UNIVERSIDADE DE SÃO PAULO
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**Evaluation of the efficiency of polymerization of composite resins in
proximal restorations**

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**Avaliação da qualidade de polimerização de resinas compostas em
restaurações proximais**

**Evaluation of the efficiency of polymerization of composite resins in
proximal restorations**

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DEDICATÓRIA

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“Só se pode alcançar um grande êxito quando nos mantemos fiéis a nós mesmos. “

Friedrich Nietzsche

ABSTRACT

ABSTRACT

Evaluation of the efficiency of polymerization of composite resins in proximal restorations

Statement of the problem. The insertion and polymerization of the first resin composite layer in the proximal cavity of class II restorations require attention to achieve cervical sealing as well as good physical properties and clinical longevity.

Objective. To evaluate the polymerization efficiency of four resin composites (Filtek Z250XT-3M ESPE, Filtek One Bulk-Fill-3M ESPE, Filtek Bulk-Fill Flow-3M ESPE and Opus Bulk Fill-FGM) in the cervical region of class II restorations.

Material and methods. Sixteen groups ($n = 12$) were prepared by inserting 2mm increments of the resin composites in a bipartite matrix and being cured with a lightsource of $1000\text{mW}/\text{cm}^2$ in continuous mode during 20 or 40 seconds directly on the material (M group) or through a slot preparation (S group) in typodont teeth and all were stored at $37 \pm 1^\circ\text{C}$, for 24 hours. The Knoop microhardness was evaluated with 25-g-load and 5-s dwell time. Data were analysed with three-way Anova and Tukey's HSD ($\alpha = 5\%$).

Results. The results of relative hardness did not show significant difference for the M groups, regardless of the time and type of resin. All the resins had a relative hardness higher than 0.80. In contrast, for S groups, Z250 20s (0.39 ± 0.08) and Bulk FGM 20s (0.47 ± 0.04) showed significant lowest ratios. Bulk Flow 20s (0.70 ± 0.12) and 40s (0.72 ± 0.09), One Bulk 20s (0.65 ± 0.05) and 40s (0.71 ± 0.06) presented no statistical difference with group Z250 40s (0.63 ± 0.05).

Conclusion. It would be beneficial to increase the time of photoactivation for resins Z250XT and Bulk FGM, differently for Bulk Flow and One Bulk in class 2 proximal slot restorations to ensure adequate hardening.

Key words: Polymerization. Composite Resins. Hardness Tests.

RESUMO

RESUMO

Avaliação da qualidade de polimerização de resinas compostas em restaurações proximais

Problematização. A inserção e polimerização do primeiro incremento de resina composta na caixa proximal de restaurações classe II deve ser efetuada com atenção para garantir um bom selamento cervical, bem como alcançar boas propriedades físicas e longevidade clínica.

Objetivo. Avaliar a eficiência da polimerização de quatro resinas compostas (Filtek Z250XT-3M ESPE, Filtek One Bulk-Fill-3M ESPE, Filtek Bulk-Fill Flow-3M ESPE e Opus Bulk Fill-FGM) na parede cervical de restaurações classe II.

Material e métodos. Dezesesseis grupos ($n=12$) foram preparados através da inserção de incrementos de 2mm das resinas em uma matriz bipartida, sendo fotoativados com uma fonte de luz de 1000mW/cm^2 em modo contínuo durante 20 e 40 segundos diretamente no material (M) ou através do preparo slot (S) em um dente artificial e armazenados em estufa a $37 \pm 1^\circ\text{C}$, por 24 horas. A microdureza Knoop foi avaliada com carga de 25gramas e tempo de permanência de 5segundos. Todos os grupos foram submetidos aos testes estatísticos e avaliados pela análise de variância com três fatores (Anova) e pelo teste de Tukey HSD ($\alpha = 5\%$).

Resultados. Os resultados de dureza relativa não apresentaram diferença significativa para os grupos M, independente do tempo e tipo de resina. Todas as resinas apresentaram dureza relativa superior a 0.80. Por outro lado, para os grupos S, Z250 20s (0.39 ± 0.08) e Bulk FGM 20s (0.47 ± 0.04) apresentaram valores significativamente menores. Bulk Flow 20s (0.70 ± 0.12) e 40s (0.72 ± 0.09), One Bulk 20s (0.65 ± 0.05) e 40s (0.71 ± 0.06) não apresentaram diferença estatística com o grupo Z250 40s (0.63 ± 0.05).

Conclusão. Seria benéfico aumentar o tempo de fotoativação para as resinas Z250XT e Bulk FGM, ao contrário das resinas Bulk Flow e One Bulk em restaurações de classe 2 com preparo slot para melhorar a dureza.

Palavras chave: Polimerização. Resinas Compostas. Testes de Dureza.

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LIST OF ABBREVIATIONS AND ACRONYMS

μm	Micrometer
μ	Micro
°C	Degrees Celsius
mm	Millimeter
mW	Megawatt
KHN	Knoop Hardness Number
cm	Centimeter
g	Gram
nm	Nanometer
s	Seconds

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1 INTRODUCTION

1 INTRODUCTION

The search for an ideal direct esthetic restorative material is still ongoing, but resin-based composite (RBC) is the most prominent esthetic restorative materials because of their universal applications, minimum intervention and the ability to be directly placed without laboratory procedures.³⁴ Furthermore, this material has been an alternative for amalgam restorations in posterior teeth. However, a meticulous diagnosis is fundamental to restore functional characteristics of natural teeth beyond color, texture, brightness, fluorescence, and translucency.

But, one of the problems associated with RBCs in posterior teeth is marginal infiltration, being consequence of the polymerization shrinkage, which is result of converting monomers into polymers after photoactivation causing a decrease in composite volume, and the coefficient of expansion different from the dental structure.⁴⁷ This condition will lead to gaps in the tooth-restoration interface, where bacterial invasion may occur and, consequently, recurrent caries lesions.³⁸

Although the development and use of bonding agents decreases the occurrence of marginal infiltration, there is no reduction in the phenomenon of polymerization shrinkage. In class II restorations of posterior teeth, RBC present disadvantages such as low resistance to mastigatory forces and critical marginal adaptation. Correct and sufficient polymerization results in improvement of mechanical properties; however, some factors affect them directly: the exposure time, light intensity, distance from the tip of the photoactivator, nature, thickness and surface of restorative material.¹ It is important to insert the RBC in layers, using incremental technique not exceeding 2mm in volume of each layer.²⁵ The first layer is the most important because it promotes cervical sealing of the cavity in proximal area. The extended form in proximal cavities of a Class II preparation can be considered "unfavorable", leading to an inevitable polymerization shrinkage in addition marginal microleakage,² so it requires the use of a metal matrix for a better adaptation in order to achieve the success of the technique.

It is expected that a typical Class II cavity will present a proximal slot with 4mm, approximately. The use of a long polymerization mode results in a higher conversion which has been proved to be important for Class II composite restorations since it leads to a sufficient polymerization of the restoration in the cervical region.¹⁵

In an attempt to accelerate the restorative procedure¹ in addition to improving the properties of a conventional resin, a new generation of composites has been studied, named as “Bulk-Fill” composite (BFC) that can be photoactivated after the insertion of 4 to 5mm increments, leading to a working time decrease and an improvement of restoration quality.⁴⁵ Some studies report that BFCs reduce or relieve unavoidable restorations polymerization shrinkage, being result of an increased translucency, low modulus of elasticity and high amount of charge particles.⁴⁷ These resins may be indicated for restorations on posterior teeth while others are used as intermediary bases. However, nowadays, not all BFCs needs the coverage of a conventional resin to improve esthetic qualities in an anterior or posterior tooth being consequence of an improved in opacity and individual properties like Filtek One Bulk (3M ESPE). Considering all these informations, the aim of this study was to evaluate the efficiency of polymerization by hardness measure of four RBCs, being three of them BFCs, in the cervical region of class II restorations.

