PONTIFÍCIA UNIVERSIDADE CATÓLICA DE MINAS GERAIS
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EFEITO DA ESPESSURA DA CERÂMICA DE DISSILICATO DE LÍTIO E DO TEMPO DE FOTOATIVAÇÃO NA RESISTÊNCIA BIAXIAL DE DIFERENTES CIMENTOS RESINOSOS

Belo Horizonte
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Dissertação apresentada ao Programa de Pós-graduação em Odontologia da Pontifícia Universidade Católica de Minas Gerais, como requisito parcial para obtenção do título de Mestre em Odontologia, Área de Concentração: Clínicas Odontológicas, Área Temática: Prótese dentária.
Linha de pesquisa: Propriedades físicas, químicas e biológicas dos materiais odontológicos.

Orientador: Prof. Dr. Alberto Nogueira da Gama Antunes.

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Dedico este trabalho a minha família,
que sempre embalam os meus sonhos.

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RESUMO

Cerâmicas cristalinas foram desenvolvidas para serem usadas como infraestruturas de prótese sem metal. Atualmente, estes materiais são empregados para a produção de próteses monocamadas, ou seja, em um bloco único, garantindo boa estética e boas propriedades mecânicas. Com isso, é escasso na literatura estudos que comprovem as alterações existentes na camada de cimento, que está logo abaixo da cerâmica, quando alteramos sua espessura e tempo de fotoativação. A proposta desse estudo foi avaliar a resistência biaxial de cimentos resinosos auto-adesivos e convencionais, fotoativados através de duas espessuras diferentes de cerâmica como barreira (e.max CAD, Ivoclair Vivadent, Liechtenstein). A metodologia utilizada foi de tensão biaxial para análise de comportamento mecânico (n=10), a partir de corpos de prova discoides (12 mm de diâmetro e 0.7 mm de espessura). Três variáveis foram estudadas na análise estatística: espessura da cerâmica (1 ou 2 milímetros), tipo de cimento e tempo de fotoativação da camada de cimento (20 ou 40 segundos). Na cerâmica com 1 mm de espessura, dentro de cada tempo de fotoativação (20 ou 40 segundos) não foi encontrada diferenças estatisticamente significantes. No entanto, a análise das diferenças dentro de cada cimento pelo teste t permitiu observar que houve diferença estatisticamente significante em todos os cimentos quando polimerizados pelo tempo de 20 ou 40s. Já na cerâmica com 2 mm de espessura, dentro de cada tempo de fotoativação (20 ou 40 segundos) não foi encontrada diferenças estatisticamente significantes. A análise das diferenças dentro de cada cimento pelo teste t permitiu observar que não houve diferença estatisticamente significante entre o tempo de fotoativação. Concluindo que em cerâmicas de 1 mm de espessura, o tempo de fotoativação influenciou na resistência biaxial dos cimentos resinosos.

Palavras-chave: Cerâmica. Cimentação. Estética.

ABSTRACT

Crystalline ceramics were developed to be used as prosthesis infrastructures without metal. Currently, these materials are used for the production of single-layer prostheses, that is, in a single block, ensuring good aesthetics and good mechanical properties. As a result, there are few studies in the literature that prove the changes in the cement layer, which is just below the ceramic, when we change its thickness and time of photoactivation. The purpose of this study was to evaluate the biaxial strength of self-adhesive and conventional resin cements, photoactivated through two different thicknesses of ceramic as a barrier (e.max CAD, Ivoclair Vivadent, Liechtenstein). The methodology used was biaxial tension for the analysis of mechanical behavior (n=10), from discoid specimens (12 mm in diameter and 0.7 mm in thickness). Three variables were studied in the statistical analysis: thickness of the ceramic (1 or 2 mm), type of cement and time of photoactivation of the cement layer (20 or 40 seconds). In 1 mm thick ceramics, no statistically significant differences were found within each photoactivation time (20 or 40 seconds). However, the analysis of the differences within each cement by the t test allowed us to observe that there was a statistically significant difference in all cements when polymerized for 20 or 40s. In the 2 mm thick ceramic, within each photoactivation time (20 or 40 seconds), no statistically significant differences were found. The analysis of the differences within each cement using the t test allowed us to observe that there was no statistically significant difference between the photoactivation times. Concluding that in 1 mm thick ceramics, the photoactivation time influenced the biaxial resistance of resin cements.

Keywords: Ceramics. Cementation. Aesthetics.

LISTA DE ABREVIATURAS E SIGLAS

®	marca registrada
a	diâmetro do suporte metálico
b	diâmetro da haste metálica
CAD/CAM	computer-aided design/ computer-aided manufacturing
DSI	dissilicato de lítio
Mm	milímetros
Mpa	megapascal
mW/cm^2	miliwatts por centímetro quadrado
N	número de amostras
P	carga em Newtons
p	nível de significância
R	raio da cerâmica ou cimento em mm
S	segundo
SET PP	Set PP SDI, Austrália
t	espessura da cerâmica em mm
U200 RelyX	U200 3M ESPE, Estados Unidos
ULTIMATE RelyX	Ultimate 3M ESPE, Estados Unidos
v	coeficiente de Poisson da cerâmica

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1 INTRODUÇÃO

Cerâmicas odontológicas apresentam características que as tornam uma boa opção restauradora de estruturas dentais perdidas (ZHANG; KELLY*,* 2017). Propriedades físicas e mecânicas, além de excelente estética popularizaram o seu uso. Somado a isso, o desenvolvimento dos materiais resinosos, a criação de novas técnicas restauradoras e a crescente expectativa do paciente por restaurações estéticas, tornaram as cerâmicas o material de primeira escolha.

