MARGINAL SEAL OF SONIC-ACTIVATED COMPOSITE RESIN RESTORATIONS USING DIFFERENT DISPENSING RATES

Al-Zahraa M. El-Marhomy *🆔 and Ahlam Abd El-Galil Nassar *🆔

ABSTRACT

Aim: To evaluate the marginal seal of sonic-activated composite resin using various dispensing rates in class V restorations.

Materials and methods: Standardized class V cavities were performed in forty extracted sound human molars that were arbitrarily divided into four equal groups (n=10) according to the extrusion force magnitude and dispensing technique as follows: Group I (Control), manual extrusion force (FM), Group II: low extrusion force (F1) of sonic energy, Group III: medium extrusion force (F3) of sonic energy and Group IV: high extrusion force (F5) of sonic energy. Composite resins were packed inside the prepared cavities and photopolymerized. For groups II, III, and IV, a Sonic Fill handpiece was used to deliver sonic energy. While for group I, no sonic energy was used. All specimens were thermocycled, gold-sputtered, and examined under a scanning electron microscope for marginal seal assessment. Statistical analysis was done using Kruskall-Wallis and Mann-Whitney tests, with a significance level of $P \leq 0.05$.

Results: Group I showed higher marginal gaps (1.70±0.67) compared to sonic-activated groups (p<0.05). Marginal gaps of group II (1.0 ± 0.82) were nearly similar to that of group III (0.80±0.79) (p>0.05), while group IV (0.20 ± 0.42) revealed a significant decrease in the marginal gaps to that of group II and III (p<0.05).

Conclusions: Using the Sonic Fill handpiece at the highest extrusion force enhances the marginal sealing of SonicFill 2 composite resin restorations compared to the medium and lowest extrusion forces.

KEYWORDS: Sonic-fill bulk fill composites, Magnitude of extrusion force, Class V, Marginal seal

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*   Lecturer of Restorative Dentistry, Faculty of Dentistry, Tanta University, Egypt.

INTRODUCTION

The aesthetics, wear, and handling characteristics of composite resins have all been enhanced. These advancements have not eliminated the fundamental problems with composite resin materials, the most significant of which being polymerization shrinkage and shrinkage stresses[1]. The polymerization shrinkage induces high stresses on the bond interface leading to microleakage and gap formation of composite resin restorations, particularly in class V restorations[2].

The C-factor of these cavities reduces the flow of composite resin during shrinkage, which puts more stress on the tooth-restoration interface [3,4]. In addition, these cavities have different margins: an occlusal margin with plenty of enamel and a cervical margin with very little enamel [5] making it challenging to achieve optimal marginal sealing. [4]

The main clinical issues associated with dental composites, such as hypersensitivity, pulpal inflammation, restoration failure, discoloration at the restoration margins, and recurrent caries resulting from microleakage, are causes for concern.[6]. As a result, the degree to which a restoration fits or approximates the tooth surface—the marginal adaptation—is a crucial attribute of composite resin restorative material. Composite resin restorations' lifetime and aesthetics are heavily impacted by the marginal integrity's durability and quality [7].

The introduction of "Bulk-Fill composite resin" to the dental market was the result of ongoing research into improving the handling and clinical performance of composite resin while overcoming the issue of polymerization shrinkage. Because it may be placed and light-cured in a single step of 4 to 5 mm thickness, bulk fill composite might streamline clinical restorative operations by reducing the likelihood of contamination or air bubbles included between the increments [8].

Polymerization shrinkage and stresses are supposedly reduced in bulk-fill composites compared to conventional composites. The packability, mechanical qualities, and handling qualities of these materials are enhanced by increasing their viscosity and filler loading, which in turn enhances their sculpting ability [9]. However, a thicker layer resulted in increased void entrapment inside the material and poor fitting to the walls of the prepared cavity during packing [10].

