Advances in Science and Technology Research Journal

Advances in Science and Technology Research Journal, 2025, 19(9), 516–522
https://doi.org/10.12913/22998624/207424
ISSN 2299-8624, License CC-BY 4.0

Received: 2025.06.22
Accepted: 2025.07.15
Published: 2025.08.01

Compressive strength and fractographic analysis of fractures in glass fibre-reinforced dental composite material

Janusz Tarczydło[1], Monika Ostapiuk[2*], Karolina Jurek[3], Bożena Tarczydło[4]

[1] Private Practice of Dentistry "Perfekt Dent" ul. Ułanów 1, 20-554 Lublin
[2] Faculty of Mechanical Engineering, Department of Materials Engineering, Lublin University of Technology, ul. Nadbystrzycka 36, 20-618 Lublin
[3] Graduate of Lublin University of Technology, ul. Nadbystrzycka 36, 20-618 Lublin
[4] Faculty of Medicine and Dentistry, Department of Conservative Dentistry with Endodontics, Medical University of Lublin, ul. Chodźki 6 20-093 Lublin
* Corresponding author's e-mail: m.ostapiuk@pollub.pl

ABSTRACT

The objective of this study was to evaluate the compressive strength of a glass fibre reinforced (GFR) composite material used in restorative conservative dentistry. The following dental composites were used in the work: EverX Posterior (GC Europe) GFR composite and Filtek Z250 (3M ESPE) conventional composite for fabricating phantoms which imitated molar crowns. Compression tests were performed and an analysis is provided here for the fractures formed during the application of compressive forces. It was found that the short fibres, rather than the polymer matrix itself, were responsible for the load transfer. The voids visible after removal of the fibres and the cracks in the polymer matrix are indicative of a force required to cause a GFR composite failure that is higher than the force required to cause a conventional composite filling failure. The phantoms made of the GFR composite showed greater strength than polymer-filled phantoms, devoid of short glass fibres.

Keywords: compression, short glass fibre, composite fillings, everX Posterior.

INTRODUCTION

Dental restorative materials are used to repair teeth damaged by injury or disease. Therapeutic treatment should result in the reconstruction of the shape, aesthetics and function of the teeth. Dysfunctions in the stomatognathic system associated with the destruction or loss of teeth can cause pain, malnutrition, speech disorders, temporomandibular joint disease and other pathologies, as well as systemic diseases. In addition, dentition as an important part of facial appearance is important for continued high self-esteem, mental health, well-being and interpersonal relations. There are an increasing number of reports in the reference literature demonstrating the link between oral health and systemic disease, and the health and function of the whole body [1–4].

The restoration of the aesthetics and function of teeth is therefore the primary objective of restorative dentistry. Hence, there is a very high demand for dental restorative materials that reproduce the appearance and function of natural tooth tissue. The choice of material is driven by aesthetic qualities and its physical and mechanical performance. Dental material manufacturers have introduced bulk-fill composites to simplify the application procedure, condensation and polymerisation of the material in the cavity.

As mentioned by Kumar, bulk-fill materials are present in unidoses, syringes or tubes. The filler content and incorporation of fibres in the bulk-fill composites are classified into various types [5].

The placement procedure for bulk-fill restorations is faster in time because of the feasibility of introducing and polymerising these composites in a 4–5 mm layer. In addition, the relatively low shrinkage of these materials, coupled with the high filler content result in low shrinkage stresses, allowing thicker layers to be deposited. The main advantages of resin-based composite restorations require minimal tooth preparations, and the entire restorative procedure which could be in one single appointment; it is cost-effective, too [6].

There are many composite materials on the dentistry supplies market used for reconstruction of missing tooth tissues. The compositions of these materials include micro, macro, and nanoparticles and feature different physical and mechanical properties, along with different aesthetic finish qualities. However, they did not include a material comprising glass fibres which improve the strength of the polymer matrix. Glass fibre-reinforced (GFR) composite materials are unique and innovative solutions which have been available on the market for a few years only, under brand names EverX Posterior and EverX Flow GC. As tooth enamel substitutes, most composite materials provide optimum properties, like high abrasion resistance and good aesthetic qualities. However, they cannot be put on par with dentin in terms of cracking resistance. The EverX composite material solves this issue with an excellent cracking resistance which is comparable to that of dentin, by virtue of short glass fibres that are strongly bonded to the resin matrix [3].

