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Original Article

The Influence of Sonic Activated Bulk Fill Packing Technique on the Fracture Resistance of MOD Resin Composite Restorations: A Comparative in Vitro Study

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Abstract

Aim: This study aimed to evaluate impact of sonic activation bulk placement technique on the fracture resistance of Mesio-occluso-distal resin composite restorations, in contrast to the conventional bulk placement technique.

Materials & Methods: Sixty maxillary premolars were allocated into six groups, with each group including ten premolars (n=10) (A). Groups (A1&A2) were utilized as positive controls and were not subjected to cavity preparation. Mesio-occluso-distal cavities were formed in the remaining 40 premolars. Afterwards, these cavities were divided into four groups of comparable magnitude. Groups (A3&A4) were restored using a sonic activated bulk fill resin composite. Conversely, groups (A5&A6) were repaired using Tetric N-Ceram Bulk Fill resin composite. Every sample was subjected to thermal load cycling using a chewing simulator device called ROBOTA in order to recreate circumstances seen in the mouth. 50% of the specimens were subjected to 417 cycles, which imitated a 24-hour loading period, while the remaining 50% underwent 75,000 cycles, which represented a 6-month loading period. The specimens underwent compressive axial stress until they shattered, utilizing an Instron Universal Testing Machine. The data was subjected to statistical analysis.

Results: There was no noticeable difference detected among the groups assessed after 24 hours of loading. Following a 6-month period of load cycling, the control group displayed the highest average values, which did not show any significant difference compared to the sonic fill group.

Conclusions: The Sonic Fill™ composite is a feasible treatment option that can improve the structural strength of deficient maxillary premolar teeth.

Keywords: Fracture resistance, Sonic Activated Bulk-fill Resin Composite, Nanohybrid bulk-fill resin composite, Thermo-mechanical aging.

Introduction

Tooth fracture is a prevalent issue in dentistry and is widely recognised as a primary contributor to tooth loss, alongside dental caries and periodontal disease. The strength of a tooth diminishes in direct proportion to the reduction in dental tissue, resulting in increased fragility and a heightened vulnerability to fractures [1]. The absence of marginal ridges in premolar teeth has been discovered to negatively impact the structural integrity of the tooth and greatly diminish its capacity to withstand occlusal forces.

Consequently, this poses challenges in the repair of mesio-occluso-distal (MOD) cavities in premolar teeth [2]. Dentists often utilise adhesive techniques to reinforce weaker teeth, so improving the durability of the restored dental structure and safeguarding it against potential fractures during regular use.

The fracture resistance of dental materials is a crucial property that depends on the material's capacity to withstand crack propagation, both internally and externally. This property is crucial in preventing marginal or bulk fractures of dental restorations that may result from these fissures [3]. The criteria for adhesive restorations include not only aesthetic factors but also the ability to preserve a greater amount of healthy tissue and enhance the structural strength of the remaining teeth. Resin-based composite restorations have been the preferred option in modern conservative dentistry because they effectively transmit and distribute functional stresses throughout the bonding contact, as demonstrated by adhesive restorations [4].

Although conventional resin composite material possesses satisfactory durability, attractive aesthetics, and exceptional mechanical properties, it nevertheless exhibits a few significant limitations, specifically marginal leakage and polymerization shrinkage. The observed strains and marginal microleakage can be attributable to the gradual approach, which is influenced by the flowable capacity and voids of the material [5]. A new composite resin has been introduced and is currently being used. "Bulk-fill" resin composites (BFRC) are resin composites with a high increment thickness. To achieve a single layer with a thickness of around 4 or 5 mm, one can modify the organic matrix, use different sizes and shapes of inorganic particles, and include various modifiers and photo-initiations [6].

Manufacturers have utilised various ways to improve the bulk-fill category. The solutions encompass using fibres for reinforcement, modifying the monomers, and employing specialised equipment for restorative application. The introduction of Sonic-Fill ™ to the market was to simplify the process of creating well-fitted restorations on the cavity walls during insertion [7]. The material is a resin composite with a high concentration of fillers, combined with specialised modifiers that respond to sonic energy produced by a specifically constructed handpiece. This interaction reduces the thickness of the composite and improves its capacity to move smoothly during the initial phases of placement. The material is a bulk-fill resin composite that experiences a change in viscosity when subjected to sonic vibrations. This property enables the resin-based composite to be easily placed as a flowable substance into the cavity, and then revert back to a more thick and sticky form that can be moulded by dentists. These benefits include increased durability for extensive cavity filling, well-fitted restorations, and a greater depth of curing [8, 9].

