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EFFECT OF PREHEATING ON FRACTURE RESISTANCE OF BIS-GMA FREE AND CONTAINING RESIN COMPOSITE AFTER CYCLIC LOADING (IN-VITRO STUDY)

Nermin Alsayed Mahmoud*

ABSTRACT

Aim: Evaluation of preheating effect on fracture resistance of Bis-GMA free and containing resin composite after cyclic loading.

Materials and Methods: Two different resin composite were used, Bis-GMA free composite (Admira Fusion) and Bis-GMA containing composite (Grandio). One hundred sound maxillary premolars were selected, MOD cavity prepared in 90 teeth of them, and 10 teeth remained intact (control gp.). The prepared teeth classified into 9 groups according to type of resin composite used, heating temperature (room temperature (23°C) & 54±1°C) and cyclic loading time (24 hours & 3 months). The mechanical ageing test was carried out utilizing a four-station multi-modal ROBOTA chewing simulator, and universal testing machine was used to determine fracture resistance, The amount of force required to fracture was measured in Newtons. IBM® SPSS® Statistics Version 20 for Windows was used to perform the statistical analysis.

Results: At varied temperatures and cyclic loading, the mean value of fracture resistance of teeth restored by Admira (A1) was higher than that of teeth restored by Grandio (A2). Teeth restored with heated composite at 54±1 °C had stronger fracture resistance than teeth restored at room temperature. After 24 hours of cyclic loading, the mean fracture resistance load of all groups tested was higher than that observed after three months ($P<0.001$).

Conclusion: Even without preheating, Bis-GMA-free resin composite restorative materials restored the fracture resistance of maxillary premolars with MOD preparation under cyclic stress. Preheating, on the other hand, improves the fracture resistance of teeth repaired with the two resin composites evaluated.

KEYWORDS: Fracture resistance, Bis-GMA free composite, preheating, cyclic loading.

* Lecturer of Operative Dentistry Faculty of Dentistry, Minia University

INTRODUCTION

Despite the fact that resin composites based on Bis-GMA have become indispensable for dental restoration because to their higher aesthetic quality, ease of use, and increased mechanical strength, there are still issues. The monomer phase suffers from polymerization shrinkage, which is a significant concern. Post-operative sensitivity, marginal discoloration, secondary caries, cuspal displacement, and even fissures in healthy tooth structure can be caused by polymerization shrinkage and subsequent contraction pressures. As a result, one of the most critical difficulties in the creation of dental composites is removing or minimising the amount of volumetric contraction during polymerization.[1]

To combat this, methacrylate-free resin composites have been developed with the goal of improving biocompatibility and reducing shrinkage stress. In 2007, Silorane monomers were used to develop a methacrylate-free composite resin with low polymerization contraction (around 1%) and insolubility, which inhibits leaking into the oral environment. As a result, the restorations' stability is satisfactory, and they work well.[2]

Ormocer, an organically modified ceramic, was introduced more recently. It combines the toughness of glass with the characteristics of resin by using an inorganic base of silicon dioxide and polymerizable organic components. The goal of this material is to improve not only the aesthetics, but also the abrasion resistance, allowing for a reduction in polymerization shrinkage and surface roughness, as well as caries protection. Furthermore, because it is free of Bis-GMA and other common methacrylates, it is devoid of cytotoxicity concerns, is considered inert, and improves biocompatibility.[3]

Chairside preheating of resin composites has been introduced to improve their handling capabilities. It reduces microleakage and gap formation by lowering the viscosity of composites, resulting in better flowability and marginal adaptation and reduces microleakage and gap formation.[4] It can be used for any form of composite restoration, but it's especially useful in deep cavities of posterior teeth, where adequate adaption and polymerization are required in the material's deeper layers.[5]

Because resin composite materials can bond to the dental structure, their use in healing MOD cavities has increased recently. However, a clinician should examine their mechanical properties, handling properties, and marginal sealing capacity. It's a little tricky to use them in MOD cavity preparations because they're technique sensitive.[6]

The necessity for knowledge regarding the mechanical properties of dental materials before they are used in clinical settings has led to the development of a number of devices that simulate mastication in order to offer data on how a material will behave over time. Simultaneously, several in vitro studies must imitate the physiological aspects of human mastication, as well as the direction and force of jaw motions, as closely as feasible.[7]

As a result, the purpose of this research was to see how preheating affected the fracture resistance of Bis-GMA free and containing resin composites after cyclic loading.

