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| ORIGINAL

Effect of thermocycling on internal microhardness of high and low viscosity bulk fill composite resins in class I cavities

Efeito da termociclagem na microdureza interna de resinas compostas bulk fill de alta e baixa viscosidade aplicadas em cavidades classe I

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ABSTRACT

Objective: To evaluate the effect of thermocycling on the Knoop internal microhardness of high- and low viscosity bulk fill resins applied in Class I cavities. **Methods**: Thirty third molars with Class I cavity preparations were randomly divided into 3 groups according to the restorative system: nanoparticulated composite resin (Filtek™ Z350 XT 3M ESPE) (oblique increments of 2mm); low viscosity bulk fill resin (Filtek™ Bulk fill Flow, 3M ESPE) (3mm increments covered with a 1-mm layer of nanoparticulated resin); high viscosity bulk fill resin (Filtek™ Bulk fill, 3M ESPE) (single 4-mm increment). After 24h, half of samples was submitted to thermocycling (1,000 cycles). All samples (n=5) were sectioned in half to measure the internal microhardness at bottom and top of restoration. **Results**: Analysis of variance indicated that, for nanoparticulated composite resin, without thermocycling, the microhardness at the top was statistically lower than at the bottom. After thermocycling, there was no difference in microhardness between the top and the bottom. For low viscosity bulk fill resin, without thermocycling, there was no significant difference in microhardness means between the top and the bottom. After thermocycling, significantly higher microhardness was found at the top than at the bottom ($p < 0.05$). For high viscosity bulk fill resin there was no significant difference between the microhardness values at the top and bottom, regardless of thermocycling ($p > 0.05$). In all composite resins, an increase in microhardness was observed after thermocycling ($p < 0.05$). **Conclusion**: Thermocycling increased the internal microhardness of resin restorations, and, for the low viscosity bulk fill resin, the microhardness at the top was higher than at the bottom after thermocycling.

Indexing terms: Composite resins. Hardness. Polymerization.

RESUMO

***Objetivo**: Avaliar o efeito da termociclagem na microdureza Knoop interna de resinas bulk fill de alta e baixa viscosidade aplicadas em cavidades classe I. **Métodos**: Trinta terceiros molares com cavidades Classe I foram divididos aleatoriamente em três grupos de*

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acordo com o sistema restaurador: Resina composta nanoparticulada (Filtek™ Z350 XT 3M ESPE) (incrementos oblíquos de 2mm); resina bulk fill de baixa viscosidade (Filtek™ Bulk fill Flow, 3M ESPE) (incremento de 3mm mais 1mm de resina nanoparticulada); resina bulk fill de alta viscosidade (Filtek ™ Bulk fill, 3M ESPE) (único incremento de 4mm). Após 24h, metade das amostras foi submetida a termociclagem (1.000 ciclos). Todas as amostras (n=5) foram seccionadas ao meio para mensuração da microdureza interna na base e topo da restauração. ***Resultados****: Análise de variância indicou que, para a resina composta nanoparticulada e antes da termociclagem, a microdureza no topo foi estatisticamente inferior do que na base (p<0,05). Após a termociclagem, não houve diferença entre topo e base. Já para a resina bulk fill de baixa viscosidade, antes da termociclagem, não se constatou diferença significativa nos valores de microdureza entre topo e base. Após termociclagem, valores significativamente mais elevados de microdureza foram encontrados no topo do que na base (p<0,05). Para resina bulk fill de alta viscosidade, não houve diferença significativa na microdureza entre topo e base, realizando-se ou não termociclagem (p>0,05). Em todas as resinas compostas foi verificado aumento de microdureza após termociclagem (p<0,05).* ***Conclusão****: A termociclagem aumentou a microdureza para todas as resinas compostas, sendo que para a resina bulk fill de baixa viscosidade a microdureza no topo foi maior do que na base após termociclagem.*

Termos de indexação: *Dureza. Resinas compostas. Polimerização.*

INTRODUCTION

With the advancement of dental materials and restorative techniques, conventional composite resins have become widely used direct restorative materials to reproduce aesthetics and restore function of dental elements [1]. Studies demonstrate that commercially available conventional composite resins have satisfactory mechanical properties and that the amount of filler particles is related to the improvement of these properties [2].

