# TECNOLOGIAS APLICADAS À PRÁTICA E AO ENSINO DA ODONTOLOGIA

EMANUELA CARLA DOS SANTOS
(ORGANIZADORA)

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# APRESENTAÇÃO

Historicamente falando a odontologia já atingiu patamares inimagináveis. Relatos sobre a ciência odontológica datam desde a Antiguidade. Agora, imagine se pudéssemos contar à um praticante da odontologia da época que, no futuro, seria possível reabilitação oral completa, com implantação de parafusos, especialmente preparados para se fixarem no osso, e enxerto de tecido ósseo, caso necessário.

A tecnologia possibilita realizações na Odontologia que, cada dia mais, beneficiam pacientes e profissionais. Já não podemos mais ensinar a odontologia da década de 90 para os acadêmicos. É necessário acompanhar a evolução e o desenvolvimento, sempre.

Este e-book traz um compilado de artigos que retratam como a tecnologia vem sendo aplicada à prática e ao ensino da Odontologia atualmente. Estas duas áreas do conhecimento podem e devem colaborar mutuamente, sendo possível alcançar resultados infinitamente melhores.

E, a partir da apreciação do conteúdo que vos é apresentado, convido-os à uma reflexão: O que nos é dito hoje sobre o futuro da Odontologia? Ousamos dizer até onde a tecnologia nos levará?

Ótima leitura!

Emanuela C. dos Santos

## SUMÁRIO

# CAPÍTULO 18

# FATIGUE RESISTANCE AND CRACK PROPENSITY OF LARGE MOD BULK FILL COMPOSITE RESIN: *IN VITRO* STUDY

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**ABSTRACT:** Objective: To evaluate the influence of different restorative techniques on shrinkage-induced crack propensity and accelerated fatigue resistance in MOD cavities. Methods: A standardized MOD slot-type was prepared on 26 extracted maxillary third molars (4mm depth and 5mm bucco-palatal width) and they were randomly distributed into two groups (n=13). In TC group, MOD cavities were restored with a single increment using bulk fill composite resin Tetric N-Ceram. In group VT, a modified sandwich restoration was performed, using a resin-modified glass ionomer cement (RMGIC) as a base layer, and the remaining restored with the same bulk fill composite resin. Enamel shrinkage-induced cracks were tracked with photography and transillumination. Cyclic isometric chewing (5Hz) was simulated, starting with a load of 200N (5000 cycles), followed by stages of 400, 600, 800, 1000, 1200 and 1400N at a maximum of 30000 cycles each. Specimens were loaded until fracture or to a maximum

185000 cycles. Groups were compared using Kaplan-Meier life table survival analysis.
Results: Both groups survived 100%. There was no significant difference between them. Just a few specimens had cracks induced by polymerization.
Conclusions: The restorative techniques presented excellent results for accelerated fatigue resistance, without any catastrophic failure. Most of the specimens, in both groups, did not have stress contraction cracks.
**KEYWORDS:** Bulk fill. Fatigue resistance. Glass ionomer cements. Transillumination. Stress, Mechanical.

## RESISTÊNCIA À FADIGA E PROPENSÃO A TRINCAS EM RESTAURAÇÕES AMPLAS COM RESINA COMPOSTA BULK FILL: ESTUDO *IN VITRO*

**RESUMO:** Objetivo: Avaliar, *in vitro,* a diferença de diferentes técnicas restauradoras quanto a resistência à fadiga acelerada e a propensão a trincas em cavidades MOD. Métodos: Uma cavidade tipo slot MOD padronizada (4 mm de profundidade X 5 mm de largura no sentido vestíbulo-palatal) foi preparada em 26 terceiros molares superiores extraídos. Os dentes foram distribuídos aleatoriamente em dois grupos (n = 13). No grupo TC, as cavidades foram restauradas com incremento único, utilizando a resina composta bulk fill Tetric N-Ceram. No grupo VT, foram realizadas restaurações tipo sanduíche super-fechado, usando um cimento de ionômero de vidro modificado por resina (CIVMR) como base, sendo o restante restaurado com a mesma resina composta bulk fill. As trincas decorrentes da contração de polimerização foram mapeadas através de fotografia e transiluminação. Foi realizado o teste de resistência à fadiga acelerada, com cargas cíclicas isométricas (5Hz), iniciando com uma carga de 200N (5000 ciclos), seguida por 400, 600, 800, 1000, 1200 e 1400N com um máximo de 30000 ciclos cada. Os espécimes foram submetidos a ciclagem até a fratura ou até um máximo de 185000 ciclos. Os grupos foram analisados através da curva de sobrevivência de Kaplan-Meier. Resultados: Os dois grupos apresentaram sobrevivência de 100%. Não houve diferença significativa entre eles. Apenas algumas amostras apresentaram trincas induzidas pela contração de polimerização. Conclusões: As técnicas restauradoras apresentaram excelente resultado quanto a resistência a fadiga, sem apresentar qualquer falha catastrófica. Além disso a maioria dos espécimes não apresentou trincas pela tensão de contração de polimerização.
**PALAVRAS-CHAVE:** Bulk fill. Resistência à fadiga. Cimento de ionômero de vidro. Transiluminação. Tensão Mecânica.

