EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 71, 909:920, January, 2025

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 01-11-2024 • Accept Date : 08-12-2024 • Available online: 10-01-2025 • DOI : 10.21608/edj.2024.332598.3246

FRACTURE RESISTANCE AND SURFACE HARDNESS OF DIFFERENT POSTERIOR PROXIMAL TOOTH-COLORED RESTORATIONS

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ABSTRACT

Objectives: This study aimed to compare fracture resistance (FR) and surface micro-hardness (SH) of teeth restored using both conventional and bulk-fill resin composites (RCs).

Materials and methods: One conventional RC and four bulk-fill RCs were used. For FR test, 75 healthy molars had proximal boxes made in them, and they were split into 5 groups at random (n=15). Each group was restored with one of these RCs following manufacturers' instructions. All the specimens were finished, polished, and aged by 500 cycles of thermo-cycling before testing. By applying compressive force until fracture, FR was measured in Newton (N) using Instron Testing Machine (ITM). For SH test, 75 cylindrical discs were made by using Teflon mold (5 X 2 mm) between 2 glass slabs, finished, polished, and divided into 5 groups as before. Discs were subjected to 500 cycles of thermo-cycling and evaluated by Vickers Hardness Testing Machine (VHTM).

Results: One-way ANOVA showed significant differences in FR and SH among all the different restorative materials.

Conclusions: The conventional and bulk-fill RCs have incomparable FR and SH due to the differences in compositions.

KEYWORDS: Conventional and bulk-fill composites, Proximal restorations, Fracture resistance, Surface hardness

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INTRODUCTION

Nowadays, most of posterior direct restorations are done using resin composite restorative materials due to their worldwide popularity and dental practitioners can choose between various materials and techniques for restoring posterior teeth.[1] The vast evolved filler architecture through nanotechnology, monomers, and adhesive protocols led to excellent esthetics, minimal cavity preparations, and good retention by bonding with the tooth structure, long-term durability, and wear resistance.[2] However, the volumetric shrinkage stress during polymerization is an important problem causes marginal defects, cuspal movements and fractures.[3]

Hereupon, the seek for fast, and simple restorative procedure led to the technological development of bulk-fill resin composites (BFRCs) as another group of low-shrinkage RCs that are cured in thicker increments more than 2 mm to extend to 5mm layer which may be located in large-size posterior cavities.[4,5] These BFRCs improved the chemical makeup of the matrix and filler by adding polymerization stress-modulators, or stress-relieving pre-polymers, monomers had high molecular weight, and novel photo-initiators.[6,7] The reduction of the filler/matrix interface by filler size enlargement and the reduction of pigment content are the processes to improve the depth of light curing.[8] In addition, more translucency enhanced light penetration to lead to low post-gel shrinkage and strong reactivity to light.[9]

Another development of BFRC was by addition of bioactivity as the alkasite-based RC (Cention forte) with alkaline fillers that are implemented in a methacrylate resin matrix to release acid-neutralizing calcium and hydroxyl ions prevents tooth demineralization and is regarded as a sub-group of composite material class.[10] Moreover, it contains patented filler (isofiller) to relieve shrinkage stress and its low modulus of elasticity could reduce polymerization shrinkage.[11]

The lifespan or durability of the tooth and restoration is mostly determined by the restorative materials' mechanical properties. The oral cavity's posterior region, proximal aspects loss caused by caries or fractures that weakened the teeth and makes them more brittle.[12] An appropriate restorative material that can withstand complex mastication forces must be used to restore this loss. In teeth with moderate to wide Class II preparations, these recurrent routine mastication loads may have the tendency to drive cusps apart, resulting in cusp fractures.[13] By using BFRCs to restore these teeth, the shrinkage stress and deformation of cusps can be reduced, improving FR.[14] Furthermore, micro-mechanical adhesion of RCs in proximal aspects restorations can reinforce the tooth increasing FR that lost by preparation of the cavities.[15]

One of the most crucial characteristics of restorative materials is FR property, which shows how much stress a dental material can bear before failing and how well it can withstand crack propagation.[16, 17] The amount of stress yielded, RC composition, restoration method, and cavity design all affect FR.[18] In the same way, when comparing restorative materials, SH is a crucial mechanical feature. Mostly, when they are subjected to strong masticatory force, as in posterior stress-bearing zones, SH is considered.[19] A higher SH is thought to be more wear resistant. It is defined as the resistance to permanent indentation or penetration. Variations in resin matrix's composition, quantity, and filler distribution could change RCs behaviour.[20] It was reported that the highest inorganic filler content raises the composites' hardness and wear resistance to levels close to enamel.[21, 22] The quality of SH of RC restoration is directly related to its depth of cure. That means lower hardness material is more prone to surface flaws and scratches, which can lead to early surface failure.[23]