This is of fundamental importance in clinical practice, as the composite material allows retaining the organic tooth tissues while reinforcing them without any need of enhanced grinding (deduction) otherwise require to crown a tooth. Another important matter is cost efficiency; direct reconstruction of teeth using an innovative GFR composite that meets the parameters and specifications concerning the occlusion forces is a far less expensive alternative to patients than a laboratory-fabricated prosthetic crown [5].

EverX Posterior is a glass fibre-reinforced (GFR) bulk-fill composite used as a dentin ‘substitute’. Thanks to the presence of glass fibres, it boasts very good strength properties. The fibres inhibit the propagation of cracks in the material and dental structures. Thanks to its properties, EverX Posterior is used for the restoration of large and deep cavities, particularly in posterior teeth. It also finds applications in tooth restoration after endodontic treatment. The manufacturer recommends covering the EverX Posterior composite with a layer of conventional light-curing composite. FiltekTM Z250 is a universal light-curing composite material. It designed for filling cavities in anterior and posterior teeth.

According to Drummond JL, the damage to composite material may results from deterioration of the matrix and fillers or is due to mechanical and environmental loads, interfacial debonding, microcracking or filler particle fracture, which may reduce the survival probability of composite restorations during in vivo tests [7]. Properties like compressive strength test, flexural strength, hardness and elastic moduli improve as the filler content increases [8].

The objective of this study was to evaluate the compressive strength of a glass fibre reinforced (GFR) composite material used in restorative conservative dentistry.

MATERIALS AND METHODS

The following dental composites were used in this study (Table 1). In the everX Posterior composite, the short glass fibres protect from and inhibit fracture growth in the restoration and in the teeth. Moreover, a fracture resistance similar

Table 1. The composition of the two composite materials used in the study [9]

Composite	EverX posterior	Z250 Filtek
Manufacturer	GC Europe	3M ESPE
Type	Fiber-reinforced composite	Nano-hybrid zirconia filled composite
Resin matrix	Bis-GMA TEGDMA PMMA	Bis-GMA UDMA TEGDMA Bis-EMA PEGDMA
Fillers	E-glass fibers length (1–2 mm) Diameter (17 μm) Barium borosilicate glass (0.1–2.2 μm)	Surface modificate zirconia/silica (≤ 3 μm) Non-agglomertaed/nonggregated surface-modified silica (20 nm)

to that of dentin and almost double that of any composite is achieved. There is minimal linear contraction due to the orientation of fibres.

These materials were used to fabricate molar crown phantoms in dedicated celluloid moulds imitating the shape and size of human molars. Two types of phantom models were made. The first type group comprised dental crown phantoms, made of the everX Posterior GFR composite coated with a conventional composite, Filtek Z250 Group One ($_{\text{Phantoms E}}$). The second type group ($_{\text{Phantoms F}}$) comprised phantom models in which the crown was restored with a single composite material, Filtek Z250, layered and polymerised.

Compressive strength

Compressive strength tests were carried out on a Shimadzu AG-X testing machine with a force range of 20 kN. The feed rate was 2mm/min for each specimen. The counter-specimen in the compressive strength test was a rod with a 10 mm spherical tip. This rod ensured that the applied load represented the true state when the highest bite forces were present (Figure 1).

Fracture analysis

A detailed analysis of the fractures produced by failure of the phantoms in compressive strength test was carried using a Nikon SMZ 1500 stereo microscope (Nikon, Japan).

Figure 1. View of a compression test specimen with the phantom mounted

Microstructure

The microstructure examination of failed phantoms made of the composite materials was performed on a Nova NanoSEM 450 high-resolution scanning microscope (ThermoFisher, USA) set to 100 Pa low vacuum, 4.0 spot size and 10 kV voltage. In addition, an analysis of the interphase connections and an analysis of the fractures resulting from the compressive strength test were done.