The Tetric N-Ceram Bulk-Fill Resin Composite is a Nano-hybrid composite that consists of ceramic particles with a size smaller than 100 nm. Furthermore, the material has a substance called Ivocerin that reduces its sensitivity to light. This enables for a longer amount of time to shape the restoration. The material also includes a shrinkage stress inhibitor, which helps to get a precise fit at the edges [10].

Preclinical in vitro testing of dental materials is crucial for demonstrating their mechanical prowess and suitability for use in the oral cavity. The oral environment around dental restorations encompasses several demanding conditions such as humidity, acidic or alkaline pH levels, and cyclic loading, which can lead to fatigue failure and result in microstructural degeneration in certain restorations. Conventional laboratory testing methods used to involve submerging samples in water. While this type of testing can offer insights into material strength, assess the likelihood of failure, and compare different material options, it falls short in accurately predicting the durability of dental restorations over an extended period of use [11]. Hence, it is essential for laboratory testing to replicate several elements of the oral environment in order to generate failure modes that closely resemble those observed in clinical settings [12].

Hence, it is imperative to evaluate the efficacy of various techniques for repairing maxillary premolar teeth with MOD cavities in terms of their capacity to resist fractures following thermo-mechanical ageing. The hypothesis propose that the fracture resistance of premolars with MOD cavities restored with sonic activated bulk fill resin composite, is higher than that of premolars restored utilizing Nano-hybrid composite. An alternative hypothesis is that there is no difference in the fracture resistance between restorations subjected to load cycling for 24 hours and 6 months.

Materials and Methods

Study Design

An in vitro experimental investigation with multiple groups

Sample size calculation

The sample size was obtained based on the approach outlined by Fahad and Majeed [13]. The minimum needed sample size was 30, with each subgroup including 5 samples. The effect size was 1.235, the significance level (α) was 0.05, and the intended statistical power was 95%. The sample size was increased by 50% to incorporate ten premolars per group, resulting in a total of sixty premolars divided among six groups, to accommodate any potential failures during the pre-test phase.

The present study has been reviewed and approved from the Ethics Committee of the Institutional Review Board of the Faculty of Dentistry, Mania University (registered as number 481).

This study included sixty sound recently extracted maxillary premolars for orthodontic purposes. In order to achieve uniformity, a digital caliper was employed to measure the precise dimensions of each tooth and determine their mean mesio-distal width (7 ± 0.5 mm) and bucco-lingual width (8mm ± 0.5mm). Following the extraction, all selected teeth were immediately cleansed using a manual scaler (Wood Pecker, China) and then polished using a rubber cup and diamond paste (Prisma Gloss, Dentsply). The teeth were examined using a magnifying lens with a 7x magnification to detect and remove any teeth with cracks. The teeth were sterilized using a solution of 0.05% Sodium Azide, followed by a water rinse. They were then stored at a temperature of 4°C in a 0.1% thymol disinfectant solution to inhibit the growth of germs for a duration of not more than one month [14].

Sample grouping

A random sequence was generated and divided into six equal groups, using computer software from http://www.random.org/.

Group 1 consisted of intact premolars without any cavities. These premolars were used as a positive control and were subjected to cyclic loading, which represented a 24-hour loading period consisting of 417 cycles.

Group 2 consisted of intact premolars without any cavities, which were used as a positive reference. These teeth were subjected to cyclic loading, simulating a 6-month period of continuous use, with a total of 75,000 cycles.

Group 3: Specimens were restored using Sonic-Fill ™ bulk-fill resin composite and exposed to cyclic loading for a 24-hour period (417 cycles).

Group 4: Specimens were repaired using Sonic-Fill ™ bulk-fill resin composite and exposed to cyclic loading simulating a 6-month period (75000 cycles).

Group 5: The specimens were restored utilizing Nano hybrid bulk fill composite (Tetric N-Ceram) and subjected to cyclic stress to simulate a 24-hour loading period (417 cycles).

Group 6: The specimens were restored utilizing Nano hybrid bulk fill composite (Tetric N-Ceram) and subjected to cyclic stress to simulate a 6-month period (75000 cycles).