By considering that BFRCs are popular among clinicians, and many studies indicated that BFRCs have no significant difference in properties as compared to conventional RCs. Also, the bulk-inserted dual-cured alkasite RC is added to materials that received attention. Thus, the aim of our study was to compare the fracture reliability and SH of three different BFRCs and alkasite RC and one conventional RC. The null-hypothesis tested was: (1) there was no significant difference in fracture resistance of Class II restorations with the tested five resin composites, and (2) there was no significant difference in surface hardness of the tested five resin composites.

MATERIALS

All the tested RCs brand names, compositions and manufacturers were detailed in the following Table (1).

METHODS

Sample Size Calculation

The data for sample size calculation considered fracture resistance and surface hardness, and based on these, the largest sample size was chosen. The sample size calculation was performed according to previous studies conducted by Tsertsidou et al. which the formula for analysis of variance was applied in G*Power statistical software (version 3.1.9.7).[24] This study's estimated sample size was 12 specimens for each group at error prop (α) = 0.01 and power (1- β) 0.99 of the study, and increased by 20% to 15 specimens for each group to compensate for incomplete data or pre-test failures.

TABLE (1) Materials utilized for the research

Restorative material	Composition	Manufacturer	Lot number
Cention forte	Liquid: stabilizers, initiators, and dimethacrylates. Powder: iso-fillers, ytterbium trifluoride, initiators, pigments, calcium fluoro-silicate glass, barium glass, and calcium-barium-aluminum fluoro-silicate glass	Ivoclar vivadent, Liechtenstein	Z00547
Tetric-N Ceram Bulk fill	BIS-GMA, UDMA, BIS-EMA, barium glass, co-polymers, iso-fillers, ytterbium trifluoride glass, pre-polymerized filler, mixed oxides glass	Ivoclar vivadent, Liechtenstein	V24958
Aura Bulk Fil	UDMA,Bis-GMA,Bis-EMA,TEGDMA,barium aluminosilicate glass, amorphous sio_2, pre-polymerized fillers	SDI, Melbourne, Australia	200126
Filtek Z350 XT	Bis-GMA, UDMA, TEGDMA, PEGDMA, Bis-EMA resin, non-(agglomerated and aggregated) silica and zirconia fillers	3M ESPE, St Paul, MN,USA	NA60111
Reveal BF	UDMA , Bis-GMA, trimethoxysilylpropyl metchacrylate, tert-butyl perbenzoat, ytterbium, fluoride	Bisco, Schaumburg, IL, USA	2000005228
Total Etch	37% phosphoric acid etching gel	Ivoclar vivadent Schaan/ Liechtenstein	
Tetric N-Bond	Bis-GMA, UDMA, HEMA, phosphonic acid acrylate, ethanol, nanofiller, catalysts, stabilizer	Ivoclar vivadent Schaan/ Liechtenstein	Z0109C

Fracture Resistance Test

Selection and preparation of samples

Seventy-five freshly extracted lower first molars for periodontal purpose; from the clinic of Oral and Maxillofacial Surgery Department, Faculty of Dentistry, Mansoura University; were chosen for this investigation. Teeth were collected after patients' approval, and Ethical Approval for Scientific Research code was (M0103024DM). After removing any remaining tissue or calculi deposits from the teeth, they were cleaned with running water and examined with a stereomicroscope (Nikon, Tokyo, Japan, 2 X). All the molars were inspected for caries or visible cracks. Then, they stored in 0.5% chloramine solution at 37°C in distilled water in an incubator (BTC, Model: BT1020, Cairo, Egypt) for no longer than one month until the study started.[18]

For periodontal ligament and alveolar bone simulation; the roots of molars were immersed into molten wax (Cavex, Holland B.V) to deposit about 0.3mm thick wax layer. The samples were centered in plastic molds which acted as a jig for mechanical testing, and self-curing acrylic resin (Acrostone, Egypt) inserted in plastic molds around roots. After resin hardening, the teeth were removed, roots cleaned, wax spacer removed, and replaced with light body polyvinyl siloxane material (Speedex, Coltene Whaldent AG, Switzerland). The samples were then put back into the molds, one mm away from cement-enamel junction (CEJ).[25]