RESULTS

Table 2 shows the results which define the most important parameters obtained during the phantom compressive strength test. In the analysis of the maximum force values (Table 2, Figure 2) at which the Phantoms F and Phantoms E failed revealed that the failure force was approximately 1750 N and 2000 N, respectively. The yield point defines a stress value that causes irreversible plastic deformation in the material. Comparing these force values, it is apparent that Group One (E) had a higher compressive strength of approximately 300 N compared to Group Two (F). In addition, Group One (E) achieved a Young's modulus value that was close to that of the glass fibres themselves.

The t-student test was done. The parametric student's T test showed that there were statistically significant differences $p = 0.000005$, i.e. $p < 0.05$.

Figure 3 shows the fractures of the phantoms of both groups after the compressive strength tests. Figure 3 reveals that the failure mode of the phantoms varies between the groups. In Group One $_{\text{Phantom E}}$ a clear separation of the two composite materials at the separation boundary can be seen. In contrast, in Group Two $_{\text{Phantom F}}$ the fracture ran from the nodule through the entire composite. A fractographic analysis of the fractures in the phantoms is shown in the Figure 4 and 5.

In Group One $_{\text{Phantom E}}$, fracture was found across the fibre boundaries and voids were observed after removal of the glass fibres (Figure 4a, b). The composite also revealed areas of recoil from the oriented glass fibres, shown in highlighted in red in the figures. In Figure 4c, there is presence of glass fibre fractures formed during

Table 2. Average force values for the test groups one and two

Name	Group one $_{Phantoms\ E}$	Group two $_{Phantoms\ F}$
Young's modulus [GPa]	18.81 ± 0.12	14 ± 9.89
Max force [N]	2010 ± 65.66	1742 ± 35.09
Max stress [MPa]	40 ± 2.46	34 ± 3.86

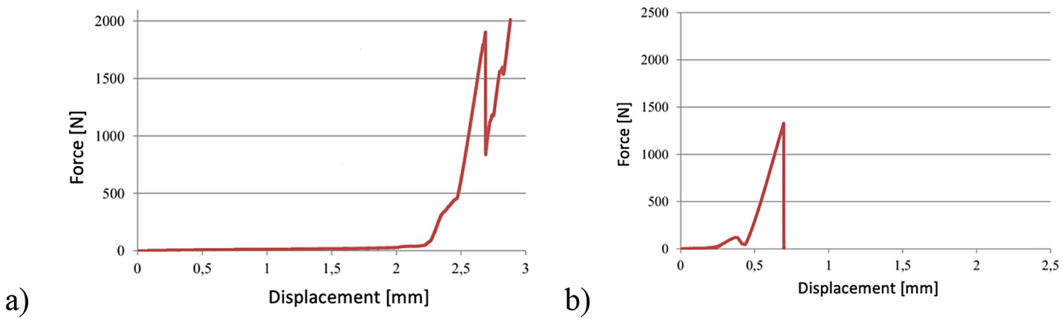

Figure 2. Compressive strength force vs. displacement diagram for: (a) Group One $_{Phantom\ E}$ and (b) Group Two $_{Phantom\ F}$