2 ARTICLE

2 ARTICLE

The article presented in this Dissertation was written according to Operative Dentistry instructions and guidelines for article submission.

Evaluation of the efficiency of polymerization of composite resins in proximal restorations

Clinical Relevance

The first layer of resin composites in proximal of class II restorations is an important aspect to considerate because it promotes cavity cervical sealing.

SUMMARY

The insertion and polymerization of the first resin composite layer in the proximal cavity of class II restorations requires attention to achieve cervical sealing as well as good physical properties and clinical longevity. The aim of this study was to evaluate the polymerization efficiency of four resin composites (Filtek Z250XT-3M ESPE, Filtek One Bulk-Fill-3M ESPE, Filtek Bulk-Fill Flow-3M ESPE and Opus Bulk Fill-FGM) in the cervical region of class II restorations. Sixteen groups ($n = 12$) were prepared by inserting 2mm increments of the resin composites in a bipartite matrix and being cured with a lightsource of $1000\text{mW}/\text{cm}^2$ in continuous mode during 20 or 40 seconds directly on the material (M group) or through a slot preparation (S group) in typodont teeth and all were stored at $37 \pm 1^\circ\text{C}$, for 24 hours. The Knoop microhardness was evaluated with 25-g-load and 5-s dwell time. Data were analysed with three-way Anova and Tukey's HSD ($\alpha = 5\%$). The results of relative hardness did not show significant difference for the M groups, regardless of the time and type of resin. All the resins had a relative hardness higher than 0.80. In contrast, for S groups, Z250 20s (0.39 ± 0.08) and Bulk FGM 20s (0.47 ± 0.04) showed significant lowest ratios. Bulk Flow 20s (0.70 ± 0.12) and 40s (0.72 ± 0.09), One Bulk 20s (0.65 ± 0.05) and 40s (0.71 ± 0.06) presented no statistical difference with group Z250 40s (0.63 ± 0.05). It would be beneficial to increase the time of photoactivation for resins Z250XT and Bulk FGM, differently for Bulk Flow and One Bulk in class 2 proximal slot restorations to ensure adequate hardening.

INTRODUCTION

Despite the fact that amalgam is still considered suitable for restoring Class I and Class II cavities,¹ this material is facing its demise around the world and resin-based composites (RBCs) have been the first choice for direct posterior restorations and are increasingly popular among clinicians and patients. However, the material properties showed a minor effect on longevity since the main reasons for posterior composite restorations are secondary caries, related to the individual risks like fracture, presence of a lining and bruxism, while in anterior teeth esthetic is the main concern that could lead to restoration failures. RBCs restorations can be considered a reliable treatment as long as both the professional and the patient are aware of the factors involved in restoration failures, besides the improvement of material properties should address the prevention of failure rate.²

During the years, different restorative techniques with RBCs have been used to minimize the shrinkage stress³ and manufacturers aim to improve the effectiveness and longevity of resin adhesive bonds to tooth structure at the cervical margins of class II cavities, where the problem of microleakage becomes more pronounced^{4,5} and more prone to recurrent caries.⁶ Normally, RBCs have been placed in increments of 2 mm by horizontal or oblique incremental layering technique to guarantee the penetration of the curing light deeply enough to initiate and complete curing into the material and improve the degree of conversion (DC).^{7,8}

In an attempt to accelerate the restoration process and optimize clinical time, a new class of material, the bulk-fill composite (BFC), was recently introduced, enabling up to 4 or 5mm thickness increments to be cured in one step.⁸ Several BFCs are already on the market, including low- and high-viscosity formulations. Each BFC adopts different strategies to achieve high light transmission and flowability. A sufficient depth of cure may be achieved using specific polymerization modulators, improving the translucency or using different

initiator systems.⁹ Generally, low-viscosity BFCs present low filler content to increase flowability. The manufacturer's recommendation to finish a BFC restoration by adding a capping layer made of conventional RBC is a necessity, since the modulus of elasticity and hardness of some materials were considerably below the mean values measured in nanohybrid and microhybrid RBCs.⁸ However, at now, not all BFCs require coverage to enhance the esthetic in an anterior or posterior tooth due to their translucency, because as more and more properties are being improved and a increase in opacity has been made by manufactures like the case of Filtek One Bulk (3M), which recently arrived the market.

The aim of this study was to evaluate the polymerization efficiency of four resin composites by hardening in the cervical region of class II restorations. The null hypotheses tested were: There would not be a difference in the polymerization efficiency between the resin composites, there would not be a difference in the polymerization efficiency at the different times and there would not be a difference in the polymerization efficiency between the distances evaluated.

MATERIALS AND METHODS

Experimental Design

This in vitro study presents 3 variation factors:

- Resin Composite (at 4 levels: Filtek Z250XT, Filtek One Bulk-Fill, Filtek Bulk-Fill Flow and Opus Bulk Fill, Table 1);
- Photoactivation, performed by VALO Cordless – ULTRADENT by Standard Power, distance (in 2 levels: direct photoactivation on the resin composite and photoactivation through the proximal slot);
- Photoactivation time (in 2 levels: 20 and 40 seconds);

And it had as a response variable the surface hardness.

This study had a total of 16 groups with 12 specimens each (Table 2).

Proximal slot preparation

The section of one second mandibular molar of a typodont model (MOM - Dental Mannequins Marília) was performed at a height of 4 mm above to the marginal crest to obtain the crown separated from the root by a cutting machine IsoMet Low Speed Saw (South Bay Technology Inc. Buehler, Lake Bluff, IL, EUA). Afterwards, the tooth surface was polished in the Politriz Arotec APL4, 2V three phase (Cotia, SP, Brazil) to eliminate any remains of the root that could interfere in the results. Using a pachymeter and a diamond tip 1090 from FG, a slot preparation was made in proximal with 3 by 2 mm dimensions, 3 being the vestibular-lingual opening and 2 the mesiodistal extension. The bottom region was ruptured with the same diamond tip. The artificial molar was surrounded by Tofflemire matrix and a metal matrix with 7mm. The metal matrix was cut close to the cuspids with a thin clinical scissors and a small amount of a fast-curing cyanoacrylate adhesive (Super Bonder - Loctite) was passed with one microbrush (KG) around the prepared tooth so that the matrix does not move. Around the range tooth and matrix, a piece of black paper with little flexibility (30cm in height and 21 in length) was cut from a black cover page in a workbook and adapted with Super Bonder to avoid light dissipation of the photoactivator.

Preparation of Specimens

A bipartite matrix was made in a specialized laboratory with a height of 2mm. The material used in the ring was stainless steel on the outside and on the inside and bipartite part, polyacetal (Fig. 1).

For the Material Hardness (M) group (direct photoactivation on the resin composite), the bipartite matrix was individually positioned on a polyester matrix and a thin glass plate underneath. Inside the bipartite part, a 2mm thickness increment of the resin composites evaluated was inserted with a spatula (nº 1- Duflex) for resin and a small amalgam condenser (Duflex). Another polyester matrix and a second thin glass plate were positioned above with a

sufficient pressure to remove any excess material. The photoactivation was performed by light source Valo Cordless (Ultradent, South Jordan, UT, EUA), LED-type, wide-spectrum, standard power pre-calibrated with 1000mW/cm² irradiance in continuous mode during 20 or 40 seconds (energy density of 20J/cm² and 40J/cm² respectively), directly on the resin composite, positioning the top of the photoactivator above the second glass plate and touching gently on the plate (Fig. 2). The LED profile had already been evaluated by an integrated sphere.