Several methods have been developed to improve its adaptability to the cavity to decrease the composite's viscosity while keeping its mechanical qualities the same [11]. The use of sonic oscillation can achieve this goal, allowing for a more precise fit between the cavity walls and the resin-based composites that are heavily filled [12, 13]. Recent innovations have included sonic-driven composite resin insertion as a means to mitigate the impact of polymerization shrinkage stresses on the tooth restoration interface. The sonic system allows dentists to use posterior composite resin restorations which combine the benefits of flowable and universal composites. Using this device's smart vibrations, provide the composite material well adaptation, better voids reduction, precise application, and layer thickness management [14].

The SonicFill™ technology is a new composite resin technology that has just hit the market. The minimal polymerization shrinkage makes it ideal for use as a bulk-fill posterior composite restoration, which means it may be layered up to 5 mm deep, as per the manufacturer's guidelines. SonicFill™ consists of a highly filled resin that is loaded with a unique modifier that responds to sonic energy. The application of sonic energy using a specially constructed handpiece with a variable dispensing rate allows this modifier to decrease the composite's viscosity up to 87% and to increase its flowability, enabling rapid insertion and improved adaption into the cavity walls. The composite is perfect for carving and contouring since it recovers to a very viscous, non-slumping form when the sonic energy is discontinued [15].

Using a single dispensing rate for the administration of the SonicFill 2 composite has been validated by all prior trials [13]. Therefore, the purpose of this in-vitro investigation was to determine how class V restorations' marginal seals were affected by varying dispensing rates of sonic-activated composite resin. The sonic-activated composite resin's marginal seal was hypothesized to remain constant throughout a range of dispensing rates.

MATERIALS AND METHODS

Study design

This study was conducted as a randomized controlled in-vitro study.

Study setting

This study was accomplished at the laboratories of the Restorative Dentistry Department, Faculty of Dentistry, Tanta University.

Sample size

The number of sample size for this study was 40 samples. The sample was collected based on a previous study [16]. The significance level was 0.05, the power sample size was more than 80% for this study, the confidence interval was 95% and the actual power was 86%. The sample size was calculated using the following equation:

$$N= \frac{(Z_\alpha)^2 * (SD)^2}{(d)^2}$$

N= Total sample size

Z_α= Is standard normal variate and its equal 7.72

SD= Standard deviation of variable and its equal 1.62

d= Absolute error or precision and it's equal to 2

Ethical consideration:

The purpose of the present study was explained to the patients and informed consents were obtained to use their teeth in the research according to the guidelines on human research adopted by the Research Ethics Committee, Faculty of Dentistry, Tanta University.

Teeth selection

Forty intact human permanent molars previously extracted at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Tanta University due to periodontal reasons from patients aged (35-55) were collected for this study. All soft debris and/or calculus were gently removed from the teeth with an ultrasonic periodontal scalar (WoodPeaker® ultrasonic scaler, China) and curettes then the teeth crown was then pumiced using a rotating brush and prophy-paste (Proxy; Ivoclar Vivadent, Schaan, Lichtenstein) followed by careful examination using a magnifying glass to exclude those exhibiting any visible cracks, white spot lesion, caries, or hypoplasia [17]. The selected teeth were stored in normal saline in a refrigerator at 4ºC, which was changed daily until experiment time which was scheduled within three months after extraction [18].

Specimen preparation

Each tooth was fixed to a plastic cylinder that was filled with self-curing acrylic resin, leaving their anatomical crowns exposed 2mm below the cementoenamel junction (CEJ). All the specimens were incubated in artificial saliva at 37ºC, 100% humidity throughout all the steps of the study to resemble a clinical situation more closely, the artificial saliva was changed every 24 hours [19].

To standardize a trapezoidal outline of class V cavities, a window was performed in Tofflemire's metal band (mesiodistal width of 4 mm occlusal and 3 mm cervically and a length of 3 mm occlusogingival). During cavity preparation, the band was held around the tooth by a Tofflemire retainer (Dentacarts Dental Supplies, Pakistan) [20].

