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CALEBE DE MELO

**FORÇA DE CONTATO PROXIMAL EM RESTAURAÇÕES POSTERIORES
DE RESINA COMPOSTA CONVENCIONAL E BULK FILL - EFEITO DO TIPO
DE DENTE ADJACENTE E DA FADIGA OCLUSAL**

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CALEBE DE MELO

**Proximal contact force in posterior bulk fill and incremental composite
resin restoration - effect of adjacent tooth type and occlusal fatigue**

Trabalho de conclusão de curso
apresentado a Faculdade de
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“Em todas essas situações temos a vitória completa por meio daquele que nos amou, pois eu tenho a certeza de que nada pode nos separar do amor de Deus, nem a morte, nem a vida; nem os anjos, nem outras autoridades ou poderes celestiais; nem o presente, nem o futuro; nem o mundo lá de cima, nem o mundo lá de baixo. Em todo o Universo não há nada que possa nos separar do amor de Deus, que é nosso por meio de Cristo Jesus, o nosso Senhor.”

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Calebe de Melo

RESUMO

O objetivo deste estudo foi medir a força de contato proximal (N) e a área superficial proximal em restaurações de resina composta classe II com preenchimento incremental e bulk fill, associadas a um dente molar sobre implante e a um dente adjacente pré-molar simulando o ligamento periodontal. Um modelo foi desenvolvido com um 1º Molar artificial com dois preparos proximais classe II bilaterais e dentes adjacentes, um deles simulando um dente 2º Molar sobre implante (TitamaxCM, Neodent) e o outro com ligamento periodontal simulando um dente pré-molar. Duas técnicas restauradoras de resina composta: Inc-Z350 (Filtek Z350, 3M ESPE) inserida incrementalmente; Bulk-OPUS, (Opus Bulk Fill APS Regular, FGM) composto bulk fill de alta viscosidade (n = 10). Após o procedimento restaurador, cada amostra foi escaneada usando o sistema de scanner óptico s600 (Zirkonzahn GmbH, IT) gerando uma superfície dental 3D e radiografada usando o sistema digital (Dürr Dental). A força de contato proximal, CF (N) foi medida com fio dental com a máquina de microtração (Microtensile ODEME, Luzerna, SC, Brasil). As amostras foram então submetidas a fadiga pela ciclagem mecânica, simulando 5 anos de envelhecimento. Todos os parâmetros foram medidos após a simulação de envelhecimento. Os raios X foram analisados qualitativamente por dois operadores para identificar cegamente a perda de continuidade no contato. As imagens de superfície 3D foram subtraídas e a diferença entre as digitalizações iniciais e finais foi expressa em esquema de cor e analisada por dois operadores. Os dados da força de contato proximal foram analisados usando ANOVA de duas vias em um arranjo de parcelas subdivididas seguido pelo teste de Tukey ($\alpha = 0,05$). A CF com molar foi significativamente maior que com o pré-molar, independentemente da resina composta ou do efeito da fadiga oclusal. O Inc-Z350 mostrou força de contato semelhante ao Bulk-OPUS. A fadiga oclusal resultou em redução significativa da força de contato proximal ($P < 0,001$), independentemente da região analisada e do material restaurador utilizado. A radiografia digital não foi capaz de detectar alteração no contorno proximal após fadiga oclusal. Não foi observada detecção de desgaste dentro do limite de sensibilidade estipulado (0,3 mm). O modelo desenvolvido para teste de força de contato foi eficiente. O contato proximal com o 2º molar foi mais eficaz do que com o pré-molar. O contato proximal diminuiu com 5 anos simulados de fadiga oclusal. A técnica de preenchimento bulk fill mostrou comportamento semelhante ao da técnica de preenchimento incremental usando resina convencional.

Palavras-chaves: resina composta, bulk fill, técnica incremental, força do ponto de contato, implantes dentários, restaurações classe II em resina composta.

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Proximal contact force in posterior bulk fill and incremental composite resin restoration – effect of adjacent tooth type and occlusal fatigue.

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Running title: Proximal contact of bulk and conventional composite resins.

Keywords: composite resin, bulk fill, incremental technique, proximal contact force, dental implants, class II composite resin restorations.

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Proximal contact force in posterior bulk fill and incremental composite resin restoration – effect of adjacent tooth type and occlusal fatigue.

ABSTRACT

Objectives: To measure the proximal contact force (N) and the proximal surface area in incremental and bulk fill class II composite resin restorations with implant molar teeth and with premolar adjacent teeth simulating periodontal ligament.

Materials and methods: The model was created with a typodont first molar teeth with two bilateral occlusal-proximal class II and adjacent teeth simulating an implant molar teeth (TitamaxCM, Neodent) and premolar simulating periodontal ligament. Two composite resin restorative technique: Inc-Z350, (Filtek Z350, 3M ESPE) inserted incrementally; Bulk-OPUS, (Opus Bulk Fill APS Regular, FGM) high viscosity bulk fill composite (n = 10). After restorative procedure, each sample was scanned using the s600 optical scanner system (Zirkonzahn GmbH, IT) generating a 3D dental surface, and radiographed using digital system (Dürr Dental). The proximal contact force, CF(N) was measured using dental floss with microtensile machine (Microtensile ODEME, Luzerna, SC, Brazil). The samples were then submitted to fatigue mechanical cycling simulating 5 years of aging. All parameters were measured after the aging simulation. The x-rays were analyzed qualitative by two operators to blindly identifying the loss of continuity in contact. The 3D surface images were subtracted and the difference between initial and final scans were expressed in color graphics, and analyzed by two operators. Proximal contact force data were analyzed using two-way ANOVA in a split-plot arrangement followed by Tukey test ($\alpha=0.05$).

