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ORIGINAL ARTICLE

Effect of preheating on the film thickness of contemporary composite restorative materials

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KEYWORDS
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Abstract *Background/purpose:* Recently, the placement of composite materials at an elevated temperature has been proposed in order to increase their flow for better adaptation in cavity walls. The aim of this *in vitro* study was to evaluate the effect of preheating on the film thickness of a variety of commercially available conventional composites and to compare them with those obtained from a variety of flowable composites at room temperature.

Materials and methods: The composites were three nanohybrid, two nanofilled, six microhybrid, one microfilled, one hybrid, and three packable composite resins, two compomers, four flowable composite resins and two flowable compomers. The conventional composite (0.05 mL) tested was placed between two matrix strip-covered glass plates and a load of 15 kg was applied vertically to the glass plates for a period of 180 seconds. The composite material was then light-cured and the thickness measured using a micrometer. Three measurements were made on each polymerized specimen and then averaged. The composite resins were placed into a commercially-available composite warmer, thermostatically controlled to 54°C or 60°C. Five specimens were made using each composite material at each temperature.

Results: Heat reduced film thickness ($P < 0.05$). The thickness of films at room temperature and of preheated conventional composites was significantly greater than flowable materials ($P < 0.05$). There was no difference in thickness between composite resins preheated to 54°C and 60°C ($P > 0.05$).

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Conclusion: The film thickness of the composites tested is material dependent. The thickness of the preheated conventional composites is significantly lower than those at room temperature. The conventional composites provide film thickness values greater than those of the flowable composites regardless of preheating temperature.

Introduction

Composite resins have become very popular in clinical practice due to the increasing demand for esthetics and continued improvement in technology. To reduce polymerization shrinkage and to increase the wear resistance of composite materials, manufacturers have increased the filler content. This modification, however, results in the higher viscosity of the materials and leads to difficult extrusion of them from the delivery devices.[1,2] Moreover, when using more viscous composite materials, these may not adapt fully or completely to the cavity walls.[3] This high viscosity has been shown to lead to greater gap formation between composite and cavity surfaces, which may result in poor marginal integrity and as a consequence to increased microleakage.[4] Furthermore, many contemporary composites are also sticky and difficult to manipulate, resulting in greater problems in placement.[5]

To avoid these problems the use of a liner of flowable composite prior to placement of the conventional composite material in cavity preparation has been suggested.[6,7] Flowable composites tend to contain a lower filler content and more resin matrix than conventional composite resins.[8] As a result, they have lower viscosity, increased wettability, and increased elasticity compared to conventional composites.[9] The primary disadvantages of flowable composites are that they undergo greater polymerization shrinkage and demonstrate higher values of expansion and contraction with temperature change than conventional composites.[10,11]

Recently, the placement of composite materials at an elevated temperature has been proposed to increase their flow and degree of polymerization. The flow of unpolymerized composite material increases with increasing temperature.[12,13] This flow change may be attributed to factors such as composition of the resin matrix and fillers.[10,11] Preheating may be achieved by placing compules or syringes of the composites in a composite warming tray, a water bath or a composite warmer. If preheating conventional composites changes their flow characteristics to resemble those of flowable composites, it might improve their ability to adapt intimately to cavity walls, which serves to increase the ease of manipulation and result in less microleakage *in vitro*[14] without using a liner of flowable composite.

An additional advantage of warming composites prior to placement and polymerizing is the accompanying increase in monomer conversion, which may lead to improved mechanical properties and increasing wear resistance.[15,16] It has, however, been reported that there is no significant difference in the microleakage, flexural strength[17] and microhardness[18] of preheated composites.

The aim of this *in vitro* study was to evaluate the effect of preheating on the flowability of a variety of commercially-available conventional composites by measuring their film thickness changes, and to compare it to those obtained from a variety of flowable composites at room temperature when tested.