Typical mesial or distal boxes were prepared with dimensions of: occluso-gingival depth = 4 mm, isthmus width = one-fourth of inter-cuspal distance (1.5-2 mm), and axial wall was 0.5 mm inside dentin with no steps.[17] These dimensions were delineate by waterproof marker on the teeth crowns. The cavity preparations were done using high speed a rotary abrasive (short parallel step with rounded edge, 6836 KR 314 018; Komet, Brasseler, Germany) under copious air-water cooling. The cutting abrasives were replaced after 5times of using in preparations. The inner line angles of boxes were rounded to reduce C factor, and dimensions were confirmed with a periodontal probe (Hu-Friedy Co., Rockwell St. Chicago).[26] According to the restorative materials used, the samples were split up into five groups at random (n=15): group A; restored using Filtek Z350 XT (FXT), group B; restored using Tetric-N Ceram Bulk fill (TBF), group C; restored using Aura Bulk Fil (ABF), group D; restored using Reveal BF(RBF), and group E; restored using Cention forte (CF).

Restorative procedures

All the following steps were performed according to all manufacturers' instructions. Before each restoration, the acid etching gel (Total Etch, Ivoclar vivadent Schaan/ Liechtenstein) was applied on box walls (enamel and dentin) for 15 seconds, 10 seconds of water rinsing followed by 5 seconds of cotton pellet drying. Then, the adhesive (Tetric N-Bond, Ivoclar vivadent Schaan/ Liechtenstein) was slowly agitated for one layer by micro-brush to walls and margins for 15 seconds, and low air pressure for 5 seconds. Light curing for 10 seconds with light emitting diode (LED) unit with wavelength ranges from 385-515 nm, and light intensity ranges from 1000-1200 mW/cm^2 (BlueLEX; Monitex industrial CO, LTD) was done. Tofflemire matrix band application was used for restoration: group A; 2 mm horizontal increments of RC were inserted and adapted using a titanium coated applicator (DuraFlex double paddle #38T, NourDent, USA), and each increment was cured for 20seconds.

For group B, BFRC was inserted in bulk one layer (4mm) and cured10 seconds. Groups C, and D received the BFRC in a single increment, and cured for 20 seconds. For group E, the liquid and powder were spread out in a 1:1 ratio amounts. The powder was then added gradually to the liquid and thoroughly mixed for 60 seconds to give slightly shiny homogenous mass. Immediately, this mass was inserted in to the box in one increment, excess material was meticulously eliminated, and cured for 20 seconds. Additional curing was applied for 20seconds after removal of the band for all the samples, and finishing and polishing procedures were performed 10 minutes later using finishing carbide bur (H246L-012UF, Kerr Corp, USA) with polishing brush (ASTRO 9102, Ivoclar Vivadent). Following one day of storage in distilled water at 37°C in an incubator (BTC, BT1020, Egypt), all samples were thermo-cycled using (Robota, Egypt). A total of 500 cycles between 5°C and 55°C with rest times of 20 seconds and transfer times of 5 seconds were done.[27] Prior to testing, all samples were then stored again in distilled water at 37°C for one day.

Fracture resistance measurements

The samples were subjected to compressive axial loading at a crosshead speed of 0.5 mm/min in the universal testing machine (Instron 3345, Canton, MA, USA) using a metal ball of 8 mm diameter and contacting only buccal and lingual cusp slopes. The causal force was measured in Newtons (N) after this force associated with sample fracture or failure.[28] The testing was performed in The Central Research Laboratory (Biomaterials Department, Faculty of Dentistry, Mansoura University).

Surface Hardness Test

Specimen Preparation

A total of seventy-five disc-shaped specimens (5mm diameter × 2 mm thickness) were made and distributed in five groups (n=15); as in FR test. The samples were prepared in custom-made Teflon molds. Mylar strips placed on glass plates and molds placed over them. Then, molds were filled with the tested restorative materials and covered with another Mylar strips. Glass slides pressed over to ensure complete adaptation of the materials to the inner portions of the molds. The glass slides were lifted and excess materials was removed.

