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**Original Article**

# Comparative Evaluation of Preheating versus Sonic Activation of Bulk-Fill Resin Composite

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## Abstract

**Aim:** This study aimed to investigate the effect different physical energies, either heat or sonic activation, on the surface microhardness of two different bulk-fill resin composites. **Materials and Methods:** Sixty disc shaped resin composite specimens with standardized diameter of 6mm and overall thickness of 4 mm were used in this study. The prepared specimens were divided into two equal groups (N=30), according to type of bulk fill resin composite **(R)**; Group 1: X-tra fil (Voco) **($R_1$)** and Group 2: SonicFill 3 (Kerr) **($R_2$)**. Each group was further subdivided into three equal subgroups according to the method of energy **(E)** delivered to the bulk fill resin composite material before light initiated polymerization (n=10); either without any energy delivered to the material **($E_o$)**, preheating at 54℃ using resin composite heating device (Calset, AdDent Inc, Danbury, CT, USA) **($E_1$)** or sonic activation (SonicFill™ hand piece, Kerr, USA) **($E_2$)**. Specimens were cured from the top using light curing unit for 40 seconds. Finally, the VHN **(S)** was evaluated at the top **($S_1$)** and the bottom **($S_2$)** surfaces of each specimen. **Results:** Three-way ANOVA revealed statistically significant differences in two main effects; the types of resin composites ($P<0.0001$), and tested depth of restoration ($P<0.0001$). On the other hand, methods of physical activation showed no statistical significant differences ($P = 0.631$). **Conclusions:** Bulk fill resin composite formulation is a major determinant of its Vicker's hardness number. Both sonication and pre-heating had the same effect on VHN of nano-hybrid, SonicFill 3 bulk fill resin composite.

**Keywords:** Bulk-fill resin composite, Resin composite preheating, Sonic activation, Microhardness.

## I. INTRODUCTION

The 60s of the last centuries witnessed the introduction of resin-based tooth colored restorations which is due to their mechanical and esthetical superiority substituted acrylic resins as an esthetic dental restoration. Further generations of resin composite (RC) showed modifications in strength, wear resistance, handling and esthetics. Such modifications increased their popularity and applications in various dental fields. Added to this improvement, resin bonding technologies have broadened the applications, rendering them a universal direct restoration[(1)].

Although the introduction of light activated polymerization of resin composite is viewed as a breakthrough, yet the depth of penetration of light in the material remain its crucial point that led to the introduction of the incremental packing technique. However, a risk of air bubbles entrapment and moisture contamination appeared in between sequential increments[(2,3)]. In the early 2000s, in a trial to solve such problem, a so-called bulk-fill resin composites were introduced in the market with a methacrylate-based matrix. The first marketed material, SDR (Dentsply Sirona, Konstanz, Germany), was a flowable resin composite based on a stress-decreasing resin technology to be used in 4-mm layers as open or closed dentin replacement beneath conventional resin composite[4]. To allow for efficient photo-initiated polymerization, literature proposed either reduction of filler content, increasing filler translucency, using fillers and matrix with close refractive indices, in addition to the use of a more sensitive initiators to boost the polymerization reaction. These materials are categorized according to their rheological properties, either as dentin substitute materials that require a 2-mm posterior hybrid composite coat or as high-viscosity resin composites that do not require an occlusal resin composite coat[5]. Degree of conversion (DC) is the number of double carbon links (C=C) present in the monomers, which are converted into single links (C-C) to form the polymer chains during the polymerization process. There is no doubt that the durability and performance of the final resin composite restoration is related to its degree of conversion, which play a major role in controlling surface and bulk properties of the material. That is why surface microhardness, shade change and bulk properties evaluation are considered in literature to be indirect methods to evaluate and compare resin composite maturation based on direct correlation claimed in literature[6,7].

