Impact of Resin Composite Restorative Material Pre-heating on Dental Pulp Temperature: A Laboratory study

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Abstract:

Objective: To investigate and compare the impact of pre-heating of an ormocer-based and a methacrylate-based restorative materials at different temperature on intra-pulpal temperature with that at room temperature. **Materials and Methods:** In the current study, two bulk-fill composite systems; one ormocer-based, and one methacrylate-based were used according to their manufacturer instructions. A total of 30 sound maxillary human molars was selected, and prepared by removal of occlusal enamel and part of dentin till remaining dentin thickness becomes 2 mm above highest pulp horn. The specimens were assigned equally into two halves, according to type restorative material used (n=15 for each). For every restorative system; each group was further subdivided into three subgroups according to the pre-heating regimen (non pre-heated, 540 C or 600 C). A K-type thermocouple was placed inside tooth pulp chamber. The intra-pulpal temperature was measured in each specimen before, after composite placement and after curing of restorative material, also after 15sec, 30sec, 60sec. **Results:** The outcome of three-way ANOVA revealed that the type of composite material, different heating temperature and different restorative stages had a statistical significant effects on intra-pulpal temperature values ($p < 0.05$). Post-hoc Tukey test outcome showed that, the ormocer-based composites showed significant intra-pulpal temperature increase compared to methacrylate-based composites. **Conclusions:** On the basis of the results of the current study, it seems reasonable to conclude that there is a proof that heating of composite restorative materials increase the intra-pulpal temperature with a noticeable increase in pre-heating of ormocer compared to methacrylate-based composite.

Introduction:

Resin composites have become the preferred restorative material for direct posterior restorations due to their esthetic properties and good clinical performance.[1] Apart from the development of minimally invasive preparation technique as well as improved adhesion to teeth structure, these materials exhibit predictable long-term stability with annual failure rates that are comparable to amalgam in stress-bearing posterior cavities.[2]

Several enhancements have been developed to improve the mechanical, physical and handling properties of resin-based composite materials to improve clinical services and durability.[3] However, Composite exhibits problems like polymerization shrinkage[4] low wear resistance, inadequate building of proximal contact, and lack of adequate adaptation in some clinical situations.[5] Furthermore, many composite resins are sticky and difficult to manipulate causing problems during placement.[6] These problems have triggered contemporary projects to find possible solutions of these problems.

There are many ways to overcome problems of adaptation and polymerization shrinkage as modification in filler component, modification in resin component as using silorane-resin composite or ormocer-based composite or modification in technique of composite placement. Combination of the use of low-shrinkage resin composite and the modified technique of composite application which was attained by pre-heating would be suggested to achieve better adaptation.

The pre-heating of dental composite resins prior to composite placement considered as modification in technique of application.[7] Pre-heating is performed by placement of composite compules or syringes into a specially-designed heating device.[8] The use of this method was claimed that it eases extrusion of the material and enhances adaptation to internal cavity walls compared to non pre-heated composites.[9] Also, increasing the wear resistance and degree of conversion which may improve the pre-heated composites physical and mechanical properties, like high surface hardness, flexural and tensile strength are claimed to be achieved by this technique.[9,10]

Previous studies[7,8] have suggested that heating of conventional resin composites is a way to enhance material's handling properties during cavity preparation and can improve marginal adaptation by enhancing fluidity and decreases their viscosity, which decrease microleakage due to improved wetting of cavity walls. In addition, pre-heating of composites increases polymerization temperature so improves both radical and monomer mobility which may improve their physical and mechanical properties through a higher degree of monomer conversion.[11,12]

Studies conducted on the effect of pre-heated composite on intra-pulpal temperature had some sort of shortage. So, the investigation of the effect of pre-heating of different composite restorative materials on intra-pulpal temperature is valuable.

The aim of current laboratory study was to investigate

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and compare the impact of pre-heating of an ormocer-based and a methacrylate-based restorative materials at different temperatures on intra-pulpal temperature with that at room temperature. The null hypotheses to be investigated were that[1] There would be no adverse effect of pre-heated composite on dental pulp temperature.[2] There would be no significant difference in increasing intra-pulpal temperature between ormocer and resin-based composite materials.

Materials and Methods:

Materials

Two different dental composite restorative systems including resin composite materials with their proprietary adhesive systems, were used in this current study. One nanohybrid Ormocer-based composite (Admira® Fusion x-tra, /Single Admira Bond Universal adhesive) and one resin-based composite (x-tra fil® Bulk Fill Composite /Single futurabond M+ Universal adhesive).

