UNIVERSIDADE DE UBERABA
MESTRADO EM ODONTOLOGIA

LAÍS CARVALHO MARTINS

EFEITO DO TIPO DE RESINA COMPOSTA E TÉCNICA RESTAURADORA SOBRE A TENSÃO DE POLIMERIZAÇÃO, DEFORMAÇÃO DE CÚSPIDE E RESISTÊNCIA À FRATURA EM PRÉ-MOLARES COM PERDA ESTRUTURAL SEVERA

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Dissertação apresentada como parte dos requisitos para obtenção do título de Mestre em Odontologia, área de concentração: Clínica Odontológica Integrada da Universidade de Uberaba.

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"A tarefa não é tanto ver aquilo que ninguém viu, mas pensar o que ninguém ainda pensou sobre aquilo que todo mundo vê."

(Arthur Schopenhauer)

RESUMO

O objetivo deste trabalho foi avaliar a tensão de polimerização, a deformação e a resistência à fratura de pré-molares com perda estrutural severa, restaurados com diferentes técnicas. Para isso cinquenta pré-molares superiores humanos íntegros foram selecionados, limpos com curetas periodontais e pedra pomes, incluídos em um alvéolo artificial simulado com resina de poliestireno ativada quimicamente e em Poliéter para simulação do ligamento periodontal. Os dentes receberam preparos MOD (mésio ocluso distal) padronizadas com 4,00 mm de profundidade cervico-oclusal e 3,5mm de largura no sentido vestíbulo lingual e foram divididos em cinco grupos (n=10): Z350XT 10 incrementos – Técnica incremental convencional; Z350XT 8incr – Técnica incremental modificada; Filtek Bulk Fill Flow / Z350XT – Técnica Bulk Fill; SDR / Spectra Basic – Técnica Bulk Fill; Tetric N Ceram Bulk Fill – Técnica Bulk Fill Flow, e cada dente foi restaurado de acordo com a técnica definida aleatoriamente. Cinco amostras de cada grupo foram submetidas ao ensaio de extensometria para avaliar a deformação de cúspide. Todas as amostras de todos os grupos foram submetidas à ciclagem térmica e mecânica. Por fim, as amostras foram submetidas ao ensaio de resistência à fratura (v=0.05mm/min). A contração pós-gel volumétrica (%) das resinas utilizadas foi avaliada por extensometria. Os valores de deformação (μS), carga de fratura (N) e contração pós-gel volumétrica (%) foram submetidos à análise estatística apropriada (ANOVA One-Way e Tukey HSD). O teste estatístico ANOVA One-way revelou diferenças estatísticas entre os compósitos restauradores ($p < 0,01$) no teste de análise da contração pós-gel onde, Z350XT apresentou o maior valor volumétrico de contração pós-gel e N Spectra basic e o Tetric N-Ceram Bulk Fill não apresentaram diferença estatística entre si ($p = 0,110$). Na análise da deflexão de cúspide pela extensometria houve diferenças estatísticas entre as técnicas restauradoras ($p < 0,01$) e os maiores valores médios da deformação de cúspide foram observados para os grupos Z350XT / 10 incr e Filtek Bulk Fill Flow / Z350XT e os valores de deformação mais elevados foram observados nas cúspides linguais, independentemente da técnica restauradora. No método pela FEA 3D, os grupos Z350XT / 10 incr e Filtek Bulk Fill Flow / Z350XT também exibem os valores médios de deformação mais elevada. A cúspide lingual também apresentou os maiores valores de tensão. Na análise da tensão de contração pela FEA-3D as técnicas restauradoras

incrementais Z350XT / 10 e 8 incrementos apresentaram os maiores valores de tensão de contração tanto na cúspide vestibular quanto lingual. ANOVA onde-way revelou que não houve diferença estatisticamente significante entre os grupos (p = 0,679) quando submetidos ao teste de resistência à fratura. As resinas Bulk Fill utilizadas apresentaram valores de contração pós-gel menores do que o compósito convencional Z350-XT e, este grupo apresentou maiores valores de deformação de cúspides. Quatro de cinco grupos apresentaram maiores valores de deformação e faturas na cúspide vestibular, demonstrando que a cúspide lingual é a cúspide mais frágil. As resinas Bulk Fill são eficientes para aplicação na prática clínica, embora mais pesquisas longitudinais precisem ser realizadas.

Palavras-chave: Deformação de Cúspide. Tensão de contração. Propriedades mecânicas. Análise de elementos finitos.

ABSTRACT

The aim of this study was to evaluate the polymerization stress, strain and fracture strength of premolars with severe structural loss, restored with different direct restorative techniques. Fifty (n = 50) intact, caries-free upper premolars with similar sizes were selected, cleansed with periodontal curettes and pumice stone, included in self-curing polystyrene resin for periodontal ligament simulation. They were prepared with MOD (distal occlusal occlusal) cavities of 4.00 mm of cervico-occlusal depth and 3.5 mm of width in the lingual buccal (L/B) sense. The prepared teeth were divided into five groups (n = 10): Z350XT 10 incr - Conventional incremental technique; Z350XT 8 incr - Modified incremental technique; Filtek Bulk Fill Flow / Z350XT - Bulk Fill Technique; SDR / Spectra Basic - Bulk Fill Technique; Tetric N Ceram Bulk Fill - Bulk Fill Flow Technique. Each sample was restored according to the technique defined by randomization. Five samples from each group were submitted to the extensometry test to evaluate the cuspal strain. All samples were then submitted to thermal and mechanical cycling. Finally, the samples were submitted to the fracture strength test (v = 0.05 mm / min). All these data were evaluated and tabulated in Excel. The post-gel volumetric shrinkage (%) of the resins used was evaluated by extensometry. The values of deformation (□S), fracture strength (N) and Post-gel shrinkage (%) were submitted to appropriate statistical analysis (ANOVA One-Way and Tukey HSD). The ANOVA One-way statistical test revealed statistical differences between restorative resin composites ($p < 0.01$) in the post-gel shrinkage analysis test, where Z350XT presented the highest post-gel shrinkage volumetric value and N Spectra basic and Tetric N-Ceram Bulk Fill did not present statistical difference between them ($p = 0.110$). In the analysis of cusp deflection by strain gage there were statistical differences between restorative techniques ($p < 0.01$) and the highest mean values of cusp deformation were observed for the groups Z350XT / 10 incr and Filtek Bulk Fill Flow / Z350XT and values were found in the lingual cusps, regardless of the restorative technique. In the method by FEA 3D, the groups Z350XT / 10 incr and Filtek Bulk Fill Flow / Z350XT also exhibit the highest mean values of deformation. The lingual cusp also showed the highest values of stress. In the FEA-3D stress analysis the incremental restorative techniques Z350XT / 10 and 8 increments showed the highest values

of stress in both the buccal and lingual cusps. ANOVA one-way showed that there was no statistically significant difference between the groups ($p = 0.679$) when submitted to the fracture resistance test. The Bulk Fill resins used presented lower post-gel shrinkage values than the conventional Z350-XT composite, and this group showed higher values of cusp deformation. Four of five groups presented higher values of deformation and invoices in the buccal cusp, demonstrating that the lingual cusp is the most fragile cusp. Bulk Fill resins are effective for application in clinical practice, although more longitudinal research needs to be done.
Key-words: Cuspal strain; Shrinkage stress; Mechanical properties; Finite element analysis

LISTA DE FIGURAS

reparável por associação com cirurgia periodontal; d) Tipo IV: fratura grave com indicação de extração dentária (pág. 56).

LISTA DE TABELAS

LISTA DE ABREVIATURAS, SIGLAS E SÍMBOLOS

% - Porcentagem

FIG. – Figura

mm – Unidade de Comprimento (milímetro)

FEA – Análise por Elementos Finitos

Mpa – Mega Paschal

MOD – Mésio Ocluso Distal

INCR – Incremental

FBF - Filtek Bulk Fill Flow

Z350XT - Filtek Z350XT

TNC - Tetric N Ceram Bulk Fill

SDR - Surefil

SB - Spectra Basic

N – Newton

μS – Microstrain

Hz - Hertz

Shr - Contração pós-gel

SD – Coeficiente de variação

E – Módulo de Elasticidade

SUMÁRIO

Introdução

1 INTRODUÇÃO

Dentes posteriores com extensas lesões cariosas e perda estrutural severa são frequentes na prática clínica e na maioria dos casos, o tratamento de escolha é a restauração direta com resinas compostas, porém este material sofre contrações volumétricas gerando tensões que podem afetar tanto à restauração quanto o dente restaurado (VERSLUIS et al., 2011; KLEVERLAAN et al., 2005; TAHA et al., 2009; LABELLA et al., 1999). O sucesso clínico resinas compostas tem sido atribuído ao módulo de elasticidade deste material eu apresenta-se semelhante à dentina, fator este que tem se mostrado essencial para obter níveis mais baixos de tensão de contração (KLEVERLAAN et al., 2005; MANTRI et al., 2013) além de apresentar capacidade adesiva com a estrutura dentária (BARRETO et al., 2015; SULIMAN et al., 1993).

Nos pré-molares a influência da quantidade de remanescente dentário é de suma importância, pois quanto maior o preparo dentário, maior é perda de estrutura e estes fatores resultam em enfraquecimento das cúspides remanescentes e com isso a quantidade de material necessário para restauração é consequentemente maior, o que significa maior tensão de contração na interface restauração-dente (COHEN et al., 2006). Segundo Cohen et al. (2006), um dos fatores relacionados às fraturas dentárias no longo eixo (fraturas verticais) é a localização do dente e, de acordo com o estudo realizado em 2006, os pré-molares superiores são os que apresentam maior incidência desse tipo de fratura, levando à exodontia do elemento dental (FERRACANE et al., 2010; BARRETO et al., 2015; SULIMAN et al., 1993).