For the Material Hardness through Slot Preparation (S) group (photoactivation through the proximal slot), the same procedure of the M group by inserting the increments inside the bipartite matrix was performed, but now placing the range prepared tooth + metal matrix with Tofflemire + black paper on the second glass plate (Fig. 3-A). The photoactivation was also during 20 and 40 seconds on the slot preparation by touching the top of the photoactivator gently over the cuspid (Fig. 3-B).

The specimens were carefully removed from the bipartite matrix immediately after each photoactivation and a small mark with a black pen was made on the upper surface to distinguish from the lower surface during the microdurometer analysis. For 24 hours, all specimens were stored separately and labelled according to resin type and photoactivation time in a black tupperware to be free from any external light inside a dental stove (37°C). After, all specimens from M and S groups were analyzed by hardness of the upper surface, which received light directly, and the lower surface, which received light indirectly.

Microhardness

For the analysis in the Microdurometer Micromet 6040 South Bay Technology Inc. Buehler (Lake Bluff, IL, EUA) (Fig. 4), the samples were first positioned individually on acrylic blocks, stabilized with red wax and analyzed by hardness of the upper and lower surface using a Knoop Diamond pyramid with a 25grams load during 5seconds.¹⁰ Each

sample were analyzed by the 50x magnifying glass through five indentations performed on upper and lower surfaces. The first one was used to be the guide, being made in the middle of the analysed surface. From this reference, the others were performed, with the second indentation at 100µm above the first one, the third at 100µm below, the fourth at 100µm at the right side, and finally the last at 100µm to the left, forming the figure of a "cross" in the final analysis. For each indentation, a KHN (Knoop Hardness Number) value was obtained.

Relative Hardness (RH)

The data were tabulated according to the five values of indentations of the upper and lower surfaces. For each specimen, the Relative Hardness Percentage (division of the mean of the lower surface over the upper X100) was calculated. The unit of measure used was KHN (Knoop Hardness Number).

Statistical analysis

All groups with their respective values of RH ratios were submitted to statistical tests and presented normal distribution, being evaluated by the three-way ANOVA demonstrating a significant difference and by the Tukey test with significance level of 5%.

RESULTS

The results of RH mean and standard deviation for the sixteen groups of this study are presented in Table 3.

Relative Hardness

Some groups demonstrated a significant difference ($p < 0,05$) and a significance level of 5% by the Tukey test and others not. It was found a statistical difference between all the variation factors: groups, resin composite, times of photoactivation and photoactivation distance.

In the M groups, there was no statistical difference between them and presented values higher than 0.8, which represents values of RH higher than 80% in percentage, representing a good depth of polymerization in specimens evaluated and, consequently, good mechanical properties (Fig. 5). The values of mean and standard deviation for groups Z250M20s, Z250M40s, ONEM20s, ONEM40s, OPUM20s, OPUM40s, BFM20s and BFM40s respectively were found: 0.90 (± 0.04); 0.95 (± 0.06); 0.93 (± 0.13); 0.95 (± 0.05); 0.87 (± 0.09); 0.86 (± 0.05) 0.93 (± 0.04); 0.92 (± 0.04). In contrast, in S groups all resin composites presented values of RH below 0.8, indicating poor DC and depth of cure (Fig. 6). Comparing all groups, higher results can be seen in all groups for Bulk Flow (BFS20s and BFS40s) and One Bulk (ONES20s and ONES40s). The following values of mean and standard deviation were found for groups BFS 20s, BFS40s, ONES20s and ONES40s respectively: 0.70 (± 0.12); 0.72 (± 0.09); 0.65 (± 0.05); 0.71 (± 0.06), but no statistical difference was seen to group Z250S40s that presented the results 0.63 (± 0.05). Groups Z250S20s and OPUS20s presented the worst values with 0.39 (± 0.08) and 0.47 (± 0.04), respectively. Group OPUS40s had intermediate values with 0.57 (± 0.05), but no statistical difference was found to groups Z250S40s and ONES20s.

DISCUSSION

The null hypotheses tested were rejected. It was detected difference in the efficiency of polymerization between the resins, at the different times and different distances evaluated.

Since their introduction, RBCs have become very popular and eventually considered universal materials, being the first choice for direct restorations in anterior and posterior teeth.^{11,12} The esthetic characteristics of matching the natural tooth color, ability to be bonded to tooth tissues, reduced need of tooth removal and the low cost compared to indirect materials are some of the reasons for the great popularity of RBCs. Many of them are introduced into the market each year to restore posterior teeth, claiming improved properties

and presenting innovations in organic and inorganic components. The main concern for a clinically effective and durable RBC restoration is to maintain tight tooth restoration margins,^{13,14} keeping attention to the cervical margins in cases of class II cavities. Class II restorations appear to be more prone to the development of secondary caries when compared to class I restorations.¹⁵

The type of RBC, the cavity and restorative procedure can influence the formation of gaps, affecting negatively the restoration.¹⁶ Shrinkage stress is a result of polymerization shrinkage of RBCs under conditions of constraint, created by bonding to cavity walls and has been associated to some clinical complications like cuspal deflection, interfacial debonding and post-operative sensitivity.¹⁷ The clinical management of the polymerization shrinkage stress in direct light curing composite depends on many parameters which involves resin composite volumetric shrinkage, material stiffness (elastic modulus), DC¹⁸ and also largely determined by the time-dependent visco-elastic properties of the material, defined by flow capacity in early stages of the polymerization reaction and elastic modulus development during polymer network formation.¹⁹

In order to evaluate the maximum increment thickness of RBCs that guarantees efficient polymerization, researchers have referred to the depth of cure²⁰⁻²² and DC measurements.^{23,24} Among several techniques, microhardness has been already proved to be the best indicator of the extent of polymerization in materials and the most frequently method performed by a lot of studies,²⁶ being an indirect way to measure DC.²⁵ Higher values of hardness typically result in color stability, elastic modulus including positive effect in biocompatibility,²⁷ water sorption²⁶ and solubility of the resin. Usually, the Knoop indenter test is the most commonly method indicated to evaluate polymeric materials, such as resin composites, and is more sensitive to surface characteristics of the material.²⁸

Measuring the hardness also has been already proved to be the best indicator of the extent of polymerization in RBCs²⁵ and has been used as an indirect method to assess the depth of cure with a value of 80% as a parameter for sufficient curing^{21,25,29,30} that could be calculated by relative hardness, which is indicative of the depth of cure.

A new generation of material has been introduced, the BFCs. Some of them are indicated for use in posterior restorations while others are used for base materials under posterior composites. Manufacturers and a few reports indicate that BFCs provide reduced or relieved interfacial polymerization contraction stresses. Furthermore, materials can be applied and light cured in bigger increments, leading to reduced restorative procedure time, minimized contamination and improved quality of the final restoration.^{29,31,32} Several BFCs are currently on the market, including low- and high- viscosity formulations. Each BFC adopts different strategies to achieve high light transmission and flowability.

Generally, flow viscosity BFCs present low filler content to increase flowability. BFCs revealed to present similar values of flexural strength like the class of nanohybrid and microhybrid resins⁸ and a similar marginal sealing quality of BFCs and RBCs was observed that can be explained by previous reports³¹⁻³³ indicating reduced polymerization shrinkage stresses²⁹ and consequently improved marginal behavior of BFCs. Other study³⁴ showed that simplified restorations with high-viscosity BFCs achieve an internal and a marginal adaptation comparable to incremental technique with a conventional one. In one systematic review and meta-analysis³⁵ was revealed that the clinical performance of BFCs and RBCs in posterior direct restorations was similar within a follow-up period of 12 to 72 months.

