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Assessment of compressive and flexural properties of three contemporary bulk fill resin composites

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ABSTRACT

Contemporary restorative materials must demonstrate how much stress they can withstand before permanently deforming under the constant forces generated during chewing. ***Aim:*** *To compare the compressive and flexural strength of three bulk fill resin composites.* ***Materials and Method:*** *This study analyzed three bulk fill resin composites: Opus™ bulk fill (OBF), Tetric® N-Ceram bulk fill (TNC), and Filtek™ bulk fill (FBF), and one conventional resin composite: Filtek™ Z350XT (FZXT) as a control group. Each composite was used to prepare 14 cylindrical specimens (n=56) for compressive strength tests, and 19 rectangular specimens (n=76) for flexural strength tests. Mechanical tests were performed using an Instron® universal testing machine - 100 kN load at a speed of 1 mm/1min.* ***Results:*** *Descriptive (Mean ± SD) and inferential statistics (Kruskal-Wallis test/ post-hoc test), p<0.05 were used. The compressive test results (Means ± SD) were: OBF (141.68MPa ± 22.20), TNC (139.03MPa ± 23.56), FBF (235.59MPa ± 26.08), and FZXT (99.28MPa ± 11.36). The flexural test results (Means ± SD) were: OBF (116.29 ± 7.20), TNCBF (109.67MPa ± 7.58), FBF (200.53MPa ± 10.32), and FZXT (90.08MPa ± 8.63). Statistically significant differences were found between the resin composites (p<0.001) in both mechanical tests.* ***Conclusion:*** *The bulk fill resin composites demonstrated higher compressive and flexural strength than the conventional resin composite. However, the use of these restorative materials may depend on specific clinical requirements and material handling preferences.*

Keywords: *compressive strength - composite resins - dental materials - flexural strength*

Evaluación de las propiedades compresivas y flexurales de tres resinas bulk-fill contemporáneas

RESUMEN

Los materiales restauradores contemporáneos deben demostrar una adecuada resistencia a la deformación frente a las fuerzas masticatorias constantes a las que se encuentran sometidos. ***Objetivo:*** *El objetivo de este estudio fue comparar la resistencia compresiva y flexural de tres resinas compuestas bulk fill— Opus™ Bulk Fill (OBF), Tetric® N-Ceram Bulk Fill (TNC) y Filtek™ Bulk Fill (FBF)—con una resina compuesta convencional, Filtek™Z350XT (FZXT), empleada como grupo control.* ***Materiales y Método:*** *Se prepararon 56 especímenes circulares para la prueba de resistencia compresiva (n=14 por grupo) y 76 especímenes rectangulares para la prueba de resistencia flexural (n=19 por grupo). Las pruebas mecánicas se realizaron en una máquina universal de ensayos Instron® (capacidad de carga de 100 kN) a una velocidad de 1 mm/min. Se emplearon estadísticas descriptivas (media ± DE) y análisis inferenciales (prueba de Kruskal–Wallis con comparaciones post-hoc; α=0.05).* ***Resultados:*** *Los valores de resistencia compresiva (media ± DE) fueron: OBF: 141.68 ± 22.20 MPa, TNC: 139.03 ± 23.56 MPa, FBF: 235.59 ± 26.08 MPa y FZXT: 99.28 ± 11.36 MPa. Los valores de resistencia flexural (media ± DE) fueron: OBF: 116.29 ± 7.20 MPa, TNC: 109.67 ± 7.58 MPa, FBF: 200.53 ± 10.32 MPa y FZXT: 90.08 ± 8.63 MPa. Se encontraron diferencias estadísticamente significativas entre las resinas compuestas en ambas pruebas (p<0.001).* ***Conclusión:*** *Las resinas compuestas bulk fill mostraron valores significativamente mayores de resistencia compresiva y flexural en comparación con la resina compuesta convencional. Sin embargo, el uso de estos materiales restauradores puede depender de necesidades clínicas específicas y las preferencias en la manipulación del material.*

Palabras clave: *resistencia compresiva - resinas compuestas - materiales dentales - resistencia flexural.*

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INTRODUCTION

Conservative restorative procedures are recommended to replace the complete removal of all carious tissues in the management of dental caries. In some clinical cases, these procedures involve extensive restoration (direct or semi-direct). However, resin composite restorations can fail due to the reduced mechanical and physical properties of this type of cavity configuration. There is often a correlation between compressive strength and flexural strength, but not always in direct proportion. During chewing and mandibular movements, resin composite restorations are subject to vertical (compression) and tangential (bending or flexure) forces, so it is important that they have good short- and long-term clinical performance[1,2]. Bulk fill resin composites seem to satisfy this requirement.