Para uma boa união entre substrato dental e sistema cerâmico, é necessário além de um preparo protético adequado (JURADO *et al*., 2020), um agente cimentante resinoso, garantindo a adesão (VARGAS; BERGERON; DIAZ-ARNOLD, 2011). O cimento resinoso prevê um bom selamento marginal, possuindo boas propriedades físicas e adesivas (NAKAMURA *et al*., 2016; SOARES *et al*., 2017). A cimentação adesiva requer muitos passos e é uma técnica sensível (SPITZNAGEL *et al*., 2014), além disso características físicas e a fragilidade inerente das restaurações cerâmicas tornam o passo a passo operatório e a cimentação críticos (BLATZ *et al.*, 2002).

O apreço pela estética não se limita apenas para dentes anteriores. As restaurações cerâmicas são amplamente empregadas em dentes posteriores apresentando um alto índice de sucesso quando comparado com outras alternativas restauradoras (HAYASHI; YEUNG, 2015). Como restaurações posteriores, as cerâmicas são submetidas a forças oclusais (TRIBST *et al.,* 2018), apresentando diferentes áreas de estresse e com isso o aumento de sua resistência mecânica é almejado, com o desafio de manter as propriedades ópticas do material, já que foi constatado que o material restaurador pode interferir diretamente no prognóstico do paciente.

Em muitas situações clínicas, o aumento da resistência mecânica foi possível com o aumento do conteúdo cristalino, o que em contrapartida necessita da aplicação de uma cerâmica com conteúdo vítreo em sua composição, a fim de equilibrar a translucidez. Embora a cerâmica de cobertura controle a opacidade causada pelo conteúdo cristalino, ela não apresenta as mesmas propriedades mecânicas, apresentando diferente valor de expansão térmica e está sujeita a um escoamento diferenciado e fenômenos como a delaminação, interferindo na interface protética (SILVA *et al*., 2017). Dessa forma, a fim de solucionar esses problemas, foi desenvolvida uma cerâmica em apenas um bloco, classificados na literatura como monolítica.

Existem diferentes técnicas de confecção das cerâmicas odontológicas (injeção, prensagem e fresagem). Del Barrio (1999) assimilou os processos de fundição das ligas metálicas a uma das mais tradicionais técnicas de confecção de cerâmicas monolíticas, onde cerâmicas compostas por dissilicato de lítio são injetadas em um molde pré-formatado. Atualmente com a evolução da tecnologia CAD/CAM, a técnica de fresagem a partir de um modelo virtual começou a ser empregada em laboratório ou até mesmo em consultório odontológico (HELVEY, 2010), onde o material passa por um processo de sinterização.

O desafio que contrapõe a facilidade de sua produção é atingir materiais que apresentem boa translucidez, a fim de realizar com êxito o mimetismo de estruturas dentais. Tal característica que é essencial para sua longevidade, no momento que interfere na fotoativação do cimento resinoso. Segundo Shim *et al.* (2017), a espessura do material restaurador e sua capacidade de permitir a passagem de luz influencia nas propriedades do cimento resinoso, causando uma possível subpolimerização, o que modifica suas propriedades físicas e adesivas (SIDERIDOU; TSERKI; PAPANASTASIOU, 2002).

O íntimo contato entre material restaurador e agente cimentante proporcionou o aumento da resistência a fratura dos espécimes cerâmicos, e a transmissão de forças mastigatórias aos tecidos dentais (GARBER; GOLDSTEIN, 1996; PAULILLO; SERRA; FRANCISCHONE, 1997). Consentindo com essa ideia, Piemjai e Arksornnkit (2007) demonstraram que o agente cimentante influencia na resistência a fratura dos laminados cerâmicos. Com isso faltam informações relacionadas à qualidade da presa do cimento resinoso que está em contato com sua porção interna.

A proposta desse estudo é avaliar a resistência biaxial de cimentos resinosos auto-adesivos e convencionais, fotoativados através de duas espessura de cerâmica (DSl, dissilicato de lítio).

Verificamos se a cerâmica, dependendo de sua espessura, exige um protocolo de polimerização individual. O estudo em questão tem uma relevância clínica pertinente, sendo uma possibilidade de aliar nas restaurações indiretas resistência e estética.

2 OBJETIVOS

2.1 Objetivo geral

Avaliar a influência da espessura de uma cerâmica com elevado conteúdo cristalino e tempo de fotoativação na resistência biaxial de diferentes marcas de cimentos resinosos convencionais e auto-adesivos contemporâneos.

2.2 Objetivos específicos

a) avaliar o efeito da espessura da cerâmica, 1 ou 2 mm, na resistência biaxial de 3 marcas de cimentos resinosos contemporâneos;
b) avaliar o efeito do tempo de exposição à luz do aparelho fotoativador na resistência biaxial de 3 marcas de cimentos resinosos contemporâneos.

3 MATERIAL E MÉTODOS

3.1 Materiais

Os cimentos utilizados (Fig. 1), bem como as cerâmicas, que serviram de barreira para a luz, estão descritos no quadro 1.