Results: The CF with molar was significantly higher than with premolar, irrespective of composite resin or occlusal fatigue effect. Inc-Z350 showed similar contact force than Bulk-OPUS. The occlusal fatigue resulted in significant reduction on proximal contact force ($P < 0.001$), irrespective of region analyzed and restorative material used. Digital x-ray was not able to detect the alteration

on the proximal contour after occlusal fatigue. No detection of wear within the sensitivity limit stipulated (0.3mm) was observed.

Conclusions: Developed model for contact force test was efficient. The proximal with the molar was more effective than with premolar. The proximal contact decreased with simulated 5 years of occlusal fatigue. Bulk fill technique showed a similar behavior to incremental filling technique using conventional composite.

Clinical relevance: *With the aging, the effectiveness of the contact points tends to decrease. This aspect is not easy to verify clinically using radiography. The bulk fill or incremental filling had similar proximal contact. Check the contact using dental floss can help the clinicians to detect proximal contact alteration.*

INTRODUCTION

Currently composite resins have been very successfully used for restoring posterior teeth, showing acceptable longevity in clinical studies.¹ More than 500 million direct dental restorations are placed each year in the world, being about 261 million direct composite resin restorations.^{1,2} Characteristics such as, secondary caries, fracture resistance, retention, marginal adaptation and discoloration and proximal contact of posterior restoration are the most important factors determining the clinical success of a posterior restorations.^{3,4}

Different filling techniques and composite resins have been developed over the years in order to minimize the polymerization shrinkage and their clinical effects.⁵ The modification on composite resin composition and the strategies used during filling procedures are approaches to reduce volumetric contraction and shrinkage stress developed.^{6,7} Although Incremental filling techniques using 2.0mm of increment results in lower shrinkage stress,⁸ the bulk-fill composite resins using 4-5mm of increment,^{9,10} have demonstrated lower residual shrinkage stresses^{11,12}.

Bulk-fill composites are gaining popularity among the clinicians because they simplify the restorative procedure by reducing the number of composite layers and thus the curing time.¹ Bulk-fill and conventional composite resins inserted incrementally in posterior teeth have shown similar clinical

performance.¹³ Bulk-fill composite resins of regular consistency compared to flowable materials have more wear resistance.^{14,15}

The proximal contact in natural dentition or implant restorations should be better understood for trying to faithfully reproduce in posterior proximal composite resin restorations.¹⁶ Proper contact relationship between neighboring teeth is extremely important to prevent food accumulation, gingiva inflammation and bone loss between the teeth and helps to stabilize the dental arches by proximal contacting.¹⁷ Food accumulation in the contact areas between teeth may have a pathological effect, and proximal contacts loss (PCL) predispose to food impaction, tooth migration, periodontal complications, and carious lesions^{16,17}

The reconstruction of a satisfactory composite resin proximal contact remains difficult when placing direct posterior restorations. Composite resin and amalgam restoration techniques differ from proximal contact reconstruction, based on several potential mechanisms, including on composites that cannot be "condensed".^{18,19} Insufficient adaptation of the matrix to the adjacent tooth, shrinkage of material polymerization, and the position of the tooth effects can influence on the initial proximal contact.^{20,21} A clinical studies of posterior composite resin restorations have already shown that change in contact force will not always remain stable over time showing that proximal contacts tend to diminish after a period of 6 months.²²

Per year, approximately 5 million implants are placed in the US, according to the American Dental Association (ADA), which is an increasing number of dental implants used as long-term dental substitutes.²³ Contact point loss is already considered a complication in implant prostheses, a 7-year clinical follow-up study evaluated the negative effects that proximal contact loss with implants and adjacent teeth, showing that periodontal ligament displacement can differ when performing composite resin restorations.²⁴

Many studies assess the strength of the proximal contact using a Tooth Pressure Meter (TPM) a device developed at the University of Technology Delft in the Netherlands that makes a standardized vertical removal of a thin strip of metal from the interdental mouth area.^{22,25-30} Similar laboratory equipment based on TPM called a universal testing machine built in Zwicki, Zwick GmbH, Ulm, Germany.³¹ On the other hand, other studies related to proximal wear associated with dental implants measured forces by scoring, with an operator flossing the

proximal contact or with the operator inserting different matrix thicknesses over time and evaluating the filling and the insertion difficulty^{24,32} On the best of authors knowledge, no study was found comparing the proximal contact force with bulk-fill composite resins influenced by simulated mechanical cycling. Therefore, the purpose of this in vitro study was to analyze the proximal contact force (N) and the proximal surface area in incremental and bulk fill class II composite resin restorations with implant molar teeth and with premolar simulating periodontal ligament. The null hypothesis was that the (1) restoration generated by two different composite resins would not influence the proximal contact force and (2) the occlusal fatigue would not reduce the proximal contact force between composite resin restorations and implant molar tooth or premolar simulating periodontal ligament.

METHODS AND MATERIALS

Study Design:

Twenty models were made, using artificial tooth TechPro (IM do Brazil Ltda., São Paulo, Brazil) with bilateral class II occlusal-proximal (OM and OD) standardized cavity preparations. The samples were restored with 2 protocols following the manufacturer's instructions. The number of samples was based on the coefficient of variability and the sample calculation. The power of test was 80% with a minimum detectable difference of 20%, there was a residual standard deviation of 15% and a significance level of 0.05, resulting in 10 samples per group. The composition of the resin composites as provided by the manufacturers are listed in Table 1. The samples were tested for detection of proximal contact opening by the Digital Radiographic Examination; for the proximal contour in 3D models generated by the Laser Scanner method (μm); proximal contact force (N) by the tensile test.