Sonic-activated bulk-fill resin composites were introduced to the market as posterior bulk restorations. They are modified with special modifiers rendering it sensitive and reactive to sonic energy. As sonic energy is applied, the modifier causes the viscosity to drop (up to 87%), increasing the flowability of the composite. This process is reversed as soon as sonic energy is stopped allowing for carving and contouring. Such process is claimed to have a positive impact on adaptation, DC and workability[8,9].

Also in a trial to improve the adaptation and DC, and reduce voids and air entrapment, of highly filled resin composite a preheating step was proposed in literature, with a claim to improve physical and mechanical properties of the final resin composite restorations[10,11].

Based on the former considerations, the aim of the present study was to investigate the effect of different physical energies, either heat or sonic activation, on the surface microhardness of two different bulk-fill resin composites. The null hypothesis was that neither resin composite formulation, physical activation energies nor tested surface (top/bottom) would affect microhardness (VHN) of the tested bulk-fill resin composites.

## *II. MATERIALS AND METHODS*

### a) Sample Size Calculation

Sample size calculation was done by power analysis used Vicker Hardness Number (VHN) as a primary outcome. The effect size f = (0.6157877) was calculated based upon the results of Abed et al. 2015[2] and assuming that the standard deviation within each group = 16.49, using alpha level of 5% and beta level of 95% i.e. power = 95%. The minimum estimated sample size was a total of 54 samples (10 samples per subgroup). Sample size calculation was done using G*Power version 3.1.9.2.

### b) Study Design and Grouping

Sixty disc shaped resin composite specimens with standardized diameter of 6 mm and overall thickness of 4 mm were used in this study. The prepared specimens were divided into two equal groups (N=30) according to type of bulk fill resin composite **(R)** used; Group 1: X-tra fil (Voco, Germany) **($R_1$)** and Group 2: SonicFill 3 (Kerr, USA) **($R_2$)**. These bulk-fill resin composite materials, their manufacturers and chemical composition are illustrated in **Table (1)**. Each group was further subdivided into three equal subgroups (n=10) according to the method of energy delivered **(E)** to the bulk fill resin composite material before light initiated polymerization; either without any energy delivered to the material **($E_o$)**, preheating at 54℃ using resin composite heating device (Calset™, AdDent Inc, Danbury, CT, USA) **($E_1$)** or sonic activation

(SonicFill™ hand piece, Kerr) **($E_2$)**. Specimens were cured from the top according to the manufacturer recommendation using light curing unit (3M ESPE Elipar™ S10) for 40 seconds. Finally, the VHN **(S)** was evaluated at the top (**$S_1$**) and the bottom **($S_2$)** surfaces of each specimen.

**Table (1):** Bulk-fill resin composite materials, manufacturer and their chemical composition.

| Material / Manufacturer | Composition | |
|---|---|---|
| | Matrix | Filler type and % |
| **Micro-hybrid RC, X-tra fil Voco, Germany** | Bis-GMA, UDMA, TEGDMA | Barium boron alumino-silicate glass (0.04-3 µm), Filler loading 86% by wt |
| **Nano-hybrid RC, SonicFill 3 Kerr, USA** | Bis-EMA and TEGDMA | Barium silicon dioxide glass (10-30 nm), Filler loading 81 % by wt |

**c) Packing and Curing of Resin Composite Specimens**

The devices and procedures of bulk fill resin composite activation, either by heat or sonic energy, are described in **Table (2) & (3)** respectively. Moreover, they are illustrated by a schematic diagram in **Figure (1)**.

A rectangular teflon split mold having 5 holes with standardized diameter 6 mm and depth of 4 mm were used. All specimens were prepared with the same manner in which the resin composite materials was injected inside the holes of the mold as a single increment, packed to avoid incorporation of voids inside the bulk of the material and then a glass slide with a light finger pressure was placed over the injected resin composite to obtain a flat specimens with uniform thickness. Finally, specimens were cured from the top according to the manufacturer recommendation using light curing unit (3M ESPE Elipar™ S10) for 40 seconds. The screws of the mold were untightened to remove the constructed discs.

