Original Article

Influence of adhesive-composite application modalities on their bonding to tooth structure and resistance of the performed restorations to failure

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Abstract *Background/purpose:* The longevity of bonded composite restorations could be affected by the utilized adhesive-composite application techniques. This in vitro study aimed to evaluate the influence of adhesive-composite application modalities on their bonding values to tooth structure and on the failure resistance of the performed restorations on loading.
Materials and methods: Resin composite studs, 2 mm in diameter and 4 mm high, were bonded in 2 groups to flattened enamel and dentin surfaces of 80 extracted premolars using pre-cured (PC) and co-cured (CC) self-etch resin adhesive. Studs in each group were built-up in 4 sub-groups using either multiple increments of nano-filled composite (IF, control) or single increment of preheated nano-filled (PH), bulk-fill (BF) and sonic-activated bulk-fill composites (SF). Another 80 premolars with standard class II cavities were also restored using the same adhesive-composite application modalities. All specimens were then stressed on a universal testing machine to assess the composite-tooth shear bond strength and the resistance of the performed restorations to failure. The modes of specimens' failure were also assessed following each test.
Results: The PC adhesive provided higher bond strength to dentin (p < 0.05) and comparable bond strength to enamel in comparison to the CC one (p>0.05%). Both PH and BF composites showed lower bond strength to dentin in presence of PC adhesive (p < 0.05). Comparable bond strengths were noticed for PH, BF and SF composites to dentin in presence of CC adhesive (p > 0.05). PH and SF restorations presented the highest resistance to failure (p < 0.05).
Conclusion: Both incrementally and bulky-inserted composites offer clinically acceptable bond strength in presence of pre-cured resin adhesive. Both Preheated and sonic-activated composite restorations offer the highest resistance to failure on loading. The preheating procedure renders regular composite material suitable for bulk-fill applications.

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Introduction

The noticed consumer interest in personal and facial esthetics prompted many advances in restorative dental materials and techniques. Currently, direct resin-based restoratives are essential utilities of dental practice that would help dentists deliver quality and esthetically-pleasant dental care. However, the differences in the chemical formulations, physical properties and insertion techniques of these materials may influence the longevity of the performed restorations.[1-4]

The high viscosity and stickiness of contemporary resin composites usually make their insertion and adaptation into the prepared cavities quite difficult and time consuming procedure.[5,6] Therefore; different simplified application techniques have recently been proposed. Several researchers[5-9] concerned about the effect of preheating procedure on restorative resin composites. This approach helped increase the mechanical properties, the degree of conversion and the flow of the material. This improvement is subsequently reflected on materials adaptation and retention into tooth cavities and can also provide the possibility to fill deep cavities using single increment of the preheated resin composite.[10-12] In addition; some dental manufacturers introduced a new category of resin composites having the advantage of bulk-fill application. These materials could be applied in single 4-mm thick increments with no drawbacks on composites' depth of cure, polymerization stresses and bond strength. Most of the concerned manufacturers modified the filler content of their composites and may also introduce flexible resins into their formulations to achieve the aforementioned advantages, although these compositional alterations might affect the mechanical properties of the set material.[13,14] Another manufacture suggested the use of ultrasonic energy to improve the flow and the adaptation of the regularly-filled resin composite paste for bulk-fill application with no adverse effect on material's mechanical properties.[15,16]

On the other hand, the co-curing of resin adhesive has been suggested to help save both patients and operator times. This technique suggested the curing of the resin adhesive through and together with the first increment of the restorative resin composite.[17,18] Certain reports confirmed the efficient bonding of co-cured adhesives to tooth enamel. However, their lower efficacy in bonding to dentin was noticed in comparison to the regularly pre-cured ones.[18,19] Some investigators[18,19] referred this weakness to the possible insufficient curing of the adhesive together with the subsequent contraction stresses of the curing overlaying resin composite. In response, the current study estimated a considerable success of the adhesive co-curing technique in presence of bulk-fill resin composite based on the documented lower contraction stresses and the ability of bulk-fill composite materials to transmit the curing light much deeper.[16,20,21]

Therefore, the aim of the current *in vitro* study was to evaluate the influence of different application modalities of the contemporary self-etch adhesive and composite restoratives on their bonding to tooth structure and on the resistance of the performed class II restorations to failure on loading. The null hypotheses accordingly suggested no effect of either self-etch adhesive or composite restorative application modalities on their bond strength either to tooth enamel or dentin as well as on the on the on loading resistance of the performed class II restorations to failure.

