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Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk-fill composites and incremental filling technique

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ABSTRACT

Objectives: To compare bulk-fill with incremental filling techniques for restoring large mesio-occlusal-distal (MOD) restorations.
Methods: Seventy-five molars with MOD preparations were divided into five groups: Z350XT, incrementally filled with Filtek Z350XT and four bulk-fills—FBF/Z350XT, Filtek Bulk Fill/Filtek Z350XT; VBF/CHA, Venus Bulk Fill/Charisma Diamond; SDR/EST-X, SDR/Esthet-X HD; TEC, TetricEvoCeram Bulk Fill. Cuspal strains were measured using strain-gauges ($n = 10$): CSt-Re, during restorative procedure; CSt-100N, during 100N occlusal loading; CSt-Fr, at fracture load. Before fracture load, teeth were load-cycled. Fracture resistance, fracture mode, and enamel cracks were recorded. The other five teeth were used for Elastic modulus (E) and Vickers hardness (VH). Post-gel shrinkage (Shr), diametral tensile strength (DTS) and compressive strength (CS) were determined ($n = 10$). Shrinkage stresses were analyzed using finite element analysis.
Results: SDR had similar CS values as TEC, lower than all other composites. CHA had similar DTS values as Z350XT, higher than all other composites. Z350XT had the highest mean Shr and SDR the lowest Shr. New enamel cracks and propagation was observed after the restoration, regardless of filling technique. Z350XT had lower fracture resistance than bulk-fill composite techniques. No significant differences in failure modes were found. E and VH were constant through the depth for all techniques. Bulk-filling techniques had lower stresses compared to Z350XT.
Conclusions: Flowable bulk-fill composites had lower mechanical properties than paste bulk-fill and conventional composites. All bulk-fill composites had lower post-gel shrinkage than conventional composite. Bulk-fill filling techniques resulted in lower cusp strain, shrinkage stress and higher fracture resistance.
Clinical significance: Using bulk-fill composites cause lower CSt wich indicates lower stress in restored tooth. Furthermore, bulk-fill composites have a higher fracture resistance. Therefore, clinicians may choose the bulk-fill composite to decrease undesirable effects of restoration while simplifying filling procedure.

1. Introduction

Resin composites have been extensively employed in restorative dentistry for several decades [1]. More than five hundred millions direct dental restorations are placed every year around the world which represents one of the most prevalent medical interventions in the human body [2]. Incremental filling technique has been used for placement of resin composite restoration [3–5]. However, the post-operative sensivity is frenquently observed, which is commonly associated with polymerization shrinkage stresses [5].

Different filling techniques and composite resins have been developed in order to minimize polymerization shrinkage and their clinical effects [6]. The latest trend in composite technology

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was the development of the so-called “bulk-fill” composites [7]. These new materials were created in order to cure up to 4 mm deep [8]. Bulk-fill composites are gaining popularity among the clinicians because they simplify the restorative procedure by reducing the number of composite layers and thus the curing time [2]. The deeper cure in bulk-fill composites is made possible by adjustements in translucency and photoinitiators. An additional initiator system has been introduced in Tetric EvoCeram Bulk Fill (Ivocerin), which is described as a germanium based initiator system with a higher photocuring activity than camphoroquinone [9]. Meanwhile, their opacity is an advantage over other bulk-fill composites in terms of acceptable esthetics for placement in the visible zone, e.g., mesial class II restorations [10].

Composite resin composition and filling techniques are among the primary approaches to reduce volumetric contraction and shrinkage stress development [11,12]. Restoration placement in increments or bulk is also widely considered a factor in the modification of shrinkage stresses [3,4,13]. Although Incremental filling techniques have often been assumed to decrease the shrinkage stresses, finite element analysis has shown that bulk placement may produce lower residual shrinkage stresses [5,14]. The concept of bulk-filling is not a novel idea [15], and has been evaluated numerous times in the literature [13,16–21]. However, how much stress is generated by polymerization shrinkage depends on more factors than mechanical properties of resin composites and restorative filling techniques, such as curing light intensity, photoactivation time, mechanical properties of the tooth structure, and geometry and extent of the cavity [14–22].

