Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2024 Feb 12; 12(1):102-106.
https://doi.org/10.3889/oamjms.2024.11828
eISSN: 1857-9655
Category: *D - Dental Sciences*
Section: *Pedodontics and Preventive Dentistry*

Effect of Preheating of Resin Composite on Microtensile Bond Strength *In Vitro* Study

M.A. Hanafy[1], O.M. Fahmy[2], A.F. Abo Elezz[3]

[1]Dentist in Ministry of Health and Population, Egypt; [2]Department of Restorative Dentistry, Faculty of Dentistry, Misr International University, Egypt; [3]Department of Restorative Dentistry, Faculty of Dentistry, Suez Canal University, Egypt

Edited by: Mirko Spiroski
Citation: Hanafy MA, Fahmy OM, Elezz AFA. Effect of Preheating of Resin Composite on Microtensile Bond Strength *In Vitro* Study. Open Access Maced J Med Sci. 2024 Feb 12; 12(1):102-106. https://doi.org/10.3889/oamjms.2024.11828
Keywords: Microtensile bond strength; Microhybrid resin composite; Nanohybrid resin composite; Preheating
***Correspondence:** M.A. Hanafy, Dentist in Ministry of Health and Population, Egypt.
E-mail: mahaadel4@gmail.com
Received: 17-Nov-2023
Revised: 04-Dec-2023
Accepted: 05-Dec-2023

Funding: This research did not receive any financial support
Competing Interests: The authors have declared that no competing interests exist

Abstract

BACKGROUND: Preheating resin composite was one of the latest achievements to improve the mechanical properties of composite.

AIM: This study was conducted to assess the effect of preheating of resin composite on microtensile bond strength to dentin.

METHODS AND MATERIALS: A total of 32 human molars were selected and divided into two groups according to the type of resin composites either microhybrid (P60) (R1) or nanohybrid (Z250 XT) (R2). The molar teeth were embedded in acrylic resin blocks then the occlusal enamel was removed parallel to cementoenamel junction to expose the dentin. Each group was subdivided into four subgroups according to the number of preheating cycles of resin composite either no heating (C0), one preheating cycle at 68℃ (C1), two preheating cycles at 68℃ (C2), or three preheating cycles at 68℃ (C3). After bonding of resin composite, specimens were cut into beams 1 mm thick and stressed in tension using a universal testing machine (4 teeth per group/12 beams per tooth).

STATISTICAL ANALYSIS USED: Two-way ANOVA and Tukey's *post hoc* tests were used to test the effect of preheating resin composites for the interaction of different variables.

RESULTS: In both variables of the study, the type of resin composite and the number of preheating cycles have a statistically significant effect on the microtensile bond strength to dentin. There was a significant interaction between the variables.

CONCLUSION: Pre-heating of Filtek P60 as a packable composite at 68℃ can achieve significantly higher microtensile bond strength compared to Filtek Z250 as a microhybrid composite.

Key Messages: Preheating of resin composite enhances the mechanical properties of resin composite. Furthermore, better adaptation is due to easily flow of the material in additional to the improvement of microtensile bond strength of resin composite due to monomer and radical mobility due to complete polymerization during preheating.

Introduction

During the past decades, resin composites have become the most common material in direct restorations due to the increasing demand for esthetics and continued improvement in technology due to its adaptation and shrinkage during its polymerization [1]. Manufacturers have increased the filler content to enhance the properties of composite but this modification, however, results in the higher viscosity of the materials so it may not adapt fully to the cavity walls, which may result in poor marginal integrity [2].

In addition, many modern composites are sticky and difficult to manipulate, making placement more challenging. It has been suggested that a flowable composite liner should be utilized before the regular composite material is placed in cavity preparation to overcome these constraints. Many studies have recommended that conventional composites should be warmed instead of using a flowable composite. In comparison to typical composites, they feature decreased viscosity, enhanced wettability, and increased elasticity [3]. Regardless of preheating temperature, conventional composites yield film thickness values larger than those of room temperature-flowable composite resin [4].