Cavity preparation

With the exception of the two positive control groups, teeth were prepared to create standardized class II MOD cavities using a high-speed round-end parallel diamond bur (881.31.014 FG; Brasseler USA Dental). The cavities were formed using a cylindrical carbide bur (Mani DIA-Burs with the identifier SF-4) which was operated by a high-speed hand piece known (PANA MAX, NSK, Japan). The depth of the cavity was measured to be (3±0.2 mm) from the center of the occlusal surface to the pulpal floor. Furthermore, the proximal extension prepared where the buccolingual dimension was 3±0.2 mm and the gingival seat exhibited a depth of 4±0.2 mm. The width of the cavities was verified with a caliper following the preparation of the cavities, whilst the depth of the cavities was assessed using a periodontal graded probe. The cavities were prepared under enough supply of air and water spray. In accordance with the specified protocol, a replacement of the carbide bur was performed after every fifth cavity preparation [15]. A single operator carried out all the preparations.

Specimen preparation

To recreate the periodontium, the root surface of each tooth was immersed in molten composition wax (VERACRIL, Colombia) 2 mm away from the cemento-enamel junction (CEJ). The result of this procedure resulted in the formation of a consistent layer, with a thickness of roughly 0.2-0.3 mm, surrounding the root. The teeth's roots were embedded into a hardened acrylic resin block using a hollow metallic cylindrical template with a diameter of 25mm. In order to assure the accurate centering and alignment of each specimen with the long axis of the tooth, the mould was securely linked to a surveyor (Ney dental Surveyor, Anaheim CA, USA). The wax spacer was extracted, and a light body poly-vinyl siloxane substance (Speedex, Coltene, Switzerland) was introduced into the vacant area between the mold and the root. Subsequently, the teeth were repositioned within the molds.

Restorative procedures

The current study utilized a method called selective enamel etching. Initially, treat the enamel cavities margins by applying a 37% phosphoric acid gel for a period of 15 seconds. Afterwards, the treated enamel was thoroughly washed with a powerful stream of water for 5 seconds and carefully dried using compressed air. Then, the adhesive was immediately applied and underwent a 20-seconds scrubbing procedure. In order to ensure complete coating of the enamel and dentin with adhesive, an oil-free compressed air was used until a shiny and fixed film layer was seen. The adhesive was cured using an LED light curing apparatus (Super Mat, Kerr, Switzerland) with a light intensity of 1200 mW/cm2 for 10 seconds, following the manufacturer's instructions [16].

The Palodent ring matrix (Dentsply, USA) was applied. The Sonic fill handpiece (KaVo Germany) and known as SONIC fill 2010, was linked to a high-speed dental handpiece and set to a speed of 3. The Sonic-Fill™ compule **(Table 1)** was placed into the sonic fill handpiece and firmly connected to the device. The compule was situated at the pulpul floor of the prepared cavities. When the hand piece was activated, resin composite was pumped into the cavity in a single, uninterrupted motion, completely filling the entire cavity and then adapting to the shape of the restorations [17]. The restorations underwent light curing utilising an LED light curing system for a duration of 20 seconds, in accordance with the guidelines provided by the manufacturer. After removing the matrix, a further 10 seconds of light curing was applied to all the restorations, considering both the mesial and distal views [18]. The procedure for applying Tetric N-Ceram bulk fill resin composite was primarily consistent, consisting of the application of a single layer with a thickness of 4 mm. The procedure involves placing the compule at the base of the prepared cavity and then injecting the composite material to completely fill the cavity, both on the walls and on the occlusal surface. Subsequently, the material was altered to suit the cavity wall, facilitating effortless shape and molding due to its sleek smoothness. The utilization of appropriate tools, such as plastic composite instruments and burnishers, facilitated the process of achieving the required final shape of anatomical features, fissures, and grooves then light cured. All restorations were ultimately completed promptly and flawlessly utilising high-quality diamond composite finishing burs (Diamond Composite Finishing Kit, Komet, USA) and flexible discs (Sof-Lex; 3M ESPE, St. Paul, MN, USA) with the aid of water cooling. The polishing process involved the utilization of polishing discs, brushes, and finishing strips in conjunction with diamond paste, particularly Prisma Gloss (Dentsply, USA).