As resinas compostas mais comumente utilizadas são as fotoativadas, que uma molécula fotoiniciadora capaz de promover a polimerização (ELSHARKASI et al., 2018; VERSLUIS et al., 1996). Entretanto, durante o processo de fotoativação, as resinas compostas sofrem contração volumétrica que gera tensões que podem afetar diretamente a longevidade e o sucesso do processo restaurador (VERSLUIS et al., 2004; BEHERY et al., 2016). Maiores valores de contração de polimerização podem atuar diretamente na restauração e na estrutura dentária resultando em forças internas que geram a aproximação das paredes opostas causando redução da distância intercuspídea (deflexão ou flexão de cúspide) o que pode resultar em sensibilidade pós-operatória, enfraquecimento dentário, trincas de esmalte e até fratura da cúspide (VERSLUIS et al., 1996; BENETTI et al., 2015).

Além da deflexão da cúspide, a tensão de polimerização pode interferir na integridade da interface entre material restaurador e estrutura dentária (BENETTI et al., 2015), uma vez que as forças durante a contração volumétrica precisam ser absorvidas ou propagadas, mas quando isso não ocorre, pode haver formação e propagação de trincas e danos à integridade marginal com consequente formação de lesões cariosas secundárias levando ao insucesso do procedimento restaurador (PETROVIC et al., 2013).

Reduzir a tensão de contração da polimerização tem sido o principal desafio quando se trata de resina composta, por isso foi constatada a necessidade de desenvolver novas técnicas, bem como novos materiais que visam melhorar a qualidade do tratamento restaurador em dentes com perda estrutural severa uma vez que estes fatores podem interferir no sucesso do tratamento, para que fatores como contração de polimerização e consequente longevidade e qualidade da restauração com resinas compostas sejam adequados clinicamente (ILIE, N; BUCUTA, S; DRAENERT, M., 2013).

Portanto, novas técnicas como, técnica de inserção incremental oblíqua e técnica de fotoativação em etapas foram introduzidas para reduzir a tensão da contração de polimerização (SOARES et al., 2013), porém a grande quantidade de etapas operatórias pode resultar em sensibilidade da técnica, obtendo restaurações insatisfatórias. Para contornar esta situação as resinas compostas de preenchimento único, também conhecidas como resinas compostas *Bulk Fill* têm sido cada vez mais estudadas e empregadas na odontologia (B GONÇALVES et al., 2018) (THUYUDUNG et al., 2014).

As resinas compostas Bulk Fill são geralmente mais translúcidas, podem ser fotoativadas em profundidades de até 5 mm, promovem redução dos passos operatórios e consequente redução da sensibilidade da técnica, menor tempo clínico para realização do procedimento, e estudos afirmam apresentar redução da tensão de contração de polimerização (GARCIA et al., 2014). Estas resinas compostas apresentam composições muito similares às convencionais, porém apresentam maior translucidez quando comparadas às convencionais, proporcionando assim, maior passagem de luz durante a fotoativação. Além disso, novos tipos de fotoiniciadores estão sendo lançados no mercado e estes possuem capacidade de fotoativação eficiente em incrementos maiores que 2mm (ELSHARKASI et al., 2018; CHESTERMAN et al., 2017).

Estudos têm sido realizados para analisar o desempenho clínico longitudinal de restaurações feitas com as resinas compostas Bulk Fill e é importante ressaltar que fatores como contração de polimerização, deflexão da cúspide, infiltração marginal e resistência mecânica devem ser analisados em cada material a ser indicado, pois podem variar de acordo com o comportamento de cada resina compotas e como são aplicadas, principalmente ao tempo de exposição ao fotoativador (ALKHUDHAIRY et al., 2017; ROSATTO et al., 2015).

Alguns testes são utilizados para obter resultados de resistência de materiais e estruturas, como, por exemplo, os testes de resistência à fratura, porém estes são considerados destrutivos, o que limita o uso das amostras (SILVA et al., 2012). Por isso testes não destrutivos como extensometria e análises tridimensionais pelo método de Elementos Finitos (MEF) estão sendo cada vez mais utilizados, pois permitem obter resultados que podem ser relacionados e comparados entre si, obtendo melhores resultados (SOARES et al., 2007; BARRETO et al., 2015). Diversos estudos avaliaram as tensões de contração pelo método de elementos finitos utilizando modelos bidimensionais com resultados satisfatórios, entretanto, para estudo da contração volumétrica de polimerização de compósitos, modelos tridimensionais podem traduzir resultados mais consistentes. Poucos estudos têm avaliado a tensão de contração de resinas compostas utilizando modelos tridimensionais.

Desta forma, o objetivo deste trabalho foi avaliar as tensões geradas, a deflexão da cúspide, a resistência à fratura e o padrão de falha em pré-molares com perda estrutural severa, restaurados com diferentes tipos de resinas compostas e técnicas restauradoras. A hipótese nula testada neste trabalho foi que as diferentes técnicas restauradoras utilizando resinas compostas Bulk Fill e Convencional, não influenciam nas tensões de contração, deflexão de cúspide, resistência à fratura e o padrão de falha.

Objetivos

2. OBJETIVOS

2.1. Objetivo Geral

Objetivo geral deste trabalho foi avaliar o comportamento biomecânico de pré-molares superiores permanentes restaurados com resina composta Bulk Fill e Convencional variando o tipo de técnica para inserção do material (técnica restauradora).

2.2. Objetivo Específico

Este estudo teve como objetivo avaliar resistência à fratura (N), deformação de cúspide e tensão (MPa) através de teste mecânico de resistência à fratura, extensometria e análise pelo método de elementos finitos tridimensional (MEF-3D), correlacionando os resultados das diferentes metodologias com os seguintes fatores em estudo:

(1) Técnica restauradora em 5 níveis:

a. Técnica incremental oblíqua + resina convencional – Z350 – 10 incrementos (grupo 1)
b. Técnica incremental oblíqua modificada + resina convencional – Z350 – 8 incrementos (grupo 2)
c. Técnica de incremento único – SDR + Spectra Basic (grupo 3)
d. Técnica de incremento único – Filtek Bulk Fill Flow + Z350 (grupo 4)
e. Técnica de incremento único – Tetric N-Ceram Bulk Fill (grupo 5)

Capítulo1

Capítulo 1 – EFFECT OF COMPOSITE RESIN TYPE AND RESTORATIVE TECHNIQUES ON STRESS POLYMERIZATION, CUSP DEFORMATION AND FRACTURE LOAD OF WEAKENED PREMOLARS

Operative Dentistry.
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Abstract

The aim of this study was to evaluate the biomechanical behavior of permanent human upper premolars with severe structural loss, varying composite resins and restorative techniques. MOD (distal occlusal cavities) of 4.00 mm of cervico-occlusal depth and 3.5 mm of width were performed in the lingual vestibular. The 5 experimental groups (n = 10) were: Z350XT 10 incr - Conventional incremental technique; Z350XT 8 incr - Modified incremental technique; Filtek Bulk Fill Flow / Z350XT - Bulk filling technique; SDR / Spectra Basic - Bulk filling technology; Tetric N Ceram Bulk Fill - Bulk Fill Flow Technique. Samples were randomly arranged and ten samples from each group were submitted to the cusp strain test to evaluate the cusp deformation. All samples were submitted to thermal and mechanical cycles and submitted to the fracture strength test (v = 0.05 mm / min). The post-gel volumetric contraction (%) of the composite resins used was evaluated by the strain gage method. The values of deformation (□S), fracture load (N) and post-gel shrinkage (%) were submitted to appropriate statistical analysis (ANOVA One-Way and Tukey HSD). The ANOVA One-way statistical test revealed statistical differences between composite resins ($p < 0.01$) in the post-gel shrinkage test, where Z350XT presented the highest post-gel shrinkage volumetric value and SB and TNC showed no statistical difference between ($p = 0.110$). Both in the cusp strain teste and in the FEA analysis there were statistical differences between restorative techniques ($p < 0.01$) and the highest mean values of cusp deformation were observed for the groups Z350XT / 10 incr, Z350XT 8 incr e; FBF / Z350XT. As in the cusp strain test and FEA 3D, the lingual cusps presented higher values of deformation, and the stress levels in the FEA were also higher. One-way ANOVA revealed no statistically significant difference between the groups ($p = 0.679$) for the fracture resistance test. Although the bulk fill composite resins showed biomechanical behavior similar to conventional composite resins, these materials are indicated as restorative materials because they facilitate the restorative process with the reduction of operative steps and consequently reduction of shrinkage stress of polymerization and deformation.

Key-words: Cuspal strain. Shrinkage stress. Mechanical properties. Finite element analysis

1. Introduction

Dental caries is one of the main etiologies that result in the formation of extensive cavities resulting from great loss of dental structure, especially in posterior teeth. In most cases the indicated treatment is the direct restoration with composite resin due to the physical and mechanical properties of this material. One of the fundamental characteristics of these materials is that they have elastic modulus (E) values similar to dentin and this property has been shown to be an essential factor to obtain lower levels of stress 2,5 and still have adhesive capacity with structures 6, 7 However, this material presents volumetric shrinkage resulting from photoactivation that generates residual stress and directly affects the restoration and restored tooth 1, 2, 3, 4.

Severe dental structural loss decreases tooth resistance and the higher the structural loss, the lower the tooth resistance, the greater the amount of material needed for tooth restoration and reconstruction, which means higher stress in the restoration, in the tooth / restoration interface, and in the structure itself. According to Cohen et al. (2006), one of the factors related to dental fractures in the long axis (vertical fractures) is the location of the tooth and, according to the 2006 study, the maxillary premolars presented a higher incidence of this type of fracture, leading to exodontia of the dental element 9, 7.

The most commonly used composite resins are photoactivated 10,11 but during the photoactivation process, these materials exhibit volumetric shrinkage which, consequently, generate stresses that can directly affect the longevity and success of the restorative process 12, 13. Higher values of shrinkage polymerization can act directly on the restoration and on the tooth, which can generate internal forces in the material that approaches the opposing walls causing a reduction of cusp distance (cusp deflection) resulting in postoperative sensitivity, weakening of the teeth, cracks enamel and even fractures of the cusp 11, 14. In addition to acting directly on the dental cusps, the polymerization stress can interfere with the integrity of the interface between the restorative material and the tooth 15, leading to the formation and propagation of cracks and damage to the marginal integrity resulting in dental caries leading to failure restorative building 16.