The primary disadvantages of flowable composites are the polymerization shrinkage and higher values of expansion and contraction with temperature than conventional composites, so for these reasons, the use of flowable composite is limited [5]. Preheating of conventional composites was evaluated that it is not a substitute for the use of flowable composite resins but it was evaluated to solve the drawbacks of flowable composite so decrease the microleakage and increase microtensile bond strength (μTBS) [6].

As a result, modern resin composites have become widely introduced for a variety of purposes in restorative dentistry, despite various drawbacks such as considerable polymerization shrinkage, worse wear

resistance than amalgam, partial monomer conversion, and unwanted water sorption [7]. Filtek P60 is a packable resin composite with almost the same composition as Filtek Z250 XT and a high cure depth [8]. The manufacturers have introduced many resin composites with different properties for each area of application which indicate that resin composites respond to an increase in external temperature by decrease in their viscosity due to their viscoelastic nature. The increased flow was caused by thermal energy, which increased the molecular mobility of monomer chains and increased the collision frequency in the composite resin [8], [9]. Compounds with higher conversion have more cross-linking and less free space in polymers, which improve their mechanical properties. The fraction of carbon–carbon double bonds that have been transformed into a single bond to form a polymeric resin is referred to as the degree of conversion [10].

Heat treatment can enhance the internal structure and filler distribution of dental composites, and these benefits last long after the material cools down [11]. Studies have demonstrated that prolonged or repeated pre-warming cycles for resins do not cause any component degradation [12]. The effect of pre-warming and pre-cooling on the nanohybrid resin composite before placement increased monomer conversion and polymerization; free radicals and propagating polymer chains became more mobile as a result of decreased resin material viscosity, resulting in a more complete polymerization reaction [13]. More improved mechanical qualities, such as hardness and flexural strength, mirrored this [14], [15]. Therefore, the present study was designed to investigate the effect of preheating nanohybrid resin composite and microhybrid resin composite on dentin. Microtensile bond strength testing was used in *in vitro* study to see how preheating affected the composite's bonding to the dentin. The tested null hypothesis was that the composite temperature and the curing cycles have no significant effect on microtensile bond strength.

Materials and Methods

Selection of teeth

A total of 32 intact sound freshly extracted human impacted third molars were collected from "The National Institute of Diabetes and Endocrinology"; they were extracted from patients aged 20–30 years old for periodontal reasons. The study was carried out after approval of the Research Ethics Committee of the Faculty of Dentistry Suez Canal University, Egypt (#267/2020). Immediately after extraction, teeth were thoroughly washed under running water to remove blood and mucous, scaled to remove calculus and remnants of periodontal ligaments, and polished with fine pumice and soft rubber cups at conventional speed. The teeth were examined for freedom of cracks using a magnifying lens to be used in this study for the preparation of specimens for microtensile bond strength tests. All the teeth exhibiting any signs of caries, microcracks, or any other defective structure were discarded. The effect size f = (0.9262159) was calculated and assuming that the standard deviation within each group = 7.75 using alpha level of 5% and beta level of 80%, sample size calculation was done using G*Power version 3.1.9.2. The teeth were then stored for 24 h in distilled water having 0.5% chloramine-T antiseptic solution at room temperature until being utilized [16]. Specimens were randomly divided into groups according to the type of resin composite into two groups – 16 teeth each, either microhybrid resin composite (R1) or nanohybrid resin composite (R2). These groups were further subdivided into four subgroups, four teeth each, according to the number of preheating cycles into either no preheating (C0), one preheating cycle (C1), two preheating cycles (C2), or three preheating cycles (C3). From each subgroup, 12 beams were prepared.