Model Development

The model with proximal metallic teeth was designed for testing proximal contact in posterior restorations (Figure 1). Mandibular posterior arcade of a

manequim (M.O.M. - Manequins Odontológicos Marília Ltda., São Paulo, Brazil), covering the 2nd molar, 1st molar and 2nd premolar was used. The alveolus was adapted to root of first molar and second premolar were sculpted with acrylic resin Vipflash® (VIP, Pirassununga, São Paulo, Brazil). An morse taper 3.5mm x 7.0mm dental implant (Neodent, Curitiba, PR, Brazil) was placed to substitute second molar. The matrix model was then duplicated using silicone rubber (Redelease, Barueri, São Paulo, Brasil) and were replicated 20 models made of polystyrene resin (Cristal, Piracicaba, Brazil). A polystyrene resin cylindrical base with 2.5mm in diameter was added in the base of all models to fit the cycling machine and after to the microtensile test machine. Metal crowns were replicated from an individual waxing pattern performed on the reference model and adapted for each model from a standard silicone matrix. Premolars were replicated in wax from an artificial tooth rubber silicone mold and cast completely into metal (Alloy free of precious metals without beryllium - nickel chrome, Kromalit, Knebel Produtos Dentários Ltda., Porto Alegre, Rio Grande do Sul, Brazil). The implant crowns were cemented using the Allcem Core (FGM, Joinville, SC, Brazil) dual cure resin cement light cured for 40s on each surface using LED light curing unit Valo Cordless (Ultradent, Salt Lake City, USA) with irradiance of 1400 mW/cm², checked using Marc resin Calibrator (BlueLight, Halifax, Canada). The typodont first molar and the second metallic premolars were included in the alveoli with the polyether impression material (Impregum, 3M ESPE, USA) simulating the periodontal ligament³³.

Sample Development and preparation:

A artificial 1° molar tooth (TechPro, IM Brasil Ltda., Brazil), received two proximal standard occlusal proximal cavity preparations using a preparation machine.³⁴ The one trained operator using a high-speed diamond bur N. 3198 drill (KG Sorensen, Barueri, SP, Brazil) under constant irrigation were used for preparing two proximal class II with 4 mm mesial/distal, 4 mm deep in occlusal surface and 5.0mm in gingival box.

Restorative Procedure

The cavities in the samples were then cleaned with 0.12% chlorhexidine, the well was dried and the adhesive system Âmbar (FGM, Joinville, SC, Brazil) was applied during 20 seconds and light cured for 20 seconds. The partial pre-shaped metal matrix (Unimatrix, TDV Dental Ltda, Pomerode, SC, Brazil) was inserted and brunished to better define proximal contact, the wood wedges (Cunhas anatômicas, TDV Dental Ltda, Pomerode, SC, Brazil) were inserted. In the Z350 group, the proximal boxes were restored in two increments using nanofilled composite resin Filtek Z350 XT A2 (3M ESPE, St.Paul, MN USA)³⁵. The OPR group restored with a single increment of Opus Bulk Fill Regular A3 (FGM). The composite resins photoactivated for 40s multipeak LED light curing unit Valo Cordless (Ultradent, Salt Lake City, USA) with irradiance of 1400 mW/cm², checked using Marc resin Calibrator (BlueLight, Halifax, Canada).

Proximal contact force calculation - Initial

The samples were subjected to a microtensile test machine (Microtensile ODEME, Luzerna, SC, Brazil) using 1mm/min crosshead speed for calculating the proximal contact force with molar and premolar teeth. For the test, two metallic accessories were created to microtensile machine, one for positioning the model during the test and the other for stabilize the dental floss during tensile test (Figure 2). A dental floss (Hillo, SP, Brazil) was inserted below the proximal contact area and was attached to the accessory haste fixed on the microtensile machine. The initial proximal contact tensile force values in Newtons (N) were measured 6 times for each sample, being 3 measurements at each proximal contact and the average of the maximum tensile force was calculated.

Digital Radiographic Examination- initial

A digital phosphor plate sensor radiography (Dürr Dentall, Bietigheim-Bissingen, Germany) was obtained to the positioned within 20 cm of the source of the Timex 70 E Parede x-ray machine (Gnatus, Ribeirão Preto, SP, Brazil). Interproximal radiographic were performed, and the images were transferred from the phosphor plate to the computer by means of the scanner (VistaScan Mini View, Durr Dental AG, Bietigheim-Bissingen, Germany) and then evaluated

for adaptation classifying the qualitatively the proximal contact in mesial and distal cavities: (1), perfect proximal contact – without visible gap between restoration and adjacent tooth; (2), proximal contact acceptable - with little areas of gap without compromising the contact with adjacent tooth; (3), unacceptable proximal contact - defined by visible gap with adjacent tooth and that compromises the function of proximal contact.

3D Scan of proximal surface

All samples were scanned with the s600 optical scanner system (Zirkonzahn GmbH, Italy), after application of scanning spray (Zirko Scanspray; Zirkonzahn GmbH, Italy), generating 3D models in CAD software (Zirkonzahn Modellier, Zirkonzahn GmbH, Italy), adjusted and saved in .stl format file for posterior superimposition.