Bulk fill resin composites were introduced in 2010 and can be placed in a single step up to 5 mm in depth, depending on the manufacturer's instructions. They are designed for use in wide and deep cavities, eliminating the need for an additional capping layer. Bulk-fill resin composites provide several advantages, including ease of handling, time efficiency during clinical procedures, reduced risk of errors in restorative applications, minimized polymerization shrinkage, and decreased cuspal deflection[2,3]. They can be applied in ≥ 4 mm increments[4,5], and contain photoinitiators such as Ivocerin and Camphorquinone, which can be activated through high-intensity light (up to 1000 nm) that enables additional light penetration to the dentin at the bottom of the cavity.

Given the increasing interest in bulk-fill resin composites, the aim of this study was to compare the compressive and flexural strength of three bulk fill resin composites and one conventional resin composite.

MATERIALS AND METHOD

This was an *in vitro* study with experimental design. It was approved by the Ethics Committee of Faculty of Health Sciences of Universidad Peruana de Ciencias Aplicadas (Number PI 121-17)

The following composites were analyzed and divided in groups according to each test: Opus™ bulk fill *(OBF)*, G2- Tetric® N-Ceram bulk fill *(TNC)*, Filtek™ bulk fill *(FBF)*, and Filtek™ Z350XT *(FZXT)* conventional resin composite as a control group. The restorative materials used in this study are described in Table 1.

Table 1. Characteristics of the materials used in the study.

Material	Shade	Country	Manufacturer	Composition	Filler amount (Wt/Vol)	Filler size (µm)	Batch Number
Opus™ Bulk Fill **(OBF)** **G1-G5**	A2	Brazil	FGM	Urethane dimethacrylate, stabilizers, camphorquinone, co-initiator, inorganic load filler of silanized silica dioxide, stabilizers and pigments.	79% (wt)	10 - 0.7 µm	030817
Tetric® N-Ceram Bulk Fill® **(TNC)** **G2-G6**	IVA	Liechtenstein	Ivoclar Vivadent	Dimethacrylates, Bis-GMA, Bis-EMA, Barium glass, Ytterbium trifluoride, prepolymer, mixed oxide, additives, stabilizers, catalysts and pigments.	53%-55% (vol)	0.04 -3 µm	W36673
Filtek™ Bulk Fill **(FBF)** **G3-G7**	A2	USA	3M ESPE	Silica, zirconia, ytterbium trifluoride, AUDMA, UDMA, AFM, 1, 12-dodecane-DMA	58.4% (vol)	0.004 -0.1 µm	N857430
Filtek™ Z350XT **(FZXT)** **G4-G8**	A2	USA	3M ESPE	Silica, zirconia, bis-GMA, UDMA, TEGDMA, and bis-EMA.	55.6% (vol)	0.6 - 20 µm	N741410

Compressive and flexural tests

To test compressive strength, 14 cylindrical specimens (3 mm x 5 mm) were prepared from each composite (n=56) (G1 to G4). To test flexural strength, 19 rectangular specimens (2 mm x 2 mm x 25 mm, ISO 4049-2000) were prepared from each composite (n=76) (G5 to G8).

The bulk fill resin composites were placed in molds using the single increment technique (5 mm), and the conventional resin composite was placed using the oblique incremental technique (2 increments/2 mm). The curing time was selected according to manufacturer's indications, and performed using a LEDdition® (Ivoclar Vivadent, Liechtenstein, 850mW/cm^2- OBF: 40 sec/5mm, TNC: 20 s /5 mm, FBF: 40 s /5 mm and FZXT: 20 s/2 mm). Compressive test specimens were cured up to 1 cm below the outer surface layer. Flexural test specimens, due to their size, were light-cured at three consecutive points (right side, middle area, and left side). Subsequently, all specimens were stored at 37 +/- 5 °C in an oven (Hotpack® 355381 - USA) for 24 hours.

The compressive and flexural strength of the specimens were tested using an Instron® universal testing machine (Model 3382 -USA). For the compressive test, the specimen was placed vertically between two compression plates, which were connected to the load measuring cell with a constant 100 kN load applied at a crosshead speed of 1 mm/1 min until the specimen fractured. For the flexural strength test, the specimen was placed horizontally on the three-point bending device (Code OA41, ODEME, Brazil) at a crosshead speed of 1 mm/1 min until the specimen fractured. The data analysis was performed using descriptive (Mean ± SD) and inferential statistics (Kruskal Wallis test / post hoc test; p<0.05) for group comparisons.

RESULTS

Table 2 provides the mean values (MPa) of the compressive and flexural strengths of the experimental groups, and the comparisons using Kruskal Wallis tests (*post hoc* test). Statistically significant differences were found among the bulk resin composites (p<0.01) and compared to the conventional resin composite. Among the bulk fill resin composites, Filtek™ Bulk Fill showed the highest mean values of compression and flexural strength, followed by Opus™ Bulk Fill and finally Tetric® N-Ceram Bulk Fill® (p<0.05; Table 2).