Reducing the stress of polymerization shrinkage has been the main challenge when it comes to composite resin, for which new techniques of insertion and photoactivation of the composite resins have been introduced to reduce the stress of the polymerization shrinkage 17, but the number of operative steps may result in technical sensitivity, leading in an unsatisfactory restoration. To overcome this situation, several materials have been researched and developed by way of example, the "Bulk Fill" composites 18,19 which are considered as single-grade and are already widely used by dentists in clinical dental practice.

Bulk Fill composites are generally more translucent and can be photoactivated at depths of up to 5 mm. Studies have stated that they can reduce the polymerization shrinkage stress 20. These composite resins have very similar compositions to conventional composite resins, but these have a higher translucency compared to conventional composite resins, providing increased light passage during photoactivation, new types of photoinitiators and capacity photoactivation in increments of more than 2mm 21, 22.

Studying the longitudinal clinical performance of restorations made with composite resins Bulk Fill is important mainly to evaluate the polymerization shrinkage, cuspal strain, marginal infiltration and mechanical resistance of these materials to be used in correct situations. 23. Tests such as resistance tests are of great importance for the biomechanical analysis of restorative materials, but they are considered destructive, which limits the use of samples 25, so non-destructive tests like the strain gage method and three-dimensional analyzes using the Finite Element Method (FEA-3D) is increasingly used because it allows obtaining results that can be related and compared to each other 26, 6.

In this way, the aim of this study was to evaluate the cuspal strain, stress generated, volumetric post-gel shrinkage and fracture load in premolars with severe structural loss, restored with different types of composite resins and restorative techniques. The null hypothesis tested was that the different restorative techniques employing bulk fill and conventional composite resins would not affect cuspal strain, stress generated, volumetric post-gel shrinkage and fracture load.

2. Material and methods

Teeth selection and cavity preparation

Fifty human maxillary premolars extracted in a maximum period of 1 year with similar coronary and root volume were selected from the UNIUBE - Uberaba University tooth bank, after approval by the Ethics Committee (93446218.8.0000.5145). The teeth presented a distance from the lingual vestibular cusp with a standard deviation of 10% of the mean, where the measure could vary from 6.5 to 7.9 mm in the direction (vestibular / lingual). The teeth were cleaned with periodontal curettes (Hu-friedy, Chicago, USA) and prophylaxis with pumice and water. The roots were covered with a 0.3 mm layer with polyether (Impregum; 3M ESPE, St Paul, Minn) to simulate the periodontal ligament and embedded in polystyrene resin (Cristal, Piracicaba, SP) up to 2 mm below the cement junction -shade to simulate the alveolar bone (Soares et al., 2005). Class II (MOD) cavities were made with a cylindrical diamond tip (no. 1095F, KG Sorensen, Cotia, SP), 4 mm deep (axio-pulpar) and 3.5 mm wide (mesio-distal). The part with the greatest wear was carried out inside the vestibular and lingual cusps with diamond tip # 3168F, the enamel remaining 1.7 mm thick in the buccal and lingual region. This measurement was determined using a specimen so that the lingual and buccal walls were measured prior to preparation to determine the amount of wear and after preparation to check the amount of remaining enamel. The teeth after inclusion and coronary preparation can be observed in figure 1A.

Groups division

The prepared teeth were divided into 5 groups (n = 10) according to restorative techniques and composite resins used: group 1: Z350XT / 10 increments (Z350XT - modified oblique incremental technique), group 2: Z350XT / 8 increments (Z350XT resin - incremental technique), Group 3: Filtek Bulk Fill / Z350XT (Filtek Bulk Fill / Z350XT - Bulk Fill Technique), group 4: SDR / Spectra Basic (SDR resin technique / Spectra Basic Bulk Fill technique), group 5: Tetric N- Ceram Bulk Fill Bulk 5 Tetric N-Ceram Bulk Fill). The composite resins used and their respective properties can be found in Table 1.

Cuspal strain during restorative procedure (CSt-Re)

For this test, ten samples (n=10) from each group and strain gauges type PA-06-125AC-350L (Excel Sensores, SP, Brazil) with a gage factor of 2.14 were used. For cuspal strain analysis, the strain gages were set free in the cusps (buccal and lingual) and observed in areas where higher stress levels analyzed by the 3D finite element test (FEA). For strain gages attachment, the buccal and lingual surfaces were conditioned with 37% phosphoric acid for 30s, washed with water for 15s, dried with air jets and then bonded with cyanoacrylate adhesive (Super Bonder, Loctite, Itapevi , SP, Brazil) (Fig. 1B). Two strain gages were also attached to a sample called the passive, which did not undergo any changes to compensate for the effects of temperature. After fixation, the gages were connected to a data acquisition device (ADS2000; Lynx, São Paulo, SP, Brazil), and restorative process were performed following the techniques evaluated as shown in Figure 2.

In the Z350XT / 10 incr technique, the increments were inserted in this order: The first increment was inserted into the distal marginal ridge in the lingual / pulp direction. The second increment was inserted into the distal marginal ridge in the buccal / pulp direction. The third increment was inserted into the mesial marginal ridge in the lingual / pulp direction. The fourth increment was inserted into the mesial marginal ridge in the buccal / pulp direction, thus concluding the reconstruction of the mesial and distal walls. The fifth increment was inserted in the weakened area located in the inner part of the lingual cusp. The sixth increment was inserted in the weakened area located in the inner part of the buccal cusp. The occlusal face was restored using 4 oblique 2mm increments, the first was inserted in the direction of the lingual / pulp walls to the limit of the dentin area, the second was inserted towards the buccal / pulp walls also to the limit of the dentin area , the third was inserted towards the lingual / pulpal walls filling the enamel area and the remainder of the occlusal / lingual face and the fourth increment of the occlusal face was inserted towards the buccal / pulpal walls filling the enamel area and the remainder of the occlusal / buccal face (Fig 2A).

For the Z350XT / 8 incr technique, the increments were inserted in the following order: The first increment was inserted into the distal marginal ridge in the lingual / pulp direction. The second increment was inserted into the distal marginal ridge in the buccal / pulp direction. The third increment was inserted into the mesial marginal ridge in the lingual / pulp direction. The fourth increment was inserted into the mesial marginal ridge in the buccal / pulp direction, thus concluding the reconstruction of the mesial and distal walls. The occlusal face was restored using 4 conventional 2 mm oblique increments, so that these increments also encompassed the weakened areas located on the inner walls of the buccal and lingual cusps. Thus, the first increment was inserted in the direction of the lingual / pulp walls up to the limit of the dentin area, the second was inserted towards the buccal / pulp walls also up to the limit of the dentin area, the third was inserted towards the lingual / pulp filling the area of the enamel, the remainder of the weakened area and the remainder of the occlusal / lingual surface and the fourth increment of the occlusal surface was inserted towards the buccal / pulp walls filling the area of the enamel and the remainder of the occlusal / buccal surface (Fig. 2B).

The Filtek Bulk Fill Flow / Z350XT (FBF / Z350) and SDR / Spectra Basic (SDR / SB) techniques were inserted into a single addition throughout the dentin area. The enamel area was restored using 6 increments of 1 mm of conventional composite resin following the conventional oblique technique. The order of insertion of the conventional increments in the samples belonging to the groups FBF / Z350 and SDR / SB were: The first increment was inserted in the marginal ridge distally in the lingual / pulp direction. The second increment was inserted into the distal marginal ridge in the buccal / pulp direction. The third increment was inserted into the mesial marginal ridge in the lingual / pulp direction. The fourth increment was inserted into the mesial marginal ridge in the buccal / pulp direction, thus concluding the reconstruction of the mesial and distal walls. The occlusal face was restored with 2 oblique increments of 1 mm each, determined as cover increments, the first was inserted in the direction of the lingual / pulp walls, completing the occlusal / lingual area and the second was inserted towards the vestibular walls / pulp completing the buccal / lingual area (Fig. 2C).

In the Tetric N-Ceram Bulk Fill technique, the single increment was used throughout the sample (Fig. 2D).

The composites were photoactivated using a LED light curing unit (VALO, Ultradent, South Jordan, UT) with intensity of 1297 (mW / cm2) in standard mode for 40 seconds at each increment, which was positioned on a support to standardize the distance between the photopolymerization and the tooth crown, thus reducing the amount of light exposed to the samples, and for each sample restored the photopolymerization unit was subjected to radiometric light intensity evaluation to control and standardize the light intensity. To simulate the real conditions the teeth were fixed in a device with the presence of adjacent teeth where it was possible to position the wooden wedges and matrix strips, standardizing the restorative process. The deformation values (μS) were obtained individually for each strain gage. In order for this measure of deformation to be obtained separately they were connected to the Data Acquisition System with ½ Wheatstone bridge configurations per channel. During the restorations the data acquisition plate collected the deformation with frequency of 4 Hz.

Thermo mechanical cycling

All the restored teeth (n=10) were submitted to 10,000 thermal cycles (5 ° / 55 ° C) in a specific MSCT-3 machine (Marcelo Nucci ME, São Carlos, Brazil) (o5 to ≈55 o, 15 s residence time). A total of 100,000 mechanical cycles were performed in a mechanical cycling machine (Odeme, Luzerna, SC, Brazil), with 50N load and 2Hz frequency, which was applied to the occlusal face of the restoration.

Fracture load and failure mode

The specimens were placed in the mechanical test machine (EMIC, DL2000, São José dos Pinhais, Brazil) and subjected to a compressive load at a crosshead speed of 0.5 mm/min until fracture. The force required (N) to cause the fracture was measured by means of a load cell connected to a software (TESC; Emic, São José dos Pinhais), and the load required to perform the fracture was recorded. The fractured specimens were analyzed in stereoscopic magnifying glass (Leica, Wetzlar, Alemanha) with 10X and 40X magnification to determine the failure pattern, and was categorized as following the failure pattern defined by Rosatto et al. (2015) [24]: (I) fractures involving part of the coronary structure (II) fractures involving a small part of the coronary structure and cohesive in the restoration; (III) fractures with involvement of part of the coronary structure, cohesive failure in the restoration and repairable root fractures through association with periodontal surgery; (IV) Severe fractures with indication of tooth extraction.