Thermo-mechanical ageing was conducted to simulate the conditions that occur within the oral cavity. A four-station multimodal ROBOTA chewing simulator, which is a programmable logic-controlled device, was utilized to administer mechanical loading. The simulator is equipped with a thermo-cyclic protocol and functions using a servo-motor (Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY). The mechanical loading was conducted to simulate two distinct stages of ageing. The ROBOTA chewing simulator comprises four chambers that replicate both vertical and horizontal movements concurrently, while maintaining thermodynamic conditions. The specimens were enclosed in a Teflon casing located inside the lower sample container. A force of 49 N, which is comparable to a weight of 5 kg, was exerted. The specimens underwent 417 iterations of testing to faithfully reproduce the chewing circumstances seen within a 24-hour timeframe. Specimens were subjected to 75000 cycles, simulating chewing conditions, over a period of 6 months [19]. The load application used a thermocycling technique that involved submerging in a cold/hot water bath with a temperature range of 50°C to 550°C and a dwell period of 60 seconds [20-22].

Table (1): Materials, specification, composition, manufacturer and batch number

Material used	Specification	Composition	Manufacturer	Batch Number
Sonic-Fill™ A3	Nano hybrid bulk-fill resin composite material	Matrix: Bis-GMA*1-5%, TEGDMA** 1-5%, EBAPDMA*** Filler: Silicon dioxide fillers, barium glass (83.5%) by weight (69 vol %)	Kerr Corporation, Orange, CA, USA. https://www.kerrdental.com/ kerr-restoratives/sonicfill-3-single-fill-composite-system	7520292
Tetric® N-Ceram Bulk Fill composite IVB	Nanohybrid bulk-fill composite material.	Matrix: Dimethacrylates 19-21% weight (Bis-GMA, Bis-EMA****, UDMA***** Fillers: 75-77% weight or 53-55% volume. Glass filler: Barium glass fillers, Ytterbiumtrifluoride, mixed oxides, prepolymers (82–83 w %). Additional contents: additives, catalyzer, stabilizer, pigments (<1w %)	Ivoclar Vivadent, Schaan, Liechtenstein, USA. https://www.ivoclar.com	Y44816
Tetric® N-Bond Universal	One step self-etch adhesive system.	Methacrylate, ethanol, water, highly dispersed silicon dioxide, initiators and stabilizers	Ivoclar Vivadent, Schaan, Liechtenstein, USA. https://www.ivoclar.com	Z00SNR
N-Etch	Etchant agent.	37% phosphoric acid etching gel.		Z014VZ

**Bis-GMA: bisphenol-A diglycidyl ether dimethacrylate. **TEGDMA: triethylene glycol dimethacrylate. ***EBAPDMA: ethoxylated bisphenol A dimethacrylate. ****Bis-EMA: ethoxylated bisphenol A glycol dimethacrylate. *****UDMA: Urethane dimethacrylate.*

Fracture resistance test

The specimens underwent compressive axial loading until they broke using an Instron Universal Testing Machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) at a crosshead speed of 1 mm/min, with a load cell of 5 kilonewtons (kN). The load was applied occlusally using a metallic rod with a circular tip measuring 3.8 mm in diameter. The tip of the rod only came into touch with the sloping surfaces of the cusps. The computer connected to the loading apparatus recorded the maximum breaking forces in kilonewtons [23].

Results

Statistical analysis

Data collecting was conducted. The data was provided in the form of mean (M) and standard deviation (SD) values. The study utilized Two-way ANOVA to do statistical analysis in order to examine the influence of resin composite material and time on the mean fracture resistance. Following that, pairwise Tukey's post-hoc tests were used to compare the means in situations where the ANOVA test produced a significant outcome. Furthermore, a One-way ANOVA and a student t-test were performed to compare the primary groups and subgroups. In addition, a Chi square test was used to analyze the relationship between failure mechanisms.

The data shown in **table 2** indicate that materials had a significant effect on the fracture resistance results at P>0.001. Furthermore, the fracture resistance was notably affected by thermal mechanical ageing at P>0.001. However, the interaction between factors (materials and ageing) did not have a significant impact on the fracture resistance results, with a p-value of 0.490237.