However, composite resins present polymerization shrinkage as a downside [3]. In order to overcome this limitation, composite resins must be inserted using the incremental technique [1]. This technique was described by Lutz et al. [4] as a way to eliminate the tensions generated by polymerization shrinkage and, consequently, improve marginal adaptation. In addition, the incremental technique improves light penetration in the increments [5]. Despite all that, the incremental technique is time consuming and is technique sensitive [6].

In order to minimize limitations of conventional composite resins, a new generation of composites named bulk fill was developed for insertion in single increments, of about 4mm allowing faster and simplified clinical procedures to be performed [7]. The use of increments of 4mm or more according to manufacturers' indications has been the subject of research that evaluates polymerization depth [6,8-12]. Approaches including the use of different photoinitiators, improved translucency and the use of "third generation" light sources are used in bulk fill composites to achieve desired polymerization depth [13,14]. Bulk fill composites are categorized into two groups, low viscosity and high viscosity. Low viscosity, usually have less filler particles and consequently lower resistance, requiring a conventional composite resin covering layer, while high viscosity ones have increased amounts of fillers, showing greater wear resistance [13,15].

Literature is inconclusive when it comes to polymerization depth of bulk fill composites inserted in 4mm single increments [2,13,15,16]. Several methodologies have been used to assess the depth of polymerization. Among the methods, the microhardness test can be defined as an indirect method of evaluating polymerization depth [17]. Although methods that directly quantify the amount of unreacted carbon double bonds are considered more accurate [18], when the network is reticulated they become less sensitive than the evaluation of the hardness in detecting small changes in the degree of conversion [19].

Another important factor is the aging that composite resins are subjected to in the oral cavity. One way to verify this aging in vitro is through thermocycling studies, which simulate temperature differences that clinically occur [20]. Thermocycling can affect the durability of resinous materials through water absorption, interfering with their mechanical properties [21]. Pereira et al. [22] evaluated the bond strength, nano-infiltration and marginal adaptation of three bulk fill composite resins, among them composites with low and high viscosity consistency, in comparison to conventional composite resin, submitted or not to thermal and mechanical aging. They concluded that bulk fill composites performed similarly to conventional composite resin and remained stable after simulated aging. However, literature is scarce of studies that simulate aging of bulk fill restorations and their interference on other mechanical properties, such as internal microhardness of the base and top regions.

Thus, considering the above, it is relevant to conduct studies that evaluate the effect of thermocycling on the internal microhardness of high and low viscosity bulk fill composites.

METHODS

Experimental design

This *in vitro* research had study factors:

I. Restorative system at three levels (Control group - Conventional composite resin (Filtek™ Z350 XT, 3M ESPE, St. Paul, MN, Brazil) in 2mm oblique increments; Low viscosity bulk fill composite resin (Filtek™ *Bulk fill* Flow, 3M ESPE, St. Paul, MN, Brazil) inserted in a 3mm increment with a 1mm covering layer); High viscosity bulk fill composite resin (Filtek™ *Bulk fill*, 3M ESPE, St. Paul, MN, Brazil), inserted in a single 4mm increment.

II. Thermocycling, in two levels: present or absent.

III. Internal microhardness measurement location, in two levels: base and top.

Experimental units were composed of class I cavities, randomly distributed among the three experimental groups (n = 5). The quantitative response variable was Knoop microhardness (KNH).

Sample preparation

Thirty third molars extracted for surgical reasons were selected after approval by the Research Ethics Committee (CAAE: 83438218.1.0000.5374), after naked eye inspection for the absence of caries lesions and stored in a 0.1% solution of Thymol at 37 °C. Teeth were obtained and used after approval by the Research Ethics Committee of São Leopoldo Mandic, Campinas, Brazil.

The cusps of the teeth were abraded, using 400 grade sandpaper under irrigation, in the politrix, followed by double-sided diamond discs on a hand piece, to obtain a flat occlusal enamel surface. First, the teeth were sectioned at the cervical portion of the root with diamond discs on a hand piece, and then the pulp chamber was emptied to perform the cavity preparation in order to analyze the integrity of the pulp wall.