Post-gel shrinkage (%)

Post-gel volumetric shrinkage (%) was measured by the strain gauge method for each composite resin. First, a Teflon matrix was used to standardize the size of the resin samples, the amount of composite resin determined was then transferred to a hemisphere above a biaxial strain gage (CEA-06-032WT-120, Measurements Group, Raleigh, North Carolina, USA) that measured shrinkage deformations in two perpendicular directions. A strain conditioner (ADS0500IP, Lynx Electronic Technology) has converted electrical resistance changes in the strain gage into voltage variations through a quarter-bridge circuit with an internal reference resistance. The values were then calculated and transferred to a worksheet in Excel. The samples were photoactivated using a LED light curing Valo (Ultradent, South Joradan, UT) which was coupled on a carrier (MARC) to standardize the distance from the tip to the samples, and was used for 40s. The post gel shrinkage (%) was used for simulation in FEA-3D.

Residual shrinkage stress calculation – Three-dimensional finite element analysis (3D-FEA)

A three-dimensional (3D) finite element simulation was carried out simulating the tooth MOD preparation and the restorative techniques used in the experimental test. The 3D model was created from and intact sound maxillary human first premolar (Approved by UNIUBE Ethics Committee) by using computer-assisted design (CAD) software (Rhinoceros 3D 5.0; McNeel North America). The tooth was scanned for generation of a stereolithography file (*.STL) (Fig. 2A). Based on the STL, polylines were created using the anatomical marks of the crown (Fig 2B). Non-Uniform Rational Basis Splines (NURBS) surfaces were created using the lines (Fig 2C and 2D). The MOD preparation and the cusp weakening were created using boolean differences and the dimensions were the same as in the experimental test (Fig. 2E, 2F, and 2G). Each composite resin increment of the restoration techniques were created using CAD techniques (Fig. 3).

The models were exported in *.STEP files to the preprocessing software (Patran, MSC software, Santa Ana, Ca, USA) and the meshing of each structure were perfomed with solid tetrahedral elements with 4 nodes. The mesh of each structure were exported in *.OUT files. The meshes were then imported to the finite element program (Marc & Mentat, MSC softwares) for boundary conditions and contact definitions. Nodal displacements were constraint in X, Y and Z directions at the bottom surface of the model. Polymerization shrinkage was simulated by thermal analogy. Temperature was reduced by ºC, while the linear shrinkage value (Post-Gel Shrinkage) was entered as the coefficient of linear thermal expansion. Each composite resin increment was activated in the same sequence of the restoration technique employed at the cusp strain test with the strain gage method. Material properties used in the finite element analysis are shown in the table 2.

Modified von Mises equivalent stress was used to express the stress conditions. Furthermore, microstrain values in the Y-direction (vertical) were obtained during the analyses at nodes of the buccal and lingual external surface corresponding to the same position where the strain gauge was fixed in laboratory tests.

Statistical analysis

The values obtained in the cusp deflection tests; fracture resistance and post-gel analysis were submitted to statistical analysis by analysis of variance - ANOVA one way to evaluate if there was difference in mean values in the use of different restorative techniques. When ANOVA indicated a statistically significant difference in the mean values of the dependent variable, the Tukey test was applied to evaluate if the samples showed if all the techniques obtained statistical difference between them. All tests employed a significance level of 0.05 and all analyzes were performed with the Sigma Plot version 14.0 statistical package (Systat Software Inc., San Jose, CA, USA).

3. Results

Volumetric Post gel Shrinkage (%)

Volumetric post gel Shrinkage values (%), and standard deviation (SD) for the different composite resins are shown in table 3. One-way ANOVA revealed statistical differences among the restorative composite resins ($p<0.01$). Resin composite Z350XT had the higher volumetric post-gel shrinkage value. There is no statistical difference between the Spectra basic and Tetric N-Ceram Bulk Fill ($p=0.110$).

Cuspal strain during restorative procedure (CSt-Re)

The buccal, lingual and mean cusp strain values (µS) and standard deviations (SD) for the different restorative techniques measured by strain gage method are shown in table 4. One-way ANOVA revealed statistical differences among the restorative techniques ($p<0.01$). The higher mean values of cusp strain were observed for the groups Z350XT/10 incr, Z350XT/8 incr and Filtek Bulk Fill Flow/Z350XT. Higher cusp strain values were observed for the lingual cusp regardless the restorative technique. SDR/Spectra Basic and Tetric N-ceram Bulk Fill had the lower mean cusp strain values and there is no statistical difference between these groups ($p=0.956$). The buccal, lingual and mean cusp strain values for the different restorative techniques measured by the 3D-FEA are also shown in table 1. For the 3D-FEA strain measurements, the Z350XT/10 incr, Z350XT/8 incr and Filtek Bulk Fill Flow/Z350XT also exhibit the higher mean cusp strain values. The lingual cusp also had the higher values of strain. The lower values of mean cusp strain values were observed for SDR/Spectra Basic and Tetric N-ceram Bulk Fill.

Residual stress calculation-finite element analysis (3D)

The modified Von Mises shrinkage stress distributions at the buccal and lingual cusps for the different restorative techniques are observed to the 3D-FEA strain measurements are show in figure 3 and 4. The stresses can be visualized using a linear color scale in which blue indicates the lowest stress values, and yellow and light gray the highest stress values. For the 3D-FEA shrinkage stress distributions at the buccal cusp, the Z350XT/10 and 8 incr restorative techniques exhibited the highest shrinkage stress values. Z350XT/10 incr concentrated higher stress over a larger area of the buccal cusp while the z350/8 incr concentrated the stresses on the cervical area of the buccal cusp. The SDR/Spectra Basic techniques and Tetric N-ceram showed the lower values stress than Z350XT – 10 and 8 incr. For the lingual cusp, Z350XT/ 10 and 8 incr exhibit the higher shrinkage stress distributions than the SDR / Spectra Basic techniques and Tetric N-ceram. The lingual cusp showed higher value of shrinkage stress distributions than buccal cusp regardless the restorative technique.

Fracture load and failure mode

The mean fracture load values (N) and standard deviation (SD) for the different restorative techniques are shown in table 5. One-way ANOVA revealed that there is not a statistically significant difference between the groups ($p=0.679$). The fracture load mode distribution for the experimental groups is presented in figure 6. Type III fractures was dominant in most of the restorative techniques. The SDR / Spectra basic group showed the higher percentage of restorable fractures (type I).

4. Discussion

The results of present study confirmed that restorative techniques using different composite resins, Bulk Fill and Conventional, and different techniques affected the values of cuspal strain, post-gel shrinkage, and stress of polymerization shrinkage rejecting the null hypothesis. Pre-molars with severe structural loss consequently present lower values of mechanical resistance, and greater susceptibility to fractures, since, in the act of chew or occlusal efforts, teeth that show loss of structure demonstrate less capacity to distribute coronal stress when compared to a healthy tooth, thus the structural loss of dental tissue deceases the capability of a tooth withstand the masticatory forces and structural failure develops [11].

When comparing pre-molars with non-severe structural involvement with premolars with greater structural loss it can be observed that the values of deformation and stress are more considerable and the values of load are more critical [17]. Therefore, it is important to observe the mechanical properties of the materials used in cases of teeth with greater loss structure, can lead to loss of the dental element [6, 31].

The composite resin, as mentioned above, is a material that undergoes volumetric shrinkage when it is activated and reacts by converting monomers into polymers, therefore, for teeth with severe structural loss, it is necessary to evaluate that the use of composite resins with high shrinkage values are not indicated [27], since it is normal that when the composite resins are photoactivated there is shrinkage [11], but those with higher shrinkage values generate higher levels of stress that can be transmitted and can generate degradation of the adhesive interface and dental deformation.

To evaluate it, the post-gel shrinkage was defined as the portion of the total shrinkage of the stress-causing polymerization, and was measured by the strain gage technique [24]. At the present study, all the composite resins analyzed presented statistical difference in relation to post-gel shrinkage. The conventional Z350XT composite resin presented higher shrinkage values than the Bulk Fill composites used, these results are associated with the load volume and the post-gel shrinkage, because the higher the volume of charge, the higher elastic modulus. The more rigid the material is, the higher the levels of post-gel shrinkage values generated by it and consequently the higher the stress and strain levels[24].

On the other hand, composites resins whit low filler content have a lower post-gel shrinkage when compared to composite resins with higher elastic modulus (E), but they have lower mechanical properties when compared to resins as higher volume of filler.

The stress analysis obtained by the 3D-finite element test (FEA) was performed using the values of post-gel shrinkage obtained through cuspal strain and elastic modulus of this resins as shown in the consulted literature [17, 24]. The results showed that the Z350XT - 10incr group was the model with the highest stress values and the area with the least dentin remaining was the area that presented more expressive stress values in both the buccal cusp and the lingual cusp.

For both techniques the same composite resin used in the group with 8 increments presented smaller values of stress when compared with the group of 10 increments concluding that the greater number of increments of resin greater is the stress generated by the material in the tooth [28]. Although the fluid consistency SDR and FBF belong to the same material category, the present results showed that they not very similar, since FBF when compared to the SDR composite resin presented values of stress by FEA-3D considerably high both in the buccal and lingual cusps.

The values of cusp deformation obtained by the cuspal strain test demonstrated that there was statistical difference and relation to the values of deformation obtained by the techniques used. The values obtained in the analysis of strain and concentration of stress show that in most of the samples and techniques the cusps that presented greater values of deformation and stress were the lingual cusps. It could be can be explained by the fact that the lingual cusp presents a smaller size when compared with the bucal one. Clinically during the preparation of the teeth, more attention should be driven to the lingual cusp that becomes more fragile [24, 25]. This can be confirmed in the present results by the analysis of the fracture modes that showed that most fractures occurred in the lingual cusps.

In general, the bulk fill composites presented lower values of deformation when compared to Z350XT (conventional composite resin). These results demonstrate that, because of higher modulus of elasticity values and post gel shrinkage, the Z350XT composite resin may be much more critical in teeth with severe structural loss. The strain values obtained in the cuspal strain and Finite Element Analysis - 3D (FEA) tests were very similar. The Z350XT / 10 and Filtek Bulk Fill Flow / Z350XT techniques, were the techniques that showed the highest deformation values in the buccal and lingual cusps, and the technique with the lowest values was Tetric N Ceram Bulk Fill.