Cavities were prepared with a depth of 2 mm on the buccal surface of each molar using straight plain carbide bur size 57 (Midwest, Dentsply) in a high-speed contra-angled handpiece (NSK, JAPAN) with air-water coolant spray. The bur was changed by a new one after every five cavities to ensure the bur cutting efficiency[20]. The cavities were finished with fine-grained diamond finishing bur (Midwest, Dentsply). No bevel was prepared on all the cavity margins. The cavity depth was judged with a permanent mark on the bur and verified using a periodontal probe. The cervical margins were located 2 mm coronal to CEJ [21].

Specimens grouping:

The specimens were haphazardly classified into four equal groups, with ten specimens in each, based on the extrusion force magnitude and the dispensing technique as follows: **Group I (control group):** manual extrusion force (FM), **Group II:** low extrusion force (F1) of sonic energy, **Group III:** medium extrusion force (F3) of sonic energy and **Group IV:** high extrusion force (F5) of sonic energy.

Adhesive and composite resin placement:

The SonicFill handpiece (Orange, CA, USA: Kerr Corporation) was fixed into the dental unit by a MULTIflex-compatible connector. A manometer was put in between the MULTIflex connector and handpiece to assess the driving air pressure. It should be within the manufacturer's recommended limits [22].

SonicFill 2 composite compule was loaded into the SonicFill handpiece and then the regulating ring at its end was turned to provide sonic energy at different magnitudes of the extrusion force (F1), (F3), and (F5) according to the tested groups. The foot control of the dental unit was utilized at maximum range and constant pressure during the delivery of sonic energy to be sure that dispensing was achieved through the adjustment of the regulating ring of the handpiece only.

All the cavities were rinsed thoroughly with water and allowed to be air-dried using air spray and blotting paper [23]. The enamel margins of each prepared cavity were selectively acid-etched for 20 seconds with 37% phosphoric acid, rinsed with water spray, and air-dried with gentle air spray. After that, they were restored with SonicFill 2 composite by the recommended manufacturer' Optibond All-in-One adhesive application as follows: the adhesive was applied and scrubbed using a disposable micro brush rubbed to the entire surface of the prepared cavity for 20 seconds, air-dried for 5 seconds by gentle air jets to vaporize any solvent and then light-cured using LED curing unit (Guilin Woodpecker Medical Instrument Co., China) with 1000mW/cm^2 light intensity for 10 seconds. Light intensity was checked regularly using a radiometer of the unit to be sure that the lowest irradiance was 1000 mW/cm^2 [24].

SonicFill 2 Bulk Fill composite was inserted inside the prepared cavity from bottom to top as one piece using its dispenser and then manually packed by hand plastic applicator (Hilton plastic filling instruments Teflon coated) to be well adapted and sealed. After that, the material was pressed and contoured by a special transparent cervical matrix for class V (Hawe Transparent Cervical Matrices, Kavo Kerr, Bioggio, Switzerland) which was selected based on the cavity's dimensions to have a smooth, polished surface and light-cured through the matrix for 20 seconds.

Regarding group I, in which no sonic energy was applied (FM), each compule was loaded to a composite unidose gun dispenser (Kerr, Orange, CA, USA) and was inserted inside the prepared cavity by manual extrusion force in the same way as mentioned previously in the sonically activated groups.

All restorations were then finished by just removing any excess restorative material around margins using sharp scalpel no. 11 [25] and polished using a polishing kit [26] (Kenda dental polishers, Liechtenstein) followed by polishing paste

(EZ-SHINE, EZ-PAC, Egypt) and golden brush (Kavo Kerr Composite Polishing Brush, China). All specimens were subsequently preserved in distilled water for 24 hours at 37°C, then restored in artificial saliva at 37°C until subsequent use.

All the specimens were thermocycled in a thermocycling machine by alternating immersion in a water bath for 500 cycles between 5 and 55°C at a dwell time of 30 seconds in each bath and a transfer time of 15 seconds to represent clinical service of 6 months [27].