The specimens were photo-cured as mentioned before. The transparent Mylar strips were peeled immediately after curing and this surface was marked with a small dot using a permanent pen (un-tested surface). All samples unmarked surfaces were polished using Sof-Lex discs (3M ESPE) in recommended order (coarse, medium, fine and superfine), and stored in distilled water as mentioned before.[29] After that, the samples were thermo-cycled and stored as mentioned in FR test.

Surface hardness measurements

It was measured using Vickers micro-hardness tester (JINAN PRCISION TESTING EQUIPMENT CO, Model HV-1000 LTD, China). Indentation was made on the surface under a load of 100 gram (g) for 10 seconds using a diamond micro-indenter in the shape of a pyramid with a 136° angle in-between. Vickers hardness number (VHN) was automatically calculated using the following equation: VHN=1854.4P/d2 where P is the applied load (g), and d is the average length of the indentations' diagonals (µm). Each specimen was loaded 3 times and the mean (VHN) parameter was calculated.[30] This test also was done in the central research laboratory.

Statistics analysis

Statistical analysis was performed using IBM SPSS Statistics Version 2.0 for Windows. Data were presented as mean and standard deviation (SD). The significance level was set at $P \leq 0.05$. One Way ANOVA test was used and Tukey's post-hoc test for pairwise comparisons in significant difference.

RESULTS

The FR force (N) mean values and standard deviations were presented in Table 2, and these values are visually graphed in Figure 1 for understanding the data. Multi-comparisons among study groups were performed using One Way ANOVA test, and followed by Tukey's post-hoc test for pairwise comparisons in significant difference. Significant differences in FR between the various kinds of restorative materials were found by applying One-Way ANOVA test. The highest FR (1172±234.6) showed by Tetric-BF, and the lowest showed by RBF (788.1±98.26). Tukey's post-hoc test showed significance between; FXT and TBF, ABF and TBF, and RBF and TBF. Also, CF was significant to FXT and ABF and RBF.

Statistically, a significant difference between the various types of restorative materials was found for SH using One-Way ANOVA test. The highest mean was (102.3±6.600) and showed by TBF, but the lowest mean was for RBF (48.59±6.636). A significant relationships were markedly between; FXT and TBF, ABF and TBF. In addition, RBF was significant to FXT, TBF, and ABF. Cention forte was significant to FXT, TBF, ABF, and RBF as shown by Tukey's post-hoc test analysis and seen in Figure 2, and Table 3

TABLE (2) The various evaluated restorative materials' fracture resistance (N) values

Groups	FR mean ± SD
Group A (Filtek Z350 XT)	**927.7±177.2**
Group B (Tetric-N Ceram Bulk fill)	**1172±234.6** a
Group C (Aura Bulk Fil)	**813.3±98.97** b
Group D (Reveal BF)	**788.1±98.26** [c]
Group E (Cention forte)	**1128±268.9** [ac]d
P	**<0.0001**

P < 0.05 is considered significant; [a] showed significance to group A,
[b] significant to group B, [c] showed significance to group C, [d] significant to group D

TABLE (3) The various evaluated restorative materials' SH values

Groups	SH mean ± SD
Group A (Filtek Z350 XT)	**91.97±7.734**
Group B (Tetric-N Ceram Bulk fill)	**102.3±6.600** [a]
Group C (Aura Bulk Fil)	**90.54±12.09** [b]
Group D (Reveal BF)	**48.59±6.636** [abc]
Group E (Cention forte)	**64.88±7.171** [abcd]
P	**<0.0001**

P < 0.05 is considered significant; a significant to group A, b showed significance to group B, c showed significance to group C, d significant to group D

DISCUSSION

The primary goal of dental restoration is to re-establish the biological, functional and esthetic properties of healthy tooth structures after their loss.[31] The posterior teeth are mostly affected by the occlusal loads, and the oral cavity experienced significant forces during mastication ranging from 300-600 N.[32] Therefore, to achieve superior FR in compound posterior restorations is critical for long-term preservation of tooth structure and durability of restorations. The mechanical resistance of restorative materials to fracture is clinically very important. Strong materials resist deformation and fracture in a better pathway; provide more evenhanded stress distribution and stability.[33] The selection of restorative material and technique for molar teeth area is regarded crucial complex issue. The composites which are routinely used for restoration always undergo polymerization shrinkage and stress.[34] This stress is generated within RC material and tooth structure forming micro-cracks in the restoration, tooth, and tooth/restoration interface by application of the occlusal forces later. These micro-cracks could propagate to cause fracture in tooth and restoration leading consequently to restoration failure.[35]