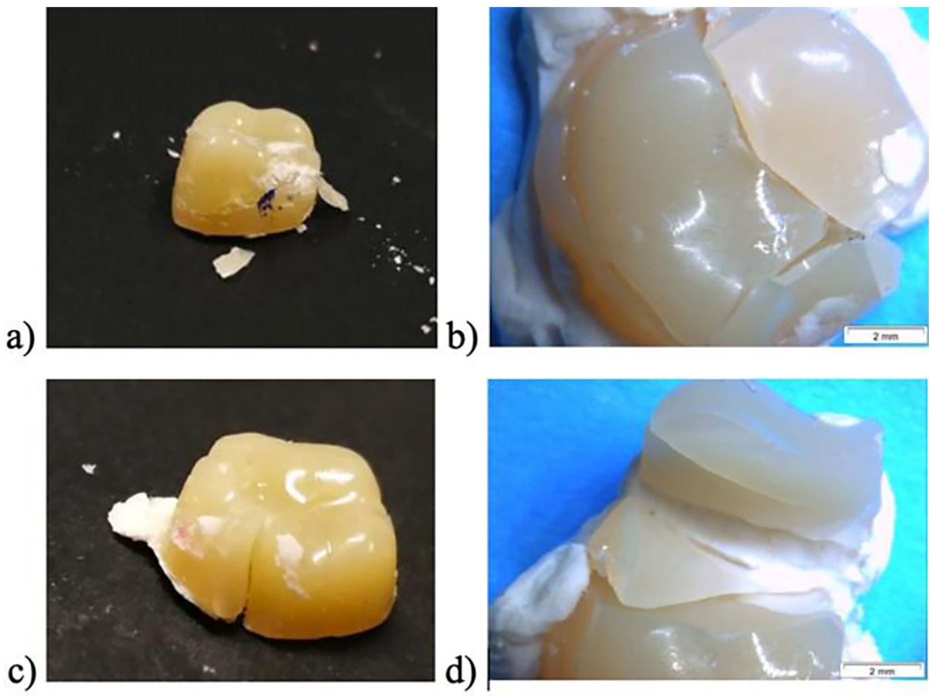

Figure 3. View of the two phantoms after the compression test for: a), b) Group One $_{Phantom\ E}$ and c), d) Group Two $_{Phantom\ F}$; stereoscopic microscope imaging

the compressive strength tests. The weakest point can be noticed, which was the location of fracture initiation, with fracture propagation lines.

Figure 5 reveals the separation boundary of the two composites in Group One $_{Phantom\ E}$. In addition to the readily visible separation boundary where the fracture occurred, voids can be seen left by the pulled out glass fibres.

Figure 6 shows an analysis of the fractures in Group Two $_{Phantom\ F}$. The cracks in the composite are visible, along with the internal structure, where individual filler particles are evident.

This work presents a failure analysis of selected composite materials used in restorative conservative dentistry. The tests were performed in two groups of phantoms, which were formed to

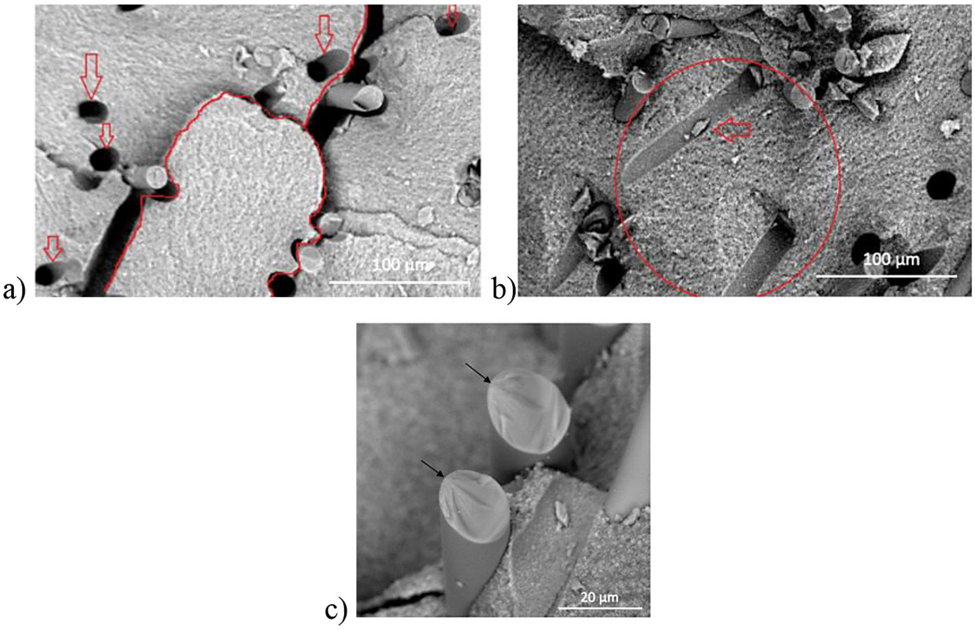

Figure 4. Fractures: a), b) of phantoms in Group One $_{\text{Phantom E}}$ with a clear fracture mode and c) failure of fibres; SEM imaging