Marginal seal assessment

For assessment of marginal seal, each specimen was seated on custom-made aluminum stubs, gold-sputtered, and assessed under the scanning electron microscope (SEM) (JEOL JXA-840A scanning microscope, USA) initially at magnifications up to ×17 or 18 (For the restoration overall view) then a higher magnification ×200 (For the entire restoration margin). All the margins of each restoration were assessed for gaps and the average of the width of gaps was calculated if present regardless of their location, then each one was scored as follows [28]:

Score 0: No gaps at the margins.

Score 1: Gaps with an estimated maximum width of less than 30μm

Score 2: Gaps with an estimated maximum width of more than 30μm.

Statistical Analysis

Collected data were tabulated, and statistically analyzed at a 95 % level of significance using Statistical Package for Social Sciences (SPSS Inc, Chicago, IL, US) Version 26. Non-parametric tests were used for comparison between different groups. Kruskall-Wallis test was used to compare the difference in marginal adaptation of the four tested groups followed by Mann Whitney test for pair-wise comparison between tested groups.

RESULTS

The marginal gap scores and the percentage at the restoration-tooth interface of the four different groups are shown in Table 1. In group I (Control group) in which no sonic energy was applied (FM), eight of the tested specimens recorded score 2 with micro gaps width of >30μm at the tooth-restoration interface (Figure 1 A, B), while the remaining two specimens recorded score 1 with micro-gaps width <30μm and score 0 with no marginal gaps. Concerning group II in which sonic energy with low extrusion force was applied (F1), seven tested specimens exhibited non-continuous margins, three with score 2 and four with score 0 (Figure 1 C, D), while the remaining three specimens recorded score 0 with sealed margins.

A nearly similar finding was found in group III in which sonic energy with medium extrusion force was applied (F3), six tested specimens exhibited non-continuous margins, two with score 2 and four with score 1 (Figure 1 E, F), while the remaining four specimens recorded score 0 with sealed margins (Figure 1 G, H). On the other hand, in group VI in which sonic energy with high extrusion force was applied (F5), eight of the tested specimens exhibited continuous margins with a score of 0 (Figure 1 I, J), and only two specimens recorded score 1. There was no specimen scored 2 in this group.

The calculated Mean ± SD values of marginal gap width at the restoration-tooth interface of the four tested groups were statistically analyzed and presented graphically in Table 1 and Figure 2. As shown, the lowest mean value of the marginal gap width of Sonicfill 2 composite resin was found in Group IV (0.20). These were increased to be (1.0) and (0.80) in groups II and III respectively, whereas group I showed the highest mean value of marginal gap width (1.70).

Statistical analysis using the Kruskall-Wallis test for comparison of the mean values of marginal gap width of the four tested groups revealed a statistically

significant difference between the tested groups (P=0.002) denoting that SonicFill 2 composite resin marginal seal was altered by changing the SonicFill handpiece dispensing rates.

Therefore, further statistical analysis using the pair-wise Mann-Whitney test was done to identify the statistical difference between each two groups. It revealed a statistically significant difference between group I versus the other three tested groups (P= 0.030, 0.006, and 0.001) denoting that