Figura 1: Cimentos resinosos utilizados

Fonte: Elaborado pelo autor

Quadro 1: Materiais cimentadores que serão usados

Material	Tipo	Fabricante
e.max CAD	Cerâmica de dissilicato de lítio Translucidez: medium opacity	Ivoclair Vivadent, Liechtenstein
RelyX Ultimate	Cimento resinoso convencional Cor:A2	3M ESPE, Estados Unidos
RelyX U200	Cimento resinoso autoadesivo Cor:A2	3M ESPE, Estados Unidos
Sett PP	Cimento resinoso autoadesivo Cor:A2	SDI, Austrália

Fonte: Elaborado pelo autor

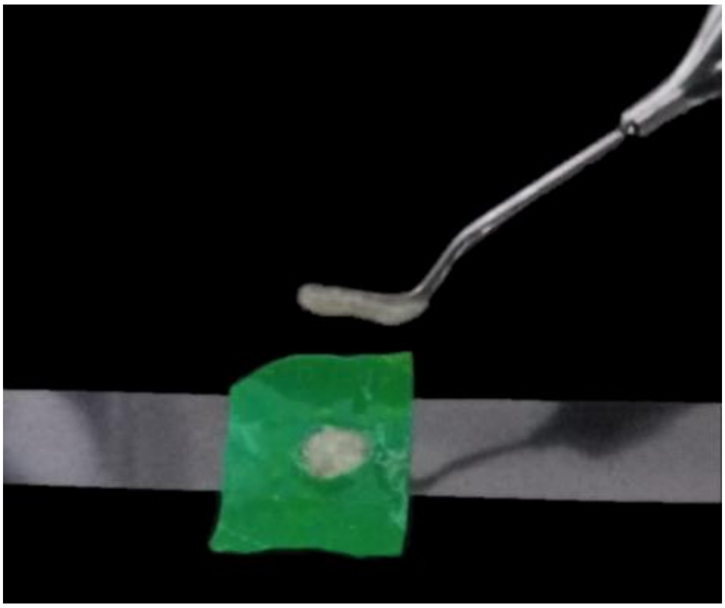
3.2 Preparo da amostra

Primeiramente foram produzidos 2 discos através do sistema CAD/CAM (IPS e.max CAD, Ivoclair Vivadent, Liechtenstein) serviram como barreira para o procedimento de fotoativação de cada cimento resinoso, com espessuras de 1 e 2 mm com a cerâmica listada (Fig. 2). Posteriormente, cada cimento foi fotoativado com o uso da barreira, e foi usado um molde de borracha com formato discoide de 12 mm de diâmetro e 0,7 mm de espessura, para inserção do cimento (Fig. 3). Uma leve pressão digital em uma lâmina de poliéster sobre o cimento permitiu o extravasamento do material, homogeneizando a superfície (Fig. 4). Por fim, a fotopolimerização foi feita com aparelho Valo (Ultradent, Estados Unidos) por 20 ou 40s, com 1000 mW/cm^2. Foram produzidos 10 corpos-de-prova para cada cimento exposto no quadro (Figs. 5a e 5b), armazenados em água destilada por 48 horas em eppendorfs (Fig. 6).