**Table (2):** The devices used for bulk fill resin composites activation.

| Apparatus | Manufacture | Description |
|---|---|---|
| **Calset™** | AdDent Inc, Danbury, CT, USA | Allows heating of resin composites up to 98°F (37°C), 130°F(54°C) or 155°F(68°C) |
| **SonicFill™ hand piece** | Kerr, USA | Allows sonically activated delivery |
| **Elipar™ S10 light curing unit** | 3M ESPE, USA | Intensity: 1200mW/cm$^2$ Wavelength: 430-480 nm |

**Table (3):** Procedures of bulk fill resin composites activation.

| Group | Sub-group | | Procedure |
|---|---|---|---|
| **$R_1$ (X-tra fil)** | $E_o$ | $R_1$ $E_o$ | Non activated resin composite compule. (Figure 1-a) |
| | $E_1$ | $R_1$ $E_1$ | Resin composite compule pre-heated at 54 °C (Calset™, AdDent Inc, Danbury,CT, USA). (Figure 1-b) |
| | $E_2$ | $R_1$ $E_2$ | Resin composite was loaded in an empty compules that is designed to be mounted on SonicFill™ hand piece, after the cap of the compules were unscrewed carefully without distorting the compule (Figure 2-a), and injected with SonicFill™ hand piece at power 3. (Figure 1-c) |
| **$R_2$ (SonicFill 3)** | $E_o$ | $R_2$ $E_o$ | Resin composite were loaded in empty regular compules [Figure 2-b] to facilitate its injection. (Figure 1-d) |
| | $E_1$ | $R_2$ $E_1$ | Resin composite were loaded in empty regular compules to facilitate pre-heated at 54 °C (Calset, AdDent Inc, Danbury, CT, USA). (Figure 1-e) |
| | $E_2$ | $R_2E_2$ | Resin composite compules were mounted on SonicFill™ hand piece and injected at power 3 that was adjusted on the hand piece as an average power. (Figure 1-f) |