DISCUSSION

Compressive and flexural strength are key properties for dental composites, reflecting their ability to withstand chewing forces without permanent deformation. In this study, all three bulk-fill resins – Opus™ Bulk Fill (OBF), Filtek™ Bulk Fill (FBF), and Tetric® N-Ceram Bulk Fill (TNC) – performed better than the conventional resin composite. Filtek™ Bulk Fill consistently demonstrated the highest values of compressive and flexural strength. These results align with previous studies and highlight the advantages of bulk-fill materials for posterior restorations[1,3,4,6-8].

The strong mechanical behavior of these materials is largely provided by their composition. Higher filler content and smaller particle sizes increase stiffness and strength, while high-molecular-weight monomers such as UDMA, AUDMA, and bis-EMA help reduce polymerization shrinkage and stress, creating a more stable, cross-linked polymer network[1,4,6,8]. In addition, AFM (Addition–Fragmentation Monomer) acts as a stress-relieving agent by allowing reversible bond cleavage during polymerization, particularly in deeper layers, which helps maintain both compressive and flexural

Table 2. Comparison of compressive and flexural strength of bulk fill resin composites

Resin composites	Compressive Strength			Flexural strength		
	Mean (MPa)	SD	p*	Mean (MPa)	SD	p*
Opus™ Bulk Fill **(OBF)**	141.68 b	22.20	<0.001	116.29 b	7.20	<0.001
Tetric® N-Ceram Bulk Fill® **(TNC)**	139.03 b	23.56		109.67 b	7.58	
Filtek™ Bulk Fill **(FBF)**	235.59 a	26.08		200.53 a	10.32	
Filtek™ Z350XT **(FZXT)**	99.28 c	11.36		90.08 c	8.63	

* Kruskal Wallis test (post hoc) among all groups. Significance level (p<0.05).
The same letters indicate no significant statistical difference.

integrity[1,6]. Specifically, Opus™ Bulk Fill combines ~79% filler by mass with a UDMA-based matrix to dissipate stress effectively; Tetric® N-Ceram Bulk Fill uses high-molecular-weight monomers such as dimethacrylates, Bis-GMA, Bis-EMA with filler-refractive index, matching to optimize light penetration; and Filtek™ Bulk Fill further combines UDMA, bis-EMA, AFM, and AUDMA stress-relieving monomers, with an optimized zirconia/silica filler system, enhancing its compressive and flexural properties[3,7,8].

Polymerization efficiency and depth of cure are equally important. Proper light penetration and a high degree of conversion produce a stable, cross-linked network that minimizes residual monomers and stress concentration, directly influencing mechanical strength[8-10]. Bulk-fill composites are designed for increments of 4–5 mm, and their resin-filler systems, combined with refractive index matching and internal light reflection, ensure uniform curing even in deeper regions of the restoration[3-5]. Inadequate polymerization at greater depths, however, can reduce cross-linking, lowering stiffness and compressive and flexural resistance, which underscores the need for proper curing strategies, including correct light intensity, exposure time, and additional techniques for proximal and deep areas[3,6,7,10,11]. In Opus™ Bulk Fill, the urethane dimethacrylate matrix and high filler content facilitate stress dissipation, improving compressive and flexural resistance[1,7]. Filtek™ Bulk Fill benefits from high-molecular-weight monomers (UDMA, bis-EMA, AUDMA) and stress-relieving AFM, which stabilize the polymer network and allow superior depth of cure, particularly in deeper increments[1,6,8]. Tetric® N-Ceram Bulk Fill achieves adequate polymerization through high-molecular-weight monomers and optimized filler-refractive index matching, ensuring a sufficient degree of conversion in deeper regions and supporting mechanical strength[3-5]. Efficient polymerization throughout the entire increment depth is essential for maximizing compressive and flexural performance, especially in deep or extensive cavities [3-5,9,11]. Clinicians should consider complementary strategies to achieve adequate polymerization at high-increment depths in deep cavities[3,6,7,11], both on occlusal surfaces and in proximal regions, after removal of the sectional or other matrix systems.

High-intensity curing lights (>1100 mW/cm²) are optimal for bulk-fill composites, though sufficient polymerization can also be achieved with lower-intensity lamps (~850 mW/cm²) if exposure time is properly adjusted[10,11]. In essence, the combination of optimized monomer systems, stress-relieving agents, high filler loading, and effective polymerization explains the excellent mechanical performance observed in all three bulk-fill resins. Whilst Filtek™ Bulk Fill showed stronger mechanical properties than the others, Opus™ Bulk Fill and Tetric® N-Ceram Bulk Fill also demonstrated good mechanical properties, supporting them as reliable dental materials for extensive posterior restorations[1,3,6-8].

New restorative dental materials are continuously being developed, so it is of the utmost importance to constantly evaluate the mechanical properties that improve the clinical and functional behavior of extensive restorations.

CONCLUSION

The bulk fill technique can be considered an effective alternative to the incremental fill technique for restoring extensive occlusal and proximal cavities. The bulk fill resin composites tested demonstrated superior compressive and flexural strength to the conventional resin composite. Use of these restorative materials may depend on specific clinical requirements and material handling preferences.

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CONFLICT OF INTEREST

The authors declare no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

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