The bulk fill composites resin presented lower values of deformation, lower post-gel shrinkage values and lower stress values when compared to the conventional Z350XT composite, but even the Spectra Basic resin being a conventional composite the average of its post-gel shrinkage was similar to the values of Bulk Fill resins and much smaller than the Z350XT resin values.

This can be explained by the fact that Spectra Basic resin is a microhybrid composite resin composed of nanoparticles that during the photoactivation process generate lower shrinkage stress, resulting in lower values of post-gel shrinkage, as well as a low elasticity when the Z350XT and an Elastic modulus close to the value represented by SDR [30]. The Z350XT is a nano filler composte resin that presents greater percentage of filler when compared to Spectra basic composite resin, thus generating a greater stress from the shrinkage when subjected to the photoactivation.

Another factor related to these data is that studies indicate that the Z350 XT composite resin may not be completely photoactivated because it has a higher volume of charge, depending on the type of light curing agent used and the amount of light exposed to the composite resin, and these factors may influence the stress that the material generates when inserted in the tooth and also in microhardness values that may be smaller [32].

From the group of composite resins used in a single increment (Bulk Fill), the Filtek Bulk Fill Flow composite resin showed higher values of post-gel shrinkage, higher values of deformation and higher values of stress, in counterpart also was the Bulk Fill resin that presented the largest values of fracture load. Although the fracture load values did not present statistical differences between them, the Bulk Fill composite resins showed less catastrophic failure than the techniques using the Z350 XT resin[31].

Several factors can influence the ability of the tooth to absorb and propagate stress, such as those generated by the degree of conversion of the composite resins, and the curing depth of the composite resin [32].

All these information and characteristics must be observed so that a suitable clinical restorative protocol is determined for the teeth that need restoration, and still more for the teeth that present a great structural loss, as was the case in this study where we can observe that laboratory tests and computational results show that the Bulk Fill composite resins present stress, shrinkage and deformation values that indicate that these materials present more effectiveness and simplicity in the clinical practice when compared with conventional resins.

5. Conclusions

Based on the results of the present study it was concluded that:

1. The bulk fill composite resins used had lower volumetric shrinkage values than the conventional Z350-XT composite.

2. The samples of the groups that used conventional composite resin presented higher values of cuspal strain.

3. Filtek Bulk Fill Flow composite resin was the composite that presented higher values of cuspal strain among the Bulk Fill resins used.

4. Four out of five groups presented higher values of cuspal strain and invoices on the buccal cusp, demonstrating that the lingual cusp is the most fragile cusp.

5. Although Bulk Fill composite resins presented lower values of load resistance, cuspal strain, stress and volumetric shrinkage values were lower when compared to Z350XT composite resin.

Clinical Significance: The use of Bulk Fill composites resins is indicated for treatment of weakened pre-molars because these materials present lower values of shrinkage of deformation, which indicates less stress in the restored tooth and good results when submitted to the fracture when they are compared with the co-functional compposite resins. Thus the use of these materials by dental surgeons is a strategy to reduce factors that can affect direct restorations of composite resins in weakened teeth.

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Tables

Table 1.Composite resins composition.

Material	CODE	Shade	Composite type	Incrementsize and light activation time	Organic matrix	Filler	Filler % wt /Vol	Manufacturer
Filtek Z350XT	Z350XT	A2	Nanofiled Composite	2.0mm – 40 s	Bis-GMA, Bis-Ema, UDMA,TEGDMA	Silicaandzirconiananofillers, agglomeratedzirconia-silicananoclusters	82/60	3M-ESPE (St. Paul, MN, USA)
Filtek Bulk Fill Flow	FBF	A2	Bulk Fill Flowable composite	4.0mm – 40 s	UDMA, BISGMA, EBPADMA Procrylatresin	Silane treated ceramic and YbF3	64/ 42.5	3M-ESPE (St. Paul, MN, USA)
Surefill SDR	SDR	A2	Bulk Fill Flowable Composite	4.0mm – 40 s	Modified UDMA, dimethacrylate and dysfunctional diluents Bis-Gma adduct, EBPADMA, TEGDMA	Bariumandstrontium alumino-fluoro-silicateglasses	68/44	Dentsply, (Konstanz, Germany)
Spectra Basic	SB	A2	Mycrohybrid Composite	2.0mm – 40 s	Bis-GMAadduct, EBPADMA, TEGDMA	Ba-F-Al-B-Si-glass, silica	76/60	Dentsply, (Konstanz, Germany)
Tetric N-Ceram Bulk Fill	TNC	IVA	Bulk Fill Past Composite	4.0mm – 40 s	UDMA, BISGMA	Barium glass, ytterbium trifluoride, mixed oxide prepolymer	79/61	(IvoclarVivadent, Schaan, Liechtenstein)

Table 2. Mechanical properties applied for the dental structures and materials.

Material	Elastic modulus	Coefficient of poisson	Post-gel linear shrinkage
Z350XT	14.300	0.24	0.002469
Filtek Bulk Fill Flow	10.100	0.24	0.001667
SDR	12.600	0.24	0.001133
Spectra basic	9.800	0.24	0.001336
Tetric N-Ceram Bulk	10.800	0.24	0.001507

Table 3. Post gel Shrinkage mean values and (standard deviation) measured by strain gage method.

Composite	Post Gel Shrinkage (%)
Z350XT	0.86 (0.02) A
Filtek Bulk Fill	0.53 (0.03) B
Spectra basic	0.40 (0.04) CD
SDR	0.34 (0.03) E
Tetric N-Ceram Bulk Fill	0.45 (0.02) D

*Different letters indicate a significant difference between the restorative techniques ($P<0.05$).

Table 4. Mean strain values (µS) (standard deviation) measured by strain gages and 3D finite element method.

Group	Strain gage method			3D finite element analysis		
	Buccal strain (µS)	Lingual strain (µS)	Mean Cusp strain	Buccal strain (µS)	Lingual strain (µS)	Mean Cusp strain
Z350XT/10 incr	160,08 (69,50)	174,95 (95,67)	247,56 (101,96) A	129.73	203.38	166.56
Z350XT/8 incr	127,36 (24,78)	169,69 (73,26)	227,00 (74,18) A	56.40	127.54	91.97
Filtek Bulk Fill Flow/Z350	137,4 (100,55)	141,99 (56,78)	210,68 (82,95) AB	84.95	103.27	94.11
SDR – Spectra Basic	99,54 (58,24)	59,72 (33,84)	109,49 (55,22) C	51.44	59.29	55.37
Tetric N-Ceram Bulk Fill	64,50 (48,36)	100,56 (35,19)	132,81 (45,76) BC	44.66	54.38	49.52

*Different letters indicate a significant difference between the restorative techniques (P<0.05).

Table 5. Mean fracture load (N) and standard deviation values.

Group	Fracture load (N)
Z350XT/10 incr	530.99 (189.80) A
Z350XT/8 incr	453.70 (107.04) A
Filtek Bulk Fill Flow/Z350	494.15 (205.75) A
SDR/Spectra Basic	462.46 (144.76) A
Tetric N-Ceram Bulk Fill	436.66 (97.46) A

*Different letters indicate a significant difference between the restorative techniques (P<0.05).

Figure Legends

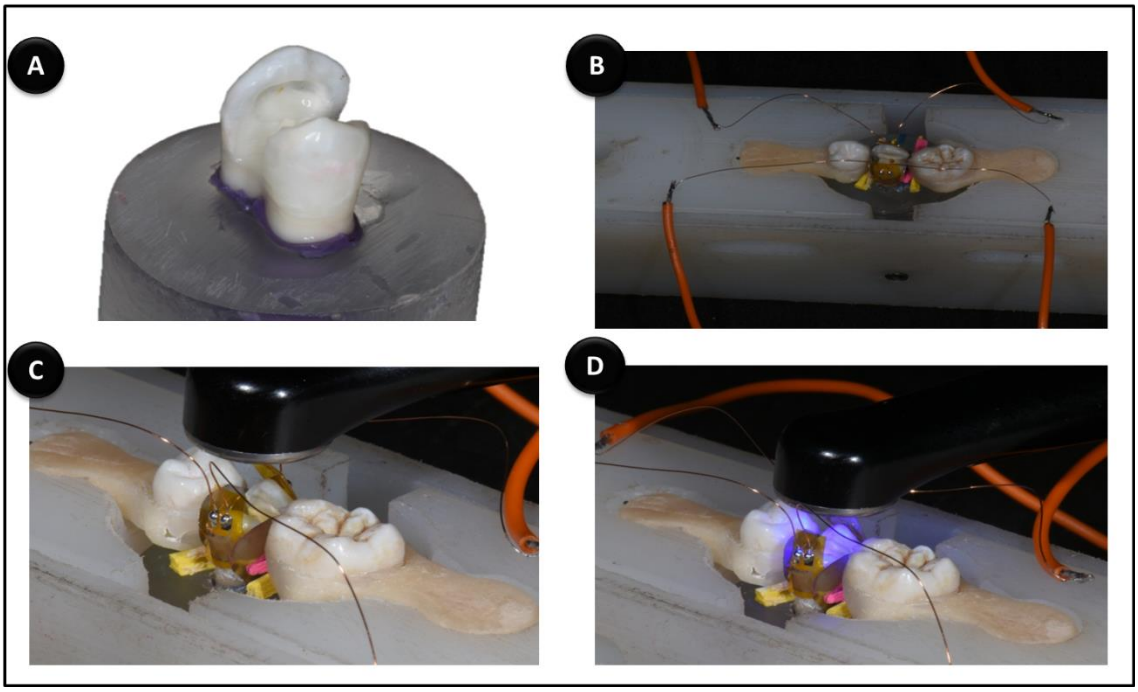

Figure 1. Strain gage method. (a) MOD prep; (b) The strain gages were fixed to the external buccal and lingual cusps with cyanoacrylate adhesive (Super Bonder, Loctite, Itapevi, SP, Brazil); (c) The composites were inserted into the wells according to the insertion techniques defined for each material described in the study; (d) Light curing for 40 seconds.