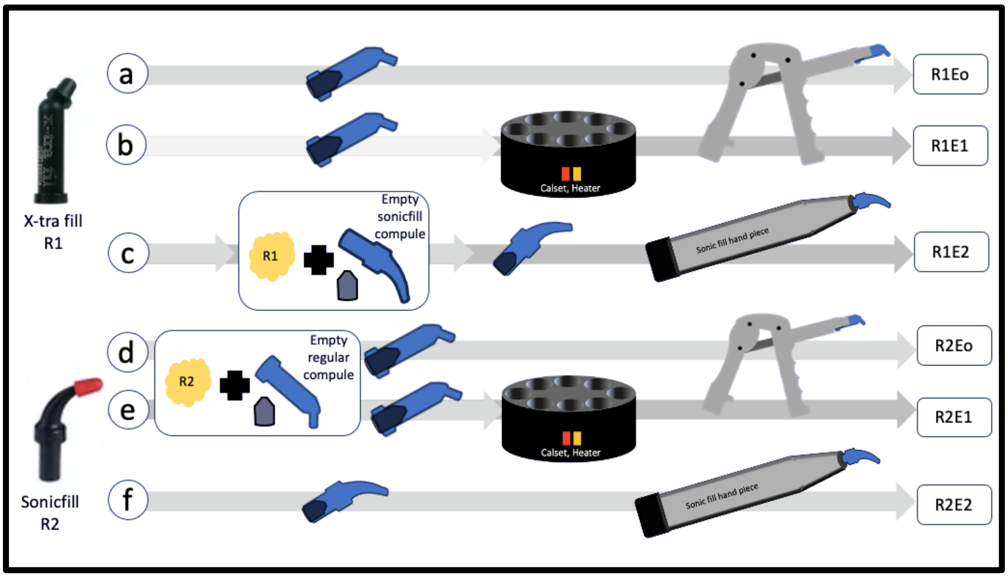


**Figure (1):** Schematic diagram illustrating activation of bulk fill resin composites.

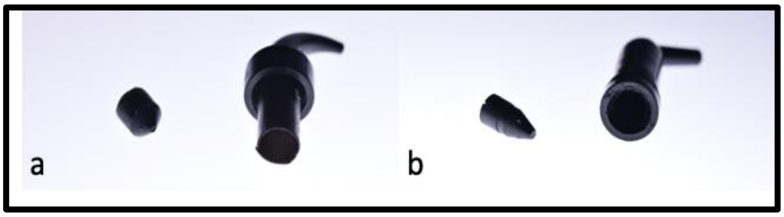


**Figure (2):** Empty compules after the caps were removed carefully without compules distortion [(a) SonicFill compule. (b) Regular compule].

#### d) Hardness Test

Vickers hardness numbers were determined using a micro-hardness tester (Wilson® Hardness Tester, Model Tukon 1102, Buehler, Lake Bluff, IL, USA). The test was carried out by using a load of 100g (HV 0.1), time = 10 seconds dwell time. The Vickers's hardness number ($N/mm^2$) was recorded as an average of six readings, three from each surface [Top ($S_1$) and Bottom ($S_2$)] for each specimen. Percent drop in VHN at the tested surface were calculated by equation [(VHN Bottom/VHN Top) X 100][12].

#### e) Statistical Analysis

Numerical data from the experiment was collected, tabulated and checked for normality using test of normality (Shapiro–Wilk test). The data was found to be normally distributed and a parametric test, three way ANOVA, was used to detect the effect of variables of the study, and post-hoc test was used to detect significance if present between different subgroups. The significance level was set a $p \le 0.05$. IBM SPSS statistics for windows, was used for statistical analysis.

## *III. RESULTS*

Three-way ANOVA was used to test the three main effects namely, the type of resin composite, the mode of physical activation and the tested surfaces **[Table (4)]**. The first main effect (type of resin composite) had two levels namely; X-trafil (Voco, Germany) and SonicFill 3 (Kerr, USA). The second main effect (modes of physical activation) had three levels namely; no physical activation, preheating or sonic activation. The third main effect (tested surface of specimen) had two levels namely, top and bottom of specimen. Three-way ANOVA revealed statistical significant for two main effects; the types of resin composites ($P<0.0001$) and tested surface ($P<0.0001$). On the other hand modes of physical activation showed no statistical significant effect ($P = 0.631$). There was no statistical significant interaction between the three main effects ($P = 0.499$). The value for all subgroups in group I showed a higher statistical significant VHN than those of corresponding subgroups in group II.

Mean values, standard deviations and percent drop in VHN at the tested surface were calculated by equation [(VHN Bottom/VHN Top) X 100] of VHN for the tested subgroups are presented in **[Table (5) & Figure (2)]**. All the tested subgroup showed a statistical significant drop upon comparing the top versus bottom VHN, yet it is very clear that all tested materials suffered from less than 20% drop in VHN, that is to say the bottom surface achieved over 80% of the maximum hardness of the top surface except for the $R_2E_o$ subgroup where the drop was 20.8%. The highest recorded VHN value was 86.27±3.32 recorded for preheated X-tra fill, while the lowest was for the preheated SonicFill 3 66.05±1.68. Statistical significance was detected between all the subgroups yet no significant difference was detected inside the subgroups.

**Table (4):** Three-way ANOVA for the three main effects of the study.

| *Source* | *Sum of Squares* | *df* | *Mean Square* | *F* | *Sig.* |
|---|---|---|---|---|---|
| ***R*** | 4696.843 | 1 | 4696.8 | 426.99 | 0.00001 |
| ***E*** | 10.234 | 2 | 5.1 | 0.47 | 0.631 |
| ***S*** | 1956.722 | 1 | 1956.7 | 177.89 | 0.00001 |
| ***R * E * S*** | 15.526 | 2 | 7.8 | 0.7 | 0.499 |