Specimen preparation

The occlusal enamel was removed parallel to the cementoenamel junction to expose the dentin using a slow-speed diamond saw sectioning machine (Buehler IsoMet Low Speed Saw, Lake Bluff, IL, USA) under water coolant and then the molar teeth were embedded in acrylic resin. Dentin surfaces were finished and wet polished with 600-grit sic paper to have a roughened surface and smear layer. The exposed dentin surface was etched for 15 s occlusally, rinsed with water for 15 s then blot dried. Two successive layers of bonding agent were applied on the etched dentin surface using a microbrush, then a gentle air stream in one direction was applied for 10 s then cured for 10 s. The resin composite in this test was applied in two increments, 1.5 mm each, with a final of thickness 3 mm. The resin composite was supported by celluloid matrix all around and tightened by glue to be secured and the thickness was measured by marking a black mark on the matrix as a guide for the total thickness then measured by manual caliper to assure the right thickness. Each increment was cured for 20 s of total 40 s for both increments. The tip of the light curing unit was set at 0 mm distance from the resin composite. The first group of each composite resin was applied on dentin surfaces with no heating temperature (C0) in two increments of 1.5 mm thickness than light cured for 40 s. In the second group, the composite resin was subjected to one preheating cycle at 68℃ (C1) using a Calset Composite Warmer device (AdDent, Inc., Danbury, CT, USA) then the preheated composite was applied in two increments then cured. In the third group, the composite resin was subjected to two preheating cycles at 68℃ (C2), between each of the heating cycles the composite syringe was left on the table for 4 min to

allow it to return to room temperature and then reheated for another heating cycle and the preheated composite was applied in two increments then cured. In the fourth group, the composite resin was subjected to three preheating cycles at 68℃ (C3), with 4 min of cooling between each of the heating cycles then the preheated composite was applied as previously mentioned. After specimen preparation, all specimens were then stored in artificial saliva at room temperature until being tested.

Microtensile bond strength (μTBS) measurement

The test was applied on beams that were obtained by sectioning each tooth longitudinally into multiple sticks. From each tooth, the central beams of similar cross-sectional area and remaining dentin thickness were tested (n = 4/12 beam per tooth). The Geraldeli's jig separated to let each beam mounted to it with a cyanoacrylate adhesive and apply tensile force using a universal testing machine (Lloyd Instruments Ltd., Ametek company, West Sussex, UK).

Statistical analysis

The mean and standard deviation of μTBS values of the tested groups were collected and tabulated. Data were explored for normality using Kolmogorov–Smirnov and Shapiro–Wilk tests, and data showed parametric (normal) distribution. Two-way ANOVA tests were used to test the interactions between different variables. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Results

The results showed that different resin composites had a statistically significant effect at $p < 0.0001$. Furthermore, the number of cycles had a statistically significant effect at $p < 0.009$ and this is shown in Table 1. The interaction between the two variables also had a statistically significant effect at $p < 0.004$.

Table 1: Results of two-way ANOVA for the effect of different variables on microtensile bond strength

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2766.13	7	395.161	6.153	0.0001
Intercept	48399.450	1	48399.450	753.635	0.0001
Resin composite	990.754	1	990.754	15.427	0.0001
Number of cycles	809.672	3	269.891	4.203	0.009
Resin composite*Number of cycles	965.704	3	321.901	5.012	0.004
Error	3596.397	56	64.221		
Total	54761.977	64			
Corrected Total	6362.527	63			

df: Degrees of freedom = (n−1), *Significant at $p \leq 0.05$.

The results showed Table 2 and Figure 1 that the effect of a number of cycles for the microhybrid resin composite (R1) that there was a statistically significant difference between (C0), (C1), (C2), and (C3) groups where (p = 0.001). A statistically significant difference was found between (C0) and (C2) where (p = 0.001), whereas no statistically significant difference was found between (C0) and each of (C1) and (C3) groups where (p = 0.050) and (p = 0.415). No statistically significant difference was found between (C1) and each of (C2) and (C3) groups where (p = 0.397) and (p = 0.645). No statistically significant difference was found between (C2) and (C3) groups where (p = 0.050). On the other side, the results for the nanohybrid resin composite (R2) showed that there was no statistically significant difference between (C0), (C1), (C2), and (C3) groups where (p = 0.634).