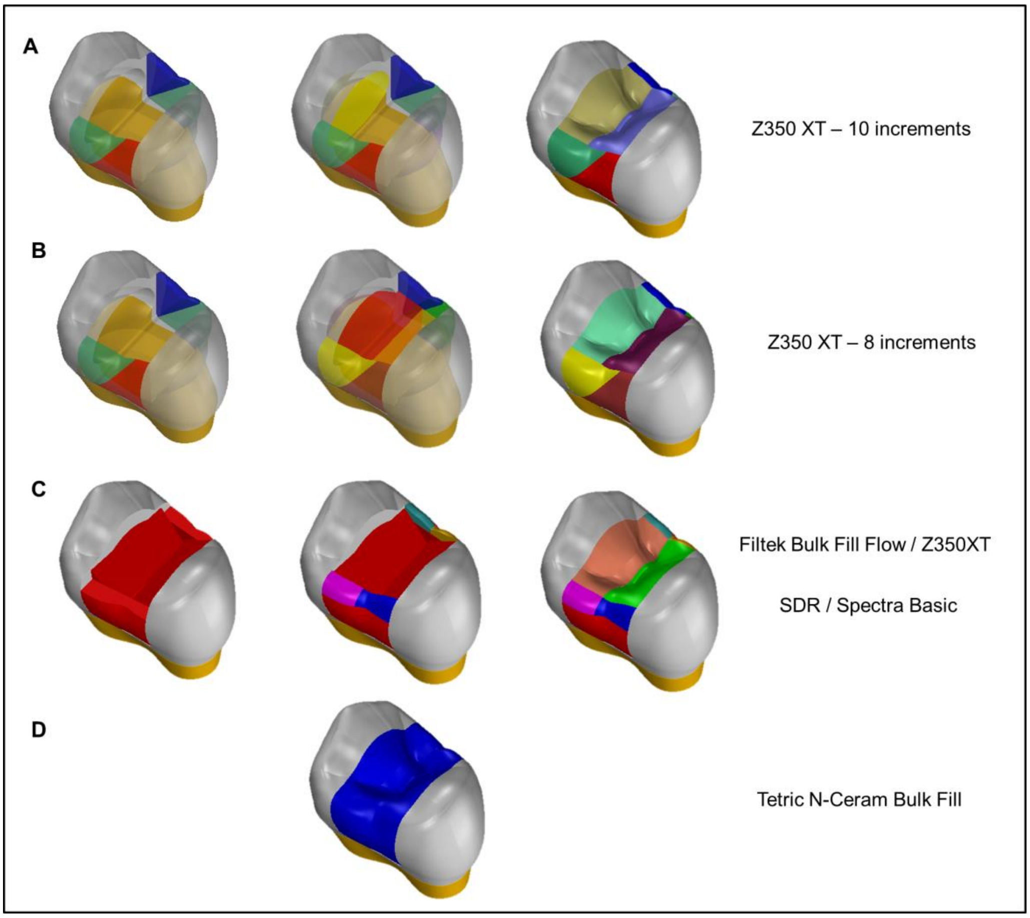

Figure 2. Order of insertion of the increments according to the techniques used. (a) Z350 XT – 10 increments; (b) Z350 XT – 8 increments; (c) Filtek Bulk Fill Flow / Z350XT; (d) SDR / Spectra Basic; (e) Tetric N-Ceram Bulk Fill.

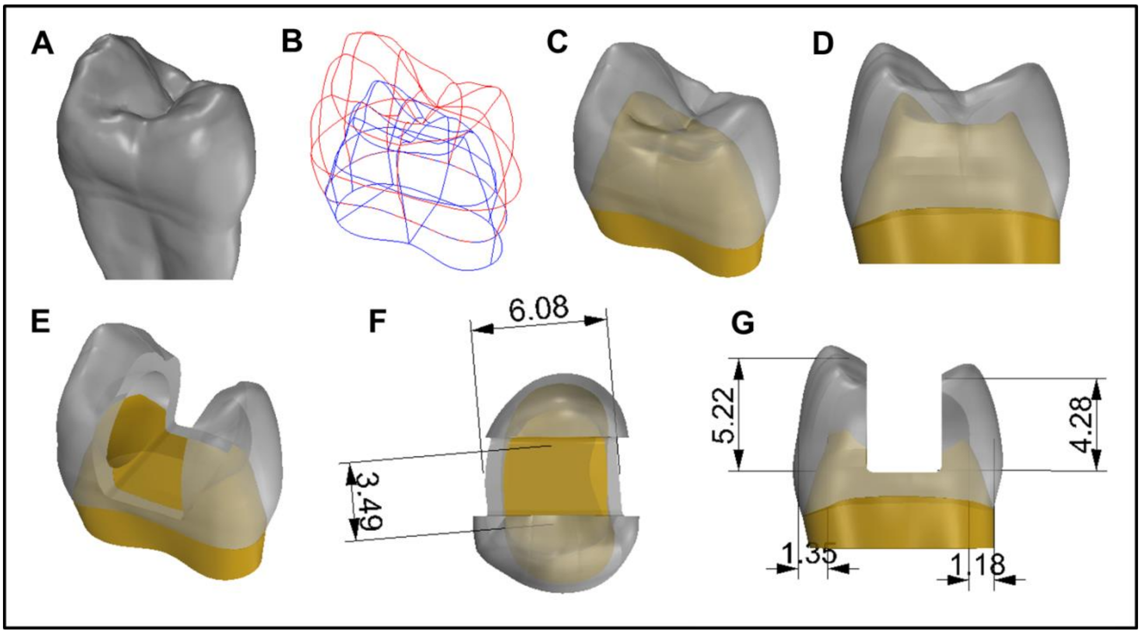

Figure 3. Three-dimensional finite element modeling (3D); a) STL file; (b) Polylines created using the anatomical crown marks; c and d) NURBS surfaces created; e, f and g) Dimensions of the MOD preparation and weakening of the buccal and lingual cusp.

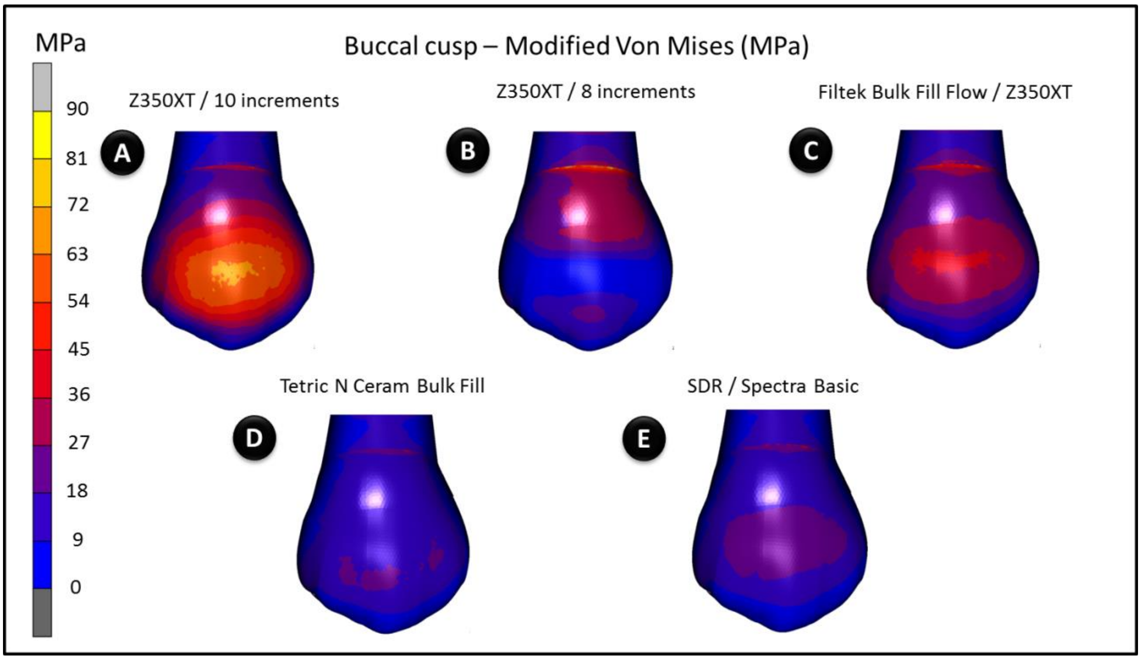

Figura 4. Modified von Mises stress distributions in the buccal cusp. (a) Stress generated on the buccal cusp using the technique Z350 XT – 10 increments; (b) Stress generated on the buccal cusp using the technique Z350 XT – 8 increments; (c) Stress generated on the buccal cusp using the technique Filtek Bulk Fill Flow / Z350XT; (d) Stress generated on the lingual cusp using the technique Tetric N-Ceram Bulk Fill; (e) Stress generated on the lingual cusp using the technique SDR / Spectra Basic.