Table (2): Regression analysis of fracture resistance test results showing effect of each factor and interaction between material groups and thermo mechanical aging

Source of Variation	Sum of Squares	DF	Mean Square	F	P-value (sig)	F crit
Material	247563.3	2	123781.7	19.14491	P>0.001 *	3.168246
Thermo mechanical aging	647137.8	1	647137.8	100.0907	P>0.001 *	4.019541
Interaction (material x aging)	9340.869	2	4670.434	0.722361	0.490237 **NS**	3.168246
Within	349137.7	54	6465.513			
Total	1253180	59				

**; Significant (p < 0.05) Ns; Non-significant (p>0.05) DF= degrees of freedom*

As shown in **Table 3 and Figure 1** indicate that there was no statistically significant difference among the Control, Sonic-fill, and Tetric-N groups after 24 hours of thermo-mechanical ageing. The validation of this was obtained by doing an analysis of variance (ANOVA) test, which yielded a p-value of 0.0857. The value surpasses the designated significance level of 0.05. Following a 6-month period of thermal mechanical ageing, the control group exhibited the highest average ± standard deviation values of fracture resistance (915.65± 159.8N), with the sonic fill group (901.71±87.16N) coming in second. On the other hand, the Tetric-N group exhibited the lowest mean ± standard deviation fracture resistance value of 746.4±78.76N. Nevertheless, no statistically significant distinction (P>0.05) was detected between the Sonic Fill group and the control group. The analysis of variance (ANOVA) test revealed a statistically significant difference (P=0.0042< 0.05) in the observed variation between groups. Tukey's post-hoc test revealed that there was no statistically significant disparity (P>0.05) between the Sonic Fill group and the Control group.

Upon analyzing the number of cycles to which the specimens were exposed, it was shown that all specimens subjected to load and heat cycling matching a 24-hour period displayed statistically significant higher mean fracture resistance values compared to those treated with cycles resembling a 6-month period.

Table (3): Fracture resistance test results (mean± SD) as function of material and thermo-mechanical aging.

Variable		Thermo-mechanical aging								
		24 hrs				6 months				Paired t-test
		Mean	SD	95% CI		Mean	SD	95% CI		
				Low	High			Low	High	P value
Experimental Groups	Control	1103.77[A]	107.9	1036.89	1170.65	915.65[A]	159.8	816.60	1014.69	0.006 *
	Sonic Fill	1093.78[A]	147.92	1002.10	1185.46	901.71[A]	87.16	847.68	955.73	0.002 *
	Tetric-N	989.32[A]	105.92	923.67	1054.97	746.4[B]	78.76	697.58	795.21	0.0001*
ANOVA test	P value	0.0857 NS				0.0042*				

CI; Confidence intervals **; Significant (p<0.05)* *NS; Non-significant (p>0.05)*
Columns with the same letter are non-statistically significant at p>0.05.

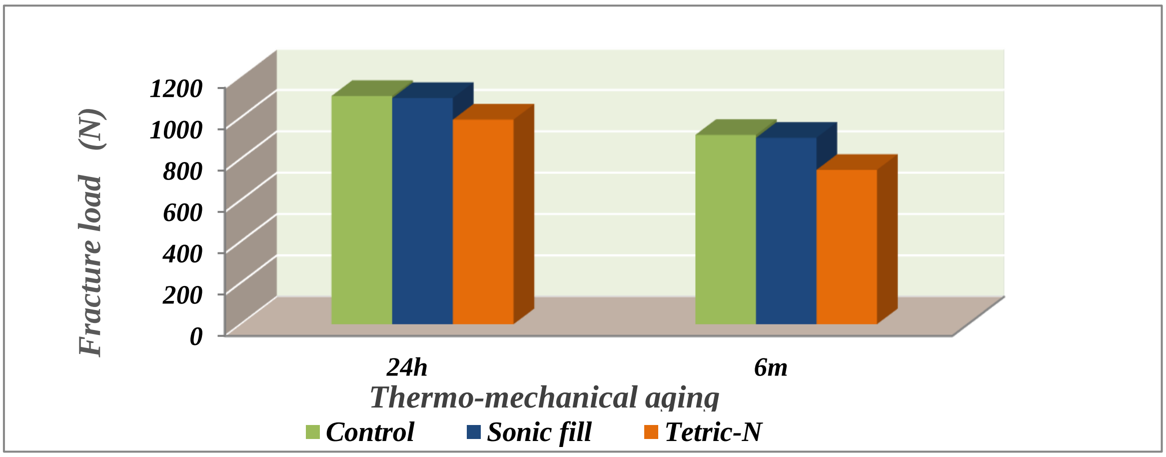

Figure (1): Column chart showing fracture resistance load mean values for all groups as a function of thermo-mechanical aging

Discussion

The restoration of maxillary premolar teeth with defects is an intricate and contentious subject in the field of conservative dentistry. When a substantial fraction of the dental structure is harmed, leading to a reduction in dental tissue, the tooth's strength diminishes proportionately. This enhances its vulnerability to fractures, particularly in relation to the bucco-palatal width of the occlusal box preparation [24]. This study focuses on tooth preparation for Class II MOD cavities, specifically due to their anticipated reduced fracture resistance. The probability of cusp fractures in maxillary premolars is increased when they are subjected to occlusal strain, mostly due to their unfavorable anatomical shape, crown-root ratio, and crown volume [25]. Furthermore, prior research has shown that these teeth are prone to fractures, particularly when the marginal ridge is weakened or totally eliminated during cavity preparation [26].