## 1 I INTRODUCTION

Although composites are well established restorative material, there are always new researchers looking for innovation in their formula or usage to turn rehabilitation most predictable. Possibly, the major inherent challenge is the polymerization shrinkage since some deleterious effects for tooth structure and for adhesive interface could result in marginal failure and pigmentation, secondary caries, restoration displacement and post-operatory sensitivity (MANTRI; MANTRI, 2013; SARRETT, 2005; TANTBIROJN et al., 2004; VAN DIJKEN; LINDBERG, 2015). Proportionally, the larger the cavity, the grater is the stress transmitted to the remaining dental structure, which can cause deflection and cuspal deformation. There is a tendency to occur horizontal cracks in cusps base, especially when there is no marginal ridge left, as in MOD cavities (BATALHA-SILVA et al., 2013; CLARK; SHEETS; PAQUETTE, 2003; MAGNE; MAIA, 2016; MANTRI; MANTRI, 2013; PINTADO et al., 2004; SULIMAN; BOYER; LAKES, 1993a, 1993b; TANTBIROJN et al., 2004). Despite this, usually, restoration shows a good survival as an annual failure of 1,8% after 5 years and only 2,4% after 10 years (OPDAM et al., 2014).

As an attempt to reduce polymerization stress, the widely used incremental technique indicate that composite increments should have a maximum of 2mm thickness. However, the incremental technique presents some disadvantages, as the possibility of voids incorporation, bonding failure and contamination between increments, as well as more clinical time for restorative procedure, due to the time needed for placing and polymerizing each increment (ABBAS et al., 2003; PARK et al., 2008). Therefore, composites known as bulk fill, were introduced to the market promising less polymerization shrinkage and allowing increments of 4-5mm thickness (BRAGA; FERRACANE, 2004). This kind of composite presents unique properties, as special modulators, different filler contents and better cure, even with thicker increments (BENETTI et al., 2015; YAP; PANDYA; TOH, 2016). According to manufactures, bulk fill technology avoids or compensates stress of composite polymerization, reduces negative effects on hybrid layer and marginal sealing, as well as presents initiators activation in all layers of the composite (FRONZA et al., 2015). However, as a new class of composites, there are still some doubts about its real ability to, limit the polymerization shrinkage, the proper monomer conversion and their mechanical resistance (LEPRINCE et al., 2014).

In contrast to new materials, a revisited posterior restoration technique can minimize polymerization stress. The called sandwich restoration consists on a base layer of glass ionomer cement (GIC) as dentine replacement, in combination with a composite resin cover as enamel replacement (MCLEAN et al., 1985; MCLEAN; WILSON, 1977). This technique was very popular in the 1970s because it was a solution to the poor dentine bonding strength of firsts adhesive systems. Nowadays, with effective dentin bonding, it still has advantage because this combination enables less composite volume, and thereby it minimise the undesirable effect of polymerization shrinkage without significantly decrease mechanic resistance (ANDERSSON-WENCKERT; VAN DIJKEN; KIERI, 2004; MAGNE; MAIA, 2016; TAHA; PALAMARA; MESSER, 2012). Therefore, the aim of this in vitro study is to evaluate fatigue resistance and crack formation by polymerization shrinkage, in two different techniques: teeth restored with bulk fill composite and teeth restored by sandwich technique, with RMGIC as base layer covered with bulk fill composite.

