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Initial fracture resistance and curing temperature rise of ten contemporary resin-based composites with increasing radiant exposure

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ABSTRACT

Objectives: The principal objective of this study was to determine whether the bulk fracture resistance of ten light activated composites varied over a clinically realistic range of radiant exposures between 5 and 40 J/cm^2.

Methods: Ten operators were tested for clinically simulated radiant exposure delivery from a Bluephase® (Ivoclar Vivadent, Schaan, Liechtenstein) LED light to an occlusal cavity floor in tooth 27 in a mannequin head using a MARC®-Patient Simulator (Bluelight Analytics Inc., Halifax, NS) device. Notch disc test samples were prepared to determine the torque resistance to fracture (*T*) of the composites. Samples were irradiated with the same monowave Bluephase® light for 10 s, 20 s or 40 s at distances of 0 mm or 7 mm. After 24 h, storage samples were fractured in a universal testing machine and torque to failure was derived.

Results: Radiant exposure delivered in the clinical simulation ranged from 14.3% to 69.4% of maximum mean radiant exposure deliverable at 0 mm in a MARC®-Resin Calibrator (Bluelight Analytics Inc., Halifax, NS) test device. Mean torque to failure increased significantly ($P < 0.05$) with radiant exposure for 8 out of 10 products. The micro-fine hybrid composite Gradia Direct anterior (GC) had the lowest mean (S.D.) *T* between 10.3 (1.8) N/mm and 13.7 (2.2) N/mm over the tested radiant exposure range. Three heavily filled materials Majesty Posterior, Clearfil APX and Clearfil Photo-Posterior (Kuraray) had mean *T* values in excess of 25 N/mm following 40 J/cm^2 radiant exposure. Mean *T* for Z100 (3MESPE) and Esthet-X (Dentsply) increased by 10% and 91% respectively over the tested range of radiant exposures.

Conclusions: Individual products require different levels of radiant exposure to optimize their fracture resistance. Light activated composites vary in the rate at which they attain optimal fracture resistance.

Clinical significance: Unless the clinician accurately controls all the variables associated with energy delivery, there is no way of predicting that acceptable fracture resistance will be achieved intra-orally.

1. Introduction

Light-activated resin-based composites dominate the market for direct restorations because of increased patient demand for affordable aesthetic treatments. A long service life is possible for posterior composite restorations if patient, operator and materials factors are all controlled.[1] However the median longevity of direct posterior composites placed in

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dental offices is only 6 years.[2,3] Evidence from recent clinical studies identifies bulk fracture as a common cause of failure of large posterior composite restorations.[4,5] Fracture toughness is related to the ability of a material to resist the propagation of a crack from a critical flaw. The relatively low fracture toughness of dental composites makes them susceptible to bulk failure and marginal fracture or chipping.[6,7] Bulk fracture of composites has been correlated to fracture toughness from in vivo and in vitro investigations.[8,9] Fracture resistance is determined by material composition and test method.[10] Many investigations have reported on the fracture properties of dental composites. However it is difficult to make conclusions about the relative fracture resistance of different materials due to differences in test methods and experimental protocols.[11] Adequate polymerization is a fundamental requirement for predictable clinical service of composite restorations. A radiant exposure requirement, that is the product of irradiance and exposure time, may differ with material. Manufacturers recommend minimum radiant exposures for different shades of their products ranging between extremes of 5 J/cm^2 up to 40 J/cm^2. Manufacturers report only test data for products cured under ideal laboratory conditions. This does not account for myriad clinical variables such as underperforming light sources, light dispersion with distance, inadequate access or poor operator technique. The irradiance of commercially available dental curing lights ranges from below 300 mW/cm^2 to above 5000 mW/cm^2. Numerous surveys have shown that many practitioners' lights have inadequate output intensity (defined variously as irradiance $<$200 to $<$400 mW/cm^2). The percentage of inadequate units in these studies ranges from 12% to 95% with a median of 46%. Whilst the dental radiometers used in all but 2 of these surveys are inaccurate in absolute irradiance terms they give us an overall picture of clinical practice.[12,13] A South African survey reported a 100% satisfaction level by dentists with the performance of their light curing units even though nearly half of the units had inadequate output.[14] Prolonged irradiation time may compensate for low irradiance. However many practitioners use short radiation times. Predictable irradiance close to the specimen surface is readily achieved in the laboratory. Clinically, distances of up to 1 cm may occur between the resin and the light source.[15] Correct light alignment and stabilization may be difficult in posterior intra-oral locations. There is up to a tenfold difference in the

Table 1 – Summary of the constituents and quantities/ratios of components contained in the RBCs.

Composite/batch number(s)	Classification	Matrix	Filler type	Filler load	
				wt%	vol%
Filtek Z100 (Z100) 8YR & 7YP	Microfill	BisGMA TEGDMA	Zirconia/silica; 0.01–3.5 μm (84.5 wt%)	84.5	66
Filtek Z250 (FZ) 7MB & 8MB	Microhybrid	BisGMA UDMA BisEMA TEGDMA	Zirconia/silica; 0.01–3.5 μm (84.5 wt%)	84.5	66
Filtek Supreme Body (SuB) 7JH & AY	Nanofill	BisGMA UDMA BisEMA TEGDMA	Silica; 5–20 nm nanoparticle (8 wt%) Zirconia/silica; 0.6–1.4 μm nanocluster (71 wt%)	79	59.5
Filtek Supreme Translucent (SuT) 7CT & 7EA	Nanofill	BisGMA UDMA BisEMA TEGDMA	Silica; 75 nm nanoparticle (40 wt%) Zirconia/silica; 0.6–1.4 μm nanocluster (30 wt%)	70	57.5
Gradia Direct (GD) (anterior) 001969	Microfill/hybrid	UDMA	Silica and pre-polymerized fillers (avg. Particle size 0.85 μm) fluoro-alumino-silicate glass	73	64
Esthet-X (EX) 60701102	Micro-hybrid	BisGMA BisEMA TEGDMA	Barium alumino fluorosilicate glass (BAFG) < 1 μm. BAFG from 0.02 to 2.5 μm (with an average of from 0.6 to 0.8 μm) Nano-sized silicon dioxide particles (10–20 nm)	77	60
Clearfil Majesty Aesthetic (ME) 010CA	Nanofill	Bis-GMA Hydrophobic aromatic dimethacrylate	Silanated barium glass filler (average; 0.7 μm) Prepolymerized organic filler including nanofiller	78	66
Clearfil Majesty Posterior (MP) 008BB	Nanofill	Bis-GMA Hydrophobic aromatic dimethacrylate TEGDMA	Glass ceramic filler (average: 1.5 μm) Surface treated alumina microfiller (average: 20 nm)	92	82
Clearfil AP-X (APX) 1222AA	Micro-hybrid	BisGMA TEGDMA	Barium glass particles (0.04 μm), silica, colloidal silica, silicon dioxide (0.1–15 μm) average = 3 μm	85	71
Clearfil Photo-Posterior (PP) 222BA	Micro-hybrid	BisGMA TEGDMA UDMA	Silanated silica, barium glass, colloidal silica Particle size (0.04–20 μm) average = 4 μm	86	