Mechanical cycling test

The samples were submitted to occlusal mechanical fatigue simulating 5 years of oral aging. The samples were submerged in water at about 37°C simulating chewing and mouth temperature and cycled 1,200,000 times from 0 to 50 N axial compressive loading with 8.0mm diameter stainless steel sphere on the occlusal cusps with a 2 Hz frequency (ER-11000 Mechanical Fatigue; ERIOS equipment, São Paulo, SP, Brazil).^{36,37}

Post mechanical fatigue tests

After mechanical aging, the proximal contact tensile force values in Newtons (N) were measured 3 times for each sample and the average of the maximum tensile force as describe before. The difference of proximal contact force was calculated: $\Delta \text{PCforce} = \text{Final PCforce} - \text{Initial PCforce}$.

Final Digital Radiographic Examination

A final x-ray was taken of all samples following the initial method. The initial and final x-ray images were mounted in PowerPoint screen without any manipulation or adjust of the images. The x-ray images were blinded evaluated by two experienced and calibrated professionals, they analyzed qualifying the

proximal contact using the following scores: (1), perfect proximal contact – without visible gap between restoration and adjacent tooth; (2), proximal contact acceptable - with little areas of gap without compromising the contact with adjacent tooth; (3), unacceptable proximal contact - defined by visible gap with adjacent tooth and that compromises the function of proximal contact (Figure 3).

Final 3D Scan and composite resin volume loss (μm)

Alignment and visual comparison of initial and final scans were performed by importation of the .stl files to open source software: MeshLab (Visual Computing Lab - ISTI CNR, available for download at <http://meshlab.sourceforge.net>)³⁸. With this software, the alignment tool and its “point-based alignment” were used by selecting eight possible points in each of the two 3d images of each model. The fitting process was blindly performed by two trained operators. The 3D files were superimposed and the initial and final mesh models were overlaid on CloudCompare software (available at <http://danielgm.net/cc>). With the aid of the “cut” tool, it was possible to limit the bottom of the two selected objects to ensure models with the same vertical size. The comparison of clouds selecting the initial model as reference and the other as compared, and a color map generated for each proximal contact area. The green color representing if matching points are found and red or blue indicating a mismatch.³⁹

The colored images were analyzed by 2 experienced and calibrated operators who identified the color difference in the point of contact region, establishing overlap and wear scores (I -blue color, meaning the presence of wear; II- green color, meaning no wear with no overlap; III- green color with yellow pigments, meaning final scan overlap from 0.07mm to 0.11mm from initial model; IV- yellow color with orange/red pigments, meaning an overlap of 0.11mm to 0.18mm from the initial model; V- predominance of red color, meaning overlap of 0.18mm to >0.3mm).

Statistical Analysis of Data

The contact force data were tested for normal distribution (Shapiro-Wilk) and equality of variances (Levene test), followed by parametric statistical tests.

Two-way ANOVA was performed in a split-plot arrangement, with the plots are represented by restorative material and contact region and the subplot represented by the moment of the cavity. Multiple comparisons were made using a Tukey test. All tests used $\alpha = 0.05$ as the significance level, and all analyses were carried out with the statistical package Sigma Plot version 13.1 (Systat Software Inc, San Jose, CA, USA). The x-ray and the 3D superimposition proximal contact analyses were described by frequency.

RESULTS

Microtensile

The proximal contact force between restored molar using incremental and bulk fill filling technique with adjacent molar and premolar measured by using microtensile test before and after aging process are shown in Table 2. Two-way repeated ANOVA revealed significant influence of contact region ($P < 0.001$), however no significant difference was observed for composite resin type ($P = 0.102$), neither for interaction between contact region and restorative material ($P = 0.622$). The force measured in the molar contact region was significantly higher than force calculated on premolar contact, irrespective of composite resin used or moment of the measurement. Z350XT showed always similar contact force than Opus Bulk Fill. The occlusal fatigue resulted in significant reduction on proximal contact force ($P < 0.001$), irrespective of region analyzed and restorative material tested.

Proximal contour - Digital Radiographic Examination

The results of the Digital Radiographic Examination analysis are shown in Table 3. For Z350 group, perfect proximal contact (score 1) was predominant for proximal contour after fatigue mechanical cycling test, regardless of the region analyzed (molar or premolar). Proximal contact acceptable (score 2) was three samples for molar and four samples for premolar. No tooth had any unacceptable proximal contact (score 3) for Z350 group, regardless of the region analyzed (molar or premolar). For OPUS group, the same predominant behavior for "perfect proximal contact (score 1)" was found. Proximal contact acceptable

(score 2) was four samples for molar and two samples for premolar. For unacceptable proximal contact (score 3), was detected one sample in molar region and two in the premolar region.

Proximal contour - 3D superimposition

The results of the 3D superimposition analysis are shown also in Table 3. For both groups, regardless of region no detection of wear within the sensitivity limit stipulated in the 3D analysis (0.3mm) was observed. For Z350 group, in premolar region, the score IV (overlap 0.11-0.18mm) were observed in 5 samples. For molar region, the frequency was similar for scores III, IV and V. For OPUS group, the frequency was similar for scores II, III, IV and V; regardless of the region analyzed (molar or premolar).

DISCUSSION

In the present study, the first null hypothesis was accepted: the posterior restoration created using incremental and bulk fill techniques had similar proximal contact force. However, the occlusal fatigue simulating 5 years aging decreased significantly the proximal contact force irrespective of region of the contact with metal implant or tooth with periodontal, therefore the second null hypothesis was rejected.

Assessing proximal contact force in in vitro studies has as advantages the possibility of standardization of the conditions to be tested. Among the studies addressing the proximal contact reporting wear or strength, many use pre-fabricated mannequin models or prepared typodont, however without a simulation of periodontal ligament for tests.^{16,22,25,26,40} For this reason a model was developed in order to approximate the characteristics tested in vitro study of the oral physiological conditions, using the simulation of the periodontal ligament using the polyether impression material.³³ In the conditions used in the present study, the proximal wear could occur only in the composite resin, because both crown on implant and the simulation of the natural tooth were made in metal.^{16,40} To evaluate the influence of the absence of flexibility on proximal contact adjacent

teeth, the implant was added to the model, simulating a frequent clinical condition observed.