## 2 I MATERIALS AND METHODS

Upon approval of Ethics Committee of Federal University of Santa Catarina, Brazil, 26 maxillary third molars extracted with similar size and shape were carefully selected. They were cleaned using periodontal curettes and prophylaxis paste, examined by transillumination to certify they were free of cracks or other structural defects and stored in 0,1% thymol solution (Flora Medicinalis Farmácia de Manipulação, Itapema, Brazil).

For specimen preparation, the roots of all teeth were embedded in a 25mm diameter cylinder using a self-curing acrylic resin. Teeth insertion were performed in order that the occlusal surface remained parallel to the cylinder base and to cement-enamel junction (CEJ), it was positioned 2 mm above the resin level to simulate bone tissue. During the study, specimens were stored in distilled water in 37ºC.

### 2.1 Cracks detection and localization

For “enamel crack tracking” during the study, each surface of each tooth was photographed under standardized conditions at x1.5 magnification (Nikon D3200 and Sigma 105mm) using a circular flash (Sigma EM-140DG) in three different times: before dental preparation, after dental restoration, and after fatigue test. The second set of images was produced using transillumination (Microlux, Addent, Danbury, CT, USA) to detect the existence of new cracks after each procedure (Figure 1).

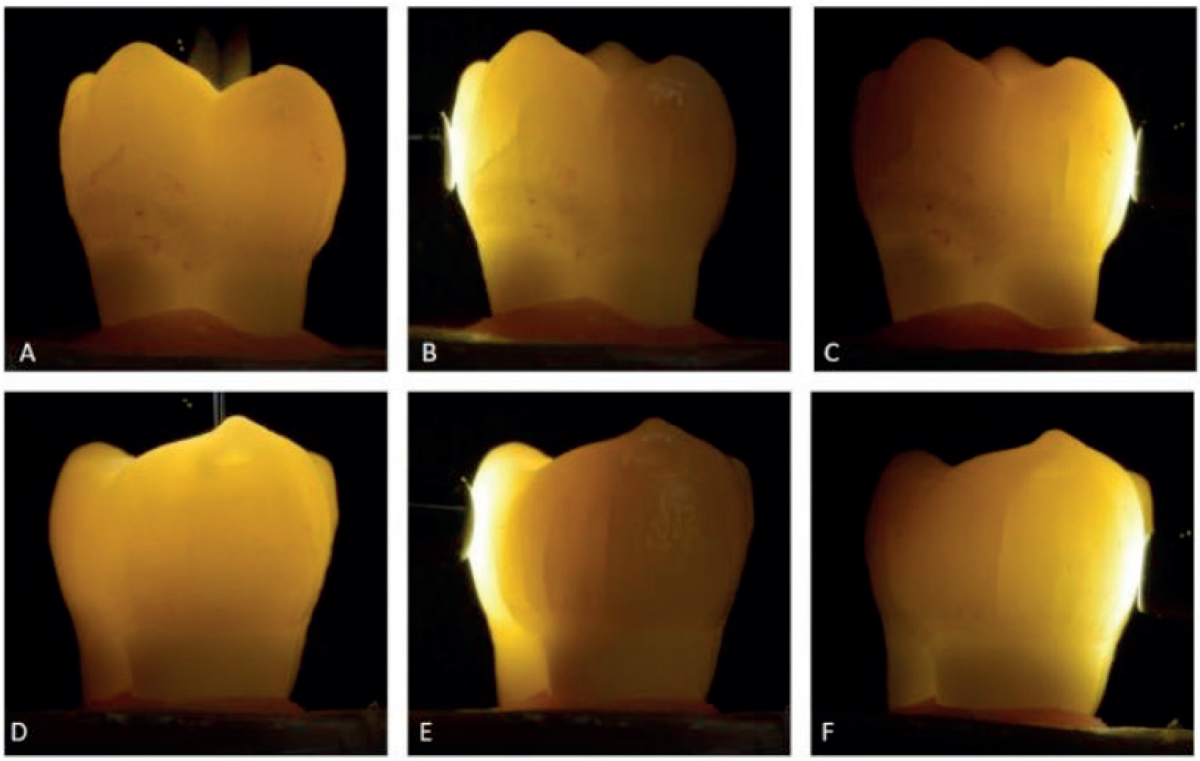

Figure 1 – Enamel crack tracking, light source applied on occlusal, mesial and distal, picture from buccal and patatal surface.

