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Effect of Preheating and Vibration on Microhardness and Microleakage of Microhybrid Resin Composite (*In Vitro* Study)

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Abstract

BACKGROUND: Preheating and sonic vibration are two methods for the treatment of microhybrid resin composites that may effect on their mechanical and physical properties.

AIM: This study was conducted to assess the effect of using preheating and sonic vibration on microhardness and microleakage of microhybrid resin composite

METHODS AND MATERIALS: For microhardness test, a total of 30 samples of resin composite discs were prepared. Samples were divided into three groups according to the method of treatment of resin composite, controlled group (T_0), preheated group (T_1), and sonic vibration group (T_2). Surface microhardness values were evaluated at baseline and after thermocycling. For microleakage test, a total of 30 Class-V cavities were prepared on the labial surfaces of extracted human anterior teeth. The cavities were then divided into three groups according to the method of resin composite treatment as mentioned before in the microhardness test. All samples were sectioned; then two-dimensional cross-sectional images from each sample. Each cross-sectional image was analyzed using Image J software to quantify interfacial microleakage at the cavity floor.

STATISTICAL ANALYSIS USED: Two-way ANOVA analysis was used to test the effects of thermocycling on three groups of each test. One-way ANOVA was used to compare between three different methods of resin composite treatment.

RESULTS: For microhardness at baseline revealed that the highest mean value was recorded for the control group, followed by the sonic vibration group meanwhile, the lowest mean value was recorded for the sonic vibration group, followed by preheated group at microleakage test.

CONCLUSION: Preheating and sonic vibration of microhybrid resin composite does not improve its microhardness; however, sonic vibration provides better marginal adaptation than the preheating and the conventional methods.

Introduction

Esthetic is an important factor in dentistry so that there is increasing use of dental resin composites in dentistry. The success of dental composites in restorative dentistry depends on their good esthetic properties and adequate durability [1]. Polymerization shrinkage is a major problem, which may initiate failure at the resin composite tooth interface, resulting in interfacial gaps. To improve resin composite adaptation, many ways have been proposed, including incremental layering to reduce C factor, soft start, and pulse delay curing methods to modify polymerization rate, and the use of flowable composite to allow greater marginal adaption [2]. Flowable resin composites with their low filler content and more flowability act as stress absorbers as they are resilient, but the lower filler content of flowable composite materials results in greater polymerization shrinkage which is expected to be greater than conventional composite [3].

Many trails were introduced to enhance resin composite adaptation through increasing flowability of hybrid resin composites, among which preheating method, sonic or ultrasonic method as those techniques have been introduced to improve the convenience of manipulation and increase the adaptation of dental composites to the cavity without affecting the resin composite formulation [4], [5]. Recent literature recommended chair side warming of resin composites before photopolymerization where, increased temperature of conventional composite with high filler loading may improve flowability, which can aid in composite placement and better adaptation to the cavity, increasing the restoration's durability. Calset warmer, a device that preheats resin composite before its application was introduced to the market, and it was claimed that preheating the resin composite may be advised to improve physical and mechanical properties [6]. Many questions about the influence of preheating on the mechanical properties of resin composite and whether preheating enhances them remain unanswered. Furthermore, it may improve or prevent microleakage by increasing the flowability of the material [7], [8], [9].

On the other hand, sonic vibration energy has been proposed as a suggested method to pack the bulk-fill resin composite. The principle of this technique assumes that vibration lowers the viscosity of the resin composite, allowing the material to flow and easily adapt to the cavity walls similarly as a flowable resin composite [10]. To increase the adaptation of a resin composite, a handpiece-type loading device using vibration was introduced. Its idea depends on reducing the viscosity of high viscosity resin composite with high filler content through vibration to enable the bulk application. However, the device requires a specially designed, expensive handpiece and a special resin composite containing a vibration modifier [11]. Hence that, recently, a portable vibratory packing device that could be used with the conventional resin composite and of lower cost has been introduced with the intent of increasing the adaptation of the tooth-composite interface by applying a vibration of 60 Hz or more. Therefore, the present study was designed to investigate the effect of preheating and sonic vibration on microhardness and microleakage of microhybrid resin composite before and after thermocycling. Thermocycling has been used in *in vitro* studies to simulate changing intraoral temperature conditions and therefore recreate the aging effects that restorative materials are subjected to in the mouth [12]. The null hypothesis of the current study was that there is no effect of either preheating or sonic vibration on microhardness and microleakage of microhybrid resin composite.