Figura 2: Discos de cerâmica confeccionados pelo CAD/CAM

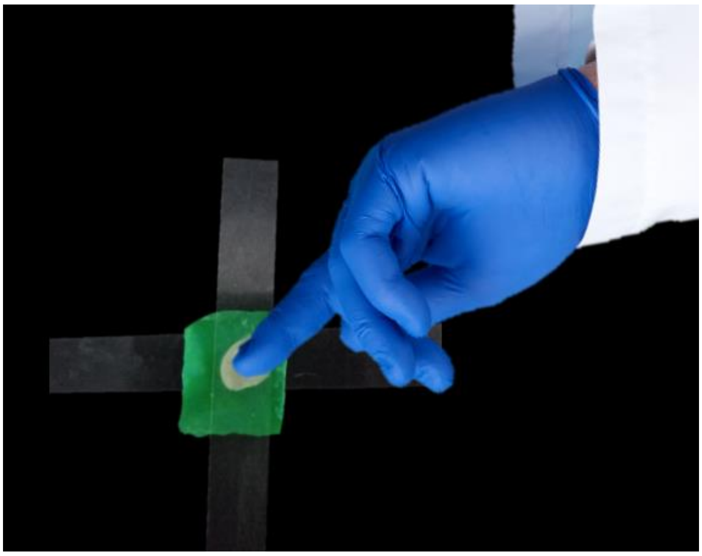
Fonte: Elaborado pelo autor

Figura 3: Inserção do cimento no molde de borracha com formato discoide



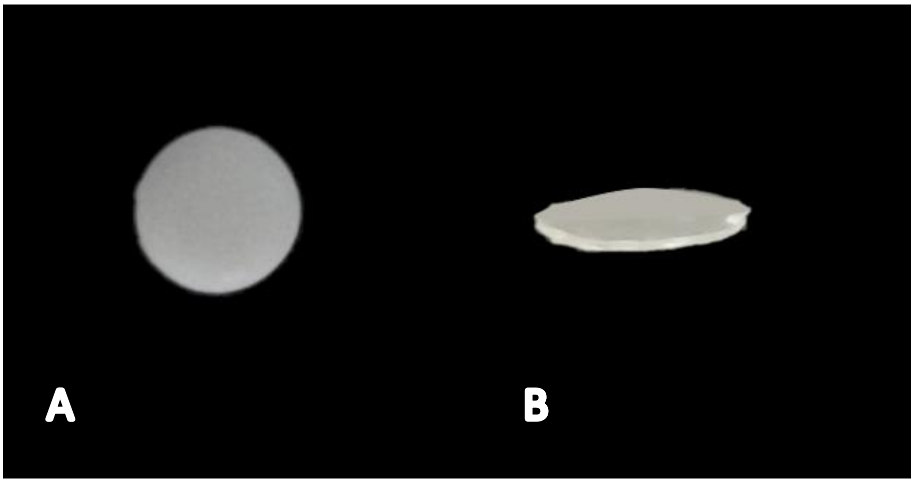
Fonte: Elaborado pelo autor

Figura 4: Pressão digital em lâmina de poliéster



Fonte: Elaborado pelo autor

Figura 5: Corpos de prova. A) discoide vista frontal; B) discoide vista lateral



Fonte: Elaborado pelo autor

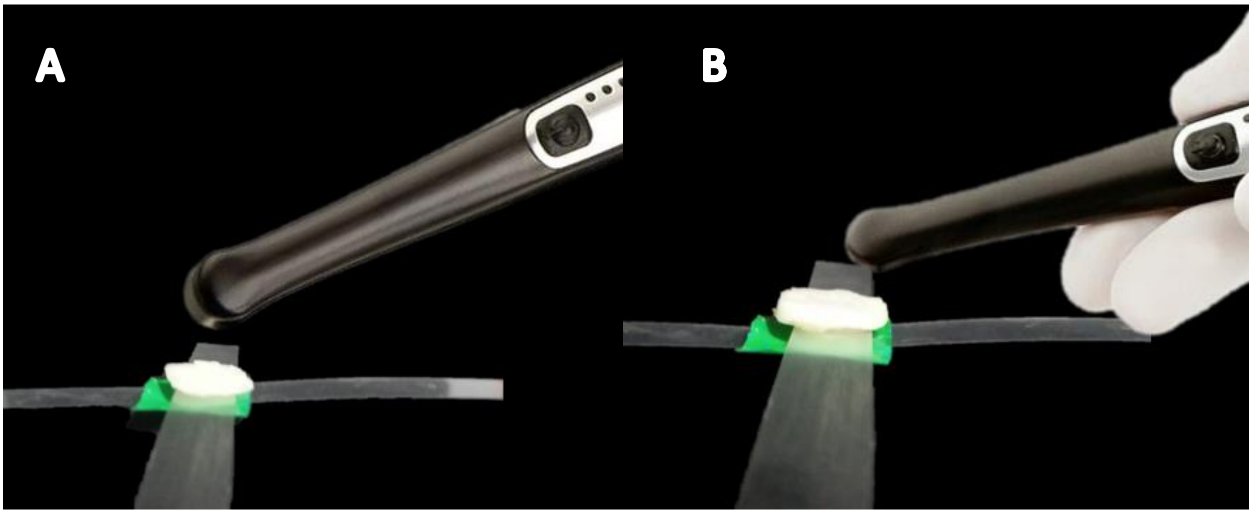
Figura 6: Corpos de prova armazenados em eppendorfs

Fonte: Elaborado pelo autor

3.3 Produção dos corpos de prova dos grupos tratamento

Foi empregada a cerâmica em suas duas espessuras, 1 e 2 mm (Figs. 7a e 7b). Elas funcionaram como barreiras para a passagem da luz. Para cada condição experimental (cimento x espessura x tempo de exposição) foram produzidos 10 discos (n=10).

Figura 7: Fotoativação dos corpos de prova. A) Cerâmica de 1 mm sobre o corpo de prova; B) Cerâmica de 2 mm sobre o corpo de prova



Fonte: Elaborado pelo autor

3.4 Cálculo de tensão biaxial dos cimentos

$$\sigma_{bf} = \frac{3P(1+v)}{4\pi t^2}\left[1 + 2ln\left(\frac{a}{b}\right) + \frac{1-v}{1+v}\left[1 - \frac{b^2}{2a^2}\right]\frac{a}{R^2}\right]$$

P = carga em Newtons

v = coeficiente de Poisson da cerâmica

t = espessura da cerâmica em mm

a = diâmetro do suporte metálico

b = diâmetro da haste metálica

R= raio da cerâmica ou cimento em mm

3.5 Análise estatística

Os resultados foram submetidos ao teste de normalidade *Kolmogorov-Smirnov.* Em seguida, foi feito análise de variância e teste t (ensaios paramétricos) usando o software GraphPad Prism Software (GraphPad Software, EUA).

4 ARTIGO CIENTÍFICO

Effect of the thickness of a lithium disilicate ceramic and the photoactivation time on the biaxial strength of different contemporary resin cements

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Effect of the thickness of a lithium disilicate ceramic and the photoactivation time on the biaxial strength of different contemporary resin cements

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Resume

Dental ceramics are a restorative option widely used in dentistry. For its bonding to the dental substrate, it uses adhesive cementation. The objective of this study was to evaluate the thickness of a ceramic with high crystalline content and photoactivation time in the biaxial strength of different brands of resin cements. Material and methods:The methodology used was biaxial tension for analysis of mechanical behavior (n = 10), from discoid specimens (12 mm in diameter and 0.7 mm in thickness). Three variables were studied in the statistical analysis: thickness of the ceramic (1 or 2 mm), type of cement and time of photoactivation of the cement layer (20 or 40 seconds). Results: In the 1 mm thick ceramic, within each photoactivation time (20 or 40 seconds), no statistically significant differences were found. However, the analysis of the differences within each cement by the t test allowed us to observe that there was a statistically significant difference in all cements when polymerized for 20 or 40 seconds. In the 2 mm thick ceramic, within each photoactivation time (20 or 40 seconds) no statistically significant differences were found. The analysis of the differences within each cement by the t test allowed us to observe that there was no statistically significant difference between the photoactivation time. Conclusion: The value of biaxial resistance was affected in 20 seconds in the situation in which simulated cementation with a 1 mm ceramic barrier was used.

Key words: Mechanical properties, Cementation, Aesthetics.

Introduction

Dental ceramics have characteristics that make them a good option for restoring lost dental structures (1). Physical and mechanical properties, in addition to excellent aesthetics popularized its use. In addition, the development of resinous materials, the creation of new restorative techniques and the growing expectation of the patient for aesthetic restorations, made ceramics the material of choice.

For a good union between dental substrate and ceramic system, it is necessary in addition to an adequate prosthetic preparation (2), a resinous cementing agent, guaranteeing adhesion (3). The resin cement provides a good marginal seal, having good physical and adhesive properties (4,5).