## 2.2 Specimen preparation

Cavities were prepared to simulate large class II MOD slot-type cavities using tapered diamond bur (3139 KG Sorensen, Cotia, Brazil) at high speed under constant water cooling. Every cavity had 4 mm depth from cusp tips, and 5mm in bucco-palatal width. Specimens were randomly divided into two groups and identified: TC (n=13) - bulk fill resin composite (Tetric N-Ceram), and VT (n=13) - modified closed sandwich restoration called "super closed" (SCSR) with a resin-modified glass ionomer cement as base (Vitremer-3M ESPE) covered with bulk fill composite (Tetric N-Ceram) (Table 1).

## 2.3 Restorative procedures

For both groups, a 2-step total-etch bonding system (Tetric N-Bond, Ivoclar Vivadent, Barueri, Brazil) was used, and lightly cured for 20s at 1,200mW/cm² (Radii-Cal, SDI, Bayswater, Australia). First, the proximal walls were build individually, converting a class II in a class I cavity, the remaining cavity was restored according to the restoration group. TC group, was restored by a single increment of 4mm (Figure 2).

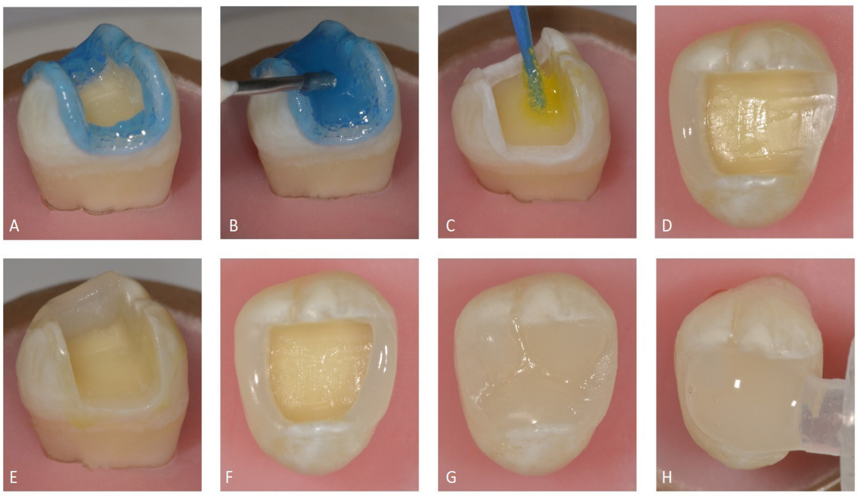


Figure 2 – Restoration procedure TC group

In VT group, approximately 50% of the remaining class I cavity was filled with RMGIC Vitremer base, (3M ESPE, St. Paul, USA).which was inserted in the cavity with a tip and plunger (Centrix Maquira, Maringá, Brazil) in a 1:1 proportion of powder and liquid, manipulated for 45s with a spatula, starting in the bottom to avoid bubbles. This base was condensed, light cured for 40s, and a finishing gloss, part of Vitremer kit, was applied and light cured for 20s. Special care was taken to create a smooth RMGIC surface and obtain about 2 mm of occlusal clearance for final layering with Tetric N-Ceram bulk fill composite (Figure 3). In both groups the occlusal anatomy was carefully created using a template made previously, where all cusps had the same high and favourable inclination for the antagonist sphere accommodation. Each increment was light cured for 40 s at 1,200mW/cm² and a final light cure was performed under an air-blocking barrier (KY Jelly, Johnson & Johnson) for 20s. Polygloss Composite Set (Microdont, São Paulo, Brazil) was used for finishing and polishing procedures. Each tooth surface was subjected again to enamel crack tracking, including transillumination and photography.