The first null hypothesis of the study was that the composition of the composite materials tested does not affect their film thickness. The second null hypothesis of the study was that preheating of the composite materials does not affect their film thickness. The third null hypothesis of the study was that there is no difference in film thickness between preheated conventional composites and flowable composites.

Materials and methods

To evaluate the effect of preheating on the flow of composites, the film thickness of a wide variety of commercially-available, light-activated composite materials was measured at 23°C, 54°C, and 60°C. The composite materials tested included three nanohybrid, two nanofilled, six microhybrid, one microfilled, one hybrid, and three packable composite resins, two compomers, four flowable composite resins and two flowable compomers (Table 1). Specimen fabrication followed the guidelines for ISO Specification No 4049.

When testing at room temperature, the composite materials were allowed to stabilize to room temperature (23°C) for 24 hours, before the test. For preheated specimens, the composites were placed into a commercially available composite warmer (ENA Heat, Micerium SpA, Avegno GE, Italy), thermostatically controlled to 54°C or 60°C. Five specimens were made using each composite material at each temperature.

In the current study, 0.05 mL of uncured composite material was extruded from 1 mL tuberculin syringes onto a matrix strip (Have-Neos Dental Bioggio, Switzerland) in the shape of a flattened ball and placed on the top surface of a 1.5-cm-thick polished slab. Another piece of matrix strip was placed on top of the uncured composite, and a glass slab was placed on top. A load of 15 kg was immediately applied vertically to the glass plates for a period of 180 seconds utilizing the apparatus shown in Fig. 1. Prior to measurements, the testing apparatus (not the composites) had been placed into a large laboratory oven (Binder, Typ. BFEK 115, 7200 Tuttlingen, Germany) and kept at 37°C for 24 hours, in order to simulate the clinical conditions.

After application of the load, the top glass was removed and the composite specimen was light-cured for 40 seconds at 1300 mW/cm^2 with a light-curing unit (Elipar 2500, 3M

Table 1 The composite materials used in the present study.