The adhesive restorative materials should possess the capacity to evenly distribute functional stresses throughout both the restorative material and the tooth contact. Moreover, it is crucial that they have the capacity to assist the delicate and poorly cared for dental framework. The utilization of resin-based composite material in direct restorations has proven to be an effective approach for repairing teeth with a moderate MOD preparation. These repairs have shown fracture resistance values that are similar to those of a fully undamaged tooth [27, 28].

Two bulk fill resin composites were compared and tested due to the growing acceptance of a novel resin composite bulk-fill approach that has demonstrated notable progress. It has been demonstrated that using bulk-fill resin composite restorations effectively reduces the occurrence of cuspal deformation and shrinkage stress, leading to enhanced fracture resistance [29].

All specimens underwent thermal and mechanical cycling treatments. Simultaneously applying cyclic mechanical strains and temperature cycles leads to the development of thermo-mechanical stress. The degree to which a test accurately replicates the clinical situation is strongly linked to the likelihood of the results having clinical importance. It is crucial to include moisture, stress, and controlled temperatures ranging from 5 0C to 55 0C in the experimental conditions to accurately evaluate the fracture resistance of direct resin-based composites. A fatigue test was conducted, after subjecting the restorations to cyclic loading for 417 and 75,000 cycles, representing the equivalent of 24 hours and 6 months of clinical case, respectively. Furthermore, thermo-cycling was performed within a temperature range of 5 0C to 55 0C.

Both the tested materials and thermo-mechanical aging had a significant effect on the resistance to fracture of premolar teeth with MOD cavities (Table 2). The findings of this study indicate that there was no statistically significant variation detected among the control group, Sonic-fill group, and Tetric-N group after 24 hours of thermal mechanical ageing (Table3). The incorporation of Nano composites into novel resin composite materials, together with advancements in bonding techniques, has led to mechanical properties that closely resemble those in natural teeth. Moreover, it is likely that this outcome can be attributed to the implementation of a conservative standardized cavity preparation technique, aimed at maximizing the preservation of intact tooth structure and enhancing the resilience of repaired teeth against fractures [30]. The present study's results were found to align with the research carried out by Dalpino et al. and Bassir et al [31,32]. The monoblock concept involves the fusion of several interfaces and tooth structures to operate as a cohesive entity. The careful selection of suitable bond can improve the creation of a monoblock restoration that functions effectively as a cohesive unit, ultimately achieving a level of similarity to the structural integrity of a natural tooth. Establishing a strong link between materials is essential for achieving a more advantageous distribution of stress and improved resistance to fractures.

Moreover, over a 6-month period of thermo-mechanical ageing, the control group demonstrated the greatest average fracture resistance values, followed by the sonic fill group, with no significant difference between them. Conversely, the Tetric-N group exhibited the lowest mean value with highly significant difference from other two groups. The observed differences across the groups were determined to have statistical significance ($P=0.0042<0.05$) (Table3 & Fig1). The hypothesis proposed that the fracture resistance of premolars with MOD cavities restored with sonic activated bulk fill resin composite, would exceed that of those treated using Nano-hybrid composite. This confirms that the hypothesis could not be rejected and the sonic activated bulk fill resin composite is more effective in repairing premolar teeth with MOD cavities.

The experimental group, which served as the positive control, exhibited a notable higher fracture resistance value. This can be due to the existence of intact palatal and buccal cusps, as well as undamaged mesial and distal marginal ridges that leads to strengthening and maintaining the structural integrity of a healthy tooth. Nevertheless, the Nano-hybrid composite possess a restricted capacity to completely reinstate the mechanical characteristics that might be impaired as a result of inherent disparities between the tooth structure and the restorative material [33]. In addition, the presence of several surfaces increases the challenge of generating strong adhesion, thereby presenting significant barriers [34]. The results of this study align with previous studies conducted by Cobankara et al. and Mohan et al. [35, 36], which investigated the resilience of mandibular molars that underwent endodontic treatment to resist fractures when repaired using different techniques. The researchers recorded the utmost degree of resistance to fractures witnessed in intact teeth. It was shown that none of the assessed restoration techniques were able to fully restore the reduced fracture resistance resulting from MOD cavity preparation. Javaheri et al. [37] also found that the control group, which included teeth without any restorations, showed the highest level of fracture resistance.