Thirty class I cavities with a mesiodistal distance of 3.0 mm, buccolingual distance of 3.0mm and a depth of 4.0 mm were prepared. During cavity preparations, some teeth were discarded due to the perforation of the pulp chamber and, in other teeth, it was necessary to deviate to the mesial or distal region in order to obtain cavities 4 mm deep. A periodontal probe was used to check the dimensions of the preparation during its execution. The preparations were made with diamond burs (nº 3131, KG Sorensen, Cotia, Brazil) in high-speed drill (Kavo, Joinville, SC, Brazil) with water cooling and standardized angulation. The diamond tips were changed every five preparations and all margins of the cavo superficial limit were surrounded by enamel. After that, the pulp chamber was restored, and then the occlusal surface was restored.

The teeth received the application of an adhesive system and were randomly divided into three groups according to the restorative system and the filling technique, which followed the manufacturer's instructions described in table 1.

The conventional nanoparticulate composite resin (control group) (Filtek™ Z350 XT (3M ESPE, St. Paul, MN, Brazil) was inserted by the incremental technique. For this, two oblique increments of approximately 2mm were placed, placed in a wedge shape and each was polymerized for 20s.

Low viscosity bulk fill composite resin (Filtek™ B*ulk fill* Flow, 3M ESPE, St. Paul, MN, Brazil) was inserted in a single 3mm increment, which was light cured for 40s. Then, a 1mm cover layer of the nanoparticulate composite resin was inserted (Filtek™ Z350 XT, 3M ESPE, St. Paul, MN, Brazil), which was photoactivated for 20s. High viscosity bulk fill composite resin (Filtek™ *Bulk fill*, 3M ESPE, St. Paul, MN, Brazil) was inserted in a single 4mm increment, light cured for 40s.

Table 1. Materials, trademarks, manufacturers, compositions, and application protocols.

Material/ Manufacturer Batch	Composition	Application Protocol
Adper™ Single Bond Universal 3M ESPE, Sumaré, São Paulo, Brazil **Batch:** 647463	2-hydroxyethyl methacrylate Bisphenol A-glycidyl methacrylate (BisGMA) Decamethylene dimethacrylate Ethanol Silane treated silica water 1.10-Decanediol phosphate methacrylate Copolymer of acrylic and itaconic acid Camphorquinone N, N-Dimethylbenzocaine	The cavity was rinsed and dried with absorbent paper. Then the adhesive system was actively applied for 20s, light air jet for 5s and photoactivation for 10s.
Conventional nanoparticulate composite resin Filtek™ Z350 XT 3M ESPE, Sumaré, São Paulo, Brazil **Batch:** 671670 shade A2 Body	Treated silanized ceramics Silane treated silica Dimethacrylate diurethane (UDMA) Bisphenol A polyethylene glycol diether dimethacrylate Bisphenol A-glycidyl methacrylate (BisGMA) Treated silanized zirconia Polyethylene glycol dimethacrylate Triethylene glycol dimethacrylate (TEGDMA) 2,6 Di-tert-butyl-p-cresol	- Two oblique increments of approximately 2mm were applied in the shape of a wedge, and light cured for 20s each.
High viscosity bulk fill composite resin Filtek Bulk Fill 3M ESPE, Sumaré, São Paulo, Brazil **Batch: N874606** Shade A2	-Treated silanized ceramics Aromatic urethane dimethacrylate Ytterbium fluoride (YbF3) Dimethacrylate diurethane (UDMA) Silane treated silica Dodecane dimethacrylate (DDDMA) Treated silanized zirconia Water Modified methacrylate monomer Ethyl 4-dimethyl aminobenzoate (EDMAB) Benzotriazole	Insertion in a 4mm single increment and light cured for 40s.
Low viscosity bulk fill composite resin **Filtek Bulk Fill Flow** 3M ESPE, Sumaré, São Paulo, Brazil **Batch: N886476; N922060** Shade A2	Treated silanized ceramics Dimethacrylate diurethane (UDMA) Substituted dimecrylate Bisphenol A polyethylene glycol diether dimethacrylate (BISEMA) Ytterbium fluoride (YbF3) - Bisphenol A-glycidyl methacrylate (BisGMA) Benzotriazole Triethylene glycol dimethacrylate (TEGDMA) Ethyl 4-dimethylaminobenzoate	Insertion in a 3mm single increment and light cured for 40s. Insertion of a 1mm cover layer with nanoparticulate composite resin and light cured for 20s.