MATERIALS AND METHODS

MATERIALS

TABLE (1): Materials, specification, composition, manufacturers and batch number.

Material	Specifications	Composition	Manufacturer	Batch number
Admira Fusion	Nanohybrid ORMOCER based resin composite	**Matrix:** Resin ORMOCER® **Filler:** glass ceramics, Silicon oxide Nano filler, pigments. **Filler:** Inorganic filler **filler content % :** 84 (W/w)	**Voco, Cuxhaven, German. Service @voco.de**	**1934381**
Grandio	Nanohybrid Bis-GMA-Based resin composite	**Resin matrix:** based on dimethacrylates, contains Bis-GMA and TEGDMA **Inorganic filler particles:** Nano-sized silica) **Filler content %** (87 % w/w-71.4vol)		**1948567**
Futurabond DC	Dual-curing universal adhesive	Organic acids, Bis-GMA , HEMA , TMPTMA, BHT(butyle-hydroxy toluene; inhibitor), ethanol, fluorides , CQ , amine, catalysts		**1924397**
Vococid etchant	Etchant agent	35% phosphoric acid, silica, water		**1507285**

METHODS

Teeth selection:

Non carious 100 sound maxillary premolars were extracted for orthodontic purpose and examined using lens 7X magnification to exclude cracked and or fractured premolar teeth. Teeth dimensions were measured using a digital caliper with an accuracy of 0.01 mm. Buccolingual dimension of chosen teeth was 9.5 ±0.5 mm while mesiodistal dimension was 7.5±0.5mm.

Teeth preparation:

The current study used two half Teflon split mold with dimensions of 30 mm diameter and 25mm height. The mold was filled with self-curing resin, then each tooth was immersed in acrylic resin until the cemento-enamel junction (C.E.J).was reached.

Each tooth was mounted inside an acrylic block using Dental Surveyor (Ney Dental Surveyor, Anaheim, CA, USA) to ensure that it was centralized and aligned perfectly parallel to the long axis of the tooth.

Using a fissure carbide bur with flat end (Kerr, Switzerland), operated in high speed hand piece (Sirona, Germany) under copious water coolant MOD cavities were prepared with the following dimensions: (2 ±0.2 mm pulpal depth, 1.5 ±0.2 mm gingival width, 1.5 ±0.2 mm axial height), and the occlusal isthmus width was one-third of the intercuspal distance **(fig. 1).**

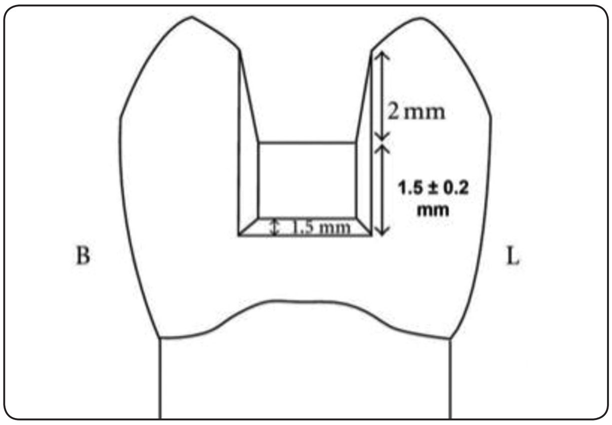

Fig. (1) Dimensions of the prepared cavity.

Grouping of the specimens:

One hundered maxillary premolars were selected, 80 premolars divided into two groups of 40 specimens each according to types of restorative materials used in the study (A). The first group restored by Admira Fusion Bis-GMA free resin composite (A1) and the second group restored by Grandio Bis-GMA containing resin composite (A2).

Each group was subdivided into 2 subgroups of 20 specimens each according to preheating of resin composite (B), the first subgroup (B1) at room temperature (23 °C), and the second subgroup (B2) preheated at 54±1 °C.