sonic energy application decreases gap formation in comparison to manual packing of the material regardless of dispensing rate. Also, group VI revealed a statistically significant difference versus both group II and group III (P=0.014 and 0.047 respectively) denoting that F5 reduces gap formation significantly in comparison to (F1) and (F3). On the other hand, there was no significant difference between group II and group III (P=0.523) denoting a similar marginal seal between F1 and F3.
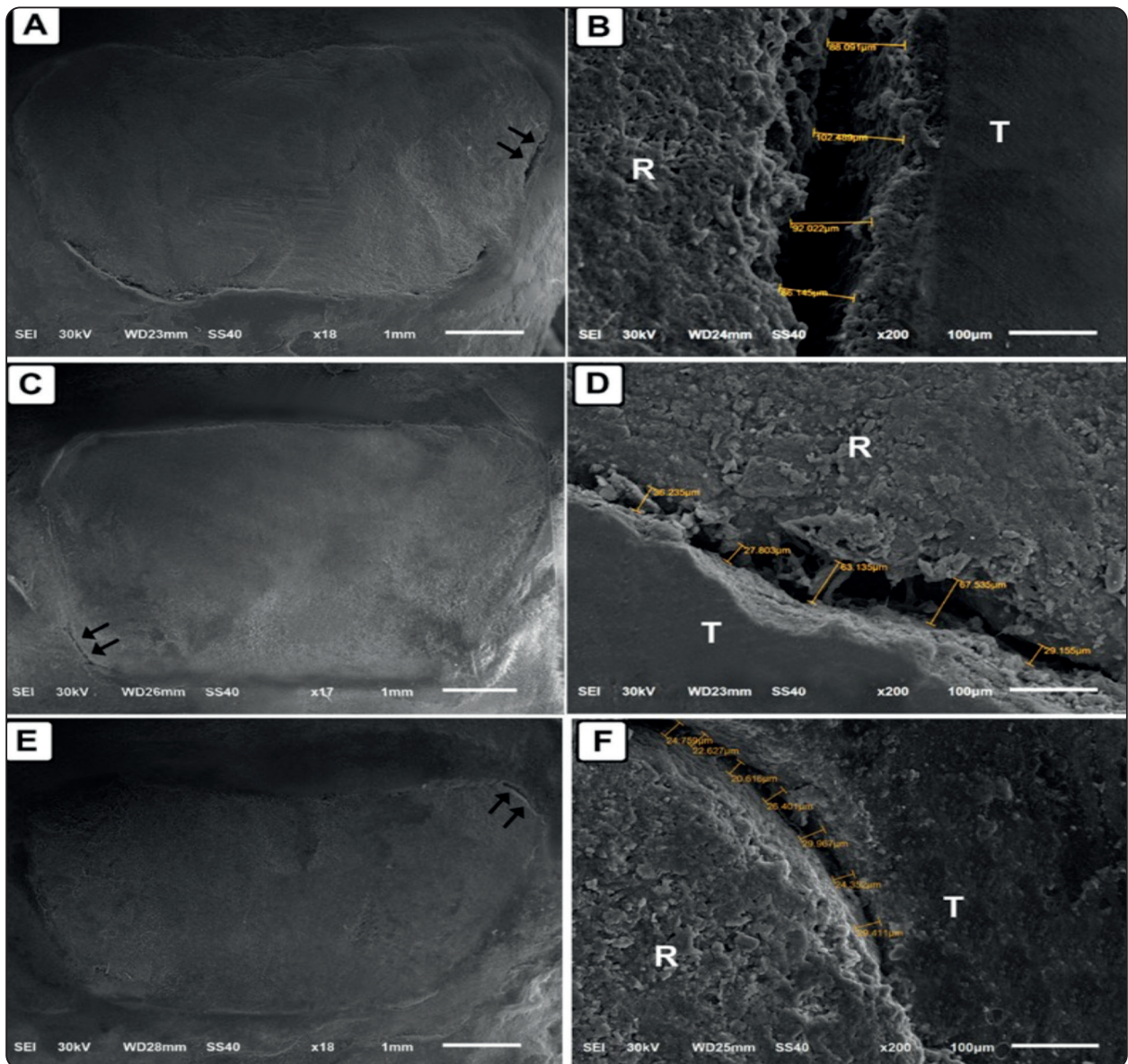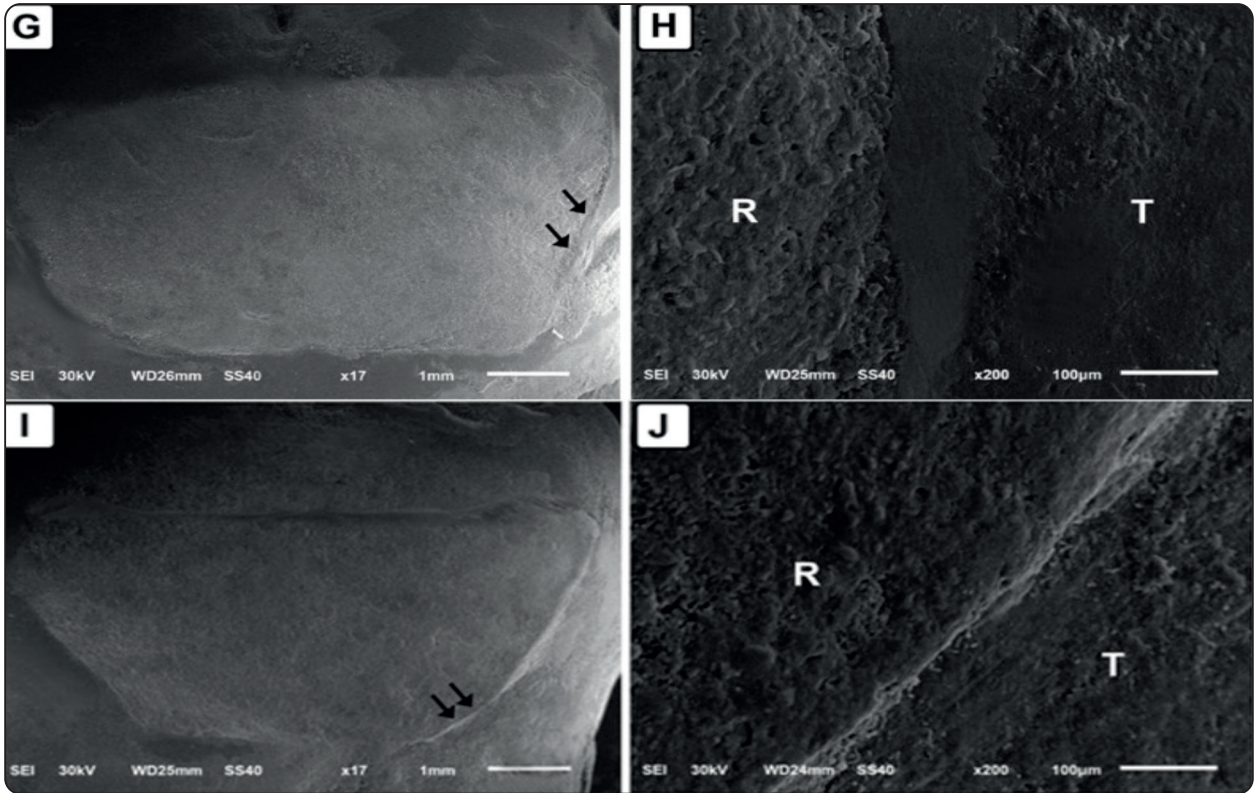
Fig. (1) Some representative specimens of scanning electron micrographs: (A) Showing the whole parameter of group I restoration with unsealed margins "arrow" (Mag. ×18). (C) Clarifying the whole parameter of group II restoration with unsealed margins "arrow" (Mag. ×17). (E) Representing the whole parameter of group III restoration with unsealed margins "arrow" (Mag×18). The higher magnification (×200) in (B, D, F) shows an unsealed margin at the tooth (T)- restoration (R) interface in groups I, II, and III. (G) Displaying the whole parameter of group III restoration with sealed margins "arrow" (Mag. ×17). (I) Showing the whole parameter of group IV restoration with sealed margins "arrow" (Mag. ×17). The higher magnification (×200) in (H, J) shows a sealed margin at the tooth (T)-restoration (R) interface in groups III and IV.