As posterior restorations, the ceramics are subjected to occlusal forces (6), presenting different areas of stress and with that the increase of their mechanical resistance is desired, with the challenge of maintaining the optical properties of the material, since it was found that the material restorative can directly interfere with the patient's prognosis.

In many clinical situations, the increase in mechanical strength was possible with the increase in crystalline content, which in turn requires the application of a ceramic with glassy content in its composition, in order to balance translucency. Although the covering ceramic controls the opacity caused by the crystalline content, it does not have the same mechanical properties, presenting different thermal expansion values and is subject to different flow and phenomena such as delamination, interfering in the prosthetic interface (7). Thus, in order to solve these problems, a ceramic was developed in only one block, classified in the literature as monolithic.

Currently with the evolution of CAD / CAM technology, the milling technique from a virtual model started to be used in the laboratory or even in the dental office (8), where the material undergoes a sintering process.

According to Shim et al. (9), the thickness of the restorative material and its ability to allow the passage of light influences the properties of the resin cement, causing a possible underpolymerization, which modifies its physical and adhesive properties (10).

The intimate contact between restorative material and cementing agent provided an increase in the fracture resistance of ceramic specimens, and the transmission of masticatory forces to dental tissues (11,12). Consenting to this idea, Piemjai & Arksornnkit (13) demonstrated that thecementing agent influences the fracture resistance of ceramic laminates. As a result, there is a lack of information related to the quality of the resin cement setting that is in contact with its internal portion.

The purpose of this study is to evaluate the biaxial strength of self-adhesive and conventional resin cements, photoactivated through two ceramic thicknesses (DSl, lithium disilicate).

Material and methods

Materials

The cements used (Fig. 1), as well as the ceramics, which served as a barrier to light, are described in table 1.

Sample preparation

First, 2 discs were produced using the CAD / CAM system (IPS e.max CAD, Ivoclair Vivadent, Liechtenstein) served as a barrier for the photoactivation procedure of each resin cement, with thicknesses of 1 and 2 mm with the listed ceramic (Fig. two). Subsequently, each cement was photoactivated using the barrier, and a rubber mold with a discoid shape of 12 mm in diameter and 0.7 mm in thickness was used to insert the cement (Fig. 3). A light digital pressure on a polyester sheet over the cement allowed the material to overflow, homogenizing the surface (Fig. 4). Finally, photopolymerization was done with a Valo device (Ultradent, United States) for 20 or 40s, with 1000 mW / cm2. 10 specimens were produced for each cement exposed in the table (Fig. 5a and 5b), stored in distilled water for 48 hours in eppendorfs (Fig. 6).

Production of specimens from treatment groups

Ceramics were used in their two thicknesses, 1 and 2 mm (Fig. 7a and 7b). They functioned as barriers to the passage of light. For each experimental condition (cement x thickness x exposure time) 10 discs were produced (n = 10).

Calculation of biaxial stress of cements

$$\sigma_{bf} = \frac{3P(1+v)}{4\pi t^2}\left[1 + 2ln\left(\frac{a}{b}\right) + \frac{1-v}{1+v}\left[1 - \frac{b^2}{2a^2}\right]\frac{a}{R^2}\right]$$

P = charge in Newtons

v = Poisson's ratio of ceramics

t = thickness of the ceramic in mm

a = diameter of the metallic support

b = diameter of the metal rod

R = radius of the ceramic or cement in mm

Statistical analysis

The results were subjected to the Kolmogorov-Smirnov normality test. Then, analysis of variance and t test (parametric tests) were performed using the GraphPad Prism Software (GraphPad Software, USA).

Results

Table 1 shows the MPa results of the biaxial resistance test of the photoactivated specimens through the 1 mm thick barrier.

Within each photoactivation time (20 or 40 seconds), no statistically significant differences were found. However, the analysis of the differences within each cement by the t test allowed us to observe that there was a statistically significant difference in all cements when polymerized for 20 or 40 seconds. This was the case with Ultimate ($p = 0.033$) in which there was an improvement in results (23.94%) with increased time of exposure to light. Similarly, SeTpp cement showed a 23.45% increase in biaxial strength values and the two averages also differed statistically ($p = 0.0342$). For U200 cement, the increase in the time of exposure to light meant an increase of 35.71% (from 12.44 MPa to 16.89 MPa, $p = 0.0113$).

Table 2 shows the MPa values of cements polymerized through the 2 mm ceramic barrier. Within each photoactivation time (20 or 40 seconds), no statistically significant differences were found. The analysis of the differences within each cement by the t test allowed us to observe that there was no statistically significant difference between the photoactivation time.

For the Ultimate, polymerizing for 20 or 40s did not increase the values of biaxial resistance ($p = 0.355$), an increase of 5.74% only. The same occurred for

SeTpp cement (p = 0.118), an increase of 8.74%. In the case of U200, there was an increase of 17.11% and the values were not statistically significant, p = 0.12.

Discussion

Resin cements are essential to fill the substrate and ceramic interfaces, ensuring adhesion (14).This close contact between cement and restoration provides an increase in the fracture resistance of ceramic specimens and the transmission of masticatory forces to dental tissues (11,12).The quality of the cement layer below ceramic restorations is a point to be discussed due to its great importance in the clinical success of prosthetic restorative treatment. Consenting to this idea, Piemjai & Arksornnkit (13) demonstrated that the cementing agent and the curing system influence the fracture resistance of ceramic laminates. According to Spazzin et al. (15), cementing agents with better physical properties present better mechanical performance.