Materials and Methods

Sample size calculation

Assessment of the effect of preheating and vibration of microhybrid resin composite on microleakage and microhardness, two-way analysis of variance is proposed (ANOVA). A minimum total sample size of 60 samples were sufficient to detect the effect size of 0.38 according to Cohen, a power (1-β) of 80% at a significance level of $p<0.05$ and partial eta squared of 0.13. The 60 samples were divided into two main tests 30 samples each; microhardness and microleakage. The sample size was calculated according to G*Power software version 3.1.9.2 where; f: is the effect size= 0.40; α= 0.05; β= 0.2; Power= 1- β = 0.80 [13], [14].

Microhardness evaluation

After sample size calculation, a total of 30 discs of microhybrid resin composite (Composan LCM ProMedica, Germany); of 8 mm diameter and 2 mm thickness were prepared by inserting the resin composite as a single increment in Teflon split mold. The resin composite was covered with a polyester strip and a glass slide to promote a flat surface [15]. The 30 samples were divided into three groups according to the method of composite treatment (T) (10 samples each) where in control group T_0: the resin composite was packed directly without any treatment at room temperature, preheated group T_1: in which the resin composite syringe was placed inside Active Resin heater (AR). The preheating device was used for the current study. The temperature was adjusted at 50 ^{0}C in the present study. Finally, in the vibration group, T_2: where the resin composite was packed by using a vibratory packing device (compothixo^{TM} KerrHawe, Switzerland) instrument that is designed to vibrate during composite packing at vibration frequency is 140Hz ± 20Hz. According to the manufacturer instructions the semi-sphere tip was selected in the current study as it is suitable for the application of the resin composite as a bulk. The instrument is activated using a button on the top surface of the handle that activate sonic tip to vibrate for packing of the resin composite material. The instrument is designed to vibrate for 10 min. All samples were light-cured for 40 s by using LED (Elipar™ DeepCure-S curing lights, USA), with exposure of 400 mW/cm^2 according to the manufacturer's instructions. Then, all samples were immersed immediately into distilled water at room temperature for 24 h [16].

Microhardness testing

The microhardness of each sample was performed after 24 h immersion in distilled water as the baseline value. Surface micro-hardness of all samples was determined using Digital Display Vickers Micro-hardness Tester (Model HVS-50, Laizhou Huayin Testing Instrument Co., Ltd. China) with a Vickers diamond indenter and a ×20 objective lens. A load of 100 g was applied to the surface of each sample for 10 s then, three indentations were made on the surface of each sample which were equally placed and not closer than 0.5 mm to each other. Microhardness was obtained using the following equation: $VHN=1.854\ P/d^2$ where VHN is Vickers hardness in Kgf/mm^2, P is the load in Kgf and d is the length of the diagonals in mm. After evaluation of the baseline microhardness values, all samples were thermocycled for 500 cycles in a thermocycling machine at temperature 5°C–55°C [17]. Then, the microhardness of all samples was reevaluated.

Microleakage evaluation

After sample size calculation, thirty sound, caries, and restoration-free extracted human anterior teeth were collected. The study was carried out after approval of the Research Ethics Committee of the faculty of Dentistry Suez Canal University (#162/2019). A total of 30 standardized class V cavities were then prepared on the labial surfaces using regular diamond burs attached to a high-speed turbine handpiece underwater coolant, followed by superfine finishing burs. The cavities were 4 mm in width and 1 mm in depth with all margins and floors located in enamel [18]. The thirty samples were divided into three groups according to the method of resin composite treatment (10 samples each, T_0, T_1, and T_2) as mentioned before in microhardness testing groups. Each cavity was filled with the micro-hybrid resin composite as a single increment, then covered with a polyester strip and a glass slide to promote a flat and smooth surface [19]. Light curing of each sample was performed with LED as mentioned before for 40 s. Then all samples were immersed immediately into distilled water at room temperature for 24 h.

All samples were sectioned longitudinally into two equal halves using low-speed diamond saw (Buehler, USA) underwater coolant [20]. A digital stereomicroscope with built-in usb camera (U500x Capture Digital Microscope, Guangdong, China) at 35X magnification was used to evaluate the degree of adaptation as gap % through using image J software (Image J 1.43U, National Institute of Health, USA). Each cross-sectional image was analyzed using Image J software to quantify interfacial microleakage at the cavity floor [21], [22].