Shrinkage stress depends on the stiffness of RC at the time of shrinkage and the volumetric shrinkage strain.[36] Numerous studies had been appealed to the gold standard 2mm thickness layering technique to ensure full depth light curing that minimize polymerization shrinkage and prevent early failure of posterior restorations.[37,38] The layering technique may cause: lack of bonding between the increments, voids incorporation, and more placement time wasting.[39] Therefore, BFRCs have been created as monoblock layer allows restoration for 4 mm thickness or more and cured once. This could be due to the improvement of photo-initiators and filler characteristics to facilitate and shorten the time during restoration procedures.[40] Shrinkage stress relievers, pre-polymers, and low-shrinkage photo-initiators were used to modify BFRCs.[17] This study was aimed to compare them to conventional RC because some studies have also found high FR with BFRCs.[14]

In order to eliminate the impact of the c-factor and overstress the remaining tooth structures by causing the loss of marginal ridges, this study focused on standardized Class II preparations.[13] The mimicking of the periodontal ligaments was emphasized on many studies.[41] In this study, an elastomeric impression material was used to evenly distribute the axially oriented load preventing stress concentration at teeth cervical regions.[42] The restorations were subjected to thermo-cycling in order to evaluate their stability and durability in close proximity to oral cavity conditions.[43] The performance of the restorations was assessed in this investigation using static compressive loading in Instron testing apparatus until failure occurred.[44] To ensure tripod contact to replicate the normal forces during occlusion and mastication, the load was distributed onto the buccal and lingual cusps of the teeth by applying load through a metal ball (8 mm diameter) that allowed even load distribution.[45]

The results of this study revealed a significant difference in FR among the restorative groups investigated, and this finding led to the rejection of the first hypothesis. Notably, a number of intricate aspects, including as the composite chemistry, cavity size, tooth structure integrity, and bonding success, contribute to the fracture of the restoration. In this study, the cavity size and adhesive were tried to be excluded, and the outcome could be interpreted and explained based on the restorative materials composition, properties and filling techniques. Prior research has verified a positive correlation between the mechanical performance and filler loading.[46] High filler loadings undoubtedly enhance the composite's mechanical qualities, including its FR and SH.[14] Also, there is a strong positive correlation between elastic modulus of RC and its filler load. The highest FR showed by TBF which claimed to be a nano-hybrid composite with superior filler technology reaches to be more than 75% (by weight). This filler load includes 61% of barium-aluminum-silicate glass and 17% of spherical mixed oxide. The iso-fillers have the ability to reduce polymerization shrinkage. Furthermore, the decreased distances between the nano-filler's particles may diminish the likelihood of crack development and spread. The stress is distributed throughout the repair by the spherical nanoparticles' rounded edges.[47] Moreover, it has patented photo-initiator (Ivocerine) added to camphorquinone, and the organic matrix consists of Bis-EMA and UDMA (2%).[48] These advantages were associated with low polymerization shrinkage, and the highest FR.[49]

Likewise, CF was not significant to TBF which may be due to its filler system that contains 78.4% (by weight) fillers. It includes iso-fillers, ytterbium tri-fluoride, calcium fluoro-silicate glass, calcium-barium-aluminum glass, and barium glass.[10] Throughout the entire restoration depth, it displays a high degree of polymerization and density of polymer networks. High fracture resistance could possibly be attributed to isofiller, which is also found in Tetric BF. This reduces shrinking force by acting as a stress reducer.[50]

Otherwise, the results revealed that the other bulk-fill composites had no significance to conventional FXT as reported by Hegde and Sali.[27] The three composites showed lower FR, and this result might be attributed to the relatively similar high filler loading (81% and 78.5% by weight) for ABF and FXT respectively. Both materials have zirconia and silica nanoparticles in their filler content. FXT is a nano-fill composite with filler loading 63.3%; non-agglomerated and non-aggregated; which may cause load slippage inside them. Besides, the clusters of nanofillers may increase the cracks propagation. [51] Pottmaier et al. reported that nanoparticle RC presented lower values of FR.[52] In addition, the incremental technique creates voids or defects within the restoration by air bubbles intrusion. These voids allow cracks propagation the overall lowering of strength of the restoration during function over time.[53]