Materials and methods

Hundred sixty crack and caries-free premolars extracted for orthodontic purposes were utilized in this study. The collected teeth were subjected to thorough ultrasonic cleaning (Pro-sonic 300 MTH, Sultan Chemists, Englewood, NJ, USA) to get rid of both soft and hard surface deposits. All teeth were inspected at X10 under low angle illumination (SZX10, Olympus Co., Tokyo, Japan) to ensure the absence of cracks before their storage in 0.2% aqueous solution of Sodium Azide at $37 \pm 1\,°C$ (Binder incubator, Model B 28, Binder Inc, Tuttlingen, Germany) for 30d at maximum. To test the influence of the suggested adhesive-composite application modalities on the bond strength to enamel and dentin, cylindrical diamond tips (#111-016, DIA-BURS BR31, Mani Inc., Tochigi, Japan) were used to create flat enamel and dentin foundation on both lingual and buccal surfaces of 80 extracted premolars. In a mimic to the real clinical situation, the cut enamel and dentin surfaces were only cleaned up with air—water spray and dried before the application of the self-etch adhesive (Adper Scotchbond SE, 3M ESPE, St. Paul, MN) primer (Liquid A). One coat of the liquid resin adhesive (Liquid B) was brushed against the primed dentin surfaces of all teeth, agitated for 20s and air dried to remove water. An overcoat of the liquid adhesive was subsequently applied and air thinned before its curing in 2 groups following either the pre-curing (G1, n = 40) or the co-curing (G2, n = 40) technique. In Group 1, the applied adhesive was directly light-cured using Elipar S10 LED curing unit (3M ESPE, Seefeld, Germany) for 10s before the application of any restorative resin composite against. In Group 2, the applied adhesive was simultaneously cured with the overlaying restorative resin composite. For each group, 4 different subgroups (SG1-SG4, n = 10 each) of resin composite studs, 2 mm in diameter and 4 mm high, were built-up in silicone rubber molds (Express XT VPS, 3M ESPE, Seefeld, Germany) against the applied adhesive. Studs of the SG1 were built up of the nano-filled resin composite restorative (Filtek Z350, 3M ESPE, St. Paul, MN) using the incremental application technique (IF). Two successive 2 mm thick increments of the selected resin composite were condensed into the rubber mold and each was light cured for 20s. Studs of the

SG2 were built up using single increment of the preheated nano-filled (PH) resin composite. Composite capsules were preheated to 68 °C in Calset composite heater (AdDent, Inc., Dandury, CT, USA) for 3min.[12] The preheated composite was then injected in bulk to fill the entire rubber mold, adapted and its top surface was then exposed to the curing light for 40s. Single increments of 2 different brands of the specifically introduced bulk-fill resin composites were used to build the studs of SG3 and SG4 specimens up. The Paste-like bulk-fill (BF) resin composite (Filtek Bulk Fill, 3M ESPE, St.Paul, MN) were condensed into the rubber molds of SG3 specimens, while the sonic-activated bulk-fill (SF) resin composite (SonicFill, Kerr Dental, Orange, CA, USA) was injected using the specifically introduced SonicFill handpiece and condensed to fill the molds of SG4 specimens. The studs constructed from both materials were then light cured through their exposed top surfaces for 40s.