A VALO® curing light (Utradent Products, South Jordan, EUA) was used in all light curing procedures with a 1000 mW/cm^2 irradiance. The composites were polymerized following the manufacturers' recommendations and the distance from the light source to the composite surface was as close as possible without touching it [23]. After performing the restorative procedure, the teeth were kept in an incubator at 37 °C in relative humidity for 24 hours.

The finishing and polishing procedures were carried out 24 hours after the restorative procedure, with Sof-Lex Pop-On® abrasive discs (3M ESPE, Sumaré, SP, Brazil) in decreasing order of granulation.

Sample preparation for internal microhardness testing

To evaluate the internal microhardness prior to thermocycling, 15 samples, five from each composite resin (n = 5), were cut transversely through their centers in the buccolingual direction using a high concentration diamond disk (Isomet Diamond Blade 15HC, Buehler Ltd., Lake Buff, IL, USA) with water cooling.

The samples were fixed in PVC tubes with a composite and then polished in a metallographic sander with sandpapers of different granulations and felts. The polishing sequence was performed as follows: use of sandpaper 600 under irrigation with water for 2min, Use of sandpaper 1200 under irrigation with water for 10min. For the use of felts, the samples were impregnated with high viscosity alumina pastes that had particle sizes of 1.0; 0.3 and 0.05 µm.

Internal knoop microhardness test

A microhardness testing machine (HMV 2000, Shimadzu, Tokyo, Japan) was used by applying a static load of 0.49N for 10s at each measurement site. For each specimen, an average of three indentations at each depth was used for statistical analysis purposes [23]. The distance between composite base and the first knoop measurement was 500µm and between base and top 2000µm, with 200µm between the indentations made at the top and at the base.

Thermocycling

The remaining 15 samples were subjected to 1,000 thermal cycles (30s in each water bath, 5 °C and 55 °C, with an interval of 30s in a 37 °C water bath) in a thermal cycling machine (MSCT-3, Elquip, São Carlos, SP, Brazil).

Internal Knoop microhardness test after thermocycling

For samples that underwent thermocycling, internal knoop microhardness test was performed in the same way as done for the samples that were not subjected to thermal cycling.

Statistical analysis

In view of the finding that the data adhered to normal distribution, in order to investigate the effects of the type of composite/filling technique, thermocycling and the location of the measurement on the microhardness values, the analysis of variance with three criteria was used for repeated measures. Two-way Analysis of variance using and Tukey tests were used to break down the interaction. Statistical calculations were performed using SPSS 23 program (SPSS Inc., Chicago, IL, USA), adopting a 5% significance level.

RESULTS

Three-way analysis of variance indicated that the triple interaction between the type of composite resin/ technique, thermocycling and the measurement site was statistically significant ($p<0,001$). To interpret this interaction, the decomposition by type of composite resin was performed by applying two-way analysis of variance for repeated measures.

For the nanoparticulate composite resin, the two-way analysis of variance showed that the Knoop microhardness values were significantly affected by the interaction between thermocycling and the measurement site ($p = 0,040$). Prior to thermocycling, microhardness of the nanoparticulate composite resin was significantly lower at the top, while post thermocycling there was no difference in the microhardness values measured at the top and base of the restoration. Both at the top and bottom, thermocycling significantly increased the microhardness of the nanoparticulate composite resin (table 2).

As for the low viscosity bulk fill composite resin, prior to thermocycling, no significant difference was found in the microhardness values measured at the top and base of the restoration. After thermocycling, significantly higher values of microhardness were found at the top. Whether at the top or base, microhardness values significantly increased with thermocycling (table 2).

Finally, for the high viscosity bulk fill composite resin, there was no statistically significant difference between microhardness values at the top and base, regardless of whether or not thermocycling was performed. Like other composite resins, for high viscosity bulk fill, thermocycling caused a significant increase in microhardness values.

Table 2. Average values and standard deviations of microhardness (Kg/mm^2) at the top and base of Class I restorations, prior and post thermocycling, dismembered by composite resin.