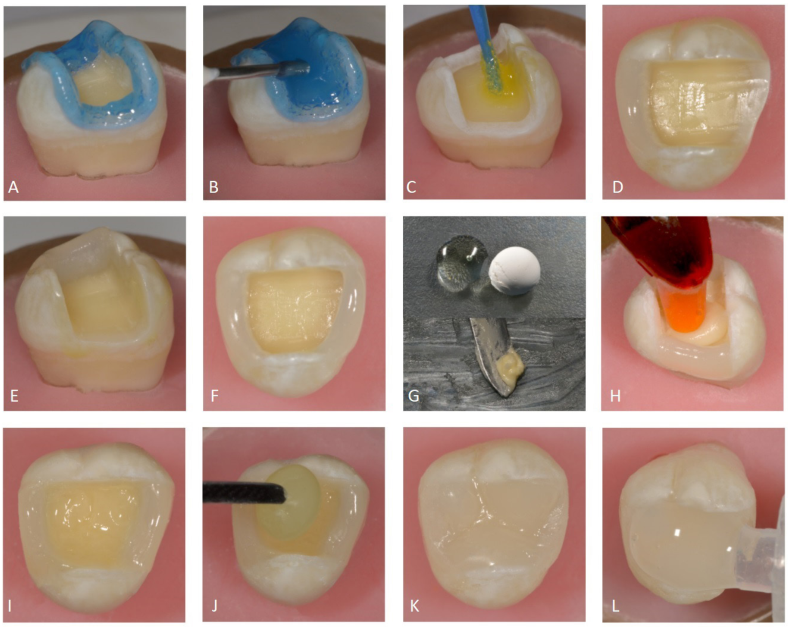


Figure 3 – Restoration procedure VT group

## 2.4 Fatigue test

After one week storage the dynamic fatigue test was performed at the Laboratory of Biomechanical Engineering of the Federal University of Santa Catarina (LEBm-UFSC) using a machine that simulate masticatory forces ElectroForce® Series II 3330 (Bose, Eden Prairie, MN, USA). For this test the antagonist was a 7mm diameter composite resin hemisphere (Z100 3M ESPE) which was post-polymerized at 104°C for 25 minutes in Targis Power Upgrade (Lumamat® Ivoclar Vivadent, Liechtenstein). This composite hemispheres contacted simultaneously and equally the mesiobuccal, distobuccal and palatal cusps (tripod contact) with isometric chewing under a 5Hz frequency. The load chamber was filled with distilled water until specimens complete immersion and maintained at 37°C throughout the experiment. The first 5000 cycles was a warm-up load of 200 N, followed by stages of 400, 600, 800, 1000, 1200 and 1400 N at a maximum of 30000 cycles each. Specimens were loaded until fracture or to a maximum of 185000 cycles, and the number of endured cycles was registered. If there was any displacement on tooth or restoration, the equipment was programmed to stop.

The fracture mode was classified according to the following criteria: Mode I, small fractures in tooth structure or restoration, Mode II, fracture of one or more cusps, with a fracture above the cement-enamel junction, Mode III, longitudinal fracture compromising tooth integrity or beyond the cement-enamel junction. Mode I and II were considered non-catastrophic failures, and restorable, while Mode III was considered catastrophic and unrestorable failures (SHIBATA et al., 2014).

Special care was taken to differentiate cracks from polymerization shrinkage, and from the fatigue test. Since many different sizes of cracks were observed, they were classified in 3 categories according to Batalha et al. (BATALHA-SILVA et al., 2013) (a) no cracks visible, (b) visible cracks smaller than 3 mm, and (c) visible cracks larger than 3 mm (Figure 4).

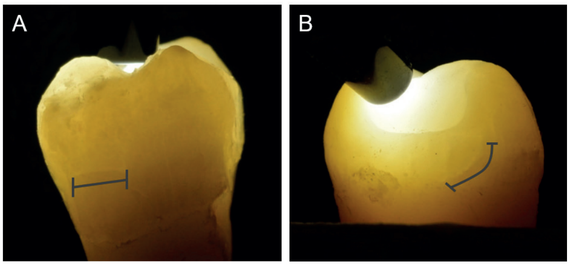


Figure 4 – Visible cracks

## 2.5 Statistical analyses

The fatigue resistance of the two groups was compared using Kaplan-Meier survival curve. After each time interval (defined by each load step), the number of specimens beginning the interval intact and the number of fractured specimens during the interval were counted, providing the survival probability (%) at each load step. The influence of the restorative technique and material on the fatigue resistance was observed comparing the survival curves using the log rank test at a significance level of 5%.