The constructed specimens in all subgroups were then subjected to 5−55 °C thermocycling (MSCT-1, São Carlos, SP, Brazil) following ISO-TR 11405 Standard for 3500 cycles with 1 min dwell time before testing the shear bond strength of resin composites to tooth enamel and dentin. The composite-tooth interfaces of all specimens were stressed using chisel-edged rod on a universal testing machine (Model 5965, Instron, Grove City, PA) running at a crosshead speed of 0.5 mm/min. The maximum load at failure was recorded to calculate the shear bond strength of each tested specimen. The collected data was then analyzed using both 2-Way ANOVA and Mann−Whitney tests at $\alpha = 0.05$ to detect the significance of differences detected between the test subgroups. The fracture surfaces of each specimen were also assessed under using a stereomicroscope at $\times 10$ original magnification under low angle illumination to determine the incidences of the bond failure modes and their severity scores. The adhesive mode of bond failure (Score 1) was recorded when a complete separation at either dentin-adhesive or adhesive composite interfaces was detected, while the cohesive mode of bond failure (Score 3) was recorded when either dentine or composite bodies were fractured. Any combination between the features of the previous modes was classified as mixed mode of failure (Score 2). The chǐ2 test at $\alpha = 0.05$ were then used to figure the significance of any differences detected between failure severity scores of the test subgroups.

On the other hand, the on loading retention test was utilized to evaluate the resistance of class II restorations to failure. Standard occluso-mesial cavities (1.5 mm wide pulpal floor and gingival seat, 2 mm deep occlusal and proximal cavities and 4 mm occluso-gingival height of the proximal box) with 6° occlusally-divergent axial walls, no sharp internal line angles and no kind of retentive means (Fig. 1) were prepared in another 80 premolars using diamond truncated cone-shaped tips (#196-020, DIA-BURS EX11, Mani Inc., Tochigi, Japan). The prepared cavities were restored in 4 subgroups utilizing the previously utilized adhesive-composite application modalities and subjected to the same thermocycling protocol. The performed restorations were stressed on the universal testing machine to assess their resistance to dislodgement. A round-ended rod, 1.5 mm in diameter, directed at 45° on the occlusal plane was used to apply oblique dislodging stresses on the
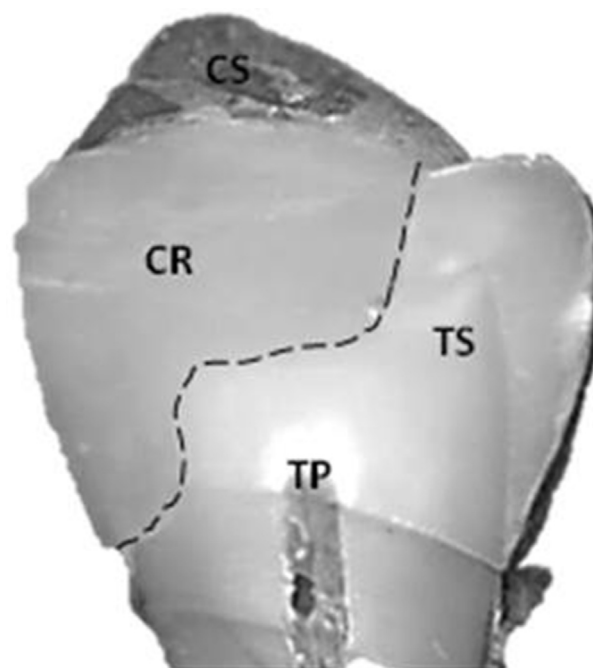

Figure 1 Non retentive design of the performed class II composite restorations: *(CR) Composite restoration; (TS) tooth structure; (TP) Tooth pulp and (CS) Cusp slope.*

mesial marginal ridge of the performed composite restorations. The maximum load at failure (The first heard cracking sound) of each specimen was recorded for further statistical analysis using both 2-Way ANOVA and Mann−Whitney tests at $\alpha = 0.05$. The mode of restorations' failure was also assessed and scored for a statistical purpose according to their severity as follows; Score 1: Fracture at the restoration's marginal ridge area, Score 2: Loss of the entire proximal restoration, Score 3: Total dislodgement of the performed restoration and Score 4: Tooth cracking or fracture. The recorded scores were then analyzed using chǐ2 test at $\alpha = 0.05$ to determine the significance of differences between test subgroups.