Methods

Teeth selection

A total of 60 sound human maxillary molars was collected from Oral Surgery clinic at Faculty of Dentistry, Mansoura University. The teeth used for this current study were collected according to the Faculty of Dentistry's institutional ethics committee's regulations. Ethical approval no. for this research (#A09100221). A hand scaler, was used to properly clean the teeth from any hard calculus deposits or associated soft tissues. The Molars were then cleaned and disinfected for 24 hours in 0.5% chloramines solutionT, then stored in distilled water till use. The storage procedure of extracted teeth preformed following the standard international and local infection control protocols guidelines.

Study design

The collected teeth were randomly assigned into 2 groups regarding the type of restorative material utilized; Ormocer-based composites and Methacrylate-based composites (n=15). Then each group was further subdivided into three subgroups according to the pre-heating regimen (non pre-heated, 540 C or 600 C) of restorative material immediately before placement and curing. In each subgroup intra-pulpal temperature values were measured at different restorative stages (at basline temperature, first initation of resin composite, after application of composite, after curing, after 15 sec, after 30 sec, after 60 sec).

Teeth preparation

Removal of occlusal enamel and part of dentin till remaining dentin thickness (RDT) becomes 2 mm using carbide disc in a low speed hand piece with copious water cooling. All preparations were controlled by radiograph to achieve standardized dentin thickness. A hole was drilled above Cement-enamel junction using along shank carbide bur (#1/2) in a high speed hand piece (Sirona T4, Bensheim, Germany) with abundant air-water cooling, the pulp remnants was removed, and irrigated with saline.

Composite application:

In subgroup (a), teeth were restored with an Ormocer based-composite (Admira fusion x-tra) which was at room temperature. For curing, light cured using LED curing light (Elipar Deep Cure, 3M ESPE, St. Paul, MN, USA) with light intensity 1200 mW/ cm2. Light curing was applied for 20 seconds according to the manufacturer's instructions. Temperature was recorded during and after the composite was injected into prepared tooth also after curing and after 15sec, 30sec, 60sec.

In subgroup (b), teeth were processed to the same methodology as before, with the exception of the addition of a pre-heating step. Pre-heating in this study was done using Therma-FloTM (Vista Dental Products, USA) which is a specific composite warming device that heats dental resin composite materials to 155°F (68°C). Ormocer composite syringes were heated for 5 min till reach to 54°C then being rapidly evacuated into the cavities immediately, adjusted, and light cured.

In subgroup (c), the ormocer-based composite was pre-heated in composite warming kit called Therma-FloTM device at 60°C then was applied to prepared teeth immediately, adjusted, and light cured. Temperature was recorded during and after the composite was injected into prepared tooth also after curing and after 15sec, 30sec, 60sec.

In subgroup (d), teeth were restored with a Methacrylate-based composite (X-trafill) which was at room temperature. Temperature was recorded during and after the composite was injected into prepared tooth also after curing and after 15sec, 30sec, 60sec.

In subgroup (e), teeth were processed to the same methodology as before, with the exception of the addition of a pre-heating step. The methacrylate-based composite was pre-heated in a composite warming kit called Therma-FloTM device at 54°C for 5 min then was applied to the prepared teeth immediately in half no. of specimens.

In subgroup (f), the methacrylate-based composite was pre-heated in composite warming kit called Therma-FloTM device at 60°C then was applied to prepared teeth immediately. Temperature was recorded during and after the composite was injected into prepared tooth also after curing and after 15sec, 30sec, 60sec.

Measuring intra-pulpal temperature:

A K-type thermocouple (Kamtop Digital Thermometer) used for the purpose of measuring intra-pulpal temperature with a temperature range of -200°C to 1372°C°. The probe of thermometer was inserted in the prepared hole of each prepared tooth then fixed with a sticky wax. Digital Thermometer was switched on, then (baseline temperature) was recorded. The composite was injected into the prepared tooth and the temperature values associated with initiation and completion of composite insertion were recorded. Immediately after light curing (after curing) and after (15 Secs, 30 Secs ,60 Secs), additional readings were obtained.