In the M group of this study, which the photoactivation was performed directly on the resin, a positive uniformity was observed for all samples because no statistical difference was detected between them. Differently in the S group, which the photoactivation was performed through the slot preparation touching on the cuspid, that was already expected.

Some resins presented greater and more reliable relative hardness ratios even though not reaching the value of 0.8 or 80% in percentage which is difficult to achieve in slot cavities because of their restricted layouts, indicating that, in these cases, it's fundamental to increase the time of photoactivation and power of the photoactivator but with caution in dental practice, because delivering high radiant exposure (above 80J/cm²) to teeth, without recovery periods could induce a pulp temperature rise upward the acceptable (5.5°C).³⁶ Variations in pulp temperature rise have been associated to higher radiant exposures and exposure times than to the light beam profile itself^{37,38} and in association with the exothermic reaction of resin composite polymerization, this might contribute to potential damage.³⁹

In deep and larger cavities we still have doubts in relation to increment thickness of some resins, depth of cure and the micromechanical properties were shown to remain constant within a 4mm layer at an irradiation time of up to 20 seconds,²³ which is the most used time for clinicians in dental practice. But in the cases of deep cavities we still have doubts about whether or not there was adequate polymerization in the first increment of inserted resin, which is responsible for the cervical sealing. The photoactivation is damaged by a lower light intensity reaching the bottom of the cavity and the diameter of the photoactivator tip is often bigger than the opening of the cavity, invalidating the closest contact of the tip with the resin.

So, it's indispensable to pay attention to the time of photoactivation to ensure that the resin located more gingivally reaches a greater DC and the power of the photoactivator, allowing a sufficient amount of photons arriving in the bottom of the cavity for adequate polymerization,⁴⁰ since as long as the photoactivator tip is distanced from the region to be polymerized in the cavity, there is divergence of light by reducing the number of photons that reach the surface of the restorative material.⁴¹ Delivery of adequate irradiance (mW/cm²) at the correct wavelengths for an appropriate period of time and from a suitable position is required to optimize curing results.⁴⁰ In cases of curing adhesives in deep proximal boxes with

a curing light of 600 mW/cm², the time should be increased to 40 to 60 seconds to ensure optimal polymerization, even for curing lights that deliver more than 1.000 mW/cm².⁴²

In the present study, the irradiance of 1.000mW/ cm² and the times of photoactivation 20 and 40 seconds were studied, the values of RH ratios for Filtek Bulk Fill Flow (0.70-20s;0.72-40s) and Filtek One Bulk (0.65-20s;0.71-40s) didn't present differences between the times, indicating that we can photoactivate a 2mm increment in a proximal slot with the irradiance studied for 20 seconds. In contrast, we should choose the time of 40 seconds for resins Opus Bulk Fill (0.47-20s;0.57-40s) and Z250XT (0.39-20s;0.63-40s). In general, low-viscosities BFCs perform better polymerization efficiency compared to the high-viscosities formulations²⁶ and can be used as an intermediate in class II cavities to absorb polymerization contraction stresses⁴³ as well can be an alternative to packable conventional BFCs.¹⁶ One studie⁴⁴ supported the idea that BFCs evaluated with high- and low- viscosity generate similar or lower stress values when compared to a high-viscosity conventional resin as control and contract less during polymerization, developing lower shrinkage forces compared with their conventional flowable and high-viscosity counterparts.

Reduced amount of organic matrix and low force rate showed the most favorable shrinkage force characteristics, which supports their use for restoring high C-factor posterior cavities.⁴⁵ Lot of studies with resin SureFil SDRFlow, shows that SDR demonstrated better DC, similar microhardness and incidence of polymerization shrinkage stress in deeper layers when compared to Z250XT.⁴⁶ It was exposed in this study that Filtek Bulk Fill Flow showed better results for RH ratios compared to other materials, suggesting better marginal behavior to Filtek One Bulk too that didn't have a statistical difference. Despite being an innovation in dental market, manufacturers of Filtek One Bulk resin ensure better mechanical properties, sufficient depth of cure and better esthetic results without the need of coverage with another conventional resin. According to the results of this study, it was shown that some BFCs can

be used safely in clinical situation of class II cavities in terms of microhardness and DC improving cervical sealing. Bulk Flow and One Bulk can be promising in clinical practices besides decreasing the procedure time in the dental office, however some limitations in this in vitro study can be seen like the use of only one photoactivator and one selected irradiance. More in vivo studies like coloring tests should be done to analyse cervical sealing and other aspects related to the long-term success of restorations with those resins better supporting the use of these materials.

CONCLUSIONS

Under the circumstances of this investigation, it was concluded that it is beneficial to increase the photoactivation time from 20 to 40 seconds in increments with 2mm for the Z250XT and Bulk FGM resins in class 2 proximal slot restorations to ensure adequate hardening.

REFERENCES

1. Cenci M, Demarco F & de Carvalho R. (2005) Class II composite resin restorations with two polymerization techniques: relationship between microtensile bond strength and marginal leakage *Journal of Dentistry* **33**(7) 603–610.
 2. Demarco FF, Collares K, Correa MB, Cenci MS, Moraes RR & Opdam NJ (2017) Should my composite restorations last forever? Why are they failing? *Brazilian Oral Research* **31**(1) e56, <http://dx.doi.org/10.1590/1807-3107bor-2017.vol31.0056>.
 3. Ilie N, Keßler A & Durner J (2013) Influence of various irradiation processes on the mechanical properties and polymerisation kinetics of bulk-fill resin based composites. *Journal of Dentistry* **41**(8) 695–702, <http://dx.doi.org/10.1016/j.jdent.2013.05.008>.
 4. El Gezawi MF & Al-Harbi FA (2012) Reliability of bonded MOD restorations in maxillary premolars: Microleakage and cusp fracture resistance *Acta Stomatologica Croatica* **46**(1) 31-42.
 5. Fabianelli A (2004) A study into the significance of tracing microleakage by color die infiltration. *Dental Materials and Clinical Applications University of Siena School of Dental Medicine*, <http://dx.doi.org/10.13140/RG.2.2.13234.20164>.
 6. El-Mowafy OM, El-Badrawy WA, Wasef M, Omar H & Kermanshahi S. (2007) Efficacy of new LED light-curing units in hardening of Class 2 composite restorations *Journal of the Canadian Dental Association* **73**(3) 253-258.
 7. Sakaguchi RL, Douglas WH & Peters MC (1992) Curing light performance and polymerization of composite restorative materials. *Journal of Dentistry* **20**(3)183-188, [https://dx.doi.org/10.1016/0300-5712\(92\)90136-Z](https://dx.doi.org/10.1016/0300-5712(92)90136-Z).
 8. Ilie N, Bucuta S & Draenert M (2013) Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. *Operative Dentistry* **38**(6) 618–625, <http://dx.doi.org/10.2341/12-395-L>.
-