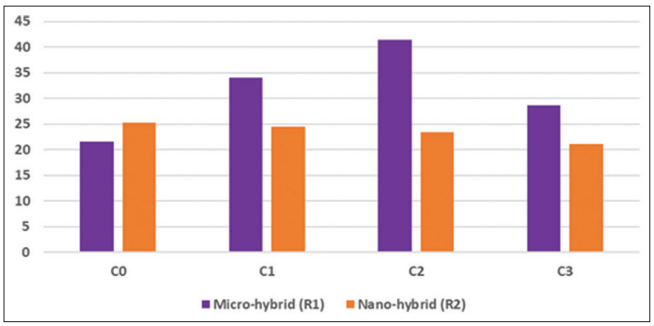

Figure 1: Bar chart representing microtensile bond strength for different tested materials

For the effect of resin composite for C0 and C3, there was no statistically significant difference between (R1) and (R2) groups (p = 0.226) and (p = 0.081), respectively. For C1 and C2, there was a statistically significant difference between (R1) and (R2) groups (p = 0.035) and (p = 0.002), respectively.

Discussion

Nowadays, composite resins are highly recommended as restorative materials due to their overwhelming mechanical and esthetic properties and as a mercury-free alternative material to amalgam [17]. Composite resins include limitations such as polymerization shrinkage, post-operative sensitivity, insufficient proximal contact, low wear resistance, and a lack of suitable adaptation in some clinical situations [18]. Due to their improved flowability, flowable composites can eliminate the gaps between the tooth and the restoration, which is one of the downsides of traditional composites. Their low filler particles, on the other hand, may result in significant shrinkage and loss of the mechanical qualities of the restorations [19], [20].

The usage of standard composites that have been preheated in a chairside warming device before

Table 2: The mean, standard deviation (SD) values of microtensile of different tested materials

Variables	Micro-tensile								
	C0		C1		C2		C3		p-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Microhybrid (R1)	21.53[(a)]	5.50	34.10[(ab)]	8.94	41.41[(b)]	12.62	28.70(ab)	8.17	0.001*
Nanohybrid (R2)	25.26	6.27	24.50	7.49	23.36	4.48	21.15	7.89	0.634ns
p-value	0.226ns		0.035*		0.002*		0.081ns		

*significant (p < 0.05), ns: Non-significant (p > 0.05).

polymerization is a recent alternative invention [21]. When polymers are heated, their viscosity decreases. This is based on the idea that heat energy pushes monomers and oligomers apart, making it easier for them to slide past one other [22], [23]. Preheating of composite restoration enhances the durability and stress relief [17], [24]. Lower composite viscosity improves the prepared cavity wall's adaptability and wettability, minimizing microleakage. Furthermore, raising the polymerization temperature improves both radical and monomer mobility, resulting in a larger total conversion, which can improve the physical and mechanical properties of preheated composites including surface hardness and flexural and diametric tensile strength [25].

Microtensile bond strength testing was used to see how preheating affected the composite's bonding to the dentin. μTBS has number of advantages over traditional bond strength testing methods, including the ability to explore interfacial bond strengths on small areas < 1 mm^2 [14]. Because numerous specimens may be collected from a single tooth, this test becomes more adaptable, allowing for more creative study settings and greater control of substrate variables [26].

In this part of the study, two composite resins were used; a microhybrid packable resin composite (P60) and a nanohybrid resin composite (Z250 XT) to investigate the effect of preheating of composite of different filler loading and different viscosities with having the same resin base material. As a bonding agent, Single Bond™ could be used in one of three application modes: Self-etch, etch, and rinse or selective etching mode. In the current study, etch-and-rinse mode was selected, as it is less acidic and provides high bond strength as it was proved in previous studies [27].

The surface hardness of the preheated composite resin increased with the use of microhybrid composite resins. When compared to the nanohybrid and microhybrid composite resins, the nanofill composite resin showed the lowest diametral tensile strength. This is because the morphology of the composite resin filler varies [28].

In the present study, increasing the temperature to 68°C increased the μTBS to dentin in case of P60 microhybrid resin composite which was increased with the second preheating cycle but did not further increase with a third heating cycle. On the other hand, with the Z250 XT nanohybrid resin composite, preheating did not affect the μTBS with any cycles of preheating compared to the room temperature. Thus, the null hypothesis was partially rejected as preheating only affected the μTBS of the microhybrid resin composite.