# 3 I RESULTS

100% survival rate was achieved in both groups, TC and VT. Although all restorations survived until the last load cycle, some minor failures happened, but none were sufficient to interrupt the test. There was not any specimen with catastrophic failure (Table 1). Failure mode data were submitted to T Student Test, and there was no significant difference between groups (p=0,511). Even though a majority specimen did not show any fracture until the final cycle, is notable a slight advantage of intact specimens for the group restored with RMGIC layer, (VT group) with 76,92% compared to TC group (61,53%).

| GROUP | WITHOUT FRACTURE | MODE I | MODE II | MODE III |
|---|---|---|---|---|
| TC | 61,53% (8) | 23,07% (3) | 15,38% (2) | - |

| | | | | |
|---|---|---|---|---|
| **VT** | 76,92% (10) | 15,38% (2) | 7,69% (1) | - |

Table 1 – Failure mode classification

Most of the restored tooth did not present any crack after polymerization shrinkage, 9 specimens without crack in TC group and 10 in VT, representing 69,23% and 76,92 respectively. When present, cracks were smaller than 3mm, and none specimen in TC group had cracks bigger than 3mm. In VT group two specimen had cracks bigger than 3mm, right after the restorative procedure (Table 2).

| GROUP | WITHOUT CRACK | CRACKS < 3MM | CRACKS > 3MM |
|---|---|---|---|
| **TC** | 9 (69,23%) | 4 (30,76%) | - |
| **VT** | 10 (76,92%) | 1 (7,69%) | 2 (15,38%) |

Table 2 – Crack propensity after restoration procedure

After the fatigue test, the same photographic protocol was performed. TC group presented 9 specimens without cracks and 3 cracked specimens smaller than 3mm. This aggravation was also observed in one tooth which had previously a crack smaller than 3mm and started to have a more than 3mm after the test. In VT group from 10 teeth without cracks, just one specimen had a horizontal crack after mechanical load.

## 4 I DISCUSSION

Composites are the first indication for small cavities in direct restoration of posterior teeth. Many researchers are pursuing an improvement on material composition and its behavior, especially for less stress on polymerization shrinkage. However, a majority of failures happen because of other reasons, like patient risk factors (OPDAM et al., 2010; VAN DE SANDE et al., 2015; VAN DIJKEN, 2010). Athough clinical studies have the advantage of showing real restoration behavior, they demand a lot of time to show conclusive results. Furthermore, clinical studies have a lot of uncontrolled variables, as the presence of multiple operators with different ability levels, tooth location, tooth dimensions and anatomical differences, as well as different occlusal loads from one patient to other (DEMARCO et al., 2012; LEMPEL et al., 2015). Opdam et. Al. (OPDAM et al., 2014) with a systematic review and meta-analysis, observed that in the first year after the restorative procedure, endodontic commitment was the most founded failure, and it drastically decreases in the following years. Recurrent caries as failure reason increases significantly from the first year to the sixth year, and failure from fracture remains as the second more frequently over the years.

Among de mechanical experiments, fatigue tests are the most realistic ones because can be used to simulate a clinical behavior of a restoration (LI et al., 2017) and presents a high level of standardization: selected teeth with medium and similar size, standardized dental preparation, fatigue test protocol, and restoration performed by only one operator (DELONG; DOUGLAS, 1991; PASCAL; KNEZEVIC, 2009). Furthermore, accelerated fatigue test can present results much faster than in a clinical evaluation and also submit teeth to physiological occlusal loads, or even extrapolate these results for patients with bruxism or those who eventually suffer from masticatory incidents (BATES; STAFFORD, 1976; FENNIS et al., 2004, 2005; KUIJS et al., 2006; LI et al., 2017).

As a result, both restorative techniques tested had a 100% survival rate to accelerated fatigue test, without occurrence of catastrophic failures. Despite the fact that there was no significant difference between groups, results showed a small superiority for restoration using RMGIC in the number of intact specimens (8 in TC versus 10 in VT), as well as in failure mode type II, with 2 in TC and just one in VT (Table 1). This indicates that when there is no possibility of indirect restoration in molar large cavities, the bulk fill composite technique is a better option, with the convenience of saving clinical time by allowing the use of 4mm increment.

The remarkable results in both groups are also related to the material used as an antagonist in this fatigue test since it is most similar to natural tooth, which does not happen when a stainless-steel sphere is used. Other studies use a stainless sphere, but it has a higher elasticity module and seems to interfere directly in the results, causing less survival rate and more severe fractures, likely previously suggested by Magne and Knezevic (PASCAL; KNEZEVIC, 2009). Composite resin antagonist is a more faithful simulator of natural tooth hardness and for this reason, this same research group started to use this kind of antagonist for all their fatigue tests (BATALHA-SILVA et al., 2013; GÜTH et al., 2015; MAGNE; MAIA, 2016; ODERICH et al., 2012; PASCAL; KNEZEVIC, 2009; SCHLICHTING et al., 2011).

