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Slumping tendency and rheological properties of flowable composites

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ABSTRACT

Objectives. The aim of this study was to develop a method for measuring the slumping tendency of flowable resin composites and to correlate the results with those obtained from standard rheological methods.

Methods. Five commercial flowable composites (Aeliteflo: AF, Filtek flow: FF, DenFil flow: DF, Tetric flow: TF and Revolution: RV) were used. A fixed volume of each composite was extruded from a syringe onto a glass slide using a custom-made loading device. The composite was allowed to slump for 10 s at 25 °C and light cured. The aspect ratio (height/diameter) of the cone or dome shaped specimen was measured to estimate the slumping tendency of the composites.

In order to investigate the relationship between the slumping tendency and the rheological properties of the composites, the complex viscosity η^* of each composite was measured by a dynamic oscillatory shear test over a range of angular frequency $\omega = 0.1–100$ rad/s using a rheometer. The aspect ratios of the composites were compared by one-way ANOVA and Tukey's post hoc test at the 5% significance level. Regression analysis was performed to investigate the relationship between the aspect ratio and the complex viscosity.

Results. Slumping tendency based on the aspect ratio varied among the five materials (AF < FF < DF < TF < RV). Flowable composites exhibited pseudoplasticity in which the complex viscosity decreased with increasing frequency. Slumping resistance increased with increase in the complex modulus.

Significance. The slumping tendency could be quantified by measuring the aspect ratio of slumped flowable composites. This method may be applicable to evaluate the clinical handling characteristics of these materials.

1. Introduction

Since flowable resin composites were first introduced in 1996, a variety of products have appeared on the market. Due to their typically lower inorganic filler content, flowable composites have lower viscosity than universal hybrid composites, and demonstrate good flow and wetting ability to cavity walls. Therefore, flowable composites have been used for pit and fissure sealants, conservative restorations of small

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cavities, repair of temporary restorations, and cavity liners [1–3].

The handling characteristics of resin composites are determined by "how easily and conveniently the material can be manipulated" and are a very important factor when selecting composites for clinical use. Rheological properties, such as viscosity, are directly related to handling properties, which include easy placement into a cavity and shaping, stickiness to an instrument, adhesion, and the ability to retain shape or resistance to slumping after sculpting. These properties greatly affect the restorative procedure, treatment time, and likely the clinical outcome [3–8].

Low viscosity flowable composites are usually applied to a cavity using a syringe and a needle of small diameter. When used as an intermediate liner in Class I or II cavities or for restoring small cavities, application of the composite through a syringe results in superior adaptation to the cavity wall due to the material's flow and adhesive capacity. On the other hand, when restoring vertically oriented cavities such as Class V or III cavities, a low viscous material with excessive flow can, as a result of its own weight, flow down to the gingival area resulting in a marginal overhang or end up in an undesired position. In these cases, a material would be needed that possesses adequate slumping resistance and will not flow easily after being applied to the cavity [1–8].

There have been many studies on the rheological properties related to the handling characteristics of resin composites. Opdam et al. [9] and Tyas et al. [10] compared the relative consistency of various posterior composites using a simple press method and a penetrating method, respectively. Bayne et al. [1] also used the simple press method to compare flowable composites with universal hybrid composites, and reported that the viscosity of the different flowable composites varied greatly. However, these studies only compared relative consistency among composites, and no information is available on the absolute viscosity values of the materials. Lee et al. [3,11] and Beun et al. [12], using a dynamic oscillatory shear test, reported that considerable differences existed in the viscoelastic properties between flowable, universal hybrid, and packable composites; there were great differences in the absolute value and ratios of viscosity and elasticity, even for materials that were nominally labeled as being in the same category of composite. The three types of composites all displayed pseudoplasticity, in which the viscosity decreased with increasing shear rate.

The most important handling characteristics of flowable composites are easy flow, owing to their low viscosity, and slumping tendency after application. When extruded through a syringe needle for adequate adaptation to the cavity wall, it is beneficial for the material's viscosity to decrease and flow easily; following application onto the tooth surface, it is necessary for the material to no longer flow and retain the shape immediately after being applied. Therefore, viscosity change from shearing during extrusion and the slumping tendency after placement are very important factors that exert a considerable effect on the handling properties of flowable composites.

Lee et al. [8] devised an imprint method using an aluminum mold and the slumping resistance index (SRI) to evaluate the slumping tendencies of universal hybrid composites. They reported that the composites showed considerably different SRI values between brands even though they were of the same type of composites produced by the same manufacturer, and that a close relationship existed between the slumping resistance and the viscous modulus of the composite paste. However, no current studies exist that compare the quantitative slumping resistance of flowable composites.

The aim of this study was to present a method for measuring the slumping tendency of flowable composites and to investigate the related rheological properties. It was expected that the slumping tendency would be inversely correlated with the viscosity of the flowable composites.

2. Materials and methods

Five flowable composites were used in this study and the brand names, constituents and manufacturers of the materials are presented in Table 1.

2.1. *Measurement of the slumping tendency of flowable composites*

A custom-made loading device was fabricated onto which a syringe could be attached, and the flowable composite

Table 1 – The flowable resin composites used in this study.

Material	Constituents	Batch No.	Manufacturer
Aeliteflo (AF)	Bis-GMA, TEGDMA 0.7 μm Ba glass (56 wt.%)	0500010629	Bisco (Schaumburg, IL, USA)
Filtek flow (FF)	Bis-GMA, TEGDMA 0.01–6.0 μm Zirconia/silica (68 wt.%)	5GJ	3M-ESPE (St. Paul, MN, USA)
DenFil flow (DF)	Bis-GMA, TEGDMA 0.01–2.5 μm Ba glass/silica (60 wt.%)	FR8406135	Vericom (Anyang, Korea)
Tetric flow (TF)	Bis-GMA, UDMA, TEGDMA 1 μm Ba glass, Ba–Al–F silicate glass 0.2 μm ytterbium trifluoride 0.04 μm silica (68.1 wt.%)	F09392	Ivoclar-Vivadent (Schaan, Liechtenstein)
Revolution (RV)	Bis-GMA, TEGDMA Glass (60 wt.%)	302874	Kerr (Orange, CA, USA)