Statistical analysis

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov–Smirnov and Shapiro–Wilk tests, data showed parametric (normal) distribution. Two-way ANOVA test was used to test the interactions between different variables. One-way ANOVA followed by post hoc Tukey test was used to compare between more than two groups in non-related samples. The independent sample t-test was used to compare between two groups in nonrelated samples. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Results

Microhardness test results

Results of the effect of methods of resin composite treatment on microhardness value at baseline revealed that; the highest mean value was recorded for the control group (T_0) with a mean value (92.75 ± 0.78) followed by the sonic vibration group (T_2) with a mean value (92.11 ± 0.73). The lowest mean value was recorded for the preheated group (T_1) with a mean value (90.29 ± 1.42) without any significant difference between the three tested groups at ($p = 0.650$). After thermocycling results showed that the highest mean value was recorded by the sonic vibration group (T_2) with a mean value (91.98 ± 0.55), followed by the preheated group (T_1) with a mean value (87.31 ± 4.10). The lowest mean value was recorded by the control group (T_0) with a mean value (86.57 ± 3.79), with a significant difference between the three tested groups at ($p = 0.049$*) (Figure 1).

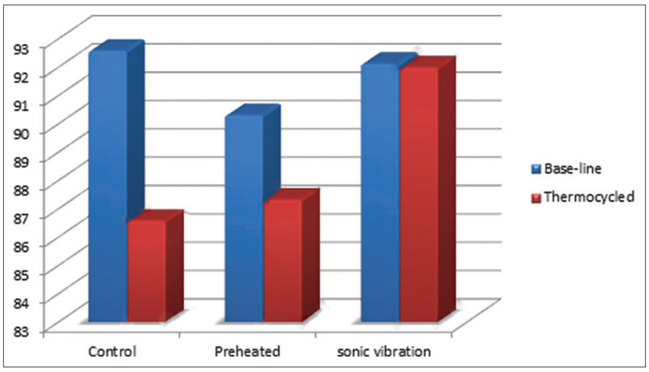

Figure 1: Bar chart representing microhardness values of all tested groups

Microleakage testing (gap %)

Results of the effect of methods of resin composite treatment on microleakage (GAP %) value at baseline revealed that the lowest mean value was recorded for the sonic vibration group (T_2) with a mean value (2.32 ± 1.64) followed by preheated group (T_1) with a mean value (4.17 ± 1.76). Furthermore, the highest mean value was recorded for the control subgroup (T_0) with a mean value (7.66 ± 0.85). There was a significant difference between the three tested subgroups at ($p < 0.001$***). After thermocycling, results showed that the lowest mean value was recorded by the preheated group (T_1) with a mean value (3.37 ± 1.61), followed by the sonic vibration group (T_2) with a mean value (3.89 ± 3.48). Furthermore, the highest mean value was recorded by the control group (T_0) with a mean value (8.76 ± 0.79). Furthermore, there was no significant difference between the three tested groups at ($p = 0.354$), (Figure 2).

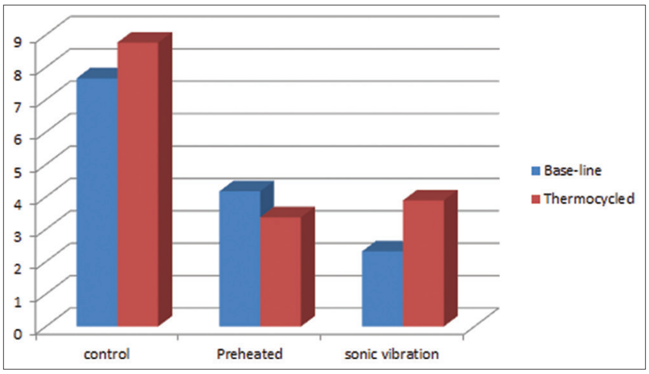

Figure 2: Bar chart representing gap % values of all tested groups

Discussion

Nowadays, resin composites are widely used due to their improved physical-mechanical properties and increased esthetic demands. The improved mechanical properties of resin composites along with good clinical performance have made them better suited for all situations. Despite improved mechanical properties, clinical data show that a major drawback of current resin composites is polymerization shrinkage, which may initiate failure at the resin composite tooth interface, resulting in interfacial gaps [23], [24]. In addition, concerns related to the ability of microhybrid resin composite to adequately adapt to the cavity walls and the cavo-surface margins have been raised. As the high viscosity of these materials could increase the possibility of internal voids, many trails suggest placing flowable resin composites to achieve a good marginal adaptation and minimize the gap between tooth and restoration, thus flowable composites with their greater flowability are expected to enhance marginal integrity. However, the low filler content of flowable composite may also cause greater net shrinkage than that of conventional composite [25]. This dilemma enthused the manufacturers to search for solutions through modifying the material make up or its technique of application to offset these problems. Some attempts were suggested such as preheating of composites resin and sonic vibrations which were proposed to enhance flowable properties of microhybrid composites resin without changing its inherent mechanical characteristics. Both techniques were suggested to reduce resin composite film thickness and improve its flow characteristics; thus, its adaptation to the cavity could be improved [26].