Fracture strength values did not show any notable disparity between the undamaged control specimens and those repaired using Sonic fill resin composite during all testing periods. Vibration reduces the viscosity of the substance by 84%, resulting in a more liquid texture that improves its capacity to adapt during use. This process enables the fabrication of accurately tailored repairs for the inside walls of a hollow space, possessing characteristics akin to a composite substance with fluidic attributes. As a result, this method may effectively minimize gaps between layers and also accommodate a larger quantity of filler material derived from a Nano-hybrid source. This allows for efficient placement and accurate fine-tuning to the walls of the cavity, while reducing the incidence of air pockets. Ensuring that the adhesive materials effectively seal the margin and enhance the retention and resistance properties of the treated tooth is of utmost importance [38]. Furthermore, it is essential to acknowledge that the sonic fill resin composite exhibits a shrinkage rate of only 1.6%. The goal of minimizing polymerization shrinkage is to reduce the occurrence of voids and the subsequent danger of fracturing, hence minimizing the possibility of fracture formation [39].

The sonic-fill and Tetric N-Ceram Bulk fill materials exhibited statistically significant variations in fracture resistance. Teeth that underwent sonic-fill therapy showed greater fracture strength values in comparison to teeth treated with Tetric N-Ceram bulk fill. There is a notable disparity of 83.5% in the filler content between the sonic-fill resin composite and Tetric N-Ceram, which has a filler concentration of 75% [40]. Moreover, the composition of additives found in the resin exhibits a wide range of variations. The phenomenon of filler loading is widely recognized as the most crucial component and has been extensively studied in the field of physical performance in dental composite resins. Augmenting the quantity of filler employed improves the physical and handling characteristics of composites. The relationship between the decrease in size and the increase in volume of fillers is directly associated with the improvement of compressive strength and surface hardness [41].

The use of Sonic-Fill composite can be considered an appropriate therapeutic method for restoring damaged maxillary premolar teeth. The teeth that were repaired using Sonic-Fill composite exhibited the highest average fracture resistance value, which was significantly different from all other repaired groups, whether they were restored using bulk fill or the incremental layering technique. This difference can be attributed to the low viscosity of Sonic-Fill composites, which allows for better adaptation to the cavity walls. This reduces the occurrence and size of critical voids at the cavity's margin and along line angles [13]. The findings of the present investigation are consistent with those of Win et al. [42], which indicate that the elevated fracture resistance values are attributed to the elevated filler content, loading, type, and size are the factors that account for the increased flexural strength, flexural modulus, and microhardness [43].

Leprince et al. [44] disputed these findings by stating that the filler loading proportion in bulk-fill resin composites varies between 60.7% and 85.3%. This association with mechanical qualities is deemed satisfactory. Furthermore, it was noted that the placement of bulk-fill composite materials under substantial occlusal pressure should be handled carefully, as the mechanical properties of the conventional high viscosity resin composite were generally better than those of the bulk-fill resin composite. Prior research has indicated that the degree of filler loading has minimal impact on the mechanical characteristics of composite resin materials. Hence, it remains unknown if the sole incorporation of filler loading exerted any influence on the study's outcome. Several supplementary factors that could influence this result encompass the existence of an alternative resin matrix, diverse varieties of filler materials, and discrepancies in the distribution and dimensions of the fillers. Hence, they proposed the use of a standard composite material layer over the bulk fill material [45].

The current study presents a divergent perspective to the conclusions reached by Julio et al. [46], whom found that the adhesive strength of Sonic-Fill restorations was inferior to that of Tetric N-Ceram bulk-fill resin composite. The variation in bond strength can be attributed to the notable interfacial tensions present in the Sonic-Fill approach at the dentin/composite contact, resulting in the production of higher tensile stresses. Sonic-Fill demonstrates a reduced modulus of elasticity and higher tensile and compressive strength in comparison to Tetric N-Ceram Bulk fill. The correlation between mechanical properties may explain the slightly increased interfacial stress. In addition, Sonic-fill composite materials with a lower elastic modulus demonstrate reduced stiffness, leading to lower stresses within the composite. However, this also causes bigger stresses at the interface. In contrast, the composite material with higher elastic modulus values (particularly, Tetric N-Ceram Bulk-fill) exhibited reduced stress levels, which can be attributed to its elevated modulus of elasticity. Materials with a high elastic modulus exhibit minimal deformation. Scanning electron microscopy analysis of the dentin surfaces showed that gaps were only present in the case of Sonic-Fill. These gaps could potentially compromise the sealing and affect the bonding strength.