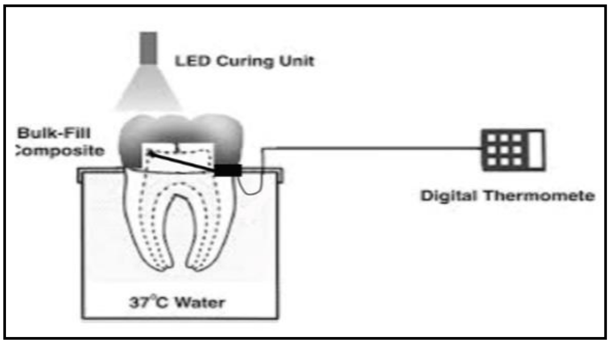

Figure: Diagram illustrating the methodology

Statistical analysis:

The row data were tabulated, processed, and analyzed utilizing the Statistical Package for Social Science (SPSS) version 26.0 computer programme (IBM, NY, USA). Shapiro-Wilk test was used to check the normality. The data was analyzed using three-way ANOVA test to evaluate the composite type's effects, different heating temperature of composite and different stages on the change in pulp temperature.

Results:

The outcome of three-way ANOVA test revealed that the type of the composite material, the pre-heating and the different stages of restorative procedure significantly affected pulp temperature values ($p<0.05$). Also, the interaction of both composite-pre-heating temperature variables were statistically significant ($p<0.05$).

When comparing the intra-pulpal temperature values between each composite material group (Admira Fusion x-tra and X-tra fill), there was a statistically significant difference ($p<0.05$). The lowest temperature values were seen in Ormocer group, while the highest temperature values were seen in Methacrylate pre-heated group.

The values of intra-pulpal temperature were statistically significant affected by different composite temperatures ($p<.05$). In Methacrylate-based composite group there were significant differences between non pre-heated, pre-heated at 54°C and 60°C temperature groups ($p<.05$). The lowest temperature values we seen in non-preheated group followed by pre-heated composite group at 54°C then pre-heated composite group at 60°C.

Table 1: Results of the three-way ANOVA test on pulp temperature values

Source of variance	Type III Sum of Squares	df	Mean Square	F	p
Composite material	147.561	1	147.561	277.334	0.000*
Pre-heating	124.208	2	62.104	116.721	0.000*
Stages	172.279	6	28.713	53.965	0.000*
Composite* preheating	61.936	2	30.968	30.968	0.000*

DF: degree of freedom, F: variance ratio, P: probability.
***: significance p <0.001**

Table 2: Means ± standard deviation of the intra-pulpal temperature changes at different restorative stages in the different tested groups

Composite		Intra-pulpal temperature values		
		Non pre-heated	Pre-heated at 54	Pre-heated at 60
Ormocer	Base line	27.48 ± 0.15 a	27.48 ± 0.11 a	27.40 ± 0.16 a
	First initiation of composite	27.58 ± 0.15 b	27.84 ± 0.13 b	27.70 ± 0.20 b
	After composite application	27.70 ± 0.13 b	28.28 ± 0.22 b	28.06 ± 0.26 b
	After curing	28.36 ± 0.16 b	29.70 ± 0.13 c	29.16 ± 0.38 c
	After 15 sec	28.78 ± 0.12 b	30.28 ± 0.31 d	29.84 ± 0.45 c
	After 30 sec	28.70 ±0.12 b	30.02 ± 0.29 d	29.72 ± 0.42 c
	After 60 sec	28.32 ± 0.09 b	29.52 ± 0.43 c	29.32 ± 0.37 c
Methacrylate	Base line	27.76 ± 0.22 b	28.64 ± 0.39 b	30.42 ± 0.37 d
	First initiation of composite	27.70 ± 0.23 b	29.10 ± 0.27 c	30.78 ± 0.38 d
	After composite application	28.42 ± 0.20 b	29.50 ± 0.34 c	31.08 ± 0.39 d
	After curing	29.04 ± 0.25 c	30.70 ± 0.34 d	32.28 ± 0.43 e
	After 15 sec	29.76 ± 0.31 c	31.58 ± 0.42 e	33.20 ± 0.52 e
	After 30 sec	29.70 ± 0.28 c	31.50 ± 0.48 d	33.10 ± 0.46 e
	After 60 sec	29.38 ± 0.43 c	30.96 ± 0.46 d	32.68 ± 0.38 e

Discussion:

Pre-heating is a modified technique of resin composites application that was suggested to attain better adaptation and reduce microleakage by improving the handling characteristics of resin-based composites during placement in the prepared cavities before photoactivation, decreasing their viscosity and increasing the wettability.[13,14] Also, increasing the degree of conversion through increasing the mobility of free radicals and propagating polymers, and improving their physical properties.[15,16,17]

The temperature to which the composite is exposed during pre-heating in the heating device is ranged between 50°C and 70°C, that is well accepted by healthy teeth and mucous membranes during routine daily activities, as temperature range between 54°C and 68°C is considered safe, it does not affect the pulp tissue. However, the temperature of the composite drops immediately when the composite compule is delivered into the cavity after being removed from the heating device. But there is still a gap of time before composite temperature cooling down can affect pulp or not.