Results

The mean shear bond strength data of resin composites to both enamel and dentin in different subgroups is shown in Table 1. Analysis of enamel results using the 2-way ANOVA indicated no difference between the utilized adhesive curing techniques (Groups, p = 0.0597), while some significant differences were detected between different composite insertion modalities (Subgroups, p = 0.0388). At the same time, no interaction was declared between both test variables (p = 0.1440). Results of the Mann−Whitney test indicated lower bonding values of BF (SG2) than the control (SG1, IF) when bonded with pre-cured adhesive in G1 (p = 0.0172), while SF (SG4) showed higher bonding values than the control when bonded with co-cured adhesive in G2 (p = 0.0113). Analysis of dentin results using the 2-way ANOVA indicated significant differences between both test groups (p = 0.0001) and between different subgroups (p = 0.0042). A significant interaction was also

Table 1 Mean Bond strength (MPa) of resin composites to tooth substrates in different subgroups.

Tooth substrate	Groups	Subgroups			
		Incrementally-inserted	Bulky-inserted		
		IF	PH	BF	SF
Enamel	PC	21.01 ± 1.84^{a1}	20.59 ± 2.05^{ab1}	18.90 ± 1.62^{b1}	20.79 ± 2.61^{ab1}
	CC	20.01 ± 2.56^{a1}	21.68 ± 2.80^{ab1}	20.66 ± 1.70^{a1}	22.69 ± 2.03^{b1}
Dentin	PC	20.01 ± 1.82^{a1}	18.19 ± 1.62^{ab1}	17.90 ± 1.74^{a1}	19.49 ± 2.15^{b1}
	CC	08.91 ± 1.39^{a2}	09.19 ± 2.25^{a2}	12.16 ± 2.35^{b2}	12.49 ± 2.29^{b2}

PC = Pre-cured adhesive; CC = Co-cured adhesive; IF = incrementally-inserted nano-filled composite; PH = Preheated bulky-inserted, nano-filled composite; BF = Bulk-fill composite paste; SF = Sonic-activated bulk-fill composite.
For each substrate, different superscript numbers in each column (within each subgroup) indicate significant differences between groups ($P < 0.05$).
For each substrate, different superscript letters in each row (within each group) indicate significant differences between subgroups ($P < 0.05$).

detected between both variables (p = 0.0003). Regardless the utilized composite insertion modality, specimens in G1 provided higher bond strength to dentin in comparison to those in G2 (P < 0.05). In Group 1, IF specimens of SG1 provided higher bond strength values in comparison to PH and BF of SG2 and SG3 (Mann–Whitney, p = 0.03764 and 0.02113), and comparable values to those of SF of SG4 (Mann–Whitney, p = 0.6232). At the same time, a comparable bond strength values were detected between PH, BF and SF of SG2, SG3 and SG4 (Mann–Whitney, p > 0.05). In group 2, IF and PH specimens in SG1 and SG2 showed comparable bond strength data (Mann–Whitney, p = 0.8501) lower than those recorded for BF and SF of SG3 and SG4 (Mann–Whitney, p < 0.05). The adhesive mode of bond failure was dominant in all subgroups; however both mixed and cohesive modes of failure were noticed in few number of the test specimens (Table 2). The chĩ2 test indicated no difference (H = 3.000) between the recorded failure scores of different subgroups.

Although any of the performed restorations did not dislodge on loading out of their cavities, their failures were considered when any sort of fracture was noticed. The mean failure loads of the performed class II restorations

and the standard deviations in all subgroups were listed in Table 3. The 2-way ANOVA indicated insignificant difference between test groups (p = 0.633), while a significant difference was noticed between test subgroups (p = 0.0001) with no interaction between the tested variables (p = 0.549). In both G1 and G2, restorations in all test subgroups showed significant difference between each other (Mann–Whitney, p < 0.05) in terms of their resistance to failure on loading. Although, none of the tested restorations were totally dislodged during the testing process (Table 4), many showed fracture of their marginal ridge area and few others showed serious fractures within the body of restored teeth (Fig. 2a and b). The chĩ2 test also indicated similar failure scores (H = 1.444) for all tested subgroups.