9. Bucuta S & Ilie N. (2014) Light transmittance and micro-mechanical properties of bulk fill vs. conventional resin based composites. *Clinical Oral Investigations* **18(8)** 1991-2000, <http://dx.doi.org/10.1007/s00784-013-1177-y>.
 10. Camargo EJ, Moreschi E, Baseggio W, Cury JA & Pascotto RC (2009) Composite depth of cure using four Polymerization techniques. *Journal of Applied Oral Science* **17(5)** 446-450.
 11. Correa MB, Peres MA, Peres KG, Horta BL, Barros AD & Demarco FF (2012) Amalgam or composite resin? Factors influencing the choice of restorative material. *Journal of Dentistry* **40(9)** 703-710, <http://dx.doi.org/10.1016/j.jdent.2012.04.020>.
 12. Nascimento GG, Correa MB, Opdam N & Demarco FF (2013) Do clinical experience time and postgraduate training influence the choice of materials for posterior restorations? Results of a survey with Brazilian general dentists. *Brazilian Dental Journal* **24(6)** 642-646, <http://dx.doi.org/10.1590/0103-6440201302361>.
 13. Van Meerbeek B, Peumans M, Poitevin A, Mine A, Van Ende A, Neves A & De Munck J (2010) Relationship between bond-strength tests and clinical outcomes *Dental Materials* **26(2)** e100-e121.
 14. De Munck J, Van Landuyt K, Peumans M, Poitevin A, Lambrechts P, Braem M & Van Meerbeek B (2005) A critical review of the durability of adhesion to tooth tissue: Methods and results *Journal of Dental Research* **84(2)** 118-132.
 15. Nedeljkovic I, Teughels W, De Munck J, Van Meerbeek B & Van Landuyt KL (2015) Is secondary caries with composites a material-based problem? *Dental Materials* **31(11)** e247–e277, <http://dx.doi.org/10.1016/j.dental.2015.09.001>.
 16. Peutzfeldt A, Muhlebach S, Lussi A & Flury S (2018) Marginal gap formation in approximal “bulk fill” resin composite restorations after artificial ageing. *Operative Dentistry* **43(2)** 180-189.
-

17. Ferracane JL (2011) Resin composite-state of the art. *Dental Materials* **27(1)** 29–38, <http://dx.doi.org/10.1016/j.dental.2010.10.020>.
 18. Gregor L, Bortolotto T, Feilzer AJ & Krejci I (2013) Shrinkage kinetics of a methacrylate- and a silorane-based resin composite: Effect on marginal integrity. *The Journal of Adhesive Dentistry* **15(3)** 245-250, <http://dx.doi.org/10.3290/j.jad.a28603>.
 19. Braga RR, Ballester RY & Ferracane JL (2005) Factors involved in the development of polymerization shrinkage stress in resin-composites: a systematic review *Dental Materials* **21(10)** 962–970.
 20. Garoushi S, Silynoja E, Vallittu PK & Lassila L (2013) Physical properties and depth of cure of a new short fiber reinforced composite. *Dental Materials* **29(8)** 835-841, <http://dx.doi.org/10.1016/j.dental.2013.04.016>.
 21. Flury S, Hayoz S, Peutzfeldt A, Hsler J & Lussi A (2012) Depth of cure of resin composites: is the ISO 4049 method suitable for bulk fill materials? *Dental Materials* **28(5)** 521-528, <http://dx.doi.org/10.1016/j.dental.2012.02.002>.
 22. Kusgoz A, lker M, Yesilyurt C, Yoldas OH, Ozil M & Tanriver M (2011) Silorane-based composite: depth of cure, surfasse hardness, degree of conversion, and cervical microleakage in Class II cavities. *Journal of Esthetic and Restorative Dentistry* **23(5)** 324-335, <http://dx.doi.org/10.1111/j.1708-8240.2011.00411.x>.
 23. Czasch P & Ilie N (2013) In vitro comparison of mechanical properties and degree of cure of bulk ll composites. *Clinical Oral Investigations* **17(1)** 227-235, <http://dx.doi.org/10.1007/s00784-012-0702-8>.
 24. Leprince JG, Palin WM, Hadis MA, Devaux J & Leloup G (2013) Progress in dimethacrylate-based dental composite technology and curing efficiency. *Dental Materials* **29(2)** 139-156, <http://dx.doi.org/10.1016/j.dental.2012.11.005>.
-

25. Rueggeberg FA & Craig RG (1988) Correlation of parameters used to estimate monomer conversion in a light-cured composite. *Journal of Dental Research* **67(6)** 932-937, <http://dx.doi.org/10.1177/00220345880670060801>.
 26. Reis AF, Vestphal M, do Amaral RC, Rodrigues JA, Roulet JF & Roscoe MG (2017) Efficiency of polymerization of bulk-fill composite resins: a systematic review. *Brazilian Oral Research* **31(1)** e59, <http://dx.doi.org/10.1590/1807-3107BOR-2017>.
 27. Krifka S, Seidenader C, Hiller KA, Schmalz G & Schweikl H (2012) Oxidative stress and cytotoxicity generated by dental composites in human pulp cells. *Clinical Oral Investigations* **16(1)** 215-224, <http://dx.doi.org/10.1007/s00784-010-0508-5>.
 28. Wang L, D'Alpino PHP, Lopes LG & Pereira JC (2003) Mechanical properties of dental restorative materials: relative contribution of laboratory tests. *Journal of Applied Oral Science* **11(3)** 162-167, <http://dx.doi.org/10.1590/S1678-77572003000300002>.
 29. El-Damanhoury H & Platt J (2014) Polymerization shrinkage stress kinetics and related properties of bulk-fill resin composites. *Operative Dentistry* **39(4)** 374-382, <http://dx.doi.org/10.2341/13-017-L>.
 30. Alrahlah A, Silikas N & Watts DC (2014) Post-cure depth of bulk fill dental resin-composites. *Dental Materials* **30(2)** 149-154, <http://dx.doi.org/10.1016/j.dental.2013.10.011>.
 31. Roggendorf MJ, Kramer N, Appelt A, Naumann M & Frankenberger R (2011) Marginal quality of flowable 4-mm base vs. conventionally layered resin composite. *Journal of Dentistry* **39(10)** 643-647, <http://dx.doi.org/10.1016/j.jdent.2011.07.004>.
 32. Moorthy A, Hogg CH, Dowling AH, Grufferty BF, Benetti AR & Fleming GJ (2012) Cuspal deflection and microleakage in premolar teeth restored with bulk-fill flowable resin-based composite base materials. *Journal of Dentistry* **40(6)** 500-505, <http://dx.doi.org/10.1016/j.jdent.2012.02.015>.
-

33. Heintze SD & Rousson V (2012) Clinical effectiveness of direct class II restorations-A meta-analysis. *Journal of Adhesive Dentistry* **14(5)** 407-431, <http://dx.doi.org/10.3290/j.jad.a28390>.
 34. Haak R, Näge T, Park KJ, Ziebolz D, Krause F & Schneider H (2018) Internal and marginal adaptation of high-viscosity bulk-fill composites in class II cavities placed with different adhesive strategies. *Odontology*, <http://dx.doi.org/10.1007/s10266-018-0402->.
 35. Veloso SR, Lemos CA, Moraes SL, Egito Vasconcelos BC, Pellizzer EP & Melo Monteiro GQ (2019) Clinical performance of bulk-fill and conventional resin composite restorations in posterior teeth: a systematic review and meta-analysis. *Clinical Oral Investigations* **23(1)** 221-233, <http://dx.doi.org/10.1007/s00784-018-2429-7>.
 36. Vinagre A, Ramos JC, Rebelo C, Basto JF, Messias A, Alberto N, Nogueira R (2019) Pulp Temperature Rise Induced by Light-Emitting Diode Light-Curing Units Using an Ex Vivo Model *Materials* **12(3)**, <http://dx.doi.org/10.3390/ma12030411>.
 37. Mouhat M, Mercer J, Stangvaltaite L, Ortengren U (2017) Light-curing units used in dentistry: Factors associated with heat development-potential risk for patients *Clinical Oral Investigations* **21(5)** 1687-1696.
 38. Kim MJ, Kim RJ, Ferracane J, Lee IB (2017) Thermographic analysis of the effect of composite type, layering method, and curing light on the temperature rise of photo-cured composites in tooth cavities *Dental Materials* **33(10)** e373-e383.
 39. Vinall CV, Garcia-Silva TC, Lou JSB, Wells MH, Tantbirojn D, Versluis A Intrapulpal Temperature Rise During Light Activation of Restorative Composites in a Primary Molar (2017) *Pediatric Dentistry* **39 (3)** 125-130.
-