Two different dental composite materials were utilized, one ormocer-based composite; (Admira fusion X-tra), and one Methacrylate-based composites; (X-trafill). They were selected because they're claimed to be universally restorative materials that may be employed for anterior and posterior prepared teeth. Additionally, the compositions of the two materials are different.

To reduce variability and bias, the same operator and standardized methodology were used throughout the procedures in this study. The degree of increasing in intra-pulpal temperature during photopolymerization is affected by many of factors, including the type of light curing unit, power intensity, exposure time, composite shade, and thickness of both the composite material and remaining dentin thickness. Hence, all these factors were standardized in the current study to decrease variability.

In order to ensure uniform, cut and smooth clean occlusal prepared surface all cavity preparations were done using carbide disc in low speed headpiece. Each root of each selected tooth were embedded in cylindrical polyvinyl chloride (PVC) rings containing auto-polymerizing acrylic resin (Acrostone, Egypt) up to 3 mm below the cement-enamel junction (CEJ) by demarcation of the teeth at this level using red pencil to ensure acrylic resin not affect intra-pulpal temperature values during procedure.

The K-type thermocouple is the most extensively used temperature sensor, with a temperature range of -200°C to 1372°C°C. Many researchers utilized it in their laboratory studies to measure intra-pulpal temperature with pre-heated composite. They used the metal probe of this K-type thermocouple, fitted it inside the tooth pulp chamber through root after removing of the pulp tissues, then measuring intra-pulpal temperature. In the present study, a hole was made in each prepared tooth above cement-enamel junction (CEJ) reaching pulp chamber to facilitate entrance of the probe of thermometer during the procedure. Cleaning the remaining pulp tissue using small excavator and using adequate saline irrigation. Using a sticky wax around probe of thermometer to ensure isolation of probe and enhance adaptation of probe, then keeping each specimen in a water bath at 37 0C to simulate body temperature.

The intra-pulpal temperature values were recorded at different composite temperature groups, non pre-heated group, pre-heated at 54°C and pre-heated at 60°C group to assess the effect of different pre-heating temperature on intra-pulpal temperature values. Also, the intra-pulpal temperature values were recorded at different restorative stages, the initial baseline measurements were recorded, during composite application, after composite application, after curing, after 15sec, after 30sec and after 60sec to evaluate change in pulpal temperature in different restorative stages.

Results of this study showed increase in intra-pulpal temperature after application of pre-heated composite either Ormocer or Methacrylate- based composite, but this increase was only 2.980C. One explanation of the minimal intra-pulpal temperature change seen during application of pre-heated composite was due to the composite not warming as planned, as when the composite is removed from the heating device and transferred to the prepared tooth, the temperature of the composite rapidly reduces 50% in 2 min and 90% in 5 min. Other explanation for low intra-pulpal temperature change in this investigation is the remaining dentin thickness which may have adequately separated the pulp chamber against heat increase from pre-heated composite. In this study remaining dentin thickness was 2mm above highest pulp horn, dentin acts as a thermal barrier against damaging stimuli.

The results of current study reported that statically significant differences were seen in intra-pulpal temperature when comparing pre-heated and room-temperature composite with respect to baseline among the stages of the restorative procedure. Although, the extent of this increase with heated composite not rich to 5.5°C, so not cause adverse effect on dental pulp. As Zach and Cohen,[18] observed a threshold temperature for permanent pulp injury when external heat was delivered to a healthy tooth by elevating 50C, which may cause necrosis in 15% of the tested pulps. Hence, the current study agreed with other studies by Daronch et.al.[19] and Karacan et al.[20]

Also, the results of current study reported that, all groups restored with pre-heated or non pre-heated ormocer-based composites and methacrylate-based composites showed a significant difference ($p<0.05$). The lowest temperature values were seen in Ormocer group, while the highest temperature values were seen in Methacrylate pre-heated group. The differences in matrix compositions between X-tra fill and Admira fusion x-tra may to be the cause of these observations.

Based on the findings of this study, the null hypothesis regarding there is no adverse effect on pulp with pre-heated composite was accepted. Also, the null hypothesis regarding the difference in intra-pulpal temperature between different type of composite material was rejected.