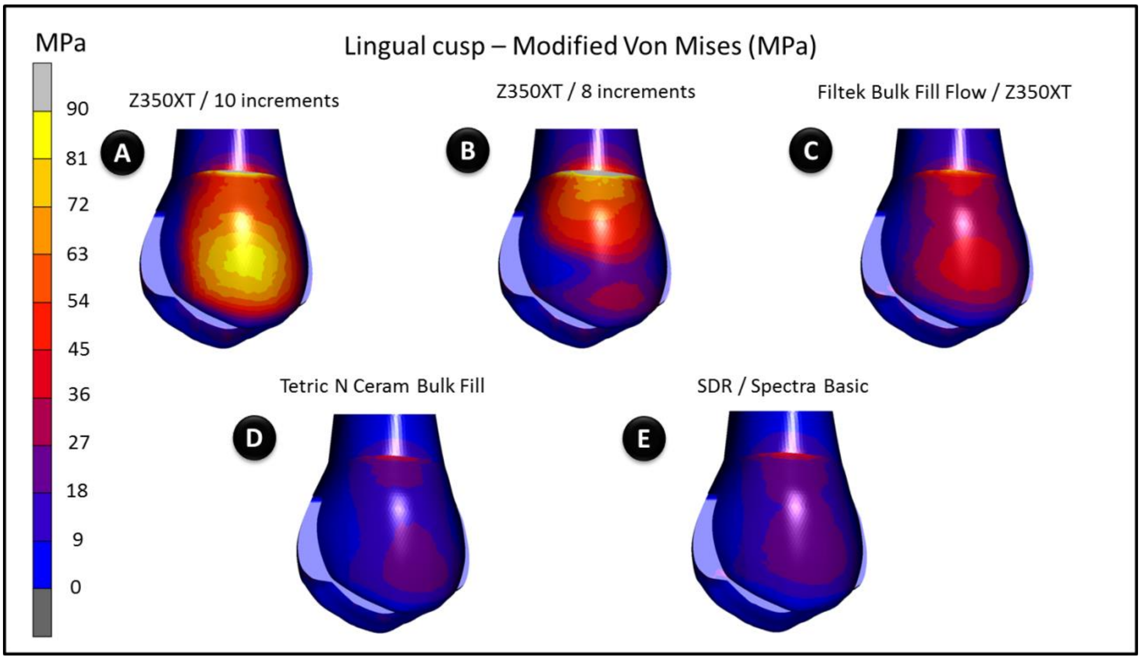

Figure 5. Modified von Mises stress distributions in the lingual cusp. (a) Stress generated on the lingual cusp using the technique Z350 XT – 10 increments; (b) Stress generated on the lingual cusp using the technique Z350 XT – 8 increments; (c) Stress generated on the lingual cusp using the technique Filtek Bulk Fill Flow / Z350XT; (d) Stress generated on the lingual cusp using the technique Tetric N-Ceram Bulk Fill; (e) Stress generated on the lingual cusp using the technique SDR / Spectra Basic

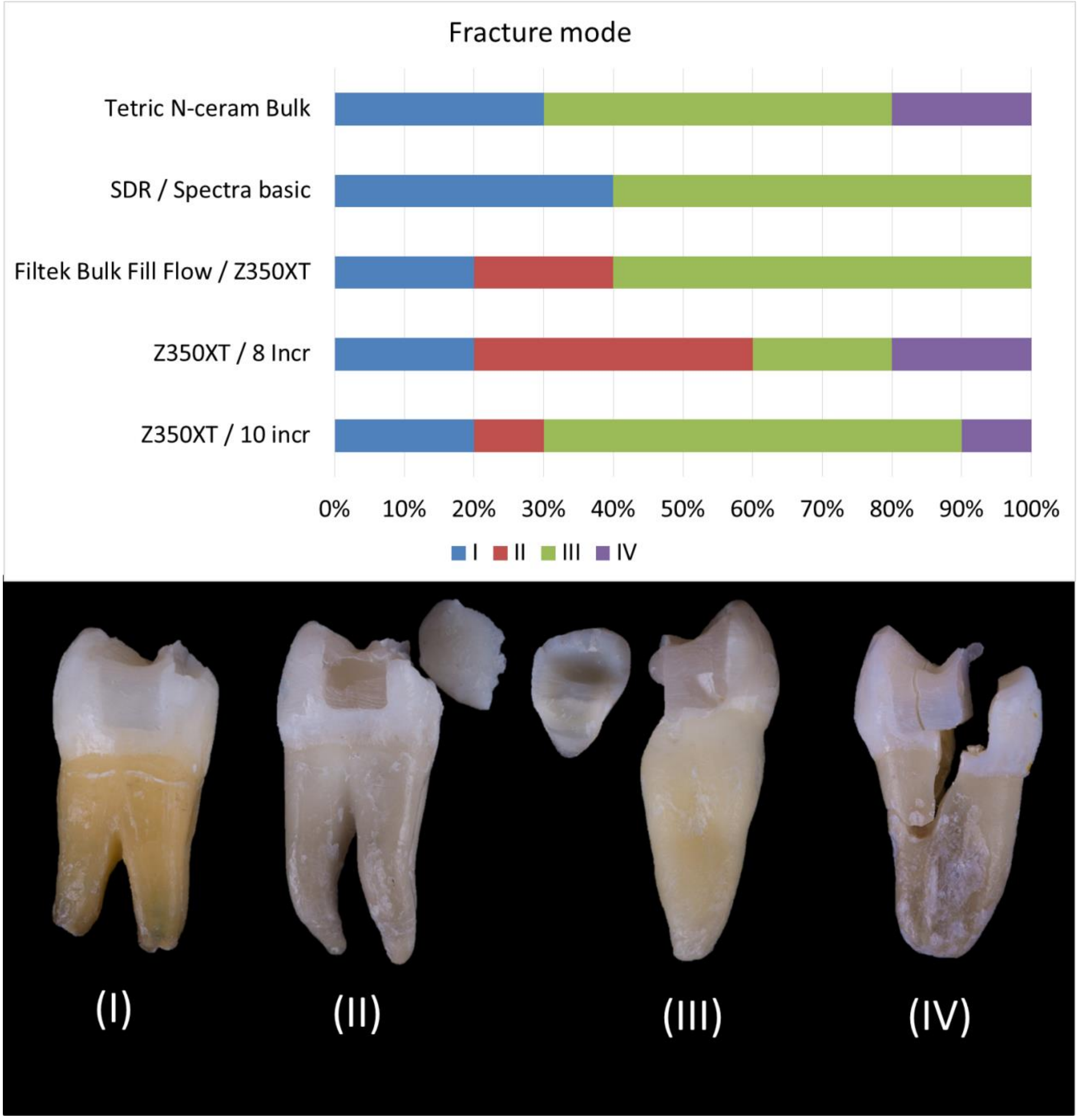

Figure 6. Failure mode analysis. (a) Type I: fracture involving part of the coronary structure; (b) Type II: fracture involving a small part of the coronary structure and cohesive in the restoration; (c) Type III: fracture with involvement of part of the coronary structure, cohesive failure in restoration and reparable root fracture by association with periodontal surgery; (d) Type IV: severe fracture with indication of tooth extraction.

Conclusão

4. CONCLUSÃO

Baseado nos resultados do presente estudo concluiu-se que:

1. As resinas compostas Bulk Fill utilizadas apresentaram valores de contração pós-gel menores do que a resina composta Z350-XT.
2. As amostras dos grupos que utilizaram resina composta Z350-XTl apresentaram maiores valores de deformação de cúspides.
3. A resina composta Filtek Bulk Fill Flow apresentou maiores valores de deformação da cúspide entre as resinas compostas Bulk Fill utilizadas.
4. Quatro de cinco grupos apresentaram maiores valores de deformação e fraturas na cúspide vestibular, demonstrando que a cúspide lingual é a cúspide mais frágil.
5. Embora as resinas compostas Bulk Fill tenham apresentado menores valores de resistência à fratura, os valores de deformação, tensão e contração pós-gel foram menores quando comparados à resina Z350XT.
6. As resinas compostas Bulk Fill são eficientes para aplicação na prática clínica, embora mais pesquisas longitudinais precisem ser realizadas.

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ANEXO A – Normas de Publicação da Revista Operative Dentistry: Instructions to Authors

New Instructions as of 20 September 2008

Operative Dentistry requires electronic submission of all manuscripts. All submissions must be sent to Operative Dentistry using the Allen Track upload site. Your manuscript will only be considered officially submitted after it has been approved through our initial quality control check, and any problems have been fixed. You will have 6 days from when you start the process to submit and approve the manuscript. After the 6 day limit, if you have not finished the submission, your submission will be removed from the server. You are still able to submit the manuscript, but you must start from the beginning. Be prepared to submit the following manuscript files in your upload:

- A Laboratory or Clinical Research Manuscript file must include:
    - a title
    - a running (short) title
    - a clinical relevance statement
    - a concise summary (abstract)
    - introduction, methods & materials, results, discussion and conclusion
    - references (see Below)
    - The manuscript **MUST NOT** include any:
        - identifying information such as:
            - Authors
            - Acknowledgements
            - Correspondence information
        - Figures
        - Graphs
        - Tables
- An acknowledgement, disclaimer and/or recognition of support (if applicable) must in a separate file and uploaded as supplemental material.
- All figures, illustrations, graphs and tables must also be provided as individual files. These should be high resolution images, which are used by the editor in the actual typesetting of your manuscript. Please refer to the instructions below for acceptable formats.
- All other manuscript types use this template, with the appropriate changes as listed below.

Complete the online form which includes complete author information and select the files you would like to send to Operative Dentistry. Manuscripts that do not meet our formatting and data requirements listed below will be sent back to the corresponding author for correction.

GENERAL INFORMATION

- All materials submitted for publication must be submitted exclusively to Operative Dentistry.
- The editor reserves the right to make literary corrections.
- Currently, color will be provided at no cost to the author if the editor deems it essential to the manuscript. However, we reserve the right to

convert to gray scale if color does not contribute significantly to the quality and/or information content of the paper.

- The author(s) retain(s) the right to formally withdraw the paper from consideration and/or publication if they disagree with editorial decisions.
- International authors whose native language is not English must have their work reviewed by a native English speaker prior to submission.
- Spelling must conform to the American Heritage Dictionary of the English Language, and SI units for scientific measurement are preferred.
- While we do not currently have limitations on the length of manuscripts, we expect papers to be concise; Authors are also encouraged to be selective in their use of figures and tables, using only those that contribute significantly to the understanding of the research.
- Acknowledgement of receipt is sent automatically. If you do not receive such an acknowledgement, please contact us at editor@jopdent.org rather than resending your paper.
- **IMPORTANT:** Please add our e-mail address to your address book on your server to prevent transmission problems from spam and other filters. Also make sure that your server will accept larger file sizes. This is particularly important since we send page-proofs for review and correction as .pdf files.

REQUIREMENTS

- **FOR ALL MANUSCRIPTS**

1. **CORRESPONDING AUTHOR** must provide a WORKING / VALID e-mail address which will be used for all communication with the journal.
   NOTE: Corresponding authors MUST update their profile if their e-mail or postal address changes. If we cannot contact authors within seven days, their manuscript will be removed from our publication queue.