In the literature, only the initial pre-restoration and post-restoration forces were measured without further clinical follow-up in clinical studies.²⁹ and a 7-year clinical follow-up observed natural tooth wear associated with the dental implant, but with no quantification the proximal contact force.²⁴ The use of identical replicas of a single prepared tooth, restored in position on the fabricated models, allowed to standardize and simulate the clinical conditions. It was possible to compare the proximal contact force between different materials before and after mechanical cycling.²⁵ Differently from what happens in *in vivo* studies, which due to the great variability of anatomical characteristics of the contact points between individuals only allows the evaluation between before and after the restorative procedure.^{26,40}

The proximal contact force has been measured using device constructed at the University of Technology Delft in the Netherlands or similar ones. A 0.05 mm thick metal strip is connected to it, which is inserted interdentally from the occlusal surface, quantifying the proximal contact tightness [N] as the maximum frictional force when the strip is slowly removed in occlusal direction.^{23,26,28-31} The proximal contact force measurement using metallic matrix was modified in the present study^{22,25,27,30,41} The dental floss was used in this study to eliminate the influence of the matrix on adjacent teeth, without change in the physiological situation.⁴⁰ Additionally, the method used in this study is similar to the method that have been used in clinical studies.³² The use of dental floss approximates the *in vitro* test of the clinical situation, the force used by the patient to floss without the pre-pressure can be easily translate to clinical recommendation and professional orientation.

The force measured in the molar contact region was significantly higher than force calculated on premolar contact, irrespective of composite resin used or moment of the measurement. This can be explained by the anatomic contour for molar and premolar and for periodontal ligament simulating in premolar teeth, different from that found in the molar, where the implant rigidity was simulated. According to Dorfer et al⁴¹, when evaluating the factors that influence proximal contact force *in vivo*, the proximal contact between second premolar and first molar were the highest forces recorded in this study. However, the *in vivo*

comparison was performed with the presence of periodontal ligament in both contact points compared.⁴¹ In this *in vitro* test performed in the present study, the absence of physiological movement simulation allowed the highest molar proximal contact force than the contact point of the second premolar with the first molar.

In vivo studies have shown that the loss of proximal contact structure tends to be greater in the mesial due to mesial displacement of natural teeth by the anterior component of the occlusal force²⁴. Using a model that simulates the positioning of samples according to natural position of teeth in vivo, the application of occlusal loads during the mechanical fatigue test leads to a reproduction of these forces in vivo, which corroborates the findings of lower force on the premolar contacts. The displacement is accentuated to mesial since the distal contact presents the simulation of absence of periodontal ligament.

Occlusal fatigue resulted in significant reduction on proximal contact force, irrespective of region analyzed and restorative material tested. The reduction in the proximal contact force can be attributed to wear resulting from the restored molar intrusion process during occlusal fatigue. The tooth moves up and down, generating friction with the adjacent metallic teeth, resulting in composite resin wear. This finding can be correlated with the observations extracted in clinical studies, since in the best of author's knowledge, no *in vitro* studies have evaluated the wear of the contact point after years aging simulation. Clinical studies have shown that proximal contact loss occurs over time, even at short follow-up of 3 months to longer couplings of 5 years, under different clinical situations.^{24,28,32,42}

Z350XT showed always similar contact force than Opus Bulk Fill. These results can be explained because Opus Bulk Fill and Filtek Z350XT have similar composition in both the organic and the inorganic matrix and thus close mechanical properties and wear resistance.^{14,15} Although a resin is conventional, inserted in oblique increments of up to 2mm, and another bulk fill inserted in a single increment, both are of high viscosity, have approximate amount of inorganic filler (Table 1). The wear of composite materials is widely depending on the size, volume and quantify the charge particles.⁶ A previous study demonstrated the high-viscosity bulk fill composites had KHN values similar to those of conventional resin composites.⁴³

The results of the present study corroborate with other studies that state that proximal contact force is related to the consistency of the restorative material and the restorative technique used.²⁷ Reaffirming that high viscosity resins produce strong proximal contact.¹⁶ Previous studies affirmed that conventional composite resin inserted in bulk filling did not provide improvement in proximal contact force values.^{27,44,45} This supports the findings in the present study that OPUS showed a similar behavior to Z350.³⁰

The 3D superimposition method used was adapted for this study, aiming to be possible to detect variations before and after the cycler machine.³⁹ The presence of little detectable wear between the groups do not correlate with from the microtensile results, mainly because the expansion scores were recorded in considerable number of the contact points evaluation. The possible proximal expansion of composite resin observed, can minimize the structure loss. The reduction on the proximal contact force measured by microtensile method should be higher, if we consider the expressive wear compensated by sample expansion, undetectable within the established sensitivity. Some samples did not show expansion and mismatch scores and yet have representative microtensile values of wear, representing a likely minimal wear undetectable by the sensitivity of the 3D method. The method proved to be effective in detecting expansion of the polystyrene sample after the mechanical cycling process. This aspect should be considered as a limitation of this study, probably using human molar teeth or ceramic teeth with cavities to be restores can solve this problem. On the other hand, before and after x-ray images analysis showed differences after cycling but maintaining the similarity behavior between the two groups tested.