Discussion

The simplified bonding and insertion procedures of resin composite restorations are currently popular among dental practitioners. These approaches not only help minimize the procedural errors, but also save both operator and patients'

Table 2 Incidence of bond failure modes in different subgroups.

Groups	Subgroups	Failure Modes						Mean score (Enamel)	Mean score (Dentine)
		Adhesive failure (Score 1)		Mixed failure (Score 2)		Cohesive failure (Score 3)			
		Enamel	Dentin	Enamel	Dentin	Enamel	Dentin		
PC	IF	60%	70%	40%	20%	0%	10%	1.4 ± 0.52	1.4 ± 0.70^{a}
	PH	70%	80%	30%	20%	0%	0%	1.3 ± 0.48	1.2 ± 0.48^{a}
	BF	80%	80%	20%	10%	0%	10%	1.2 ± 0.42	1.3 ± 0.67^{a}
	SF	50%	70%	40%	30%	10%	0%	1.6 ± 0.70	1.3 ± 0.48^{a}
CC	IF	80%	100%	20%	0%	0%	0%	1.2 ± 0.42	1.0 ± 0.00^{a}
	PH	70%	90%	30%	10%	0%	0%	1.3 ± 0.48	1.1 ± 0.32^{a}
	BF	90%	100%	10%	0%	0%	0%	1.1 ± 0.32	1.0 ± 0.00^{a}
	SF	60%	90%	40%	10%	0%	0%	1.4 ± 0.52	1.1 ± 0.32^{a}

PC = Pre-cured adhesive; CC = Co-cured adhesive; IF = incrementally-inserted nano-filled composite; PH = Preheated bulky-inserted, nano-filled composite; BF = Bulk-fill composite paste; SF = Sonic-activated bulk-fill composite.
Higher means of failure scores indicate more serious failure in the performed restorations.
Similar superscript letters indicate no significant differences between subgroups, H (chĩ2) = 3.842 and 3.000 for enamel and dentin.

Table 3 Mean failure loads (N) of class II restorations in different subgroups.

Groups	Subgroups			
	Incrementally-inserted	Bulky-inserted		
	IF	PH	BF	SF
PC	341.12 ± 19.07^{a1}	385.66 ± 21.89^{b1}	284.90 ± 15.56^{c1}	406.99 ± 24.53^{d1}
CC	332.97 ± 18.35^{a1}	387.76 ± 11.29^{b1}	290.20 ± 13.47^{c1}	400.27 ± 10.79^{d1}

PC = Pre-cured adhesive; CC = Co-cured adhesive; IF = incrementally-inserted nano-filled composite; PH = Preheated bulky-inserted, nano-filled composite; BF = Bulk-fill composite paste; SF = Sonic-activated bulk-fill composite.
Different superscript numbers in each column (within each subgroup) indicate significant differences between groups (Mann—Whitney, $P < 0.05$).
Different superscript letters in each row (within each group) indicate significant differences between subgroups (Mann—Whitney, $P < 0.05$).

Table 4 On loading failures of class II restorations in different subgroups.

Groups	Subgroups	Failure Mode				Mean score
		Fracture of restorations at the marginal ridge area (Score 1)	Loss of the entire proximal restoration (Score 2)	Total loss of the entire restoration (Score 3)	fracture within tooth body (Score 4)	
PC	IF	80%	0%	0%	20%	1.6 ± 1.26^{a}
	PH	90%	0%	0%	10%	1.3 ± 0.95^{a}
	BF	80%	0%	0%	20%	1.6 ± 1.26^{a}
	SF	100%	0%	0%	0%	1.0 ± 0.00^{a}
CC	IF	90%	0%	0%	10%	1.3 ± 0.95^{a}
	PH	100%	0%	0%	0%	1.0 ± 0.00^{a}
	BF	80%	0%	0%	20%	1.6 ± 1.26^{a}
	SF	90%	0%	0%	10%	1.3 ± 0.95^{a}