2. **AUTHOR INFORMATION** must include:
   - full name of all authors
   - complete mailing address for each author
   - degrees (e.g. DDS, DMD, PhD)
   - affiliation (e.g. Department of Dental Materials, School of Dentistry, University of Michigan)

3. **MENTION OF COMMERCIAL PRODUCTS/EQUIPMENT** must include:
   - full name of product
   - full name of manufacturer
   - city, state and/or country of manufacturer

4. **MANUSCRIPTS AND TABLES** must be provided as Word files. Please limit size of tables to no more than one US letter sized page. (8 ½ ” x 11”)

5. **ILLUSTRATIONS, GRAPHS AND FIGURES** must be provided as TIFF or JPEG files with the following parameters

- line art (and tables that are submitted as a graphic) must be sized at approximately 5” x 7” and have a resolution of 1200 dpi.
- gray scale/black & white figures must have a minimum size of 3.5” x 5”, and a maximum size of 5” x 7” and a minimum resolution of 300 dpi and a maximum of 400 dpi.
- color figures must have a minimum size of 2.5” x 3.5”, and a maximum size of 3.5” x 5” and a minimum resolution of 300 dpi and a maximum of 400 dpi.
- color photographs must be sized at approximately 3.5” x 5” and have a resolution of 300 dpi.

- **OTHER MANUSCRIPT TYPES**

1. **CLINICAL TECHNIQUE/CASE STUDY MANUSCRIPTS** must include:
   - a running (short) title
   - purpose
   - description of technique
   - list of materials used
   - potential problems
   - summary of advantages and disadvantages
   - references (see below)

2. **LITERATURE AND BOOK REVIEW MANUSCRIPTS** must include:
   - a running (short) title
   - a clinical relevance statement based on the conclusions of the review
   - conclusions based on the literature review…without this, the review is just an exercise
   - references (see below)

- **FOR REFERENCES**

REFERENCES must be numbered (superscripted numbers) consecutively as they appear in the text and, where applicable, they should appear after punctuation.

The reference list should be arranged in numeric sequence at the end of the manuscript and should include:

1. Author(s) last name(s) and initial (ALL AUTHORS must be listed) followed by the date of publication in parentheses.
2. Full article title.
3. Full journal name in italics (no abbreviations), volume and issue numbers and first and last page numbers complete (i.e. 163-168 NOT attenuated 163-68).
4. Abstracts should be avoided when possible but, if used, must include the above plus the abstract number and page number.

5. Book chapters must include chapter title, book title in italics, editors' names (if appropriate), name of publisher and publishing address.
6. Websites may be used as references, but must include the date (day, month and year) accessed for the information.
7. Papers in the course of publication should only be entered in the references if they have been accepted for publication by a journal and then given in the standard manner with "In press" following the journal name.
8. **DO NOT** include unpublished data or personal communications in the reference list. Cite such references parenthetically in the text and include a date.

EXAMPLES OF REFERENCE STYLE

- Journal article: two authors
  Evans DB & Neme AM (1999) Shear bond strength of composite resin and amalgam adhesive systems to dentin *American Journal of Dentistry* **12(1)** 19-25.

- Journal article: multiple authors
  Eick JD, Gwinnett AJ, Pashley DH & Robinson SJ (1997) Current concepts on adhesion to dentin *Critical Review of Oral and Biological Medicine* **8(3)** 306-335.

- Journal article: special issue/supplement
  Van Meerbeek B, Vargas M, Inoue S, Yoshida Y, Peumans M, Lambrechts P & Vanherle G (2001) Adhesives and cements to promote preservation dentistry *Operative Dentistry* **(Supplement 6)** 119-144.

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  Yoshida Y, Van Meerbeek B, Okazaki M, Shintani H & Suzuki K (2003) Comparative study on adhesive performance of functional monomers *Journal of Dental Research* **82(Special Issue B)** Abstract #0051 p B-19.

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ANEXO B – PARECER COMITÊ DE ÉTICA EM PESQUISA

UNIVERSIDADE DE UBERABA - UNIUBE

Continuação do Parecer: 2.959.369

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1168336.pdf	27/09/2018 14:00:06		Aceito
Folha de Rosto	Doc1.docx	27/09/2018 13:56:43	LAIS CARVALHO MARTINS	Aceito
Projeto Detalhado / Brochura Investigador	Projetomestrado.pdf	10/07/2018 19:12:38	LAIS CARVALHO MARTINS	Aceito
Declaração de Manuseio Material Biológico / Biorepositório / Biobanco	Bancodedentes.pdf	10/07/2018 18:40:35	LAIS CARVALHO MARTINS	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

UBERABA, 11 de Outubro de 2018

Assinado por:
Geraldo Thedei Junior
(Coordenador(a))

APÊNDICE – ANÁLISE ESTATÍSTICA DA DEFORMAÇÃO DE CÚSPIDE

One Way Analysis of Variance **Thursday, February 07, 2019, 9:18:18 AM**

Data source: Data 1 in Lais.JNB
Normality Test: Passed (P = 0.281)
Equal Variance Test: Passed (P = 0.190)

Group Name	N	Missing	Mean	Std Dev	SEM
Z350 - 10incr	10	0	247.556	101.963	32.244
z350 - 8incr	10	0	227.001	74.183	23.459
Filtek Bulk Fill flow - z350	10	0	210.684	82.948	26.230
SDR - Spectra basic	10	0	109.487	55.218	17.462
Tetric N-ceram	10	0	132.812	45.756	14.469

Source of Variation	DF	SS	MS	F	P
Between Groups	4	147616.854	36904.213	6.608	<0.001
Residual	45	251304.335	5584.541		
Total	49	398921.189			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Power of performed test with alpha = 0.050: 0.972

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor:

Comparison	Diff of Means	p	q	P	P<0.050
Z350 - 10inc vs. SDR – Spectr	138.069	5	5.843	0.002	Yes
Z350 - 10inc vs. Tetric N-cer	114.744	5	4.856	0.011	Yes
Z350 - 10inc vs. Filtek Bulk	36.872	5	1.560	0.804	No
Z350 - 10incr vs. z350 - 8incr	20.554	5	0.870	0.972	Do Not Test
z350 - 8incr vs. SDR – Spectr	117.515	5	4.973	0.009	Yes
z350 - 8incr vs. Tetric N-cer	94.190	5	3.986	0.053	No
z350 - 8incr vs. Filtek Bulk	16.317	5	0.690	0.988	Do Not Test
Filtek Bulk vs. SDR - Spectr	101.198	5	4.282	0.032	Yes
Filtek Bulk vs. Tetric N-cer	77.873	5	3.295	0.154	Do Not Test
Tetric N-cer vs. SDR – Spectr	23.325	5	0.987	0.956	No

A result of "Do Not Test" occurs for a comparison when no significant difference is found between two means that enclose that comparison. For example, if you had four means sorted in order, and found no difference

between means 4 vs. 2, then you would not test 4 vs. 3 and 3 vs. 2, but still test 4 vs. 1 and 3 vs.

1 (4 vs. 3 and 3 vs. 2 are enclosed by 4 vs. 2: 4 3 2 1). Note that not testing the enclosed means is a procedural rule, and a result of Do Not Test should be treated as if there is no significant difference between the means, even though one may appear to exist.

APÊNDICE – ANÁLISE ESTATÍSTICA DA CONTRAÇÃO PÓS-GEL

One Way Analysis of Variance **Tuesday, November 20, 2018, 3:54:56 PM**

Data source: Post-Gel Shrinkage

Normality Test: Passed (P = 0.355)

Equal Variance Test: Passed (P = 0.421)

Group Name	N	Missing	Mean	Std Dev	SEM
Spectra Basic	5	0	1336.980	121.292	54.243
Tetric N-Ceram Bulk Fill	5	0	1507.636	128.604	57.513
Z350XT	5	0	2864.696	67.010	29.968
Filtek Bulk Fill Flow	5	0	1776.894	94.717	42.359
SDR	5	0	1119.292	97.583	43.640

Source of Variation	DF	SS	MS	F	P
Between Groups	4	9331056.359	2332764.090	215.063	<0.001
Residual	20	216938.012	10846.901		
Total	24	9547994.371			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Power of performed test with alpha = 0.050: 1.000

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor:

Comparison	Diff of Means	p	q	P	P<0.050
Z350XT vs. SDR	1745.403	5	37.474	<0.001	Yes
Z350XT vs. Spectra Basic	1527.716	5	32.800	<0.001	Yes
Z350XT vs. Tetric N-Cer	1357.059	5	29.136	<0.001	Yes
Z350XT vs. Filtek Bulk	1087.802	5	23.355	<0.001	Yes
Filtek Bulk Fill Flow vs. SDR	657.602	5	14.119	<0.001	Yes
Filtek Bulk vs. Spectra Basi	439.914	5	9.445	<0.001	Yes
Filtek Bulk vs. Tetric N-Cer	269.257	5	5.781	0.005	Yes
Tetric N-Cer vs. SDR	388.344	5	8.338	<0.001	Yes
Tetric N-Cer vs. Spectra Basi	170.656	5	3.664	0.110	No
Spectra Basic vs. SDR	217.688	5	4.674	0.026	Yes

APÊNDICE – ANÁLISE ESTATÍSTICA DA RESISTÊNCIA À FRATURA

One Way Analysis of Variance Monday, November 19, 2018, 2:09:06 PM

Data source: Fracture Resistance

Normality Test: Passed (P = 0.712)

Equal Variance Test: Passed (P = 0.416)

Group Name	N	Missing	Mean	Std Dev	SEM
Z350 - 10 incr	10	0	530.999	189.805	60.022
Z350 - 8 incr	10	0	453.707	107.004	33.838
Filtek Bulk - Z350	10	0	494.156	205.753	65.065
SDR - Spectra basic	10	0	462.467	144.769	45.780
Tetric BulkFill	10	0	436.664	97.466	30.821

Source of Variation	DF	SS	MS	F	P
Between Groups	4	55811.656	13952.914	0.580	0.679
Residual	45	1082412.670	24053.615		
Total	49	1138224.325			

The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.679).

Power of performed test with alpha = 0.050: 0.049

The power of the performed test (0.049) is below the desired power of 0.800.

Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.