Each subgroup was divided into two classes based on the cyclic loading time (T). T1 was measured after 24 hours of cyclic loading, while T2 was evaluated after 3 months of cyclic loading (T2). The remaining 20 sound premolars served as a control group, with 10 of them being assessed after a 24-hour cyclic loading period and the other ten being assessed after three months.

preheating of resin composite:

Each type of tested resin composite was heated up to 54±1°C in a composite heater (Ceramic one input voltage 220v, output voltage 12v, power 24w. china) prior to its packing in the prepared cavity. In order to decrease heat loss during the placement of each layer, the maximum time for retrieving the resin composite from the heating unit and placing it in the cavity was 10 seconds. After adapting each layer of resin composite, allowed to cool for 15 seconds (to decrease thermal shrinkage), then it was light-cured for 20 seconds.[8]

Restorative procedures:

The etching gel was applied for 15 seconds to the prepared cavity enamel, then rinsed off with water for 15 seconds before gently air drying. The bonding agent was then evenly applied to the cavity walls and rubbed for 20 seconds before being gently dried with oil-free air for at least five seconds to evaporate solvents, followed by light curing for 10 seconds with a light emitting diode curing unit (1470 mW/cm2, 3M, Elipar, Deep Cure-S LED Curing Light USA) set to the manufacturer's specifications. During composite packing, the Tofflemire matrix system (DDP, stainless steel, Pakistan, 2014) was utilized to encircle the teeth.

The assigned resin composite for each prepared cavity was packed progressively using a gold plated composite applicator (American Eagle composite set, United States), each increment was light cured for 20 seconds as directed by the manufacturer. The final 2mm increment was placed occlusally to overfill the cavity in order to develop correct mesiodistal and occlusal contour, as well as inclines and ridges of occlusal anatomy, then light cured for 20 seconds, Finishing and polishing were done using (TOR VM Finishing and Polishing Kit, Russia).

Cyclic Loading fatigue:

Mechanical fatigue was applied to the specimens in a pneumatic fatigue apparatus to replicate intraoral conditions. The mechanical ageing test was carried out utilizing a four-station multi-modal ROBOTA chewing simulator (ACTA Fatigue tester, Netherlands) with a thermo-cyclic protocol controlled by a servomotor (Model Ach-09075dc-T, Ad-Tech Technology Co., Ltd., Germany).

A weight of 5 kg was used, which was equivalent to 49 N of chewing force. Half of the specimens were treated to 417 cycles of loading to clinically replicate the 24 hour chewing condition, while the other half were subjected to 37500 cycles to clinically simulate the three month chewing condition.[9] The load was applied in conjunction with a thermocycling method that included a cold / hot water bath with temperature difference of 5°C/55°C.

Fracture resistance measurement:

The universal testing machine (Instron, model 3345, England) was used to determine fracture resistance, Screws were tightened to secure the samples to the lowest fixed compartment of the testing machine. The specimens were placed in such a way that the occlusal surface remained perpendicular to the loading axis.

An audible crack indicated the load at failure, which was corroborated by a precipitous drop in the load-deflection curve measured with computer software (Bluehill Lite Software Instron Instruments) The amount of force required to fracture was measured in Newtons.

Statistical Analysis:

To compare different tested materials, different preheating temperatures and varying cyclic loading, an independent t-test was utilized. When the ANOVA value was significant, a two-way ANOVA test between all groups was used to examine the effect of interaction between different factors, followed by Duncan's post hoc test for pair-wise comparison between the mean. 0.05 was chosen as the significant level. IBM® SPSS® Statistics Version 20 for Windows was used to perform the statistical analysis

RESULTS

Table (2) revealed that, when comparing the two resin composites, there was a statistically significant difference between the mean value of fracture resistance of teeth restored by Admira (A1) gp. and teeth restored by Grandio (A2) gp., with (A1) being higher than (A2) at different temperatures and cyclic loading. In (A1B2T1) gp, the highest mean value was reported and the lowest mean value was observed in the (A2B1T2) gp.

The fracture resistance of teeth restored with (Admira) resin composite at room temperature insignificantly differed from that of sound teeth (control gp.) after varied cyclic loads. Whereas after preheating at 54±1°C, the mean value of teeth restored by (Admira) was higher than that of sound teeth (P=0.247).