Conclusions

Under the limitations of this *in vitro* study, the following could be concluded:

1. μTBS of the microhybrid composite P60 composite resin was significantly improved by preheating. Although repeated preheating does not significantly affect the μTBS of the nanofilled Z250 XT composite resin, the difference was statistically significant with only one material.
2. As a result of heat treatment, different composite brands exhibit differing mechanical properties.
3. However, further studies with a larger sample size, encompassing a variety of restorative materials, were used to evaluate the effect of preheating for maximum therapeutic benefit.

References

1. Khairina N, Puspitasari D, Diana S. The comparison of the storage temperature on diametral tensile strenght value of bulk-fill resin composite. Dent J Kedok Gigi. 2018;3(1):76-80. https://doi.org/10.20527/dentino.v3i1.4606
2. Li Q, Jepsen S, Albers HK, Eberhard J. Flowable materials as an intermediate layer could improve the marginal and internal adaptation of composite restorations in Class-V-cavities. Dent Mater. 2006;22(3):250-7. https://doi.org/10.1016/j.dental.2005.04.011
   PMid:160845847
3. Korkmaz Y, Ozel E, Attar N. Effect of flowable composite lining on microleakage and internal voids in Class II composite restorations. J Adhes Dent. 2007;9(2):189-94.
4. Blumer L, Schmidli F, Weiger R, Fischer J. A systematic approach to standardize artificial aging of resin composite cements. Dent Mater. 2015;31(7):855-63. https://doi.org/10.1016/j.dental.2015.04.015
   PMid:25998485
5. Dionysopoulos D, Tolidis K, Gerasimou P, Koliniotou-Koumpia E. Effect of preheating on the film thickness of contemporary composite restorative materials J. Dent Sci. 2014;9(4):313-9. https://doi.org/10.1016/j.jds.2014.03.006
6. Jin MU. Prepare the pre-heated composite resin. Restor

Dent Endod. 2013;38(2):103-4. https://doi.org/10.5395/rde.2013.38.2.103

PMid:23741715

7. Didron PP, Ellakwa A, Swain MV. Effect of preheat temperatures on mechanical properties and polymerization contraction stress of dental composites. J MASA. 2013;4(6):374-85. https://doi.org/10.4236/msa.2013.46048
8. Davari A. Effect of pre-heating on microtensile bond strength of resin to of composite dentin. J Dent Sci (Tehran). 2014;11(5):569-75.

PMid:25628684

9. Morais A, Santos AR, Giannini M, Reis AF, Rodrigues JA, Arrais CA. Effect of pre-heated dual-cured resin cements on the bond strength of indirect restorations to dentin. Braz Oral Res. 2012;26(2):170-6. https://doi.org/10.1590/s1806-83242012000200014

PMid:22473354

10. Alvarado MS, García DM, Guillén AJ, Arriaga JC, Ramírez GF, Magdaleno MO, *et al*. Evaluation of the bond strength and marginal seal of indirect restorations of composites bonded with preheating resin. Dent Investig Soc. 2020;14(4):644-50. https://doi.org/10.1055/s-0040-1716630
11. Winarta E, Suwartini T, Prahasti E, Tjandrawinata R. The effect of repeated preheating on diametral tensile strength of composite resin with different fillers. Sci Dent J. 2020;4(2):44-8. https://doi.org/10.4103/SDJ.SDJ_35_19
12. Ahn KH, Lim S, Kum KY, Chang SW. Effect of preheating on the viscoelastic properties of dental composite under different deformation conditions. Dent Mater J. 2015;34(5):702-6. https://doi.org/10.4012/dmj.2015-042

PMid:26438995

13. Tomaselli LO, Oliveira DC, Favarão J, Silva AF, Pires-de-Souza FC, Geraldeli S, *et al*. Influence of pre-heating regular resin composites and flowable composites on luting ceramic veneers with different thicknesses. Braz Dent J. 2019;30(5):459-66. https://doi.org/10.1590/0103-6440201902513

PMid:31596330

14. Van Meerbeek B, Peumans M, Poitevin A, Mine A, Van Ende A, Neves A, *et al*. Relationship between bond-strength tests and clinical outcomes. Dent Mater. 2010;26(2):e100-21. https://doi.org/10.1016/j.dental.2009.11.148

PMid:20006379

15. Daronch M, Rueggeberg FA, Moss L, De Goes MF. Clinically relevant issues related to preheating composites. J Esthet Restor Dent. 2006;18(6):340-50. https://doi.org/10.1111/j.1708-8240.2006.00046.x

PMid:170834391.