Composite resin	Location	Thermocycling		Overall mean
		absent	present	
Nanofilled	Top	38.22 (1.92) Bb	47.76 (3.5) Aa	–
	Base	41.14 (1.52) Ab	46.27 (1.11) Aa	–
Low viscosity bulk fill	Top	21.43 (4.50) Ab	52.12 (1.22) Aa	–
	Base	20.73 (2.35) Ab	27.86 (0.84) Ba	–
High viscosity bulk fill	Top	30.95 (3.09)	39.06 (2.92)	35.01* (5.13)
	Base	28.73 (3.32)	39.61 (5.44)	34.17* (7.14)
	Overall mean	29.84 (3.25) B	39.33 (4.13) A	–

Key: averages followed by different capital letters indicate a statistically significant difference between microhardness values at the top and base, separately considering moments prior and post thermocycling. For both the nanoparticulate and the low viscosity bulk fill composite resins, averages followed by lowercase letters indicate a statistically significant difference between microhardness values in prior and post-thermocycling moments, considering each location separately. For high viscosity bulk fill composite resin, overall averages followed by different capital letters indicate statistically significant difference between microhardness values prior and post thermal cycling, regardless of location. For high viscosity bulk fill composite resin, overall averages followed by asterisks indicate no statistically significant difference between microhardness values at the top and base, regardless of whether or not thermocycling was performed.

DISCUSSION

The results of this study allowed us to reject the null hypothesis, since it was observed that there was statistical difference in microhardness, depending on the composite resin, when comparing the factors under study location (top x base) and/or thermocycling (present or absent).

Prior to thermocycling, low viscosity bulk fill composite resin showed no significant difference in Knoop microhardness values between the base and top of the restoration, demonstrating that the mechanical properties were maintained in regards to the depth of the restoration, including overcoming the minimum parameter of 80% of the base/top ratio, which is recommended [8,17,19]. This result corroborates with those of Fronza et al. [23], in which the same composite resin tested in the present study (Filtek Bulk fill Flow) showed similar degrees of conversion and Knoop microhardness at all depths. Similar results were also found by Miletic et al. [8], who observed that the degree of conversion and Vickers microhardness were similar between the base and the top of Bulk fill Flow, in samples of up to 4mm. Yet, in the study by Karacolak et al. [10] the tested low viscosity bulk fill resins, including Filtek Bulk fill Flow, showed Knoop microhardness equal to or greater than the limit of 80% at a depth of 4mm, without showing statistically significant difference between base and top, corroborating with the findings of the present study. The study by Li et al. [16] also confirms that bulk fill composites can be "effectively" light cured at 4mm (in the middle of the specimen) and that the maximum average conversion degree (CD) of 80% was obtained for Filtek Bulk fill Flow composite. A probable explanation for the good performance of low viscosity bulk fill composite may be related to its translucency. It can be considered that the low viscosity bulk fill composite resin tested in the present study is a material that has an elevated light transmission, due to lower variation in the refractive indices between top and base, and a combination of monomer refractive indices. and loads [24]. The lower filler volume and low light dispersion also confirm high light transmission in this type of composite resin [6,25]. Thanks to these properties, the polymerization of this composite resin occurs even outside of the path of direct light, thanks to internal scattering and spreading, where proper positioning and orientation of the light guide may be less of a problem, as long as sufficient energy enters the restoration [10,16]. Thus, even in

conditions of inhomogeneity of the light beam, the degree of conversion to low viscosity bulk fill resin will not be affected [16].

Similar to the Bulk fill Flow composite resin, it was observed that there was no difference in the Knoop microhardness between the top and the base, for high viscosity Bulk fill composite resin prior to thermocycling. The results from Karacolak et al. [10] corroborate with those of the present study, since they demonstrated that high viscosity bulk fill composite exceeded the threshold of 80% of base/top microhardness at 4mm depth, even though the microhardness values showed a decline with the increase of thickness. This was probably due to the increased light transmission within this composite resin. Shimokawa et al. [9] evaluating high viscosity Filtek Bulk fill and Tetric Bulk fill with Valo light curing device, the same used in the present study, found no significant differences for Knoop microhardness at the top and base of the samples, at the central, medium and external measurement points, corroborating with our results. However, when other types of "polywave" and "monowave" photoactivation units were used, significant differences were found for high viscosity Filtek Bulk fill and Tetric Bulk Fill, in different regions of the top (central, medium, external). At the base, microhardness values depended on the location, reaching an average of about 70% of the maximum hardness value in the 4mm thick samples, demonstrating that the measurement location and type of photopolymerization unit can influence the obtained results.