The success of composite resin restorations is associated with their mechanical properties [4]. The first-generation flowable composites were not suitable for full-depth posterior fillings because of their inferior mechanical properties and increased volumetric shrinkage compared to conventional paste-like composites, primarily due to the lower filler content [23–26]. Bulk-fill seems very similar in chemical composition as regular nanohybrid and microhybrid resin composites [27]. Some bulk-fill composites require a final 2 mm increment of a conventional composite material while other bulk-fill composites can be placed without this final layer. This different application of the same material class may confuse some practitioners [28].

Few studies have examined the complete biomechanical performance of the new bulk-fill materials. Therefore, the aim of this study was to evaluate the mechanical properties expressed by hardness, elastic modulus, post-gel shrinkage, compressive and tensile strength and the biomechanical performance expressed by cuspal strain, enamel crack detection, fracture resistance and stress distributions of new bulk-fill composites in molars with large class II mesio-occlusal-distal (MOD) restorations. The null hypothesis tested was that the biomechanical behavior would not be affected by the restorative material and filling technique (bulk-fill or conventional composites).

2. Materials and methods

2.1. Study design

Four bulk-fill and one incrementally placed conventional composites were tested in this study. All composite resins were tested for compressive strength (CS), diametral tensile strength (DTS), which were used to determine the Modified von Mises stresses, and post-gel shrinkage (Shr). Human molars with MOD cavities were restored according to manufacturer’s instructions. Teeth were tested for cuspal strain using strain-gauges during filling (CSt-Re), during 100N occlusal loading (CSt-100N), and at fracture (CSt-Fr). Enamel crack were detected and tracked (Ect) using transillumination. Fracture strength (Fs) and fracture mode (Fm) were tested in axial occlusal compressive loading. Vickers hardness (VH) and Elastic modulus (E) of the composites were tested at different depths using dynamic indentation. Finally, shrinkage stresses and the stresses during compressive loading were evaluated by finite element analysis (FEA) using Modified von Mises (mvm) and Critical Modified von Misses (Cr-mvm).

Table 1
Composite resins composition.

Material	CODE	Shade	Composite type	Increment size and light activation time	Organic matrix	Filler	Filler% wt/Vol	Manufacturer
Tetric EvoCeram bulk fill	TEC	IVA	Bulk-fill paste composite	4.0 mm–20 s	UDMA, BISGMA	Barium glass, ytterbium trifluoride, mixed oxide prepolymer	79/61	(Ivoclar Vivadent, Schaan, Liechtenstein)
Venus bulk fill	VBF	A2	Bulk-fill flowable composite	4.0 mm–20 s	UDMA, TEGDMA	Barium glass, ytterbium trifluoride, silicon dioxide	65/38	Heraeus-Kuzer, (Hanau, Germany)
Filtek bulk fill	FBF	A2	Bulk-fill flowable composite	4.0 mm–40 s	UDMA, BISGMA, EBPADMA, Procrylat resin	Silane treated ceramic and YbF3	64/ 42.5	3M-ESPE (St. Paul, MN, USA)
SDR	SDR	A2	Bulk-fill flowable composite	4.0 mm–20 s	Modified UDMA, dimethacrylate and difunctional diluents	Barium and strontium alumino-fluoro- silicate glasses	68/44	Dentsply, (Konstanz, Germany)
Esthet X HD	EXT-X	A2	Microhybrid composite	2.0 mm–20 s	Bis-GMA adduct, EBPADMA, TEGDMA	Ba-F-Al-B-Si-glass, silica	76/60	Dentsply, (Konstanz, Germany)
Charisma diamond	CHA	A2	Nanohybrid composite	2.0 mm–20 s	TCD-DI-HEA, UDMA	Bariumm, aluminium, fluoride glass	81/64	Heraeus-Kuzer, (Hanau, Germany)
Filtek Z350XT	Z350XT	A2	Nanofilled composite	2.0 mm–20 s	Bis-GMA, Bis-EMA, UDMA, TEGDMA	Silica and zirconia nanofillers, agglomerated zirconia-silica nanoclusters	82/60	3M-ESPE (St. Paul, MN, USA)