TABLE (2): At various temperatures and cyclic loading times, mean and standard deviation (SD) values of fracture resistance load (N) for the various evaluated resin composite restorative materials:

Cyclic loading Time (T)	Sound teeth (control gp.)	Resin composite (A)				
		Bis-GMA free (Admira) (A1)		Bis-GMA containing (Grandio) (A2)		
		At room temperature (23°C) (B1)	At 54±1 °C (B2)	At room temperature (23°C) (B1)	At 54±1 °C (B2)	
	Mean± SD	**Mean± SD**	**Mean± SD**	**Mean± SD**	**Mean± SD**	**P- Value**
24 hours (T1)	$1328.16±33.19^{Ab}$	$1530.41±83.55^{Ab}$	$1762.36±73.43^{Aa}$	$922.38±91.37^{Ac}$	$1330.46±65.23^{Ab}$	<0.001*
3 months (T2)	$945.73±64.25^{Bb}$	$1190.22±90.65^{Bb}$	$1480.39±54.35^{Ba}$	$626.38±52.1^{8B}$c	$940.82±54.16^{Bb}$	<0.001*

Significant difference is shown by means with different capital letters in the same column; significant difference is indicated by means with different small letters in the same row.

****significant (p<0.05) Ns; non-significant (p>0.05).***

The mean value of sound teeth was higher than the teeth restored by (Grandio) at room temperature. However, under varied cyclic loading, no significant difference was identified between teeth restored by (Grandio) heated at 54±1°C and sound teeth (P=0.364).

Regarding the effect of composite preheating, there was a statistically significant difference between all groups restored at room temperature (23 °C) and those restored by both types of resin composite preheated at 54±1 °C, where (P<0.001). Fracture resistance of teeth restored with preheated composite at 54±1 °C was higher than tat restored at room temperature.

There was a statistically significant difference between all groups assessed after 24 hours of cyclic loading and those measured after three months, with the mean value of fracture resistance load of all groups tested after 24 hours being higher than that recorded after three months (P<0.001).

DISCUSSION

Because of its low volumetric shrinkage, high reactivity, good mechanical properties, low volatility, and low diffusivity into tissues, Bis-GMA is the most often used monomer in commercial dental composites.[10,11] Bisphenol A (BPA) and glycidyl methacrylate (GMA) were used to create Bis-GMA. BPA is an endocrine disruptive substance that has been linked to a number of health issues, including male reproductive abnormalities.[12,13] impaired spermatogenesis[14,15], and an increased risk of heart disease and diabetes .[16,17]

Admira Fusion (VOCO) is made up of ceramic polysiloxane, which has a low shrinkage (1.25 percent) when compared to other composite resins that use an organic dimethacrylate monomer matrix. This kind of ormocer increases aesthetics, biocompatibility, abrasion resistance, caries resistance, and reduces polymerization shrinkage and surface roughness while also reducing polymerization shrinkage and surface roughness It also eliminates any cytotoxicity concerns that come with traditional monomers like Bis-GMA and TEGDMA. When compared to methacrylate-based composite resins, this shows to be a significant benefit.[18]

When dentists employ composite resins in their practise, they use a variety of protocols and techniques. Preheating composite resin is a widely used technique for improving flowability and reducing film thickness.[19] Preheating composite resin can help it polymerize faster, shrink less, and have a higher surface hardness. [20,21] This influence on mechanical properties and clinical performance, has yet to be studied. [22]

Due to the absence of the marginal ridge and the formation of micro fractures induced by occlusal stresses, teeth with MOD cavities have a significantly reduced fracture resistance. Cuspal fracture is caused by occlusal stresses that drive the cusps in opposite directions. Despite the constraints of a laboratory test, it can be observed that a direct resin composite restoration can restore the fracture resistance of teeth with a moderate MOD preparation to that of a sound tooth. MOD cavities were basically prepared in the teeth because they are thought to have the lowest fracture resistance. [23,24]

For ageing of restorations, thermal and mechanical load cycling has been proposed. Because of its potential for imitating mastication, load cycling has been explored. Thermo-mechanical fatigue is caused by simultaneous exposure to cyclic mechanical strains and heat cycles. In terms of damage rates, the synergistic effects attributable to both temperature and strain are frequently greater than the damage that would be seen if these circumstances were applied separately. [25] As a result, chewing simulators (Robota) were used in this investigation.

The findings of this study revealed a statistically significant difference between the two types of resin composites tested, with the mean value of fracture resistance load of teeth restored by Bis-GMA free resin composite (Admira) being higher than that of teeth restored by Bis-GMA containing resin composite (Admira).