The lowest FR values of RBF may be attributed to the different filler composition (ytterbium fluoride) compared with zirconia and silica nanoparticles. Also, RBF accommodates higher concentration of Bis-GMA monomer, which had lower DC compared with Bis-EMA.[54] The higher FR of TBF compared to other BFRCs could be attributed to the differences in chemical compositions which rely on the existence of monomers that comply fillers (amount, particles size, nature), and photo-initiators.[12,55] Also, the key to determine FR is the distance between the filler particle, for appropriate and even distribution of stress.[56]

Surface micro-hardness is defined as the resistance that prevents the creation of permanent deformation by scratch and abrasion, and is a feature contributes to the clinical success, and is associated with the material rigidity.[57] Natural teeth and restorations are always under stress of normal occlusal and physiological masticatory cycles.[58] Thus, from a therapeutic perspective, SH matters particularly for posterior restorations.[59]

The Vickers micro-hardness test was chosen because it is a straightforward, widely used method that yields results with a modest resistance to indentation under functional loads.[19] The indenter is appropriate for measuring the hardness of delicate, brittle materials since it does not distort over time.[60] Additionally, the degree of polymerization of composites, which directly affects their mechanical qualities generally and their long-term durability in the oral environment, might be indirectly assessed using this test.[61] In this study results, significant differences in VH mean values among all the tested materials were revealed, and accordingly the second hypothesis was rejected.

Tetric BF composite, which is classified as a nano-hybrid composite, had the highest VH value. Composites are recognized to consist of heterogeneous microstructures comprising inorganic filler particles and an organic matrix.[62] As mentioned, the criteria of filler content primarily influence SH of composite restorative materials.[63] Nano-hybrid RC contains a mixture of different types and sizes of fillers particles within the matrix. The decreased filler particle sizes and increased filler volume percentages enhance their physical and mechanical properties.[64] Also, filler loading of TBF as described is regarded to be comparable to other tested RCs.[65] In addition to this, because of finishing and polishing processes, polymerization shrinkage resulted in microscopic changes that can produce surface and subsurface micro-defects. These microscopic flaws may affect the material's hardness and resistance to wear, reducing its lifetime.[66] Tetric BF was developed to modify and relieve polymerization shrinkage by technology of polymerization modulators which allows certain amount of flexibility and optimized network structure.[49]

Considering the findings of this investigation, FXT composite which is categorized as nano-fill composite was significantly lower than TBF. This outcome could be explained that the nano-hybrid high fillers load (68% by volume) as compared with the nano-fill which had an inorganic filler loading (63.3% by volume). Also, there were variations in the nano-scale composite's densely packed filler particles.[67] Other BFRCs which are categorized as nano-hybrid was not significant to FXT, and this may be due to the lower filler loadings; (65% by volume) for ABF (60% by volume) for Reveal BF; than TBF and shortage of polymerization modulators.[68] That's why RBF demonstrated the lowest SH to all other materials. The composition was confirmed to impact SH of RC restorative material.[69] The mass fractions, size, shape, and fillers distribution significantly affect mechanical properties, as SH.[70-72] Additionally, SH is influenced by the chemistry and ratio of monomers, the degree of crosslinking, and photo-initiators involved.[73] Vickers hardness ratio is related to the depth of cure (80%) and the degree of polymerization. A high degree of polymerization is an important factor for achieving superior physical and mechanical properties.[74]

Besides, CF had significant differences in SH to all the tested materials and the chemistry of this bioactive material and is provided in two-part liquid/powder systems, as opposed to composite. This change in the ratio of powder to liquid could affect the outcome. It had large filler particle size (0.1-35 μm), and nanomers refer to range in size from 20-75 nm that may lead to this result.[75] The results of this study were dependable on compositions of organic matrix, amount and type of filler particles, and also on degree of conversion of these different materials. So far, no enough data are available about some bulk-fill restorative materials as; CF, ABF, RBF. Hence, multiple *in vitro* and *in vivo* future studies are necessary. In other respects, this study had subjected to limitations of cyclic mechanical loads aging before the static compressive force applied during FR test.

CONCLUSIONS

Although the bulk-fill composites obviously have benefits over conventional composites in clinical applications by reducing time and simplifying the restoration process, not all of them have significant impact on FR and SH. BFRCs couldn't be considered on an equal footing in their performance.

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