Material	Classification	Manufacturer	Monomer composition	Filler content wt%, vol%	Lot number
Charisma Diamond	Nanohybrid	Heraeus Kulzer, Hanau, Germany	TCD-DI-HEA, UDMA	81%, 64%	010044
Beautifil II	Nanohybrid giomer	Shofu Inc. Kyoto, Japan	Bis-GMA, TEGDMA	83.3%, 68.6%	100871
Tetric EvoCeram Bulk Fill	Nanohybrid bulk	Ivoclar Vivadent, Schaan, Lichtenstein	Bis-GMA, UDMA, Bis-EMA	80%, 61%	R47764
Filtek Supreme XT	Nanofilled	3M ESPE, St. Paul, MN, USA	Bis-GMA, UDMA, Bis-EMA, TEGDMA	78.5%, 60%	7JX
Grandio	Nanofilled	Voco, GmbH, Cuxhaven, Germany	Bis-GMA, UDMA, TEGDMA	87%, 71.4%	492726
Filtek Z250	Microhybrid	3M ESPE, St. Paul, MN, USA	Bis-GMA, UDMA, Bis-EMA, TEGDMA	77.6%, 60%	7TM
Micro Esthetic	Microhybrid	Bisico, Bielefelder, Germany	Bis-GMA	81%, 65%	208465
Charisma	Microhybrid	Heraeus Kulzer, Hanau, Germany	Bis-GMA, TEGDMA	78%, 61%	010207
Clearfil AP-X	Microhybrid	Kuraray Co. Ltd, Japan	Bis-GMA, TEGDMA	86%, 70%	0014A
Spectrum TPH	Microhybrid	Dentsply DeTrey, GmbH, Kostanz, Germany	Bis-GMA, Bis-EMA, TEGDMA	77%, 57%	1008000680
Filtek Silorane	Microhybrid Silorane	3M ESPE, St. Paul, MN, USA	3,4-epoxycyclo hexylethylcyclopoly methyl siloxane Bis-3, 4epoxycyclohe-xylethylphenylmethyl silane	76%, 55%	N442897
Heliomolar	Microfilled	Ivoclar Vivadent, Schaan, Lichtenstein	Bis-GMA, UDMA, TEGDMA	67%, 46.6%	K29022
Te-Econom Plus	Hybrid	Ivoclar Vivadent, Schaan, Lichtenstein	Bis-GMA, UDMA, TEGDMA	76%, 60%	N36927
Filtek P60	Hybrid packable	3M ESPE, St. Paul, MN, USA	Bis-GMA, UDMA, Bis-EMA, TEGDMA	83%, 61%	9UL
Aelite LS Posterior	Hybrid packable	Bisco Inc. Schaumburg, IL, USA	Bis-GMA, Bis-EMA	88%, 76%	1200004044
Clearfil Majesty Posterior	Nanohybrid packable	Kuraray Co. Ltd, Japan	Bis-GMA, UDMA, TEGDMA	92%, 82%	
Dyract Extra	Compomer	Dentsply DeTrey GmbH, Kostanz, Germany	UDMA, TCB, TEGDMA	73%, 47%	0903000732
Compoglass F	Compomer	Ivoclar Vivadent, Schaan, Lichtenstein	UDMA, DCDMA, TEGDMA	77%, 55%	K31913
Wave	Flowable	SDI Limited Bayswater, Victoria, Australia	Multifunctional methacrylic ester, UDMA	65%, 40%	070966N
Filtek Flow	Flowable	3M ESPE, St. Paul, MN, USA	Bis-GMA, Bis-EMA, UDMA	68%, 47%	
Tetric EvoFlow	Flowable	Ivoclar Vivadent, Schaan, Lichtenstein	Bis-GMA, UDMA, decandioldimethacrylat	58%, 31%	J23557
Charisma Opal Flow	Flowable	Heraeus Kulzer, Hanau, Germany	UDMA, EBADMA	65%, 41%	010103
Compoglass Flow	Flowable compomer	Ivoclar Vivadent, Schaan, Lichtenstein	UDMA, DCDMA, TEGDMA	67%, 44%	M67119
Dyract Flow	Flowable compomer	Dentsply DeTrey GmbH, Kostanz, Germany	UDMA, TCB, TEGDMA	59%, 43%	090310

ESPE, St. Paul, MN, USA) through the matrix strip. The thickness of the polymerized composite was measured using a digital micrometer (± 1 μm). Three individual thickness measurements in different locations were made on each light-cured specimen and then averaged to represent the thickness of that specimen.

The film thickness data for room temperature composites and the preheated groups were analyzed using a two-

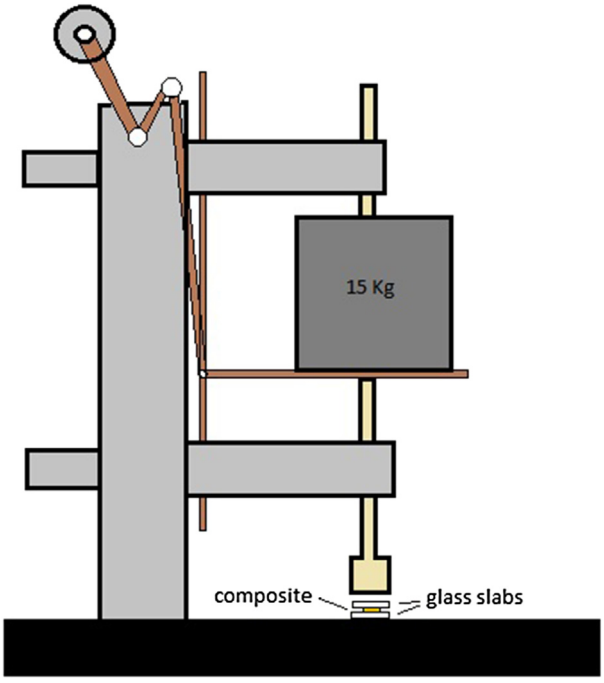

Figure 1 The testing apparatus utilized in the present study for the evaluation of film thickness.

way analysis of variance (ANOVA). To determine whether the thickness values of the conventional preheated composite groups were different from those of the flowable composites, a one-way ANOVA was performed and a pairwise multiple comparison (Tukey's test). When comparing preheated conventional composite the room temperature value was used as the control, while the room temperature flowable values were used as the control when compared to preheated composite. The statistical significance was preset at $a = 0.05$.