Conclusions:

On the basis of the results of the current study, it seems reasonable to conclude that there is a proof that heating of composite restorative materials increases the intra-pulpal temperature with a noticeable increase in pre-heating of ormocer compared to methacrylate-based composite.

References:

1. Theobaldo JD, Aguiar FHB, Pini NIP, Lima D, Liporoni PCS, Catelan A. Effect of preheating and light-curing unit on physicochemical properties of a bulk fill composite. Clin Cosmet Investig Dent 2017; 9(5):39-43.
2. Hassan R, Aslam Khan MU, Abdullah AM, Abd Razak SI. A Review on Current Trends of Polymers in Orthodontics: BPA-Free and Smart Materials. Polymers 2021; 13(5):13-18.
3. German MJJ. Developments in resin-based composites. Br Dent J 2022; 232(3):638-643.
4. Randolph LD, Palin WM, Leloup G, Leprince JG. Filler characteristics of modern dental resin composites and their influence on physico-mechanical properties. Dent Mater 2016; 32(2):1586-1599.
5. Aw TC, Nicholls JI. Polymerization shrinkage of densely-filled resin composites. Oper Dent 2001; 26(3):498-504.
6. Elkaffass AA, Eltoukhy RI, Elnegoly SA, Mahmoud SH. Influence of preheating on mechanical and surface properties of nanofilled resin composites. J Clin Exp Dent 2020; 12(3):e494-e500.
7. Lousan do Nascimento Poubel D, Ghanem Zanon AE, Franco Almeida JC, Vicente Melo de Lucas Rezende L, Pimentel Garcia FC. Composite Resin Preheating Techniques for Cementation of Indirect Restorations. Int J Biomater 2022; 2022(5):593-566.
8. Ilie N, Hickel R. Resin composite restorative materials. Aust Dent J 2011; 56 Suppl 1(3):59-66.
9. Rickman LJ, Padipatvuthikul P, Chee B. Clinical applications of preheated hybrid resin composite. Br Dent J 2011; 211(3):63-67.
10. Lucey S, Lynch CD, Ray NJ, Burke FM, Hannigan A. Effect of pre-heating on the viscosity and microhardness of a resin composite. J Oral Rehabil 2010; 37(5):278-282.
11. Darabi F, Tayefeh-Davalloo R, Tavangar SM, Naser-Alavi F, Boorboo-Shirazi M. The effect of composite resin preheating on marginal adaptation of class II restorations. J Clin Exp Dent 2020; 12(3):e682-e687.
12. Ebrahimi-Chaharom ME, Safyari L, Safarvand H, Jafari-Navimipour E, Alizadeh-Oskoee P, Ajami AA, et al. The effect of pre-heating on monomer elution from bulk-fill resin composites. J Clin Exp Dent 2020; 12(2):e813-e820.
13. Kincses D, Böddi K, Őri Z, Lovász BV, Jeges S, Szalma J, et al. Pre-Heating Effect on Monomer Elution and Degree of Conversion of Contemporary and Thermoviscous Bulk-Fill Resin-Based Dental Composites. Polymers 2021; 13(9):12-18.
14. Wagner WC, Aksu MN, Neme AM, Linger JB, Pink FE, Walker S. Effect of pre-heating resin composite on restoration microleakage. Oper Dent 2008; 33(6):72-78.
15. Blalock JS, Holmes RG, Rueggeberg FA. Effect of temperature on unpolymerized composite resin film thickness. J Prosthet Dent 2006; 96(5):424-432.
16. Trujillo M, Newman SM, Stansbury JW. Use of near-IR to monitor the influence of external heating on dental composite photopolymerization. Dent Mater 2004; 20(4):766-777.
17. El-Deeb HA, Abd El-Aziz S, Mobarak EH. Effect of preheating of low shrinking resin composite on intrapulpal temperature and microtensile bond strength to dentin. J Adv Res 2015; 6(5):471-478.
18. Zach L, Cohen G. Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol 1965; 19(3):515-530.
19. Daronch M, Rueggeberg FA, Hall G, De Goes MF. Effect of composite temperature on in vitro intrapulpal temperature rise. Dent Mater 2007; 23(4):1283-1288.
20. Karacan AO, Ozyurt P. Effect of preheated bulk-fill composite temperature on intrapulpal temperature increase in vitro. J Esthet Restor Dent 2019; 31(3):583-588.