With the results obtained in this study, it seems that the use of a base layer of RMGIC did not change restoration survival, as well as did not show any difference when referring to cracks. RMGIC was chosen for the base layer in super-closed sandwich technique based on other previous studies that demonstrated better results using this kind of glass ionomer cement than the regular ones (MAGNE; MAIA, 2016). To isolate and prevent syneresis and imbibition in the base layer, an adhesive coating was applied over RMGIC layer. Stallings et al. (STALLINGS et al., 2017) studies suggest that a layer of resin composite would protect RMGIC from damage as humidity, temperature changing and increase the bond strength. This way, even though RMGIC has lower mechanical propriety when compared to a composite resin, it acts like a space filler, which decreases composite resin volume, minimizing negative consequences of polymerization shrinkage on remaining dental structure (ALOMARI; REINHART; BOYER, 2001; MAGNE; MAIA, 2016).

The crack tracking performed in this study was based on previous photographic protocol already published by Magne et al. (MAGNE; MAIA, 2016) and this results can be compared because of the similarities of the restorative procedures. In both groups of this study, the specimens presented fewer cracks and less severity, when compared to the previous study. In TC group, 30,76% of them presented cracks, but all of them were smaller than 3mm. On the other hand, in Magne et al. (MAGNE; MAIA, 2016) study, the group restored only with conventional composite had more cracks generated by polymerization (46% of specimens presented cracks and most of them bigger than 3mm). In super closed sandwich groups, this study presented fewer polymerization induced-cracks and severity (23% of specimens showed cracks) compared to 40% of cracks in previous research (MAGNE; MAIA, 2016). These findings suggests two different reasons for this difference. First, related to differences on polymerization shrinkage of a regular composite used in the previous study when compared to a bulk fill composite in both present groups, which supposedly has less shrinkage. Furthermore, in the previous study, cavity preparations were 1mm deeper (5mm), which could result in different cusps deflection and more frequency and severity of cracks generated by stress polymerization.

In a similar study of accelerated fatigue, using the same bulk fill, there was no difference in groups restored with conventional or bulk fill composite, both in 3 or in single increment. Not even one specimen reached the end of fatigue test what suggested this is caused by some differences, as the use of pre-molars, stainless sphere as an antagonist and proximal preparation with proximal boxes in different levels (RAUBER et al., 2016).

Bulk fill composites are still new on the market, and some studies show contradictory results. On a class II study of Al Harbi et al. (AL-HARBI et al., 2016) composites inserted in only one increment presented similar marginal performance when compared with composite inserted by conventional technique or sandwich technique. Leprince et al. (LEPRINCE et al., 2014) observed that mechanical proprieties of some bulk fill composite resin were lower when compared to regular composites. Is important to highlight that some commercial brands of bulk fill require a regular composite resin as cover to reduce surface wear (HIRATA et al., 2015; ILIE; KESSLER; DURNER, 2013).

The main difference of bulk fill composites is the reduced polymerization shrinkage, several studies demonstrated that this class of composite really decrease the stress from polymerization (ALOMARI; REINHART; BOYER, 2001; BRAGA; FERRACANE, 2004; EL-DAMANHOURY; PLATT, 2014; KIM et al., 2015). There was no significant difference between groups, which suggest that bulk fill is an excellent alternative for rehabilitation of large posterior cavities, using RMGIC or not. Bulk fill composite seems to decreases cuspal deflection in large restorative procedures, even though this study tested only one commercial brand (MATIS et al., 2017; MOORTHY et al., 2012). Therefore, it is necessary more studies, using different commercial brands to declare that it is a characteristic of this type of material. Is important to state that the golden standard for large cavities is the indirect technique.

## 5 I CONCLUSION

Within the limitations of this in vitro study, it can be concluded that:

- The use of the tested bulk fill composite, in single increment to restore large cavities, or with a RMGIC as base layer, does not affect their fatigue strength since they presented 100% survival rate in fatigue test, and no occurrence of catastrophic failures.

- The group restored with RMGIC presented a slight, but not significant, advantage in evaluated failure mode.

- In both groups, the majority of specimens did not present cracks from polymerization shrinkage stress, and no crack bigger than 3mm was developed in specimens restored only with the bulk fill composite.

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