Results

The average film thickness data for materials investigated are presented in Table 2 and Fig. 2. The film thickness data for the materials tested were statistically analyzed using a two-way ANOVA for material and temperature factors. The ANOVA showed a statistically significant difference among the materials as well as among the temperatures ($P < 0.05$). There was a statistically significant interaction between material and temperature ($P < 0.05$).

Film thickness values for Aelite LS Posterior, Filtek P60 and Clearfil Majesty Posterior ranged among the highest values and were not statistically different ($P > 0.05$). The thinnest films were formed by the flowable composites (Wave, Tetric EvoFlow, Filtek Flow, Dyract Flow,

Table 2 Mean values and standard deviations (mm) of the film thickness of materials investigated at 23, 54 and 60°C and the reduction (%) in film thickness of preheating materials compared to materials at room temperature.

Material	Classification	23°C*†	54°C*	Percentage reduction	60°C*	Percentage reduction
Aelite LS Posterior	Packable	0.28 *(0.04)*^{Aa}	0.20 *(0.01)*^{B}	28.5%	0.19 *(0.01)*^{B}	32.1%
Filtek P60	Packable	0.26 *(0.03)*^{Aa}	0.18 *(0.01)*^{B}	30.7%	0.17 *(0.01)*^{B}	34.6%
Clearfil Majesty Posterior	Packable	0.24 *(0.03)*^{Aab}	0.18 *(0.01)*^{B}	25.0%	0.18 *(0.01)*^{B}	25.0%
Beautifil II	Nanohybrid giomer	0.22 *(0.02)*^{Abc}	0.16 *(0.01)*^{B}	27.2%	0.16 *(0.01)*^{B}	27.2%
Filtek Silorane	Microhybrid silorane	0.20 *(0.02)*^{Abc}	0.15 *(0.01)*^{B}	25.0%	0.15 *(0.01)*^{B}	25.0%
Filtek Supreme XT	Nanofilled	0.20 *(0.02)*^{Abc}	0.13 *(0.01)*^{B}	35.0%	0.13 *(0.01)*^{B}	35.0%
Te-Econom Plus	Hybrid	0.19 *(0.02)*^{Ac}	0.14 *(0.01)*^{B}	26.3%	0.14 *(0.01)*^{B}	26.3%
Clearfil AP-X	Microhybrid	0.19 *(0.02)*^{Ac}	0.12 *(0.01)*^{B}	36.8%	0.11 *(0.01)*^{B}	42.1%
Filtek Z250	Microhybrid	0.18 *(0.02)*^{Ac}	0.13 *(0.01)* ^{B}	27.7%	0.12 *(0.01)*^{B}	33.3%
Heliomolar	Microfilled	0.18 *(0.02)*^{Ac}	0.12 *(0.01)* ^{B}	33.3%	0.11 *(0.01)*^{B}	38.8%
Charisma	Microhybrid	0.17 *(0.02)*^{Ac}	0.11 *(0.01)*^{B}	35.2%	0.11 *(0.01)*^{B}	35.2%
Micro Esthetic	Microhybrid	0.17 *(0.02)*^{Ac}	0.12 *(0.01)*^{B}	29.4%	0.11 *(0.01)*^{B}	35.2%
Compoglass F	Compomer	0.17 *(0.02)*^{Ac}	0.10 *(0.01)*^{B}	41.1%	0.10 *(0.01)*^{B}	41.1%
Spectrum TPH	Microhybrid	0.16 *(0.02)*^{Acd}	0.11 *(0.01)*^{B}	31.2%	0.11 *(0.01)*^{B}	31.2%
Dyract Extra	Compomer	0.16 *(0.02)*^{Acd}	0.10 *(0.01)*^{B}	37.5%	0.09 *(0.01)*^{B}	43.7%
Charisma Diamond	Nanohybrid	0.16 *(0.02)*^{Acd}	0.10 *(0.01)*^{B}	37.5%	0.09 *(0.01)*^{B}	43.7%
Grandio	Nanofilled	0.15 *(0.02)*^{Ad}	0.10 *(0.01)*^{B}	33.3%	0.10 *(0.01)*^{B}	33.3%
Tetric EvoCeram Bulk Fill	Nanohybrid bulk	0.14 *(0.02)*^{Ad}	0.08 *(0.01)*	42.8%	0.07 *(0.01)*	50.0%
Wave	Flowable	0.04 *(0.01)*^{e}	—	—	—	—
Tetric EvoFlow	Flowable	0.03 *(0.01)*^{e}	—	—	—	—
Filtek Flow	Flowable	0.03 *(0.01)*^{e}	—	—	—	—
Dyract Flow	Flowable compomer	0.03 *(0.01)*^{e}	—	—	—	—
Compoglass Flow	Flowable compomer	0.02 *(0.01)*^{e}	—	—	—	—
Charisma Opal Flow	Flowable	0.02 *(0.01)*^{e}	—	—	—	—