TABLE (1): Comparison between the different tested groups regarding marginal gap scores.

Groups ⟍ Marginal gap scores	Group I (n = 10)		Group II (n = 10)		Group III (n = 10)		Group IV (n = 10)	
	No.	%	No.	%	No.	%	No.	%
0	1	10.0	3	30.0	4	40.0	8	80.0
1	1	10.0	4	40.0	4	40.0	2	20.0
2	8	80.0	3	30.0	2	20.0	0	0.0
Range	0 – 2		0 – 2		0 – 2		0 – 2	
Mean ± SD	1.70 ± 0.67		1.0 ± 0.82		0.80 ± 0.79		0.20 ± 0.42	
Median	2		1		1		0	
K^w test	15.350							
P value	0.002*							
p1			0.030*		0.006*		0.001*	
p2					0.523		0.014*	
p3							0.047*	

KW: Kruskal Wallis test and Mann Whitney test that was used for pairwise comparison

p1: p-value for comparison between group I versus each other group.

p2: p value for comparison between group II versus group III and group IV.

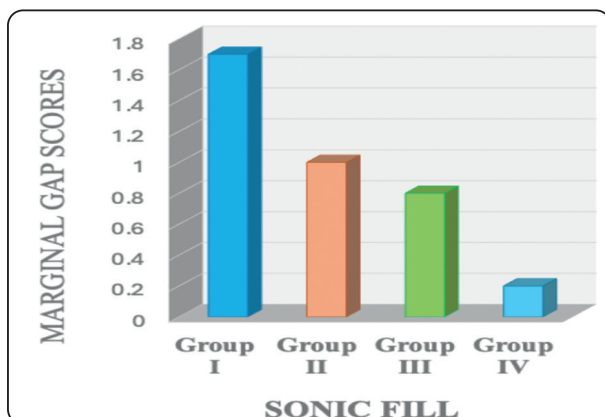*p3: p-value for comparison between group III versus group IV*

Fig. (2) Bar chart showing the mean values of marginal gap width of the different tested groups.

DISCUSSION

The marginal adaptation is a major factor that influences the prognosis of the restoration. Recurrent caries, postoperative sensitivity, unfavorable pulpal response, and marginal staining are all potential complications resulting from marginal seal failure of the final restoration to the cavity walls and margins[29]. Minimizing polymerization shrinkage stresses and increasing the marginal adaptation of composite restorations to cavity walls can be achieved by improved placing techniques, formulation, and curing techniques of composite resin[30].

The development of composite for bulk placement is one of the recent advances that have been adopted to control the polymerization stresses [31]. Those can be cured as bulk up to 4 mm thickness. Bulk-fill has a high filler content and very low polymerization shrinkage stresses [32].

Sonic-activated composite resin (SonicFill 2, Kavo Kerr) was chosen in this study to represent a category of bulk fill composites that was applied to restore the cavities by using sonic energy generated from a specially designed handpiece to decrease its viscosity and to improve its adaptability to cavity walls and margins thus improving the marginal seal [13]. The SonicFill handpiece is ideal for controlling the amount of extrusion force since it comes with

five distinct dispensing speeds. The strongest force is level 5, while the weakest is level 1. The present investigation used three distinct extrusion force magnitudes: low, medium, and high [16]. Thus, the objective of the study was to reveal the effect of using three magnitudes of the extrusion force (low, medium, and high) versus manual dispensing of sonic-activated composite resin on its marginal seal in class V restorations.

Class V restorations were an appropriate design for this study. These preparations are minimal and relatively easy to standardize, thereby somewhat reducing practitioner variability as well as providing the same C-factor for all the restoration specimens [33, 34].

Thermocycling was employed as an in-vitro approach to subject the tooth structure and restoration to severe temperatures. This simulates the transient introduction of cold and heat into the mouth and spotlights the disparity in thermal expansion and contraction coefficients between the tooth structure and the restoration, which can cause gaps to emerge [35].

Marginal sealing assessment between different specimens was achieved by scanning electron microscope because it allows high-resolution transmission electron micrographs. Moreover, elemental maps of the same specific area can be inspected. It can also produce a more accurate image of marginal micro-gaps [36, 37]. This came in agreement with several researchers [38-40].