16. Mandava J, Vegesna DP, Ravi R, Boddeda MR, Uppalapati LV, Ghazanfaruddin MD. Microtensile bond strength of bulk-fill restorative composites to dentin. J Clin Exp Dent. 2017;9(8):e1023-8. https://doi.org/10.4317/jced.53965

PMid:28936294

17. Theobaldo JD, Aguiar FH, Pini NIP, Lima DA, Liporoni PC, Catelan A. Effect of preheating and light-curing unit on physicochemical properties of a bulk fill composite. Clin Cosmet Investig Dent. 2017;9:39-43. https://doi.org/10.2147/CCIDE.S130803

PMid:28652817

18. Elolimy GA. Effect of pre-heating on hardness, flexural properties and depth of cure of dental two resin composites. Egypt Dent J. 2020;66(3):1731-9. https://doi.org/10.21608/EDJ.2020.24610.1043
19. Fróes-Salgado NR, Silva LM, Kawano Y, Francci C, Reis A, Loguercio AD. Composite pre-heating: Effects on marginal adaptation, degree of conversion and mechanical properties. Dent Mater. 2010;26(9):908-14. https://doi.org/10.1016/j.dental.2010.03.023

PMid:20557926

20. Lee JH, Um CM, Lee IB. Rheological properties of resin composites according to variations in monomer and filler composition. Dent Mater. 2006;22(6):515-26. https://doi.org/10.1016/j.dental.2005.05.008

PMid:16171856

21. Nada K, El-Mowafy O. Effect of precuring warming on mechanical properties of restorative composites. Int J Dent. 2011;2011:536212. https://doi.org/10.1155/2011/536212

PMid:221145965.

22. Moosavi H, Maleknejad F, Forghani M, Afshari E. Evaluating resin-dentin bond by microtensile bond strength test: Effects of various resin composites and placement techniques. Open Dent J. 2015;9:409-13. https://doi.org/10.2174/1874210601509010409

PMid:26966466

23. Choudhary N, Kamat S, Mangala T, Thomas M. Effect of pre-heating composite resin on gap formation at three different temperatures. J Conserv Dent. 2011;14(2):191-5. https://doi.org/10.4103/0972-0707.82618

PMid:21814365

24. Deb S, Di Silvio L, Mackler HE, Millar BJ. Pre-warming of dental composites. Dent Mater. 2011;27(4):e51-9. https://doi.org/10.1016/j.dental.2010.11.009

PMid:21145580

25. Karacan AO, Ozyurt P. Effect of preheated bulk-fill composite temperature on intrapulpal temperature increase *in vitro*. J Esthet Restor Dent. 2019;31(6):583-8. https://doi.org/10.1111/jerd.12503

PMid:311942886.

26. Karatas K, Sağsöz O, Ozakar N, Bayindir YZ. Thermal conductivity of different composite resin materials in different polymerization times and modes. J Dent Fac 2019;29(1):20-5. https://doi.org/10.17567/ataunidfd.522584
27. Ferracane JL. Buonocore Lecture. Placing dental composites--a stressful experience. Oper Dent. 2008;33(3):247-57. https://doi.org/10.2341/07-BL2

PMid:18505214

28. Demirbuga S, Ucar FI, Cayabatmaz M, Zorba YO, Cantekin K, Topçuoğlu HS, *et al*. Microshear bond strength of preheated silorane-and methacrylate-based composite resins to dentin. Scanning. 2016;38(1):63-9. https://doi.org/10.1002/sca.21242

PMid:26381904