Despite the results from the present study being confirmed by other publications, literature is still conflicting regarding the reduction or not of hardness over different depths of the composite resin. The work by Soto- Montero et al. [12] explains that higher Knoop microhardness (KHN) at the top is an expected result, since the top receives greater irradiance than the base. These differences can be explained through combined effects, such as: type of mold, misalignment of the light guide, non-homogeneous light beam and positioning of the light guide [16]. Tarle et al. [16] also mentions some variables that must be taken into account, such as: the light curing irradiance, the light curing time, the measurement site, the load and the time used to measure Knoop microhardness. Studies by ALShaafi et al. [26] and Li et al. [16] observed that both the measurement site (more centralized or closer to the matrix wall that served as a mold for the restoration, as well as the type of matrix (stainless steel, PMMA, teflon) or tooth, polymerization site, can influence the values obtained. In the present study, the slices to measure the internal microhardness were made in the central part of the sample, which may have been a place of greater light absorption from the light curing unit, which may have facilitated the achievement of similar microhardness values between the base and the top.

For the nanoparticulate composite resin tested, prior to thermocycling, the Knoop values were significantly lower at the top than at the base. This result can be explained by the fact that the composite resin was inserted using the incremental technique, so that the increment at the base received twice the light from the curing unit. Fronza et al. [23] corroborates with these findings when it states that in deeper layers there was an increase in CD when using conventional composite resin in an incremental way, although without differences regarding microhardness at the base and top, even when inserted in a single increment. The authors justify the good performance of the micro-hybrid composite resin used in their study (Herculite, Kerr) with the presence of elevated filler content (79% by weight), which may have facilitated the diffusion of light within the composite resin. Similarly, in the present study, the nanoparticulate composite resin has a relatively high filler content (around 78% by weight), added to the fact that this first increment received light from the light curing unit twice.

In the evaluation carried out after thermocycling, an increase in microhardness was observed for all composite resins tested. Comparing the results of the present study after thermocycling with literature is very difficult, since there are few studies that have evaluated the effect of thermocycling on microhardness of bulk fill composite resins. However, it is possible to make a correlation with other procedures that generate an increase in temperature, such as the preheating of the composite resin. In this sense, Lempel et al. [11] evaluated the degree of conversion of composite resins after preheating and found that, especially in the top region, there was an increase in Knoop microhardness values. This result is justified because the temperature, by preheating, alters the polymerization kinetics of the composite resin by increasing molecular mobility and increasing the conversion of monomers [26]. As a consequence, a polymeric network with cross-links and improved mechanical properties is obtained [26]. Thus, the effect of temperature rise is a fact to be considered when

justifying the higher values found after thermocycling. In fact, in the study by Ghavami-Lahiji et al. [27], the degree of conversion increased with thermocycling, which may have occurred due to the release of unreacted monomers of the composite resin with thermal shocks and storage time (Tabatabaei et al. [28], with a continuation of polymerization reaction of trapped unreacted monomers. In particular, there was an increase in the microhardness of the bulk fill flow composite resin after thermocycling in the top region, which was statistically superior to the microhardness of the base region. Lempel et al. [11] report that for low viscosity composite resins, with lower filler particles, the increase in temperature (represented in their study by preheating) provides enough energy to achieve a higher degree of conversion at the top with lower values for the base, due to the inhibition of the propagation of the polymeric chain by the drop in temperature.

It was expected that thermocycling, represented in the present study by 1000 thermal cycles, would cause a decrease in microhardness, however, this result seems to be dependent on the number of thermal cycles, as well as on the tested composite resin and the fact that most of the studies [27,28] evaluated the effect of thermocycling on the surface microhardness of the composite and not internal, as in the present study. In a previous study, microhardness stability of conventional microhybrid composite resin surface was verified after 1000 cycles, but with significant decrease after 4000 thermal cycles [27]. Yet, in the study by Pereira et al. [28], a significant reduction in surface microhardness was observed after 3,000 thermal cycles for a micro-hybrid and a microparticulate composite resin, while another micro-hybrid composite resin showed no significant difference. Therefore, standardized test conditions, such as type of composite resin, length of stay, storage and number of thermal cycles must be established so that data from different studies can be compared and analyzed [28].

Despite being an in vitro study, this study supports the use of bulk fill composite resins, which have shown to be equivalent in terms of internal microhardness to conventional composite resins. In addition, many studies have investigated the properties of composite resins at room temperature. However, the value of these tests when these composites are at higher temperatures (such as oral temperatures) must be confirmed in future studies.