*The same capital letter in each column indicates no statistically significant difference between temperatures ($P > 0.05$).
†The same small letters indicate no statistically significant difference between types of materials ($P > 0.05$).

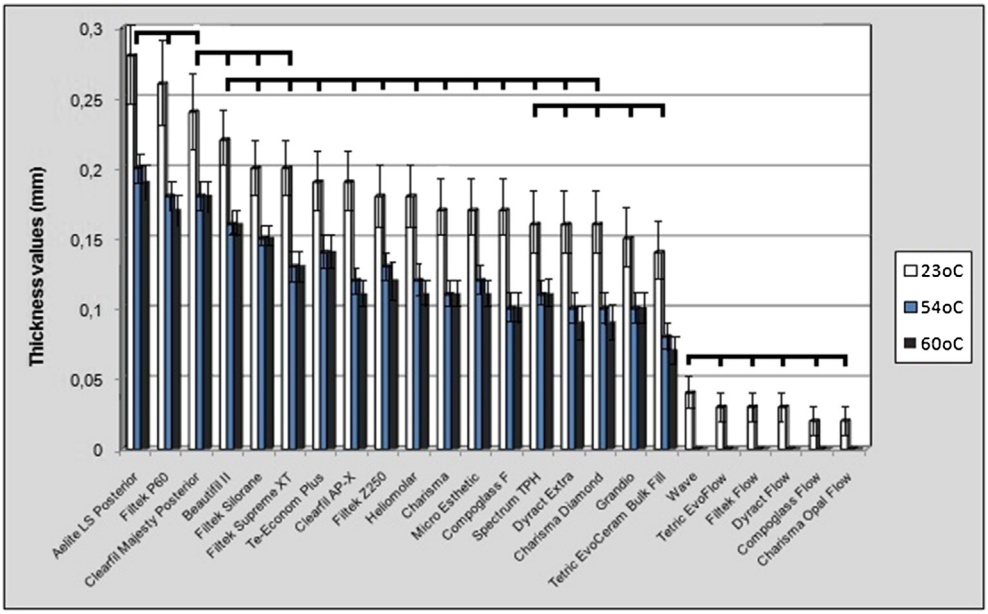

Figure 2 Mean values and standard deviations of film thickness (mm) of the composite materials investigated at 23, 54 and 60°C. Horizontal bars indicate no statistically significant differences ($P < 0.05$).

Compoglass Flow and Charisma Opal Flow), which were not significantly different to each other ($P < 0.05$).