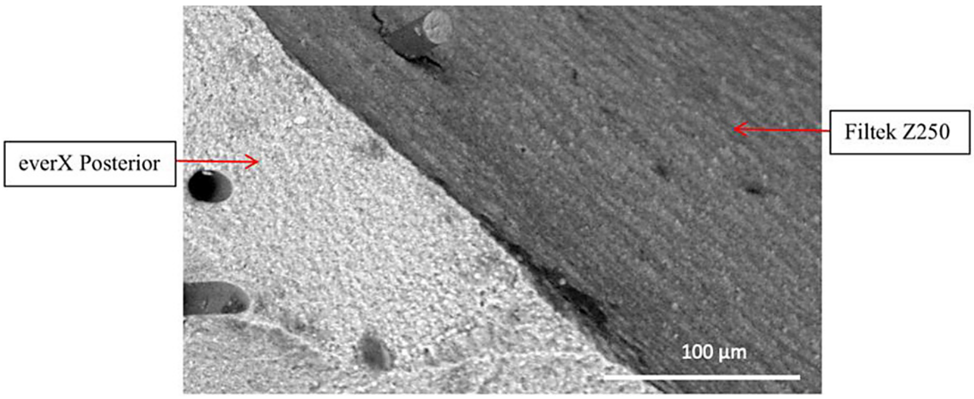

Figure 5. Separation boundary between the composites in Group One $_{\text{Phantom E}}$; SEM imaging

model tooth crowns. The first group of phantoms was fabricated using the everX Posterior GFR composite material overlaid with a conventional Filtek Z250 composite, while the second group of dental crown phantoms were made using a single type of composite material only, Filtek Z250. Compressive strength tests were carried out to evaluate the state of failure of the materials used in the phantoms. After analysing the compressive strength tests, it can be concluded from the data in the tables and graphs that each of the materials revealed correspondingly high strength levels.

Considering that the highest bite forces are present on the molars and are estimated to be around 580 N, the composite materials used for the tests, both Filtek Z250 and everX Posterior, revealed sufficiently high strength levels, as fracture of the specimens occurred at maximum force values of more than 1300 N.

In contrast, when comparing the maximum forces of specimen fracture, the phantoms using the everX Posterior GFR composite revealed significantly higher strength levels. Similar observations were made by Lassila L. et al. who demonstrated very favourable failure performance for a GFR material [10]. Lassila L. et al. observed good shearing properties. This was driven by the additional glass fibres present in the everX Posterior structure. Higher maximum stresses was found in the phantoms made with everX Posterior, which may also be significantly affected by the glass fibres, items of low stiffness. It is the glass fibres

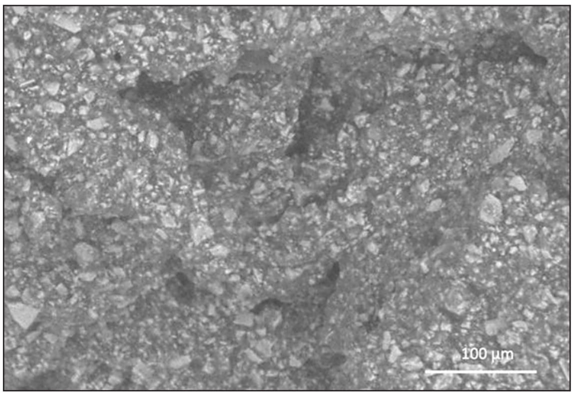

Figure 6. Fracture in Group Two $_{\text{Phantom F}}$ with clearly visible cracking in the composite material; SEM imaging

that were responsible for the transfer of stresses. They were shaped like perfectly smooth cylinders that adhered very well to the matrix [10].

The short fibres increased the material's resistance to crack propagation and reduction of stress severity within the cracks. Fracture toughness is a mechanical property that tells the resistance of brittle materials to the propagation of defects under a load, and therefore, the material's tolerance to damage [12].

Flexural strength results in Abdulp-Monem et al. [9] showed that the fiber-reinforced composite had the highest flexural strength compared to the nano-hybrid composites, similarity as the Autor's study. According with Cipmean [13] the fiber reinforced composite everX Posterior has been shown to increase the fracture resistance endodontically treated teeth. Using everX posterior as a dentine replacement in large cavities and overlaying it with a conventional composite for enamel replacement creates a biomiemetic restorations of the tooth and provides a solution for stronger more durable posterior composite restorations.

Garoushi et al. explains that the mere insertion of fibers does not enhance the fracture resistance properties, but its length and diameter play a vital role [14–15].