Food impaction caused by the lack of proximal contact between adjacent teeth can lead to problems such as tooth movement, biofilm formation increasing risk of secondary caries and periodontal disease.^{16,46} In contrast, very tight contact points can cause patient discomfort, make it difficult to floss and cause periodontal injuries because they are probably invading the interdental papilla space.⁴⁷ Clinical studies have shown that contact loss of restorations occurs over time in different intensities.^{24,28,32,42} An annual failure rate of 2,8% of composite resin restorations was observed, in which one factor evaluated was lack of contact point or overhang.⁴⁸ For this reason, the generation of a proximal contact with adequate form and function respecting the physiological characteristics is

essential for the longevity of composite resin restorations, as expected for natural teeth²² and implant prostheses.^{24,32} Using bulk-fill composite resins in this study was able to observe good performance in this characteristic, however future clinical studies should be performed.

As observed in the new methodology tested the tooth made of polystyrene resin and used as a sample can yield structurally during mechanical fatigue and may reduce or mask the effect of proximal wear. And yet occlusal fatigue was supported only by the central tooth, and the question whether perhaps inserted in the 3 elements perhaps the effect of fatigue could have been influenced by the adjacent tooth type influencing the results. Future studies varying the viscosity of composite resins and using samples with greater resistance to the effects of cycling are needed to collaborate with the current findings, leading to in vitro analysis of contact point strength closer to clinical reality.

CONCLUSIONS

Within the limitations of this in vitro study the followed conclusions can be drawn:

- The efficacy of the developed model for contact force test of resin composites approximate for clinical reality was proved.
- The proximal contact in the molar region was stronger than in the premolar region.
- The occlusal fatigue simulating aging process of 5 years decreased the proximal contact force between implant and adjacent teeth with periodontal ligament simulation.
- The bulk filling using high viscosity composite resin and incremental filling technique showed similar proximal contact force before and after occlusal fatigue.

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Conflict of Interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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ATTACHMENTS

Tables

Table 1. Resin Composites Used in This Study

Material	Code	Resin Composite Type	Organic Matrix*	Filler*	Filler% Wt/Vol*	Manufacturer	Number
Filtek Z350XT	Z350	Nanofilled	Bis-GMA, Bis-EMA, UDMA, TEGDMA	Silica and zirconia nanofillers, agglomerated zirconia silica nanoclusters	78.5/63.3	3M ESPE (St Paul, MN, USA)	N652583
OPUS Bulk Fill	OPUS	High-viscosity bulk fill	TEGDMA, Bis-EMA, UDMA	Silica with urethane dimethacrylate, salinized silica dioxide, salinized barium glass, YbF3	68/—	FGM (Joinville, Brazil)	N251017

*Composition as given by manufacturers. Abbreviations: Bis-GMA, bisphenol A diglycidylmethacrylate; Bis-EMA, bisphenol A polyethylene glycol diether dimethacrylate; UDMA, urethane dimethacrylate; TEGDMA, triethyleneglycol dimethacrylate; YbF3, ytterbium fluoride.

Table 2. Means and standard deviation of proximal contact force (N) measured using microtensile test.

Restorative Material	Region			
	initial		Post-Fatigue	
	Molar	Premolar	Molar	Premolar
Incremental – Filtek Z350XT	7.7 ± 1.9 Aa	5.8 ± 2.5 Ba	5.7 ± 2.4 Aa	4.1 ± 1.8 Ba
Bulk fill – Opus Regular APS	8.9 ± 2.3 Aa	6.1 ± 2.2 Ba	7.3 ± 1.9 Aa	4.5 ± 2.1 Ba
Pooled average	7.4 ± 2.2*		5.3 ± 2.0**	

Different letters indicate a significant difference calculated using two-way RM ANOVA ($P < 0.05$).; upper caser letters were used for comparing location at contact point (molar or premolar); and lower caser letters were used for comparing restorative material (Z350XT or OPUS); * indicate difference significant for sub-plot fatigue effect (initial and post-fatigue).

Table 3. Proximal contour analyses with Digital Radiographic Examination and 3D superimposition after fatigue mechanical cycling test.

Restorative																
Material	Number of teeth with each criterion evaluated															
	Digital radiographic examination*						3D superimposition**									
	Molar (d)			Premolar (M)			Molar (D)					Premolar (M)				
	1	2	3	1	2	3	I	II	III	IV	V	I	II	III	IV	V
Filtek Z350XT	7	3	0	6	4	0	0	1	3	3	3	0	1	2	5	2
Bulk fill Opus	5	4	1	6	2	2	0	2	2	4	2	0	2	4	2	2

* 1- perfect proximal contact; 2- proximal contact acceptable; 3- unacceptable proximal contact;

** I-blue color, meaning the presence of wear; II- green color, meaning no wear with no overlap; III- green color with yellow pigments, meaning final scan overlap from 0.07mm to 0.11mm from initial model; IV- yellow color with orange/red pigments, meaning an overlap of 0.11mm to 0.18mm from the initial model; V- predominance of red color, meaning overlap of 0.18mm to >0.3mm