PC = Pre-cured adhesive; CC = Co-cured adhesive; IF = incrementally-inserted nano-filled composite; PH = Preheated bulky-inserted, nano-filled composite; BF = Bulk-fill composite paste; SF = Sonic-activated bulk-fill composite.
Higher means failure scores indicate more serious restoration's failure.
Similar superscript letters indicate no significant differences between subgroups, H (chi\`2) = 1.444.

times.[1,4] The co-curing technique of resin adhesive had been suggested to bond resin composites to tooth structures, however the negative results of their laboratory evaluation, especially those conducted against tooth dentin, did not encourage dental practitioners to use it in their daily practice.[18,19] The idea of heating the regular resin composites before their insertion into tooth cavities had also been demonstrated some time ago. This approach helped increase the flow, depth of cure and the mechanical properties of the composite materials.[10–12] these positive outcomes suggested a possibility of using the preheating procedure to allow the regular resin composites in bulk-fill applications. On the other hand; the concept of bulk filling the prepared tooth cavities was simultaneously existed with the availability of a new category of bulk-fill resin composite restoratives.[13,14] Both bulk-fill and preheated resin composites were reported to allow the curing light to go more deep through, however most of the manufacturers' recommendations insisted that the successful bulk-fill restorations should not exceed 4 mm in depth.[16,20,21] This feature accordingly suggested a possible success of adhesive's co-curing approach in bonding the bulky-inserted resin composites to tooth structure. The null hypothesis of the current study denied any influence of either adhesive-composite application modalities on the bond

strength to either enamel or dentin as well as on the on loading failure resistance of the performed class II restorations. However, this null hypothesis was partially rejected, as a significant effect of adhesive's application and curing was clearly noticed on the bond strength of the utilized resin composites, regardless their insertion modalities, to dentin (Table 2).

Results of the current study showed comparable bond strengths of both pre-cured and co-cured self-etch adhesives to tooth enamel. This finding came in agreement with the results of Chapman et al.,[19] and could also be supported by those of Viswanathan et al.,[18] who reported higher bond strength of the co-cured adhesive to enamel than the pre-cured one, however the difference between their results and the results of the current study could be referred to the nature of the primary enamel in addition to the different types of adhesives they utilized in their study. Both studies did not show a clear explanation of their findings, but they relied on the different chemical composition, micro-morphology and chemical reactivity of enamel to self-etch adhesives in comparison to those of dentin. Other researchers[22] coincidently demonstrated an important role of enamel's etching pattern on the bond strength of self-etch adhesives. They noticed deeper and larger microporosities on enamel surfaces treated with self-etch
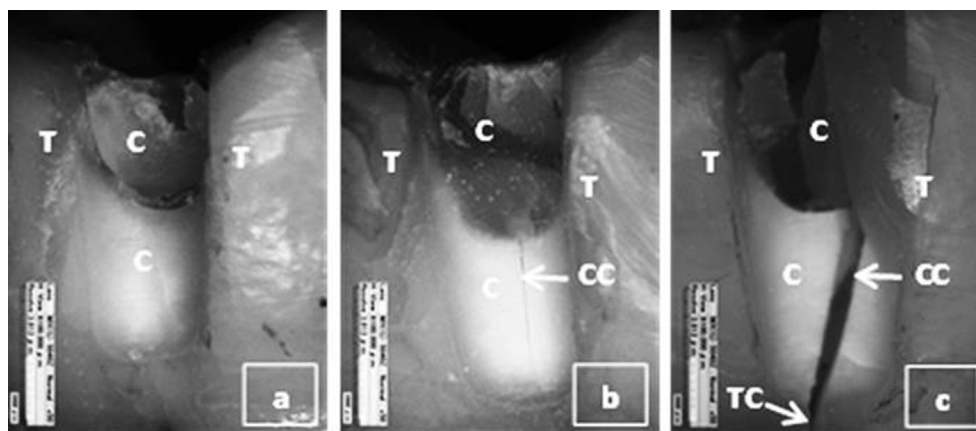
Figure 2   On loading failures of class II composite restorations *(T) tooth structure; (C) composite material; (CC) composite crack; and (TC) Tooth crack*: Images "a" and "b" represent different forms of fractures in the performed composite restorations; while image "c" represents fractured restoration combined with catastrophic tooth fracture.