CONCLUSIONS

The phantoms made of the GFR composite showed greater strength than polymer-filled phantoms, devoid of short glass fibres. The short fibres, rather than the polymer matrix itself, were responsible for the load transfer.

The deterioration of the GFR composite phantoms was less destructive, as the glass fibres absorbed the failure forces. The fracture analysis revealed that the separation boundary between specific composite layers remained intact, a tell-tale of their good mutual adhesion.

The voids visible after removal of the fibres and the cracks in the polymer matrix are indicative of a force required to cause a GFR composite failure that is higher than the force required to cause a conventional composite filling failure.

Acknowledgements

The work was carried out within the statutory activities of the Mechanical Engineering discipline of the Lublin University of Technology, no. FD-20/IM-5/077.

REFERENCES

1. Lassila L., Keulemans Silynoja E., Valittu P.K., GaroushiS. Mechanical properties and fracture behaviour of flowable fiber reinforced composite restorations Dent Mater. 2018; 34: 598–606.
2. Lasilla L. Sälilynoja E., Prinssi R., Valittu P., Garoshi S. Characterization of a new fiber-reinforced flowable composite. Odont. 2019; 107: 342–352.
3. Yancey E.M., Liew W., Nuttall C.S., Brewster J.A., Roberts H.W., Vandewalle K.S. Properties of a new nonofiber restoriative composite. Operat Dent. 2019; 444: 34–41.
4. Frater M., Lasilla L., Braunitzer G., Valittu P.K., Garoushi S. Fracture resistance and marginal gap formation of post-core restorations : influence of different fiber-reinforced comspoites. Clinic O Invest. 2019; 24: 265–276.
5. Kumar A., Sarthaj S. In vitro evaluation of fracture resistance of endodontically treated teeth restored with bulk-fill, bulk-fill flowable, fiber-reinforced and conventional resin composite. JODE. 2018; 3 1: 12–17.
6. Ploumaki A., Bilkhair A., Tuna T., Stampf S., Strub J.F. Success rates of prosthetic restorations on endodontically treated teeh; a systematic review after 6 years. J Oral Rehab. 2013; 40 (8): 618–630.
7. Drummond J.L. Degradation, fatigue, and failure of resin dental composite materials. J Dent Res. 2008; 87: 710–719.
8. Masouras K., Silikas N., Watts D.C. Corealtion of filler content and elastic properties of resin-composite. Dent Mater J. 2008; 24: 932–939.
9. Abdul-Monem M.M., El-Gayar I.L., Al-Abassy F.H. Effect of aging on the flexural strength and

fracture toughness of a fiber reinforced composite resin versus two nanohybrid composite resins. Alex Dent J. 2016; 41: 328–335.

10. Lasilla L., Keulemans F., Valittu P.K., Garoushi S. Characterization of restoriative short-fiber reinforced dental composite. Dent Mater J. 2020; 39 6: 992–999.
11. Heintze S.D., Ilie N., Hickel R., Reis A., Loguercio A., Rousson V. Laboratory mechanical parameters of composite resins and their relation to fractures and wear in clinical trials – A systematic review. Dent Mater. 2017; 33(3): 101–114.
12. Kim K.H., Kim Y.B., Okuno O. Microfracture mechanisms of composite resins containing prepolymerized particle fillers. Dent Mater J. 2000; 19(1): 22–33.
13. Cimpean S.I., Pop-Ciutrila I. S., Buduru S., Pavel L.L., Florea D.F., et al. Assesing Fracture Resistance of non vital teeth using two defferent composite systems: short-fibre-reinforced composite and glass fibre post with microfilled hybrid composite. Mater Plast. 2020; 57 (4): 286–296.
14. Garoushi S., Säilynoja E., Valittu P.K., Lasilla L. Physical properties and depth of cure of a new short fiber reinforced composite Dent Mater. 2013; 29 (8): 835–841.
15. Xu H.H., Schumacher G.E., Eichmiller F.C., Peterson R.C., Antonucci J.M., Mueller H.J. Continuous-fiber preform reinforcement of dental resin composite restoriations. Dent Mater. 2003; 9 19 6: 523–530.