Figures

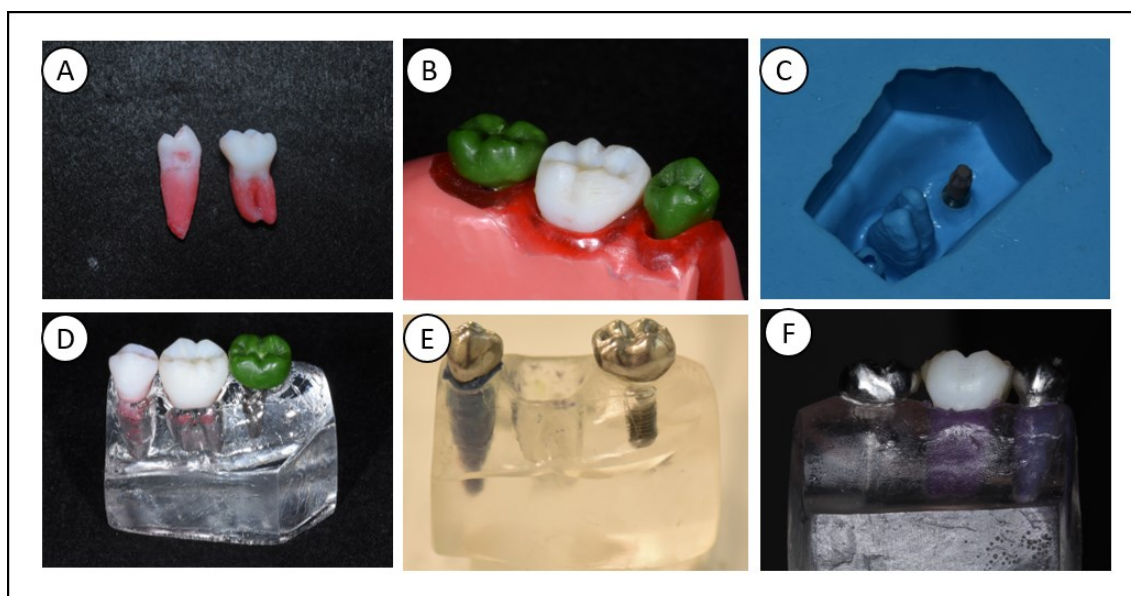


Figure 1: Device development: A- Artificial teeth with simulation of the periodontal ligament; B- Artificial teeth fitted in the base model after re-basement alveoli of red acrylic resin in shaping the roots of artificial teeth with simulation of the periodontal ligament; C- Negative base model mold with rubber silicone and embedded implant; D- Proof of fitting of artificial teeth and wax crown over implant; E- Final aspect of the model with metal teeth and metal crown in position F- Final aspect of the model completely assembled with sample.

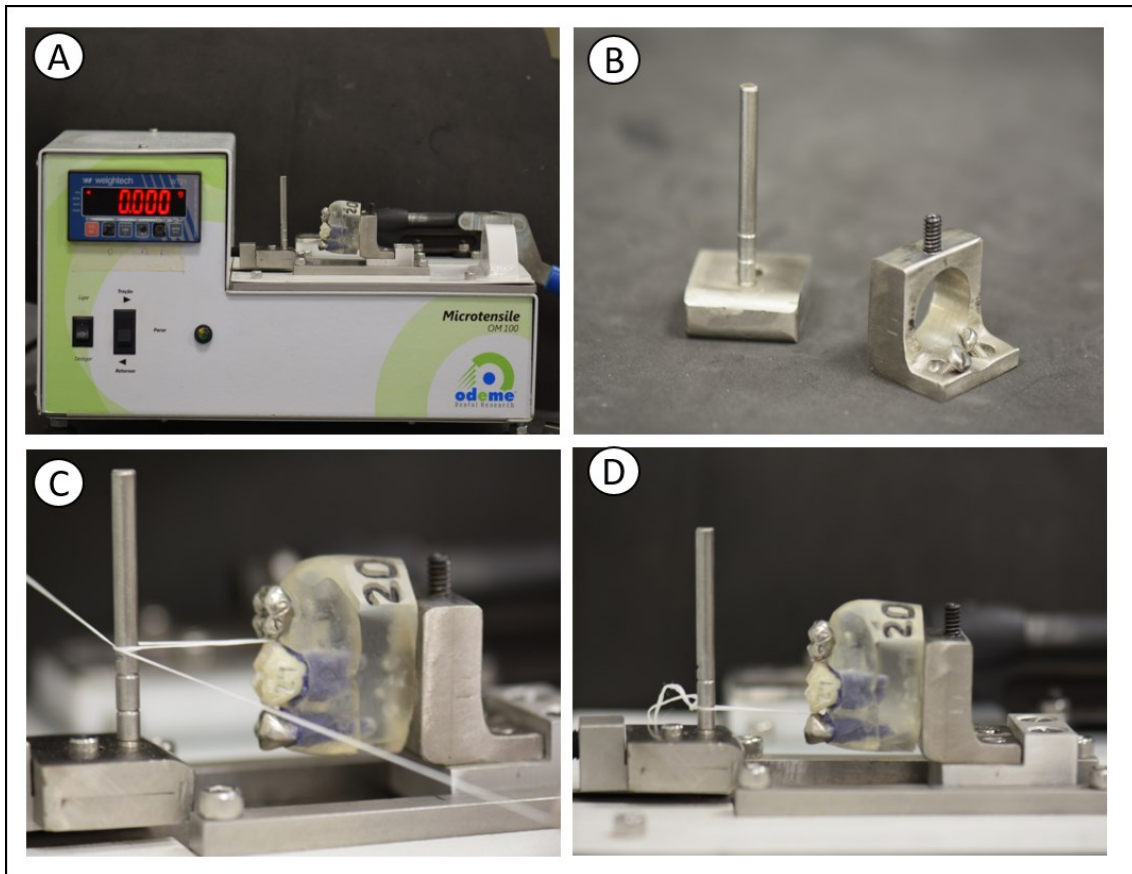


Figure 2: Microtensile method: A- Microtensile machine with sample and devices positioned the traction for measurements.; B- devices developed to standardize the sample position during test; C- clinical dental floss passed parallel around the contact point and pulled by the equipment in molar contact; D- dental floss passed in premolar contact.