primers in comparison to those treated with 35% phosphoric acid. These features could allow for easier and deeper penetration of the liquid resin with minimal chances of air pocket formation. After polymerization, the formed resin tags would, therefore, have larger frictional surface areas that lead to better resistance to dislodgment in response to the shrinking overlaying composite. Although, all composites in each group showed comparable bond strengths to enamel, non-realistic deviations from the control were noticed for BF and SF composites when respectively bonded to enamel using pre-cure and co-cured adhesives. These findings could be referred to the expected difference in enamel characteristics among teeth utilized in this study.

On the other hand, the recorded lower bond strength values of the co-cured self-etch adhesive to dentin in comparison to the pre-cured one came in total agreement with the results of some previous studies[18,19] those referred this finding to the subsequent effect of the shrinkage encountered in the overlaying resin composite on curing. Moreover, the limited exposure of resin adhesive to the curing light as a result of the possible attenuation and dispersion of the light energy through the overlying composite may result in incomplete curing of the resin adhesive that probably remain in the gel state.[23] Both situations could show a negative reflection on the ability of the formed resin tags to remain penetrating the dentinal micro-irregularities and tubules. Although the same self-etch adhesive system was used following the manufacturer's instruction in both pre-cured and co-cured groups, a possible difference could be encountered in the actual contact time between the activated acidic monomer and dentin surface in case of co-curing the adhesive.[24] The considerable delay in exposing the adhesive to curing light until the insertion of resin composite is performed may lead to dentin over-etching that leads to deeper demineralization of both intertubular and peritubular dentin. This situation usually hampers the proper infiltration of resin monomers causing, in turn, a significant reduction in bond strength.[25,26]

The incrementally-inserted resin composite showed the highest shear bond strength to dentin in presence of the pre-cured self-etch adhesive when compared to the bulky-inserted resin composites, although all of them achieved bonding values higher than 17 MPa which is usually considered sufficient for successful restoration retention.[27] This finding could be supported with the findings of Abo Al-Hana et al.,[28] and Colak et al.,[29] who reported higher shear bond strength of the incrementally-inserted resin composites than the bulk-fill ones. The recorded results could be related to the efficient curing of the adhesive together with the minimal shrinkage rate of the very first increment of the utilized nano-filled resin composite. Normally, the presence of nano-sized fillers having a refractive index similar to the resin matrix helps better transmission of the curing light through the entire thickness of composite increment. The higher surface area of the utilized nano-sized fillers also helps minimize the polymerization shrinkage and provides the composite material with higher mechanical properties in comparison to the micro and the nano-hybrid fillers those usually used in bulk-fill composite formulations.[30] At the same time, all the bulky-inserted composites showed comparable bond strength to dentin in presence of pre-cured adhesive. This finding indicated that the preheated resin composite may exhibit the same efficiency of the especially-designed bulk-fill resin composites in obtaining adequate depth of cure, low rate of polymerization shrinkage and good adaptation to the pre-applied resin adhesive.[5–12] However, to our knowledge, no published study compared the bond strength of the preheated and the bulk-fill resin composites.

In spite of the recorded overall lower bond strengths of the co-cured adhesive, the bonding values of the bulky-inserted resin composites seemed comparable or even higher than the incrementally-inserted resin composite. This finding could be explained by the ability of both preheated and bulk-fill composites to show lower values of contraction stresses on curing and deeper transmission of the curing light.[16,20,21,31] This feature, may offer a better chance for efficient curing of the resin adhesive underneath that, in turn, would resist the dislodgement of the formed resin tags out of the dentinal irregularities in response to composite's polymerization contraction. Although, the statistical analysis

of the bond failure scores showed no significant difference between the tested subgroups, the adhesive type of bond failure was common in the tested specimens of both groups. Few specimens, at the same time, showed a mixed mode of bond failure. These findings seemed favorable, in terms of maintaining the integrity of the restored teeth, and can be supported[32,33] with the findings of some other studies those tested the bond strength of both the incrementally and bulky-inserted resin composites nearly similar to those utilized in the current study.