Fig. 3 illustrates the effect of temperature on the film thickness of each type of composite material. The thickness values represent the average of the materials of each composite category. Packable composite resins exhibited the highest film thickness values, while flowable composites had the lowest. Significant differences in room temperature thickness values were found among brands ($P < 0.05$). Among those materials demonstrating a significant decrease in thickness, there was no significant difference in thickness between groups heated to 54°C or 60°C for any material ($P > 0.05$).

The reduction in film thickness of each material at 54°C and 60°C relative to its room temperature value is given in Table 2. Tetric EvoCeram Bulk Fill, a nanohybrid bulk composite resin, had the greatest reduction in film thickness (42.8% at 54°C and 50.0% at 60°C), followed by Compoglass F (compomer) at 54°C, which exhibited 41.1% reduction and Dyract Extra (compomer) and Charisma Diamond (nanohybrid) at 60°C, which exhibited 43.7% reduction. Filtek Silorane (microhybrid) and Clearfil Majesty Posterior (packable), in contrast, had the lowest reductions in film thickness: 25% at both 54°C and 60°C.

The film thickness values of conventional composites at room temperature or heated to 54°C and 60°C were

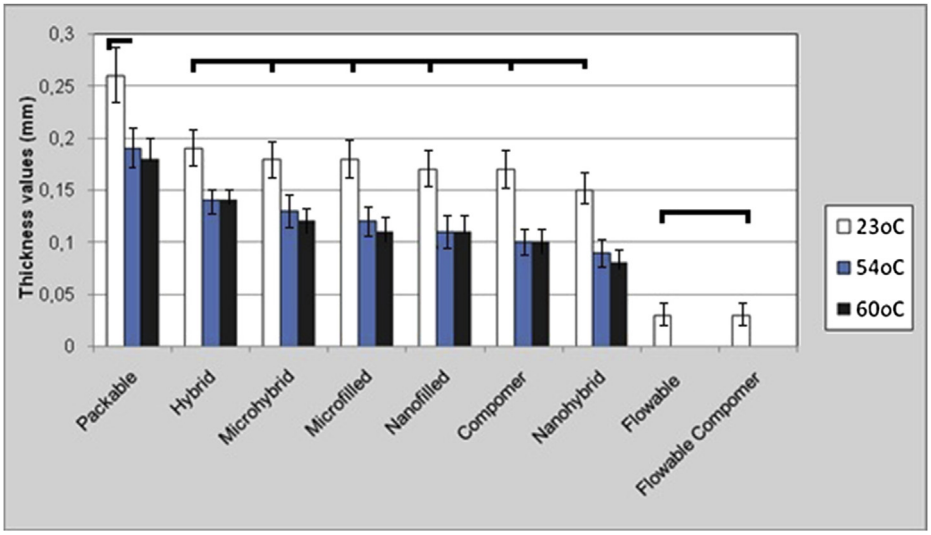

Figure 3 Mean values and standard deviations of film thickness (mm) of each type of composite material investigated at 23, 54 and 60°C. Horizontal bars indicate no statistically significant differences ($P < 0.05$).

compared to that of flowable materials. The average thickness values of the different experimental groups combined are presented in Table 2. The one-way ANOVA comparing the thickness of conventional composite groups to that of the flowable groups showed a significant difference ($P < 0.01$). Tukey's test showed that all conventional composite film thickness values (room temperature or preheated to 54°C or 60°C) were significantly greater than that of the flowable materials ($P < 0.01$).

Discussion

Composite flowability is directly related to its malleability, ease of placement and shaping on the cavity preparation, and adherence to the cavity surfaces. As a result, the flowability of composites may affect the operation time and the quality of the restorative procedure.[19,20] Thus, it is of great importance that the development of composites focus on the improvement of these handling characteristics.

The major parameter that influences composite flowability is the composition of composite materials.[21] Composites are composed of resin matrices, such as Bis-GMA and UDMA blended mainly with TEGDMA as a diluent and inorganic fillers, to improve mechanical properties, and to reduce polymerization shrinkage and thermal expansion coefficient.[22] In previous studies it has been found that the flowability of composites depends on the composition and ratio of the resin matrix,[23] as well as the content, shape, size distribution, and silane treatment of the fillers.[24] Consequently, different brands of composite materials exhibit different flow characteristics. This is in agreement with results obtained from the present study and as a result the first null hypothesis is rejected.