**Table (5):** Means, standard deviation, significance and percent drop in VHN for the tested subgroups.

| | | | **Top($S_1$)** | | **Bottom($S_2$)** | | **$S_2/S_1$** |
|---|---|---|---|---|---|---|---|
| | | | Mean | SD | Mean | SD | **x 100** |
| | $E_o$ | $R_1$ $E_o$ | 83.0533$^{ab}$ | 3.02 | 73.0067$^{cd}$ | 1.29 | 87.9% |
| | $E_1$ | $R_1$ $E_1$ | 86.2667$^{a}$ | 3.32 | 76.2333$^{bc}$ | 3.47 | 88.37% |
| **$R_1$** | $E_2$ | $R_1$ $E_2$ | 84.2333$^{a}$ | 2.02 | 72.3400$^{cd}$ | 3.1 | 85.88% |
| | $E_o$ | $R_2$ $E_o$ | 69.0983$^{cd}$ | 1.53 | 54.7767$^{e}$ | 5.9 | 79.2% |
| | $E_1$ | $R_2$ $E_1$ | 66.0533$^{d}$ | 1.68 | 55.1267$^{e}$ | 3.67 | 83.5% |
| **$R_2$** | $E_2$ | $R_2E_2$ | 67.6067$^{d}$ | 4.72 | 56.3000$^{e}$ | 2.95 | 83.68% |

*Different superscript show statistical significance p≤0.05*

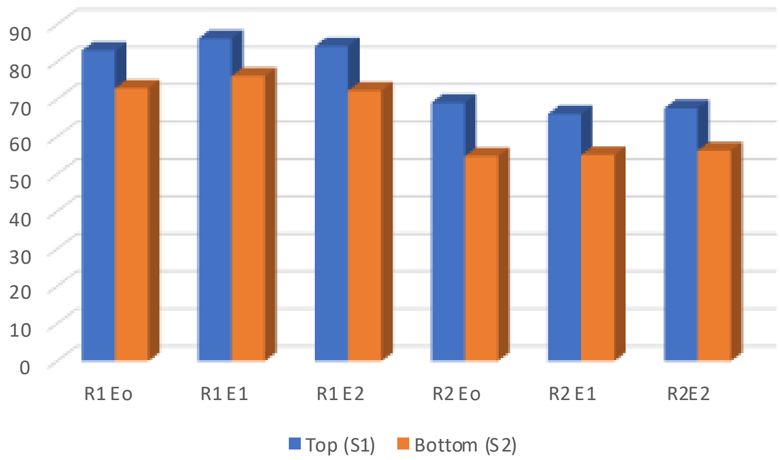


**Figure (3):** Microhardness (VHN) of all tested subgroups.

## *IV. DISCUSSION*

Nowadays, as an attempt to overcome the drawbacks of incremental packing techniques, indicated for conventional resin composites, there is a growing switch to the use of bulk fill resin composite material due to simplified restoration procedures offered by them and their ability to pack a full cavity with a single increment, saving operators' time and simplifying the technique(13).

In a trial to boost the performance of bulk fill restorations, different types of energy delivery systems were introduced throughout the last years mainly, thermal and sonic energy, in a single step. These trials targeted to eliminate the need for a cavity liner, modifying the physical and mechanical properties of resin composites and increasing the workability and adaptation of heavily filled materials(14). Preheating of resin composites was recommended as a method to improve the properties and adaptation of the final resin composite restorations. A temperature of 54°C was chosen in our study since temperatures in the range between 54°C and 68°C was described as the most proper range to improve workability and performance of the material(9,10).

In the current study only the formulation of the resin composite used together with the tested surface of resin composite either top or bottom had an effect of the mean VHN. Regarding the VHN of tested surface, the two tested bulk fill resin composite showed a significant drop in VHN however neither of them dropped below 80% at their 4mm thickness, except subgroup $R_2E_o$. Therefore, 4mm is considered a safe thickness for bulk fill resin composite used in the study, taking in considerations sonication or pre-heating(15), as a value of 80 % or more is an indicator of proper degree of conversion(16).