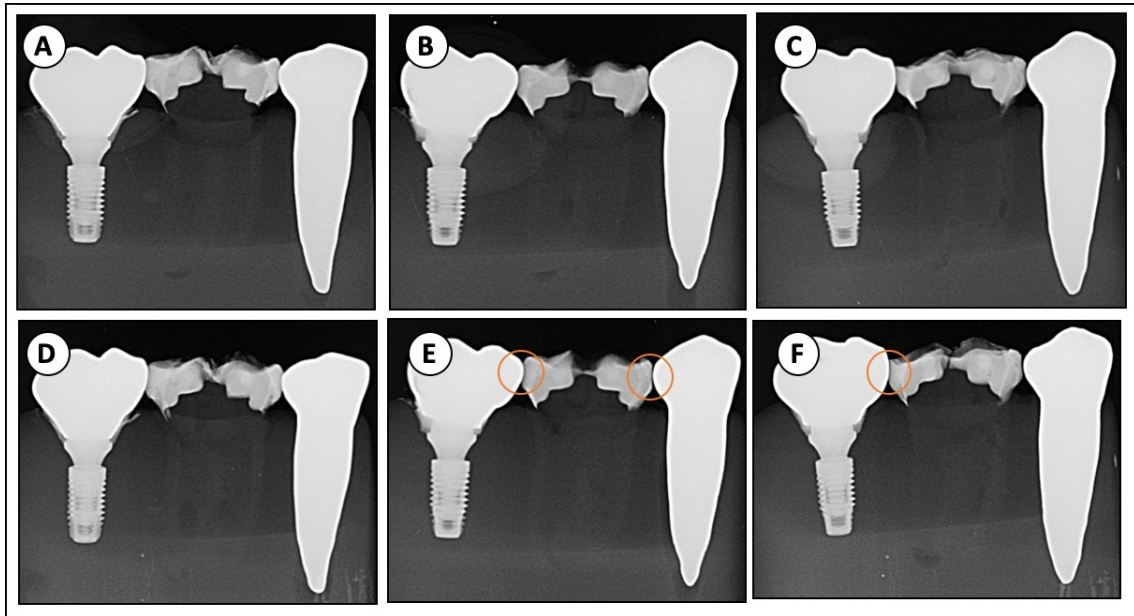


Figure 3: Digital Radiographic examination: A and D – OPR group sample score 0, with no initial to final difference at both proximal contact points; B and E – Z350 group sample score 1, with difference without continuity in both proximal contact points; C and F– OPR group sample score 2 at the mesial contact point, representing difference with discontinuity and score 0 at distal, representing no difference.

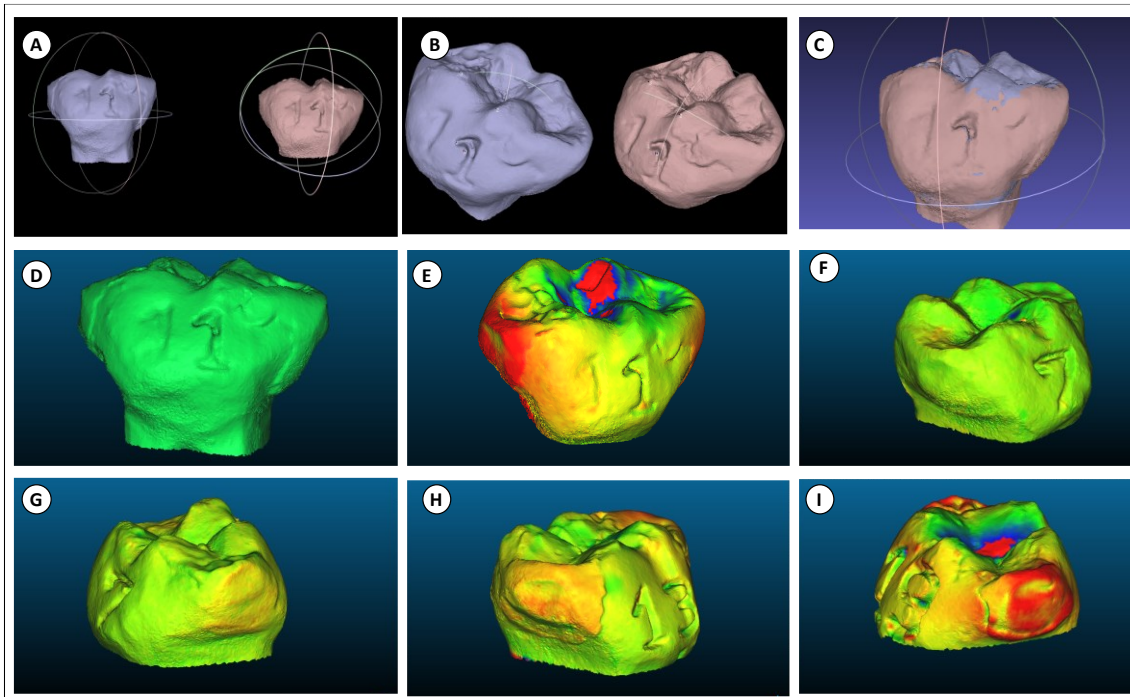


Figure 4: 3D superimposition Method: A- Initial and final MeshLab scans before overlap within the MeshLab program for similar point comparison and determination; B- Determination of similar points; C- Overlapping scans in the MeshLab program; D- Transferred scanned to CloudCompare program; E - Final sample Scan with Comparative Colors; F - Scan score II, green color; G- Scan score III, green color with yellow pigments; H- Scan score IV, yellow color with orange / red pigments; I- Scan score V, predominance of red color.