40. Karacolak G, Turkun LS, Boyacioglu H & Ferracane JL (2018) Influence of increment thickness on radiant energy and microhardness of bulkfill resin composites. *Dental Materials Journal* **37(2)** 206–213, <http://dx.doi.org/10.4012/dmj.2017-032>.
 41. Price R, Dérand T, Sedarous, Andreou P & Loney R (2000) Effect of distance on the power density from two light guides *Journal of Esthetic Dentistry* **12(6)** 320-327.
 42. Rueggeberg F, Giannini M, Arrais CAG & Price RBT (2017) Light curing in dentistry and clinical implications: A literature review. *Brazilian Oral Research* **31(1)** e61, <http://dx.doi.org/10.1590/1807-3107BOR-2017.vol31.0061>.
 43. de Mattos Pimenta Vidal C, Pavan S, Briso AL & Bedran- Russo AK (2013) Effects of three restorative techniques in the bond strength and nanoleakage at gingival wall of class II restorations subjected to simulated aging. *Clinical Oral Investigations* **17(2)** 627-633, <http://dx.doi.org/10.1007/s00784-012-0748-7>.
 44. Rizzante FAP, Mondelli RFL, Furuse AY, Borges AFS, Mendonça G & Ishikiriyama SK (2019) Shrinkage stress and elastic modulus assessment of bulk-fill composites. *Journal of Applied Oral Science* **27 (e20180132)**, <http://dx.doi.org/10.1590/1678-7757-2018-0132>.
 45. Auböck TT, Jäger F & Attin T (2018) Polymerization shrinkage and shrinkage force kinetics of high and low-viscosity dimethacrylate- and ormocer-based bulk-fill resin composites. *Odontology*, <http://dx.doi.org/10.1007/s10266-018-0369-y>.
 46. Pereira R, Giorgi C, Lins R, Theobaldo J, Lima D, Marchi GM & Aguiar F (2018) Physical and photoelastic properties of bulk-fill and conventional composites. *Clinical, Cosmetic and Investigational Dentistry* **10** 287-296. <http://dx.doi.org/10.2147/CCIDE.S184660>.
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SUPPLEMENTAL MATERIAL

Fig.1. Bipartite matrix with 2mm of height.

Fig 2. Photoactivation on M groups.

Fig.3. Range tooth + metal matrix with Tofflemire + black paper (A) and Photoactivation on S groups (B).

Fig.4. Microdurometer Micromet 6040.

Fig 5. Results of Tukey's multiple comparisons for M Group in Relative Harness (%).

Fig 6. Results of Tukey's multiple comparisons for S Group in Relative Harness (%).

Fig 1

Fig 2

Fig 3

A

B

Fig 4

Fig 5

Fig 6

Table 1: Materials used in this study.

Material/ Manufacturer	Lot Number/ Shade	Matrix composition- Filler Type/ Content (%)	Description
Filtek Z250XT/ 3M ESPE	911387/ A3	BisGMA,BisEMA, UDMA, TEGDMA, Zirconia/ Silica (82% by weight/ 68% by volume)	Microhybrid resin for direct restorations on anterior and posterior teeth in Classes I, II, III, IV and V, including occlusal surfaces
Filtek One Bulk Fill/ 3M ESPE	4868/ A3	AUDMA, AFM, DDDMA and UDMA (76,5% by weight and/ 58,4% by volume)	Bulk-Fill resin composite material that can be inserted into cavities up to 5 mm in a single step. No additional coverage layer required is required
Filtek Bulk Fill Flow/ 3M ESPE	4862/ A3	BisGMA, BisEMA, TEGDMA, Procrylat and UDMA (64,5% by weight/ 42,5% by volume)	A bulk-fill flowable composite base material that allows the insertion of a single increment of up to 4 mm
Opus Bulk Fill/ FGM	070817,251017/ A3	Uretanadimetacrylic monomers, stabilizers, photoinitiators, co- initiators, silica, stabilizers and pigments (79% by weight)	A bulk-fill resin composite material indicated for direct restorations in posterior or anterior teeth (permanent and deciduous) in increments up to 5mm, including occlusal surface

Table 2: Groups belonging to this study.

Groups	Resin Composite	Time of Photoactivation (seconds)
Z250M20s	Z250XT	20
Z250M40s	Z250XT	40
ONEM20s	One Bulk Fill	20
ONEM40s	One Bulk Fill	40
OPUM20s	Opus Bulk Fill	20
OPUM40s	Opus Bulk Fill	40
BFM20s	Bulk Fill Flow	20
BFM40s	Bulk Fill Flow	40
Z250S20s	Z250XT	20
Z250S40s	Z250XT	40
ONES20s	One Bulk Fill	20
ONES40s	One Bulk Fill	40
OPUS20s	Opus Bulk Fill	20
OPUS40s	Opus Bulk Fill	40
BFS20s	Bulk Fill Flow	20
BFS40s	Bulk Fill Flow	40

Table 3: Values of Mean (M) and Standard Deviation (SD) of all groups in Relative Hardness.

		Z250XT	Filtek One Bulk-Fill	Opus Bulk-Fill	Filtek Bulk-Fill Flow
Material	20s	0.9 (± 0.04)	0.93 (± 0.13)	0.87 (± 0.09)	0.93 (± 0.04)
	40s	0.95 (± 0.06)	0.95 (± 0.05)	0.86 (± 0.05)	0.92 (± 0.04)
Slot	20s	0.39 (± 0.08)	0.65 (± 0.05)	0.47 (± 0.04)	0.70 (± 0.12)
	40s	0.63 (± 0.05)	0.71 (± 0.06)	0.57 (± 0.05)	0.72 (± 0.09)

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3 DISCUSSION

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Despite the fact that amalgam and RBC are considered applicable for restoring Class I and Class II cavities, some advantages can be related to the second one such as better esthetic, their adhesive properties, resulting in reduced preparation size⁷ and reinforcement of the remaining dental structure⁸. However, amalgam is facing its demise, leaving RBCs as the most likely material for posterior restorations for widespread use in the near future. No “ideal” material has been developed until now,²³ so a strong challenge for RBCs is their questionable adaptability to cavity walls and margins besides the pre-disposition to marginal infiltration of posterior teeth that is due to the inherent of polymerization shrinkage, contraction stresses, the imbalance in the coefficients of thermal expansion, in the modulus of elasticity and the long-term chemical instability of the restorative material, resulting in secondary caries and bacterial invasion, affecting negatively clinical longevity.^{11,13,32} Thus, whether or not marginal gaps are formed and the extent to which gaps are formed depend on an interplay between multiple factors^{17,29}, some related to the RBC, others related to the specific cavity and restorative procedure. Generally, higher polymerization shrinkage increase gap formation and in cases of lower elastic modulus occur the opposite effect.³⁹

Contraction stresses that occur at tooth-restoration interfaces interfere in effective adhesive bonds to tooth structure and marginal sealing of direct composite restorations. Different resin adhesives, placement techniques, and RBCs have been suggested to improve the clinical reliability, to control the effect of polymerization shrinkage stresses.^{9,11,29,36} To guarantee the penetration of the curing light deeply enough to complete curing of RBCs⁴⁴ and to reduce stress at the cavity wall interface and, consequently, a lower gap formation at the interface,^{4,33,43} the technique most used and imposed for years is the “Incremental Technique”, which employs the insertion of increments with a maximum of 2mm thickness in the cavity to be restored. Appropriate light-curing is fundamental for RBCs to present satisfactory mechanical properties, providing greater clinical longevity to restoration.^{1,3} In cases of Class II composite restorations, it’s particularly important the use of a longer curing cycle for light-cure and a thorough polymerization of the increment to achieve

sufficient polymerization in the cervical area, avoiding recurrent caries.¹⁵ In this study, an irradiance of 1.000mW/cm² and the exposure times of 20 and 40 seconds were evaluated, indicating that these times are sufficient to some material and not for others. However, dentists still spend a significant amount of time replacing restorations, contributing to the repetitive restorative cycle described by Elderton¹⁴ and, unfortunately, the treatment of extensive posterior restorations with RBCs can be time-consuming,²⁰ leaving to the manufacturers the mission to reduce clinical time and facilitate the insertion in the cavity to be restored with bigger increments and better elaborated properties.

