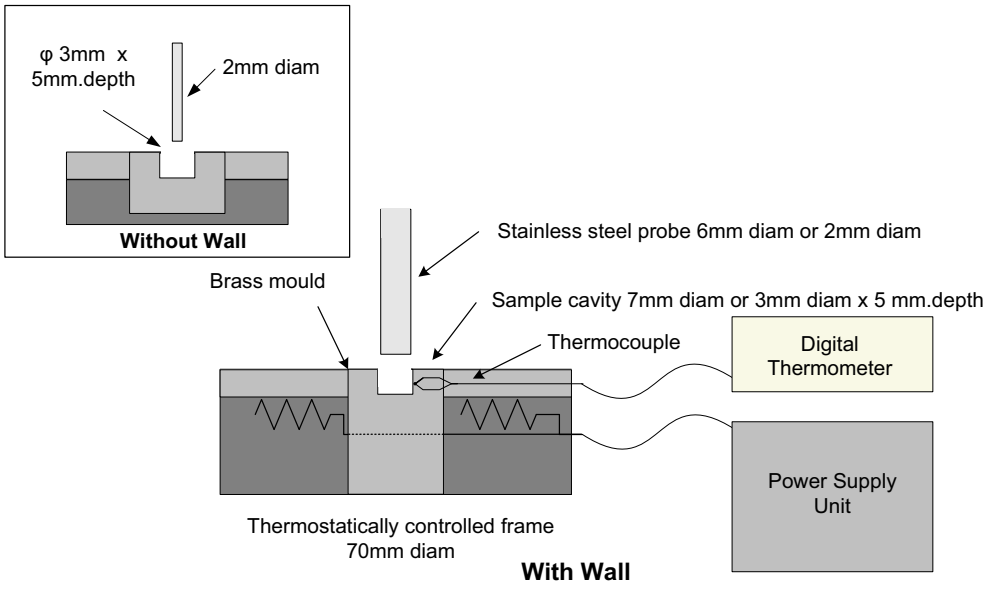

Fig. 1 – Experimental setup used for the bulk packing analysis.