Multiple studies revealed that preheating of resin composite enhanced its flowability due to its high thermal energy that allows molecular motion of the monomer chains within the composite and increases the collision frequency. Recent research also indicates that there is a higher degree of conversion of the resin composites when cured at slightly raised temperatures [9], [27]. As another trial to improve the flowability of currently used resin composite material, lately a portable vibratory packing device (compothixo) was introduced as a promising tool to increase the adaptation of the tooth-composite interface by applying a sonic vibration of 60 Hz or more. Compothixo is a tool designed to vibrate during modeling composite to enhance the thixotropic properties of resin composite by changing its viscosity, without altering the chemical and mechanical characteristics of the material [26], [28]. Limited numbers of studies are available concerning the effect of preheating and sonic vibration on microhybrid resin composite. Therefore, the present study was designed to investigate the effect of preheating and sonic vibration on microhardness and microleakage of microhybrid resin composite.

Resin composite was preheated at 50 C in the present study as there are concerns regarding placing preheated composite of higher temperature into cavities as it may cause thermal injury to the pulp [20], [29]. On the other hand, preheating resin composite below 50 °C is not effective [30], [31], [32].

Although there was no significant difference between the three tested groups at baseline after thermocycling results of the current thesis showed that the highest microhardness mean value was recorded by the sonic vibration group. In addition, results showed that microhardness mean values of the control and preheated groups recorded a significant drop after thermocycling in comparison to the baseline values. This result could be attributed to the negative influence of thermal stresses generated during the thermocycling process in the structural constitutions of composite resin material. Furthermore, due to the negative influence of water on composites can be explained by two different mechanisms. First, water influences the material behavior by converting it from elastic to plastic state. Consequently, the matrix volume of the resin composite increases. Furthermore, there is a significant decrease in stiffness of the material. The second mechanism is due to the probable dissolution of components of composite in water [33].

Surprisingly, there was no significant difference between baseline and thermocycled microhardness mean values of the sonic vibration group. This result could be attributed to that sonic vibration reduces the viscosity of the resin composite due to more mobility of free radicals and propagating polymer chains, resulting in a more complete polymerization reaction and greater cross-linking that could result in better microhardness over time [34].

In addition, microleakage evaluation was carried out in the current study for interfacial gap detection. Several methods have been proposed for determining marginal or interfacial defects. One commonly used method entails highlighting microleakage using tracers as organic dye or silver nitrate to investigate the marginal gaps formed at the tooth-restoration interface [35], [36], [37]. However, disadvantages of microleakage analysis using tracers related to its invasive semi-quantitative analysis and its limited representation of 3-dimensional geometry were found [38]. Hence, searching for another method was a mandatory, marginal analysis using image j software is another method used to investigate interfacial gaps as it provides quantitative analysis and multiple measurements of the marginal gap, so in the current study, a digital steromicroscope image with image j software analysis was used to measure the gap %.

Evaluating the marginal gap % in the present study at baseline revealed that the lowest mean value was recorded for the sonic vibration group, followed by the preheated group. The highest mean value was recorded for the control group, with a statistically significant difference between the three tested groups. This result could be attributed to that sonic vibration and preheating of resin composite before photo activation provides greater conversion that would influence the flow and enhance marginal adaptation in comparison to the control group [22]. In addition, the results of the current study showed that microleakage mean values for all tested groups recorded a nonsignificant difference after thermocycling in comparison to the baseline values. This result could be referred to using of low thermocycling number (500 cycles) which was considered a limitation in the current study as it was a self-funded one, which may be insufficient to provide a significant deteriorating effect in marginal adaptation. Since there is no standard for thermocycling methodology in microleakage studies, this allows for contradictory discussions and results in different laboratory studies [14]. From all the previous findings the suggested null hypothesis is partially accepted.

Conclusion

Under the limitations of the current study, the following could be concluded:

1- Preheating of microhybrid resin composite does not improve its microhardness.
2- Although sonic vibration does not improve the microhardness values of the microhybrid resin composite, it maintains its stability after thermocycling.
3- Sonic vibration of microhybrid resin composite provides better marginal adaptation than the preheating and the conventional methods.

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