Adhesive cementation is a critical technique that requires many operative steps that consume considerable clinical time (16). As a result, many dental surgeons still opt for water-based cements (zinc phosphate and glass ionomer cement), which have low or no adhesion with dental substrate (except ionomeric materials) or with the surface of prosthetic parts. Consequently, when there are more expulsive prosthetic preparations, in the case of those indicated for restorations without metallic infrastructure, part of the restoration retention to dental tissues can be improved with the application of resin cements. Currently, there are many options for resinous materials for cementation. They can be exclusively chemical prey, polymerized only in the presence of light or dual radiation. They may have chemical components that determine self-adhesive activity or may be used in conjunction with dental adhesives. It is true to say that there is safety for clinical use on the part of these materials, especially self-adhesive ones that are newer resinous materials.

Part of the motivation for the development of self-adhesive cements was to simplify the cementation procedure. De Munck et al. (17) in one of the first publications that addressed the laboratory use of Unicem cement from 3M ESPE, reported that the bond strength value by the microtensile testbetween said resin cement compared to Panvia F it was similar in dentin. However, when dentin was etched with phosphoric acid, the bond strength was quite unsatisfactory. This fact occurred due to the inability of the self-adhesive cement to fill in the collagen fibrils, which was visualized in the same study in transmission electron microscopy images. When conditioned with 37% phosphoric acid, the enamel showed similar results to the control group (Panavia F). This laboratory evidence was verified clinically bySckenke et al. (18) after a 2-year analysis, the best results obtained were related to the selective acid etching on the enamel

Other clinical studies have verified the clinical safety of this type of material. Saad, Atta and El-Mowaf(19) found a lower rate of postoperative sensitivity in patients who had crowns cemented with self-adhesive resin cement than when cemented with conventional resin cement. These results corroborate the clinical findings of Costa, Hebling and Randall (20), in which the self-adhesive resin cement caused less deleterious effects to the pulp than conventional resin cements. Aschenbrenner et al. (21) found similar results between self-adhesive resin cements and conventional resin cements, where they evaluated the quality of the marginal adaptation of ceramic onlays. In contrast, Tashner et al. (22) found better results in conventional resin cements in terms of color and marginal integrity in a two-year analysis.Piwowarczyk, Schick and Lauer (23) reported less inflammation of periodontal tissues in a patient who used self-adhesive resin cement compared to water-based cements. Blatz et al. (24) stated that the self-adhesive resin cement presents better results in the postoperative sensitivity than the glass ionomer cement, in an analysis seven days after cementation.

Although its clinical use is proven today, there are still operational difficulties during the polymerization of self-adhesive resinous materials. As they are materials that have a dual setting mechanism, together with the acid-base reaction, this mixture of components can behave differently when polymerization needs to happen in the presence of the aesthetic material. The choice of the thickness of the bulkhead was based on the literature. Prakki et al. (25) used 1 and 2 mm, justified by being widely found in practiceclinic and for providing the passage of light from the photoactivator with a certain quality. The choice of the ceramic system (IPS e.max CAD, Ivoclair Vivadent, Liechtenstein) was based on the study by Scotti et al. (26).

In the presence of the 1 mm thick ceramic, the photoactivation time was important, as the biaxial resistance values increased in all the tested cements when they were exposed to the 40 second photoactivation time. This indicates that in the presence of the obstacle made with IPS e.max CAD ceramic, the time of 20 seconds is insufficient to polymerize the material to its maximum. For the U200, there was an increase of 35.71% ($p = 0.0113$) in the values of biaxial resistance. The other cements experienced an increase of about 23%. When increasing the thickness of the ceramic, all cements behave equally, that is, there is no statistically significant effect if the time of exposure to light is increased. The resulting increase is slight. This is because the passage of light through the 2 mm ceramic barrier is more difficult.Jang et al. (27) evaluated different resin cements, at different times of photoactivation, concluding that 20s compromised the conversion of resin monomers.The thickness of the restoration influences the light passage of the light curing device (9), the greater the thickness, the greater the chance of underpolymerization.

Mahmoodi & Keshvad (28) observed a decrease in the Vickers hardness of a resinous cement, when activated under a ceramic with a thickness of 2 millimeters, due to a lesser degree of conversion of monomers in this cement layer. Hardy et al. (29) concluded that dual resin cements are effective in ceramic restorations with a thickness less than or equal to 4 millimeters. Pishevar, Ashtijoo and Khavvaji (30) in a laboratory study using dual resin cements (Biscem, Bisco, USA) and photoactivated (Choice 2, Bisco, USA) excluded samples of specimens of photoactive resin cement under thickness of 4 mm of ceramic, because it was not possible to polymerize it that could be tested by the hardness test.

The formation of the polymeric network, which is well polymerized and rigid enough not to be broken prematurely, is essential for the success of the restoration if the cement has considerable strength, capable of receiving masticatory forces (31). This study used three different types of dual resin cement. RelyX U200 and SET PP, both of the self-adhesive dual type, and RelyX Ultimate, dual of the conventional type. Within each experimental condition, no statistically significant differences were found between them The choice of these materials was due to their wide clinical application and be the subject of studies by some authors.

Rojpaibool & Leevailoj (32), for example, analyzed the relationship of cement thickness (U200 and ULTIMATE, plus zinc phosphate Improved ISS, SS White) and fracture resistance of dental ceramic in the mechanical strength fracture resistance test , finding better values when the ceramic was related to the Ultimate resin cement (3M ESPE, Minnesota, USA). For these authors, acid conditioning (phosphoric acid promoted a better union of the ceramic/cement/dentin combination. In the present study, the assessment of biaxial resistance occurred only in cement so that there was no other factor that interfered in the way the materials resisted the stress compression in the central region of the disc. It’s a way of isolating the factors, interesting for comparisons between materials that have different instructions for clinical use, but that should also be seen as a limitation of the work, as there is no clinical equivalent, no situation other than the use of these cements in cementation situations. The cement will always be making the restoration/dental structure junction.