The current study findings proved that the marginal seal of SonicFill 2 composite resin was affected by the different extrusion forces of the SonicFill handpiece. The flowability of the composite resin could be increased by increasing the extrusion force magnitude of the SonicFill handpiece and as a result, its marginal sealing could be influenced when they are applied to the prepared cavity, alterations in the composite resin's rheological characteristics might account for this[41]. Hence, we may say that

the null hypothesis is refused. This finding could be supported by Irmak et al. [16] who reported that the extrusion force of the SonicFill handpiece had a noticeable effect on the formation of the internal voids in SonicFill 2 composite resin.

All tested groups showed marginal gaps with different degrees between them either significant or unsignificant. This was in line with the findings of Blunck and Zaslansky, who had already concluded that achieving completely gap-free margins is an unrealistic goal [42]. Group I (control), in which no sonic energy was applied, showed the highest percentage of the marginal gap in comparison to sonic-activated groups (groups II, III, and IV). This could be a supposed finding where SonicFill 2 composite resin was initially formulated to be inserted using sonic energy but not manually. A higher percentage of marginal gaps could be observed in bulk uses of such viscous material compared to sonic-activated groups, as SonicFill 2 explained that when not excited, it becomes more viscous, similar to traditional paste-like composites[16].

In contrast, sonic-activated groups show an increase in molecular chain activity and mobility, a decrease in contact and entanglements, and a shift toward a more disordered and chaotic molecular structure as a result of the polymer absorbing sonic energy[43]. These alterations lead to an increase in the polymer flowability because of its behavior modifications[44]. Sonic energy application to composite in a paste-like state increases its flowability to be similar to that of traditional flowable composites. The enhancement in the flowability of this composite could provide better sealing to cavity walls and margins [45].

This finding could be supported by Irmak et al., [16] who found that manual extrusion of sonic-activated composite resin showed the highest percentage of intra-restoration voids than that found in sonic-activated groups. However, it couldn't be supported by other studies [46, 47] which found that using sonic

energy can lead to increasing the formation of voids inside the composite resin restorations in comparison to its traditional packing method, that aren't designed to be applied using sonic energy; thus, using sonic energy on these composites was deemed inappropriate. Despite its recommendation for use with sonic activation, SonicFill 2 had the same effect on internal void rates as conventional installation. F3 was the sole extrusion force used in these experiments.

Group IV which utilizes the highest extrusion force (F5), showed the least percentage of the marginal gap of SonicFill 2 composite resin in comparison to group II which applies the lowest extrusion force (F1), and group III which applies medium extrusion force (F3). These findings could be explained by increasing the extrusion force magnitude providing changes in the rheological properties of the composite resin that increase its flow and thereby improve its marginal adaptation to the cavity walls [41]. While there was no difference between group II (F1) and group III (F3). There may not be much of a variation in the rheological properties of the composite resin to note a change in the percentage of the marginal gap between these groups, even though increasing the extrusion force magnitude. This finding could be backed up by research conducted by Irmak et al.,[16] which stated that the lowest internal void rates in SonicFill 2 composite resin restorations were achieved with the highest extrusion force (F5) followed by the medium extrusion force (F3), and the lowest extrusion force (F1) of the SonicFill handpiece. However, no discernible difference was found between (F1) and (F3).

In this study, it could be supposed that the different extrusion forces of the SonicFill handpiece were effective in enhancing the marginal seal of sonic-activated composite resin compared to manual dispensing but none of them could produce gap-free margins. Thus, its adaptation to cavity walls and margins seems to still be an unsolved problem necessitating further studies.

CONCLUSIONS

The null hypotheses of this in-vitro study were rejected. None of the different extrusion forces of the SonicFill handpiece produced gap-free margins. Applying the SonicFill handpiece at the highest extrusion force (F5) enhanced the marginal sealing of SonicFill 2 composite resin restorations effectively in comparison to the medium (F3) and lowest (F1) extrusion forces. (F1) and (F3) extrusion forces exhibited nearly similar marginal seals despite increasing the extrusion force magnitude.

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