The alternative hypothesis was rejected as irrespective of the particular material group under investigation in this study, it was noted that all samples exposed to both load and thermal cycling, mimicking a 24-hour period, exhibited significantly higher fracture resistance values compared to samples subjected to cycles simulating a 6-month period. Bedran et al. [47] demonstrated that mechanical load cycling affects the average fracture resistance values. The researchers investigated the effects of thermal and mechanical stress cycling on the Nano leakage and fracture resistance of Class II restorations in their study. It was noted that the chewing and biting actions done by a human had an impact on the number of cycles seen. The researchers discovered a positive correlation between the number of cycles and the durability of the composites. The restoration's durability decreased as the number of cycles increased, which was mostly influenced by the chewing and biting actions of a person.

The outcomes of this investigation were in line with that of Rauber et al. [48], who conducted a comparison of the endurance against fatigue of teeth that were repaired using bulk fill composite resin, traditional composite resin with progressive insertion, and unprepared healthy teeth. The researchers concluded that the fatigue cycling procedure had a detrimental effect on the fracture resistance of all specimens. This effect can be attributed to the weakening of the adhesive contact caused by mechanical loading. The hybrid layer has a vital function in creating a connection between resin composite and dentin, hence impacting the durability of restorative materials. Hence, any alterations taking place in the hybrid layer have the potential to affect the long-lasting nature of these materials. The findings were in line with the results documented by Mohamed et al. [20]. Their analysis showed that subjecting the specimens to load and thermal cycling corresponding to a 24-hour period resulted in a statistically significant increase in the average value compared to specimens subjected to cycles resembling a 6-month period.

The outcomes of this investigation were in line with the results reported by Nagieb et al. [21], indicating that mechanical loading influenced the average fracture resistance values. More precisely, the researchers discovered that submitting the samples to repeated loading, similar to the wear and tear experienced over a period of 3 months, led to a notable reduction in fracture resistance when compared to those subjected to only 24 hours of load cycling. Isaac et al. [49] conducted a study that found that cyclic loading significantly affected the micro-tensile bond strength of the adhesive system after ageing. Shuaeib et al. [50] found that the combined effect of temperature and strain on damage rates did not consistently result in more damage compared to applying these variables separately.

There are some limitations in this study:

1. During the selection procedures of teeth: It was difficult to find extracted teeth with the same dimensions of mesio distal (7 ± 0.5 mm) and bucco lingual widths (8mm ± 0.5mm) of crown which measured by a caliper.
2. During cavity preparation: while mesio-occluso-distal (MOD) cavities were prepared, the cavities were difficult to make with the same measurements which were confirmed after cavity preparation using a caliper.
3. While the samples were subjected to mechanical aging, the test was repeated 417 cycles and 75000 times to clinically simulate the 24 hours and 6 months chewing condition so I had to sit next to the device for long hours to record the results.

Conclusions

Considering the results and constraints of the study, it can be inferred that the strength against fractures in upper premolars with MOD cavities is greatly influenced by the technique employed for packing the resin composite. A direct relationship exists between the thermo-mechanical ageing and the durability of the composite restorations. However, additional clinical trials are necessary to assess the therapeutic efficacy of the evaluated restorative materials.

Clinical relevance

Sonic-activated bulk fill resin composite can be viewed as a suitable method for restoring weakened maxillary premolar teeth. This treatment can improve the strength of weak tooth structures by achieving higher fracture resistance values, similar to those of healthy teeth.

Recommendation

Clinical trials are necessary to assess the therapeutic efficacy of the evaluated restorative materials.

Abbreviations

MOD: Mesio-occluso-distal; BFRC: Bulk-fill resin composites; CEJ: Cemento-enamel junction; KN: Kilo Newton; (M): Mean; SD: Standard deviation.

Conflict of Interest:

The authors declare no conflict of interest.

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This study protocol was approved by the ethical committee of the faculty of dentistry- Minia university on: **22 /2/ 2021** approval number: **481**

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