CONCLUSION

It is concluded that thermocycling increased the internal microhardness in restorations with conventional, low viscosity and high viscosity bulk fill composite resins. Still, after thermocycling, low viscosity bulk fill composite resin showed superior microhardness in the top region in comparison to the base region.

Collaborators

SLA Lima, conceptualization, investigation, resources and writing - original draft. LL Cabral, methodology and investigation. NR Carlos, methodology and formal analysis. SAA Lima, writing - review and editing. KR Kantovitz, writing - review and editing, visualization, project ADMINISTRATION. FLB Amaral, writing - review and editing, conceptualization, investigation, supervision, validation.

REFERENCES

1. Kwon Y, Ferracane J, Lee IB. Effect of layering methods, composite type, and flowable liner on the polymerization shrinkage stress of light cured composites. Dent Mater. 2012;28(7):801-9. https://doi.org/10.1016/j.dental.2012.04.028
2. Leprince JG, Palin WM, Vanacker J, Sabbagh J, Devaux J, Leloup G. Physico- mechanical characteristics of commercially available bulk-fill composites. J Dent. 2014;42(8):993-1000. https://doi.org/10.1016/j.jdent.2014.05.009
3. Ferracane 2005 Ferracane JL. Developing a more complete understanding of stresses produced in dental composites during polymerization. Dent Mater. 2005;21(1):36-42. https://doi.org/10.1016/j.dental.2004.10.004
4. Lutz F, Krejci I, Oldenburg TR. Elimination of polymerization stresses at the margins of posterior composite resin restorations: a new restorative technique. Quintessence Int. 1986;17(12):777-84.