Different bulk fill resin composites' formulation have been introduced in the market by manufactures, such formulas contain a varying types and concentrations of the two major ingredients of resin composite, which are the organic monomers and the inorganic fillers. Variation in organic/inorganic ratios control the full behavior, characteristics and performance of the material(17,18).

Regarding the monomer content, both tested bulk fill resin composites contains varying portions of short chain monomers. Although its exact quantity is not informed by the manufacturers, a previous study highlighted the elution of such monomers (mainly TEGDMA) from SonicFill compared to other bulk-fill resin composites(16,19), indicating that the monomer content is not low. Although TEGDMA and Bis-EMA present in SonicFill 3 is similar to Bis-GMA in having functional terminal methacrylate groups, yet being linear chain, these monomers reduce viscosity. Initial reduced viscosity of resin composites may play a role in reducing their mechanical properties(3,20), which could further explain our VHN findings. Also for the organic matrix, the presence of stiffer Bis-GMA(21), in X-tra fill, may have also played a positive role in improving the surface microhardness(9,22) detected in our study. Furthermore, monomer reactivity and filler/matrix refractive index mismatch may participate in variation of different resin composites maturation(23).

Surprisingly, Sonicfill 3 showed nearly the same response regarding VHN when subjected to either sonic or thermal energy which may be due to the potential of both energies to enhance polymerization kinetics with respect to charge distribution and inherent molecular stability of monomers(24,25). This is in agreement with the finding of Yang et al. who concluded in their study on bulk fill resin composites that sonication and pre-heating are beneficial techniques to enhance the performance of bulk fill resin composites(8). On the other side, this contradicts with Demirel et al. who found preheating considerably improve the performance of all tested resin composites, except for that of SonicFill 2(26).

The SonicFill 3 resin composite, on the other hand, is a reformulation of its predecessor SonicFill and SonicFill 2. Based on manufacturer claim, compositional modification targeted the material performance. However, to the best of our knowledge, literature is so far lacking studies evaluating in vitro and in vivo SonicFill 3 performance. Yet, one may note that the composite resin line-up remained presenting high filler content [81.3 wt %][24].

Sonication and pre-heating appeared to slightly improve microhardness of bulk fill resin composites used in our study. Microhardness is considered one of the determiners of the degree of conversion, consequently, there may be an influence of sonic and thermal energy on the degree of conversion of bulk fill materials[27].

Regarding the inorganic filler, the variation in filler loading, type and size may play a role as shown in our study, as the X-tra fill showed higher VHN that may be due to the claim in literature that as filler size increase, mechanical properties and microhardness increase[28]. Moreover, translucency also increases due to the less scattering of light as it collide with the filler particles, affecting its transmission through the polymerizing mass of resin composite, enhancing degree of maturation which will also control the mechanical properties [29]. This could explain that incase of the nanohybrid SonicFill 3, filler size may have had a negative effect on the degree of conversion, presented in the lower VHN compared to X-tra fill[30, 31].

Beside that X-tra fill resin composite with its high filler content of 86 wt% that is more that SonicFill 3 which is estimated to be 81 wt% , may have played a role by controlling the percentage organic matrix with its inferior mechanical properties[32].

Therefore, the null hypothesis was partially rejected since only resin composite formulation, and tested surface (top/bottom) had an effect on microhardness (VHN) of the tested bulk-fill resin composites.

## *V. CONCLUSIONS*

1. Bulk fill resin composite formulation is a major determinant of its Vicker’s hardness number.
2. Both sonication and pre-heating had the same effect on VHN of nano-hybrid, SonicFill bulk fill resin composite.

**Conflict of Interest**

The authors declare no conflict of interest.

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**Ethics**

The study was approved by the ethical committee of the faculty of dentistry, Suez Canal University, (Approval No 696/2023) established according to ‘’WHO-2011’’ standards.

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