These findings, which agree with those of Ibraheem M. et al., 2011[26], display that (Admira) filling material has the highest fracture resistance among the restorative materials because it is based on ormocer technology, which should not be confused with glass ceramic fillers used in conventional composites. Ormocers have a lengthy silicon-based "backbone" onto which carbon-carbon double bond-containing side-chains are attached. Ormocers are a material of interest for use as a matrix for resin composites because the bigger size of the monomer molecule can reduce polymerization shrinkage and wear, as well as monomer leaching.[27]

Also, the findings of this study were similar to those of Antonious S. et al., 2020 [28], who investigated the stress resistance of nano-hybrid composite and ormocer restorations on posterior teeth and found that the ormocer has a stronger resistance than the nanohybrid composite. It was proposed that these findings because ormocer has three-dimensionally cross-linked co-polymers with multi-polymerization and has no residual unreacted monomers, combining the surface qualities of silicones, the toughness of organic polymers, and the hardness and thermal stability of ceramics.

However, these findings contradicted those of Elena K. et al., 2018[29], who investigated the mechanical stability of Bisphenol A-glycidyl methacrylate (Bis-GMA) and Ormocer-based resin composites and found that Admira Fusion is a promising Bis-GMA-free and Ormocer-based material, but it does not perform as well as conventional Bis-GMA-containing resin composites.

The mean fracture resistance of the sound teeth (control group) was 1328.16 N, which was close to values obtained in earlier research, which ranged from 882 N to 1568 N.[30] The mean value of fracture resistance load of the (control group) and teeth restored by (Admira) at room temperature was minor, which could be attributable to the present study's conservative cavity preparation. Ragauska A et al. concluded that ceramic inlays prepared with 1/2 or 1/3 of the intercuspal distance can restore tooth strength to levels comparable to intact teeth. [31] While the fracture resistance of teeth repaired by (Grandio) was decreased at room temperature and after various cycle loading times (control group).

In terms of the effect of composite preheating, the results showed that the mean value of fracture resistance load after preheating both types of resin composite at (541) °C was higher than that used at room temperature 23 °C, similar to the findings of Othman H and Zaineb M.,2018[32], who claimed that preheating increased the fracture resistance of all groups. This could be because pre-heating composites before photo activation increased their flow capacity, which has been demonstrated to boost marginal adaption. Furthermore, raising the polymerization temperature improved both radical and monomer mobility, resulting in a better total conversion. Pre-heated composite materials may benefit from this procedure by having improved mechanical and physical qualities, such as increased flexural and diametral tensile strength and better surface hardness. [33,34]

Daronch et al., 2006[35] shown that increasing the mobility of the monomer and filler particles increased monomer to polymer conversion of composite resin. Fracture toughness was improved as a result of the improved polymerization. However, these findings contrasted from those of two prior investigations, which found that increasing the temperature had no significant impact. [36,37] The fillers in the resins utilized in this research are to blame for this result. These materials' lower filler loadings may not be able to support the strongly crosslinked network generated by pre-heating.

Due to the accumulation of damage caused by cyclic forces, composite resin repairs may fail over time (fatiguing).[38] As a result, laboratory fatiguing of composite resins before to testing is a good way to improve the clinical relevance of the results. There was a statistically significant difference between fracture resistance load after 24 hours and after 3 months of cyclic loading in this study, with the mean value after 24 hours being higher than that equivalent to 3 months. These findings are comparable to those of Abdulmajeed A. and others. Thermocycling fatigue may have resulted in filler particle loss and surface modifications, lowering fracture resistance. Chemical breakdown by hydrolysis, stress-induced impacts, and chemical composition changes by leaching or loss of strength can all cause these changes. [39]

Artificial loading causes a significant deterioration in the mechanical properties of dental composite materials, according to Sideridou et al., 2007[40] and Sevimay et al., 2008.[41] Both water sorption and contact duration with aqueous media have been shown to have a major impact on surface hardness. One of the contributing causes was the smaller filler surface area associated with prepolymerized silica fillers. Filler debonding is facilitated since the bond between individual fillers and the resin matrix is reduced. Filler ingredient leakage has been demonstrated to cause cracks at the resin–filler contact, potentially weakening the material.

CONCLUSION

The following conclusion can be drawn within the limitations of this study:

1- Bis-GMA-free resin composite restorative materials efficiently restored the fracture resistance of maxillary premolars with MOD preparation under cyclic stress, even without preheating.

2- However Preheating resin composite improves the fracture resistance of teeth restored with the two resin composites that were examined.

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