The observed values can be indirectly related to the quality of the formation of the polymeric network. Most likely, a test to evaluate the degree of conversion could be more appropriate to determine differences between cements. Using this chemical test in conjunction with a mechanical test could provide more data on these resin cements. Future studies may make use of this combination to provide even richer information regarding how much light is lost in ceramics and its physical effect on the photosensitive components of resinous materials.

Another clinical feature that can be evaluated in the future is the thickness of the cementation line. The authors cited last found that the smaller the cementation line, the better the fracture resistance value of lithium disilicate ceramic (32). In contrast, Sagsoz & Yanikoglu (33) also used different thicknesses of U200 resin cement in close contact with ceramics prepared in CAD/CAM (2 mm thick), concluding that the thickness of the cement was not effective in the fracture resistance of dental ceramics. Piemjai & Arksornnkit (13) reported that the cementing agent and the curing system influence the fracture resistance of ceramic laminates, finding better results with the Super-Bond C&B self-curing resin cement in 0.5 and 1 mm thick ceramics. Cekic-Nagas et al. (34) in a laboratory study, they used zirconia discs (0.3, 0.5 and 0.8 mm) as a conclusion that the microhardness of dual resin cements (RelyX U200, Panavia F and Clearfil SA Cement) were adequate, although with increase in thickness the light passage of the photoactivator apparatus was impaired.

This in vitro study performed an unprecedented bi-axial strength test directly on the photoactivated cement layer. Possible differences between specimens made with 1 or 2 mm thickness (1 and 2 mm) were not evaluated when the specimens were photoactivated at two different times (20 and 40 seconds). Yang et al. (35) in a microhardness test found no statistically significant differences between two types of resin cements, Unicem and PermaCem 2.0 (DMG, Germany), when photoactivated at 30 seconds under a 1.5 mm lithium disilicate. In contrast, Meng, Yoshida and Atsuta (36), using 1 to 3 mm ceramic bulkheads, found a decrease in the flexural strength of resin cements when the thickness of the ceramic was increased, which is due to a considerably greater thickness used. Scotti et al. (26) found no differences in the vickers hardness of dual and photoactivated resin cements using a lithium disilicate in thicknesses 0.6 and 1.5 mm as a screen. Kilinc, Antonson and Hardigan (37) considered 3 mm of bulkhead as a critical threshold for photoactivation of dual resin cements.

Conclusion

Within the limitations of the study, it was possible to conclude that the value of biaxial resistance was affected in 20s in the situation in which simulated cementation with a 1 mm ceramic barrier was used. When increasing the time of exposure to light (20 to 40 seconds), there was an increase in the value of biaxial resistance in all groups, however, only in the 1 mm ceramic was this increase considered statistically significant. There was no difference in the values of biaxial strength between the cements within each photoactivation condition and ceramic thickness.

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Conflict of interests

The authors have declared that there is no conflict of interest.

Tables

Table 1. Biaxial strength of resin cements photoactivated through 1 mm thick ceramic

	Ultimate	SeTpp	U200
20 seconds	13.46 (2.96) Ab	14.48 (3.30) Ab	12.44 (3.04) Ab
40 seconds	16.68 (4.29) Aa	17.87 (4.45) Aa	16.89 (4.75) Aa

[A, B]Means in MPa and standard deviation in parentheses in the horizontal direction followed by the same capital letter do not present statistical differences ($p < 0.05$). The p value was obtained through analysis of variance 1 factor within each photoactivation time. a, b Averages in MPa and standard deviation between parentheses in the vertical direction followed by the same lowercase letter do not show statistical differences ($p < 0.05$) by means of the t test, used later to analyze the values within each cement at both times (20 and 40 seconds).

Table 2. Biaxial strength of resin cements photoactivated through 2mm thick ceramic

	Ultimate	SeTpp	U200
20 seconds	15.76 (6.03) Aa	14.06 (1.98) Aa	14.03 (5.17) Aa
40 seconds	16.66 (4.64) Aa	15.29 (2.48) Aa	16.43 (3.90) Aa

[A, B]Means in MPa and standard deviation in parentheses in the horizontal direction followed by the same capital letter do not present statistical differences ($p < 0.05$). The p value was obtained through analysis of variance 1 factor within each photoactivation time. a, b Averages in MPa and standard deviation between parentheses in the vertical direction followed by the same lowercase letter do not show statistical differences ($p < 0.05$) by means of the t test, used later to analyze the values within each cement at both times (20 and 40 seconds).

Figure Caption

Fig. 1: Resin cement used

Fig. 2: Ceramic discs made by CAD / CAM

Fig. 3: Insertion of cement in the rubber mold with discoid shape

Fig. 4: Digital pressure on polyester blade

Fig. 5: Specimens. A) Discoid specimen front view; B) Discoid specimen side view

Fig. 6: Specimens stored in eppendorfs evidence; b) 2 mm ceramic over the specimen

Fig. 7: Photoactivation of the specimens. A) 1 mm ceramic on the specimen; B) 2 mm ceramic on the specimen