BFCs have been designed to simplify the restorative technique because they can be placed into posterior cavities with an unique increment of 4 to 5mm, simplifying the restoration of deep cavities.^{10,18,19} Among their characteristics, greater translucency allows high light dissipation, incorporation of more reactive photoinitiators enables a better depth of cure, monomers that achieve low polymerization shrinkage and greater degree of conversion (DC) through changes in the organic matrix composition of these materials,^{16,20,21,30,41} being essential to obtain satisfactory mechanical properties and longevity of the restorations.^{24,31} These materials present lower filler load than conventional microhybrid or nanohybrid resins and are used as a base followed by capping with a conventional one. Although, there are currently resins on the market that do not require the coverage of a conventional resin such as Filtek One Bulk.

This operative procedures simplification is quite desirable for clinicians and an alternative for posterior restorations because their viscosity that allows to be used in reconstruction of the lost tooth tissue, including areas of high masticatory load.^{5,12,35,46,48} According to some studies, BFCs present very heterogeneous behavior related to their composition besides equal or lower shrinkage stress, even for bigger increments, demonstrating a great capability of BFCs in dealing with this concern^{26,41} as well being non-toxic,²³ and perform just as conventional nanohybrid and microhybrid composites.³⁷

In an attempt to evaluate the maximum increment thickness of RBCs that guarantee efficient polymerization, researchers have referred to depth of cure^{18,22,28}

and DC measurements.^{10,29} Among several laboratory tests, microhardness is the most frequently method.⁴⁰ It was shown that the stress level in the tooth tissue decreases with increasing of the values of restored material stiffness.⁴⁹ The evaluation of hardness ratio between bottom and top surface in samples provides an accurate and simple method of assessing the efficacy of photoinitiation strategies, determining DC.⁶ Relative hardness (RH) has been an applicable method and the percentage of 80% is a reference for resins which reached a great depth of cure and, consequently, good mechanical properties. However, this value is hard to reach in cases of proximal slot, where the opening of the cavity is not favorable and the first increment to be photopolymerized is far from the tip of the photoactivator, reducing the amount of photons arriving in the deepest region. That's the reason why some of them are able to reach a degree of conversion high enough for clinical application. In studies, high-intensity LED curing (1.600 mW/cm²) was used to provide a greater DC to increase the challenging polymerization shrinkage stresses.^{25,27} However it's essential to be aware of the damages that a high-intensity and long periods of exposures could cause to dental pulp.⁴²

It's important for all clinicians to find the balance between the emitted irradiance and the photoactivation time to avoid an injury to the tooth but at the same time achieve efficient polymerization of the resin. Usually, dentists use the time of 20 seconds, but according to results of this study it would not be sufficient for RBC Z250XT and BFC Opus Bulk Fill, which had significantly lowest RH ratios of 0.39 and 0.47 respectively compared to 40 seconds (0.63 and 0.57), causing a sub-polymerization, lower DC, poor mechanical properties and, probably, a shorter clinical longevity compared to M groups that presented acceptable values for all 4 materials. In contrast, BFCs Bulk Flow and One Bulk presented higher RHs ratios using both 20s (0.70 and 0.65) and 40s polymerization times (0.72 and 0.71), respectively, indicating that it's adequate to photoactivate those resins during both times and, possibly, reach better cervical sealing in class II restorations with clinical longevity. Nevertheless, more clinical researches are needed to confirm the validity of these results.

4 FINAL CONSIDERATIONS

4 FINAL CONSIDERATIONS

Within the limitations of this in vitro study, it was concluded that the most used photoactivation time will not always result in efficient polymerization of the most critical interface, responsible for the proximal boxes cervical sealing in class II restorations, being necessary to increase this time from 20 to 40 seconds in cases of resin composites Z250XT and Opus Bulk Fill in order to ensure clinical longevity and improve mechanical properties. In contrast, some can be photoactivated by the two times, which is the case of Filtek Bulk Fill Flow and Filtek One Bulk. Future in vivo long-term studies should evaluate the clinical performance of these materials.

REFERENCES

REFERENCES

1. Aguiar FH, Andrade KR, Leite Lima DA, Ambrosano GM, Lovadino JR. Influence of light curing and sample thickness on microhardness of a composite resin. *Clin Cosmet Investig Dent* 2009; 1:21-5.
 2. Al-Harbi F, Kaisarly D, Bader D, El Gezawi M. Marginal Integrity of Bulk Versus Incremental Fill Class II Composite Restorations. *Oper Dent* 2016; 41: 146-56.
 3. Alqahtani MQ, Michaud PL, Sullivan B, Labrie D, Alshaafi MM, Price RB. Effect of high irradiance on depth of cure of a conventional and a bulk fill resin-based composite. *Oper Dent* 2015; 40:662-72.
 4. Alrahlah A, Silikas N, Watts DC. Post-cure depth of cure of bulk fill dental resin composites. *Dent Mater* 2014; 30:149-54.
 5. Alshali RZ, Silikas N, Satterthwaite JD. Degree of conversion of bulk-fill compared to conventional resin-composites at two time intervals. *Dent Mater* 2013; 29:e213-7.
 6. Bouschlicher MR, Rueggeberg FA, Wilson BM. Correlation of bottom to top surface microhardness and conversion ratios for a variety of resin composite compositions. *Oper Dent* 2004; 29:698-704.
 7. Cenci M, Demarco F, de Carvalho R. Class II composite resin restorations with two polymerization techniques: relationship between microtensile bond strength and marginal leakage. *J Dent* 2005; 33:603-10.
 8. Coelho-De-Souza FH, Camacho GB, Demarco FF, Powers JM. Fracture resistance and gap formation of MOD restorations: influence of restorative technique, bevel preparation and water storage. *Oper Dent* 2008; 33:37-43.
-

9. Cramer NB, Stansbury JW, & Bowman CN. Recent advances and developments in composite dental restorative materials. *J Dent Res* 2011; 90: 402-416.
 10. Czasch P, Ilie N. In vitro comparison of mechanical properties and degree of cure of bulk fill composites. *Clin Oral Investig* 2013; 17:227-35.
 11. Demarco FF, Corrêa MB, Cenci MS, Moraes RR, Opdam NJM. Longevity of posterior composite restorations: not only a matter of materials. *Dent Mater* 2012; 28:87-101.
 12. Didem A, Gözde Y, Nurhan Ö. Comparative mechanical properties of bulk-fill resins. *Open. J Compos Mater* 2014; 4:117-21.
 13. Drummond JL. Degradation, fatigue, and failure of resin dental composite materials. *J Dent Res* 2008; 87:710-19.
 14. Elderton RJ. Restorations without conventional cavity preparations. *Int Dent J* 1988; 38:112–8.
 15. El-Mowafy OM, El-Badrawy WA, Wasef M, Omar H, Kermanshahi S. Efficacy of new LED light-curing units in hardening of Class 2 composite restorations. *J Can Dent Assoc* 2007; 73:253-58.
 16. El-Safty S, Akhtar R, Silikas N, Watts DC. Nanomechanical properties of dental resin-composites. *Dent Mater* 2012; 28:1292-1300.
 17. Feilzer AJ, De Gee AJ, Davidson CL. Setting stress in composite resin in relation to configuration of the restoration. *Journal of Dental Research* 1987; 66:1636-39.
 18. 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; 28:521-28.
-