5. Czasch P, Ilie N. In vitro comparison of mechanical properties and degree of cure of bulk fill composites. Clin Oral Investig. 2013;17(1):227-35. https://doi.org/10.1007/s00784-012-0702-8
6. Reis AF, Vestphal M, Amaral RCD, Rodrigues JA, Roulet JF, Roscoe MG. Efficiency of polymerization of bulk-fill composite resins: a systematic review. Braz Oral Res. 2017;31(suppl 1):e59. https://doi.org/10.1590/1807-3107BOR-2017.vol31.0059
7. Alrahlah A, Silikas N, Watts GC. Post-cure depth of cure of bulk fill dental resin- composites. Dent Mater. 2014;30(2):149-54. https://doi.org/10.1016/j.dental.2013.10.011
8. Miletic V, Pongprueksa P, De Munck J, Brooks NR, Van Meerbeek B. Curing characteristics of flowable and sculptable bulk-fill composites. Clin Oral Investig. 2017;21(4):1201-12. https://doi.org/10.1007/s00784-016-1894-0
9. Shimokawa CAK, Turbino ML, Giannini M, Braga RR, Price RB. Effect of light curing units on the polymerization of bulk fill resin-based composites. Dent Mater. 2018;34(8):1211-21. https://doi.org/10.1016/j.dental.2018.05.002
10. Karacolak G, Turkun LS, Boyacioglu H, Ferracane JL. Influence of incremente thickness on radiant energy and microhardness of bulk-fill resin composites. Dent Mater J. 2018;37(2):206-13. https://doi.org/10.4012/dmj.2017-032
11. Lempel E, Őri Z, Szalma J, Lovász BV, Kiss A, Tóth Á, Kunsági-Máté S. Effect of exposure time and pre-heating on the conversion degree of conventional, bulk-fill, fiber reinforced and polyacid-modified resin composites. Dent Mater. 2019;35(2):217-28. https://doi.org/10.1016/j.dental.2018.11.017
12. Soto-Montero J, Nima G, Rueggeberg FA, Dias C, Giannini M. Influence of Multiple Peak light-emitting-diode curing unit beam homogenization tips on microhardness of resin composites. Oper Dent. 2020;45(3):327-38. https://doi.org/10.2341/19-027-L
13. Bucuta S, Ilie N. Light transmittance and micro-mechanical properties of bulk fill vs. conventional resin based composites. Clin Oral Investig. 2014;18(8):1991-2000. https://doi.org/10.1007/s00784-013-1177-y
14. Tarle Z, Attin T, Marovic D, Andermatt L, Ristic M, Tauböck TT. Influence of irradiation time on subsurface degree of conversion and microhardness of high- viscosity bulk-fill resin composites. Clin Oral Investig. 2015;19(4):831-40. https://doi.org/10.1007/s00784-014-1302-6
15. Van Ende A, De Munck J, Lise DP, Van Meerbeek B. Bulk-Fill Composites: A Review of the Current Literature. J Adhes Dent. 2017;19(2):95-109. https://doi.org/10.3290/j.jad.a38141
16. Li X, Pongprueksa P, Van Meerbeek B, De Munck J. Curing profile of bulk-fill resin- based composites. J Dent. 2015;43(6):664-72. https://doi.org/10.1016/j.jdent.2015.01.002
17. Flury S, Hayoz S, Peutzfeldt A, Hüsler J, Lussi A. Depth of cure of resin composites: is the ISO 4049 method suitable for bulk fill materials? Dent Mater. 2012;28(5):521-8. https://doi.org/10.1016/j.dental.2012.02.002
18. Shin WS, Li XF, Schwartz B, Wunder SL, Baran GR. Determination of the degree of cure of dental resins using Raman and FT-Raman spectroscopy. Dent Mater. 1993;9(5):317-24. https://doi.org/10.1016/0109-5641(93)90050-Z
19. Rueggeberg FA, Craig RG. Correlation of parameters used to estimate monomer conversion in a light-cured composite. J Dent Res. 1988;67(6):932-7. https://doi.org/10.1177/00220345880670060801
20. Jurubeba JEP, Costa AR, Correr-Sobrinho L, Tubel CAM, Correr AB, Vedovello AS. Influence of thermal cycles number on bond strength of metallic brackets to ceramic. Braz Dent J. 2017;28(2):206-9. https://doi.org/10.1590/0103-6440201701217
21. Söderholm KJ, Zigan M, Ragan M, Fischlschweiger W, Bergman M. Hydrolytic degradation of dental composites. J Dent Res. 1984;63(10):1248-54. https://doi.org/10.1177/00220345840630101701
22. Pereira S, Castilho A, Salazar Marocho S, Oliveira K, Ccahuana VV, Bottino M. Thermocycling effect on microhardness of laboratory composite resins. BJOS 2007;6(22):1372-75. https://doi.org/10.20396/bjos.v6i22.8642994
23. Fronza BM, Rueggeberg FA, Braga RR, Mogilevych B, Soares LE, Martin AA et al. Monomer conversion, microhardness, internal marginal adaptation, and shrinkage stress of bulk-fill resin composites. Dent Mater. 2015;31(12):1542-51. https://doi.org/10.1016/j.dental.2015.10.001
24. Rueggeberg FA, Ergle JW, Mettenburg DJ. Polymerization depths of contemporary light-curing units using microhardness. J Esthet Dent. 2000;12(6):340-9. https://doi.org/10.1111/j.1708-8240.2000.tb00243.x
25. Son SA, Park JK, Seo DG, Ko CC, Kwon YH. How light attenuation and filler content affect the microhardness and polymerization shrinkage and translucency of bulk-fill composites? Clin Oral Investig. 2017;21(2):559-65. https://doi.org/10.1007/s00784-016-1920-2
26. ALShaafi MM, Haenel T, Sullivan B, Labrie D, Alqahtani MQ, Price RB. Effect of a broad-spectrum LED curing light on the Knoop microhardness of four posterior resin based composites at 2, 4 and 6-mm depths. J Dent. 2016;45:14-8. https://doi.org/10.1016/j.jdent.2015.11.004
27. Ghavami-Lahiji M, Firouzmanesh M, Bagheri H, Jafarzadeh Kashi TS, Razazpour F, Behroozibakhsh M. The effect of thermocycling on the degree of conversion and mechanical properties of a microhybrid dental resin composite. Restor Dent Endod. 2018;43(2):e26. https://doi.org/10.1016/j.jdent.2015.11.004
28. Pereira R, Lima DANL, Giorgi MCC, Marchi GM, Aguiar FHB. Evaluation of bond strength, nanoleakage, and marginal adaptation of bulk-fill composites submitted to thermomechanical aging. J Adhes Dent. 2019;21(3):255-64. http://dx.doi.org/10.3290/j.jad.a42547

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