Regardless the recorded bond strength to dentin, results of this in vitro study showed acceptable retention (No dislodgement) of the performed class II restorations in all subgroups. Although failures of the performed restorations have been announced on their fractures, all restorations failed at loads beyond the known masticatory values (178—291 N)[34] and this could, accordingly, fulfill the clinical requirement of successful restorations. At the same time, no effect of the adhesive application modalities was noticed on the failure loads detected in each subgroup (Table 3). This finding could be referred to other factors such as; the large bonding surface area and the friction with cavity walls in addition to the bonding values to enamel, those normally govern the retention of the performed restorations. Some time ago, Reel and Mitchell[35] deduced no difference in the fracture resistance of teeth restored with either dentin or enamel-bonded class II composite restorations. Laegreid et al.,[36] reported higher fracture strength of class II composite restorations in presence of gingival enamel margins. They explained their results based on several factors including the ability of the achieved restoration-enamel bonding to resist the shearing forces generated by the occlusal stresses. Moreover, many studies[18,19] indicated comparable or even higher bond strengths of the co-cured adhesives to enamel than the pre-cured adhesive. Findings of the aforementioned studies can support the retention results of class II composite restorations of the current study when bonded using either pre or co-cured adhesive.

In spite of the recorded no differences between the failure loads of both test groups, composite insertion modalities in different subgroups showed a clear influence on the recorded failure loads. In disagreement to these findings, A 36 month long clinical comparison of bulk-fill and nano-fill composite restorations indicated no differences between the utilized materials in terms of restorations retention.[37] Another study also revealed comparable fatigue resistance of teeth having either bulky or incrementally-inserted class II composite restorations.[38] In the current study, the bulky-inserted SF (SG4) and PH (SG2) composites showed the highest resistance to failure followed by the incrementally-inserted IF (SG1), while the bulky-inserted BF (SG3) achieved the lowest resistance to failure. On the one hand, these findings was not reflected on the mode of restorations' failure (Table 4) as most of the specimens in all subgroups showed fractures at the marginal ridge area and within the bodies of the performed restorations.[36] Very few specimens in each subgroup showed fractures within the natural teeth and this probably came in response of cracks developed at the time of cavity preparation or even undetected at the time of teeth selection. Anyway, this observation may drag the attention to

meticulously examine the selected teeth before and after cavity preparation procedure using the trans-illumination technique or even under higher magnification than that utilized in this study. But on the other hand, similar failure resistance data of the current study could suggest a relation between the resistance of the performed restorations to loading and the utilized insertion modality. The bulky-inserted SF and PH resin composite normally show higher flow and adaptation to cavity foundation with minimal incidence of air voids or even in adequate bonding between the inserted increments when compared to both BF and IF resin composites. These advantages can surely be reflected on the mechanical properties of the performed restorations and accordingly on their resistance to fracture on loading.[10,11,15,16]

Although confirmation of the findings reported in this study must be considered following the application of cyclic fatigue loading and in further microleakage study, evaluating different types of contemporary resin adhesives under similar testing circumstances is also advisable. Within these limitations, results of the current study could be summarized as follows; both incrementally and bulky-inserted composites offer clinically acceptable bond strength in presence of pre-cured resin adhesive. Both Preheated and sonic-activated composite restorations offer the highest resistance to failure on loading. Therefore, dental practitioners may expect the clinical success of the bulky-inserted resin, although the adhesive co-curing approach should only be applied in cases with minimal cavity depth. Moreover, the ability of preheating procedure to render regular composite material suitable for bulk-fill applications could also be taken into their consideration.

Acknowledgement

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