19. Flury S, Peutzfeldt A, Lussi A. Influence of increment thickness on microhardness and dentin bond strength of bulk fill resin composites. *Dent Mater* 2014; 30:1104-12.
 20. Fronza BM, Ayres A, Pacheco RR, Rueggeberg FA, Dias C, Giannini M. Characterization of inorganic filler content, mechanical properties, and light transmission of bulk-fill resin composites. *Oper Dent* 2017; 42:445-55.
 21. Fronza BM, Rueggeberg FA, Braga RR, Mogilevych B, Soares LES, Martin AA, Ambrosano G, Giannini M. Monomer conversion, microhardness, internal marginal adaptation, and shrinkage stress of bulk-fill resin composites. *Dent Mater* 2015; 31:1542-51.
 22. Garoushi S, Säilynoja E, Vallittu PK, Lassila L. Physical properties and depth of cure of a new short fiber reinforced composite. *Dent Mater* 2013; 29:835-41.
 23. Gonçalves F, Campos LM, Rodrigues-Júnior EC, Costa FV, Marques PA, Francci CE, Braga RR, Boaro LCC. A comparative study of bulk-fill composites: degree of conversion, post-gel shrinkage and cytotoxicity. *Braz Oral Res* 2018; 32:e17.
 24. Ibarra ET, LienW, Casey J, Dixon SA, Vandewalle KS. Physical properties of a new sonically placed composite resin restorative material. *Gen Dent* 2015; 63:51-56.
 25. Ilie N, Bucuta S, Draenert M. Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. *Oper Dent* 2013; 38:618-25.
 26. Kim RJ, Kim YJ, Choi NS, Lee IB. Polymerization shrinkage, modulus, and shrinkage stress related to tooth-restoration interfacial debonding in bulk-fill composites. *J Dent* 2015; 43:430-9.
 27. Kramer N, Lohbauer U, Garcia-Godoy F, Frankenberger R. Light curing of resin-based composites in the LED era. *Am J Dent* 2008; 21:135-42.
-

28. Kusgoz A, Ülker M, Yesilyurt C, Yoldas OH, Ozil M, Tanriver M. Silorane-based composite: depth of cure, surfasse hardness, degree of conversion, and cervical microleakage in Class II cavities. *J Esthet Restor Dent* 2011; 23:324-35.
 29. Leprince JG, Palin WM, Hadis MA, Devaux J, Leloup G. Progress in dimethacrylate-based dental composite technology and curing efficiency *Dent Mater* 2013; 29:139-56.
 30. Leprince JG, Palin WM, Vanacker J, Sabbagh J, Devaux J, Leloup G. Physico-mechanical characteristics of commercially available bulk-fill composites. *J Dent* 2014; 42:993–1000.
 31. Li X, Pongprueksa P, Van Meerbeek B, De Munck J. Curing profile of bulk-fill resin-based composites. *J Dent* 2015; 43:664-72.
 32. Liu Y, Tjaderhane L, Breschi L, Mazzoni A, Li N, Mao J, Pashley DH, Tay FR. Limitations in bonding to dentin and experimental strategies to prevent bond degradation. *J Dent Res* 2011; 90:953-68.
 33. Lopes GC, Baratieri LN, Monteiro S, Vieira LCC. Effect of posterior resin composite placement technique on the resin–dentin interface formed in vivo. *Quintessence* 2004; 35:156-61.
 34. Malhotra N, Mala K, Acharya S. Resin-based composite as a direct esthetic restorative material. *Compend Contin Educ Dent* 2011; 32:14-23.
 35. Miletic V, Peric D, Milosevic M, Manojlovic D, Mitrovic N. Local deformation fields and marginal integrity of sculptable bulkfill, low-shrinkage and conventional composites. *Dent Mater* 2016; 32:1441-51.
 36. Pallesen U, Van Dijken JW, Halken J, Hallonsten AL, Hoigaard R. Longevity of posterior resin composite restorations in permanent teeth in Public Dental Health Service: A prospective 8 years follow up. *J Dent* 2013; 41:297-306.
-

37. Pereira R, Giorgi C, Lins R, Theobaldo J, Lima D, Marchi GM, Aguiar F. Physical and photoelastic properties of bulk-fill and conventional composites. *Clin, Cosmet and Investig Dent* 2018; 10:287-96.
 38. Park J, Chang J, Ferracane J, Lee IB. How should composite be layered to reduce shrinkage stress: incremental or bulk filling? *Dent Mater* 2008; 24:1501-5.
 39. Peutzfeldt A, Muhlebach S, Lussi A, Flury S. Marginal gap formation in approximal "bulk fill" resin composite restorations after artificial ageing. *Oper Dent* 2018; 43:180-9.
 40. Reis AF, Vestphal M, do Amaral RC, Rodrigues JA, Roulet JF, Roscoe MGI. Efficiency of polymerization of bulk-fill composite resins: a systematic review. *Braz Oral Res* 2017; 31:e59.
 41. Rosatto CM, Bicalho AA, Veríssimo C, Bragança GF, Rodrigues MP, Tantbirojn D, Versluis A, Soares CJ. Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk-fill composites and incremental filling technique. *J Dent* 2015; 43:1519-28.
 42. Runnacles P, Arrais CA, Pochapski MT, Dos Santos FA, Coelho U, Gomes JC De Goes MF, Gomes OM, Rueggeberg FA. In vivo temperature rise in anesthetized human pulp during exposure to a polywave LED light curing unit. *Dent Mater* 2015; 31:505-13.
 43. Sajnani A, Hegde M. Leaching of monomers from bulk-fill composites: an in vitro study. *J Conserv Dent* 2016; 19:482-86.
 44. Sakaguchi RL, Douglas WH, Peters MC. Curing light performance and polymerization of composite restorative materials. *J Dent* 1992; 20:183-8.
 45. 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; 21:559-65.
-

46. Van Ende A, De Munck J, Lise DP, Van Meerbeek B Bulkfill composites: a review of the current literature. J Adhes Dent 2017; 19:95-110.
47. Van Ende A, De Munck J, Van Landuyt KL, Poitevin A, Peumans M, Van Meerbeek B. Bulk-filling of high C-factor posterior cavities: effect on adhesion to cavity-bottom dentin. Dent Mater 2013; 29:269-77.
48. Veloso SR, Lemos CA, Moraes SL, Egito Vasconcelos BC, Pellizzer EP, Melo Monteiro GQ. Clinical performance of bulk-fill and conventional resin composite restorations in posterior teeth: a systematic review and meta-analysis. Clin Oral Investig 2019; 23:221-33.
49. Versluis A, Tantbirojn B, Pintado MR, DeLong R, Douglas WH. Residual shrinkage stress distributions in molars after composite restoration. Dent Mater 2014; 20:554-64.

APPENDIX

APÊNDICE A – DECLARAÇÃO DE USO EXCLUSIVO DE ARTIGO EM DISSERTAÇÃO/TESE**APÊNCIDE A - DECLARAÇÃO DE USO EXCLUSIVO DE ARTIGO EM DISSERTAÇÃO/TESE****DECLARATION OF EXCLUSIVE USE OF THE ARTICLE IN DISSERTATION/THESIS**

We hereby declare that we are aware of the article (Evaluation of the efficiency of polymerization of composite resins in proximal restorations) will be included in (Dissertation/Thesis) of the student (Alyssa Teixeira Obeid) and may not be used in other works of Graduate Programs at the Bauru School of Dentistry, University of São Paulo.

Bauru, may 23th, 2019.

Alyssa Teixeira Obeid
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