In the current study, packable composite resins exhibited the highest film thickness values, while among the other categories of the conventional composites there were no significant differences. This finding has been reported previously.[12,13] Since the other composite categories have similar formulations to packable composites, however, it is not possible to identify a specific compositional parameter that explains this evidence.

Although in the present study various brands of composites respond differently to preheating due to differences in their composition, all regression analyses proved non significant when relating film thickness change to filler content. This is in agreement with a previous report.[13] Thus it seems evident that composite resin classification does not impart predictive information regarding the extent to which a composite will flow with applied heat.

Increases in molecular weight and greater potential for hydrogen bonding as well as the increase in chain length and extent of chain branching will tend to reduce the flowability of composite materials, as polymer chains become more entangled.[25] With preheating, sufficient energy is given to overcome hydrogen bonding and chain entanglement to allow molecules the freedom to move.[26]

Generally, the viscosity increased with increasing filler volume fraction, and in identical filler volumes the viscosity increased in the order of spheres, grains, plates, and rods according to the filler morphology.[27] The coatings of the filler particle affected the ease with which a filler particle would move in the warmed resin fluid. Fillers that were not silanated would be more difficult to move than these that were coated.[28]

The flow characteristics of a composite affect its ability to adapt to the walls of a cavity preparation. A composite with a higher flow might adapt more easily the walls of a cavity preparation than one with lower flow values.[29] Many studies have recommended placing a flowable composite as the first layer of a posterior composite restoration.[5,6,30] The use of flowable composite in critical areas of a restoration decreases the possibilities of having voids at the margins of the restoration. Other studies, however, recommend preheating of conventional composites instead of the use of a flowable composite liner.[13]

The results of the current study indicate that preheating conventional composites at 54°C and 60°C improves its ability to flow, as evidenced by the decrease in film thickness. Consequently, the second null hypothesis of the study is rejected. This result agreed with previous findings.[13,14] The reduction of film thickness values was not dependent on the classification of composite materials, however, different brands showed different reductions.

The results of the present study also showed that heating conventional composites to 54°C and 60°C did not produce film thickness values as low as those of the room temperature flowable composites. As a consequence, the third null hypothesis of the study is rejected. This is also in agreement with the results found by other researchers.[13,14] Da Costa et al,[31] however, found no reduction in film thickness between room temperature and preheated composite resins. The results of this study showed that preheated conventional composites are not a substitute for use of flowable composite resins and agree with Wagner et al.[14]

Whether the effects of preheating are relevant *in vivo* is expected to depend on the rate of ambient cooling. The amount of cooling of the preheated composite depends on the operator quickness, the distance between the heating device and cavity preparation, and the accessibility of tooth preparation. Daronch et al[32] reported a 50% temperature drop within 2 minutes of removing a composite resin from a proprietary heating device. In the present study, it may be expected that some decrease in the temperature of the composite resins occurred on removal from the composite warmer, but this was related to the clinical situation.

Placement of a composite at such elevated temperatures directly into a cavity preparation may increase intrapulpal temperature, perhaps harming the health of this tissue. Daronch et al[33] showed that use of preheated composite (set to 54°C or 60°C) did not produce significantly greater *in vitro* intrapulpal temperatures than composite placed at room temperature, and that the major thermal risk is associated with photopolymerization.[34]

The film thickness values of the composites tested are material dependent. The values of the conventional composites tested are significantly lower when heated to 54°C or 60°C compared to room temperature. The conventional composites provide film thickness values greater than those of room temperature-flowable composite resins, regardless

of preheating temperature. Preheating of conventional composites is not a substitute for use of flowable composite resins. Preheated composites may adapt better in the cavity walls than room temperature composites.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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