Fig. 1

Fig. 2

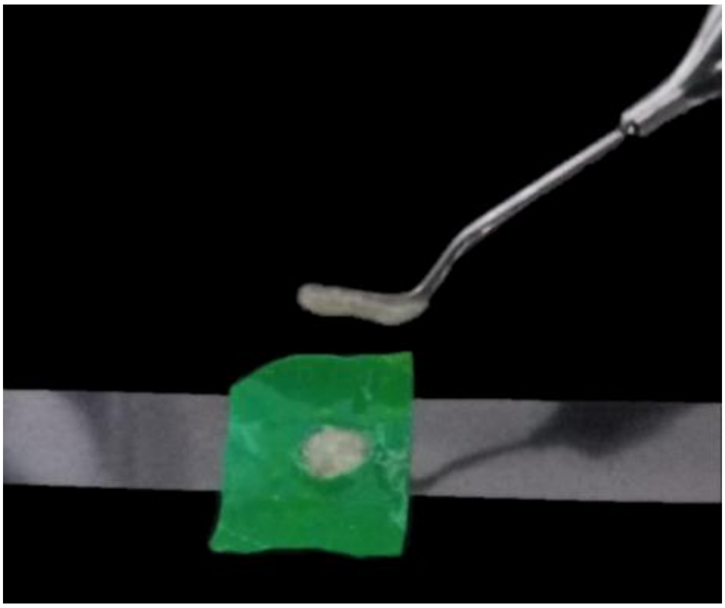

Fig. 3

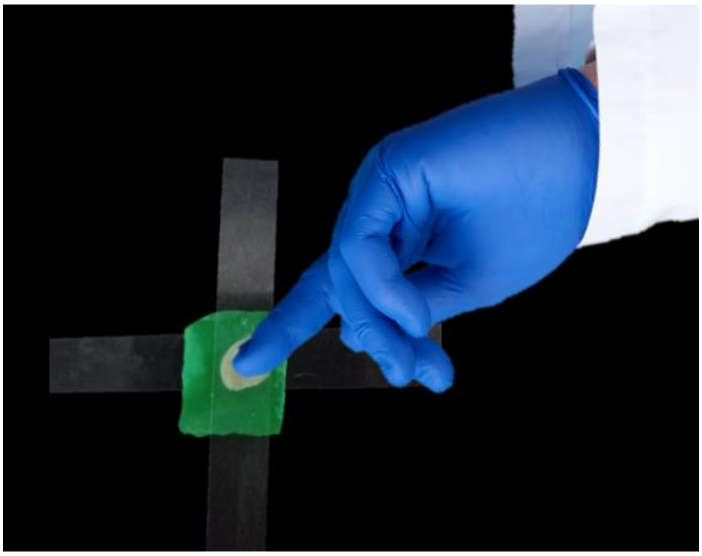

Fig. 4

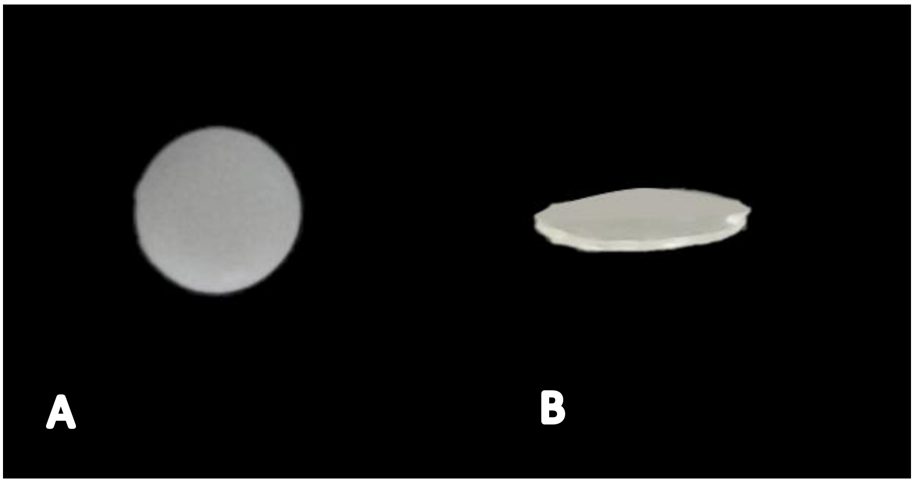

Fig. 5

Fig. 6

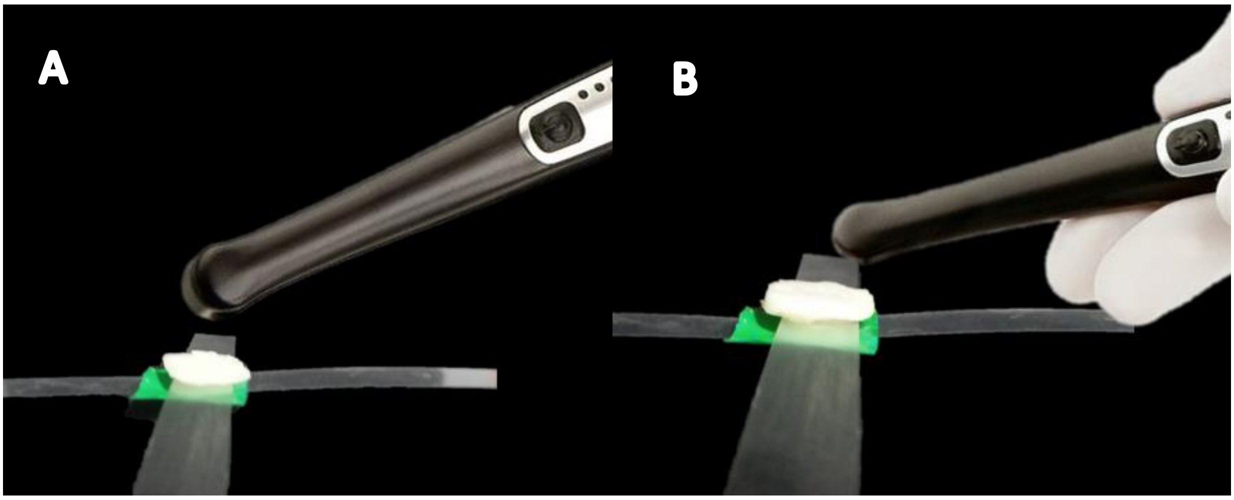

Fig. 7

Frame

Table 1. Restorative materials to be used

Material	Type	Manufacturer
e.max CAD	Lithium disilicate ceramic	Ivoclair Vivadent, Liechtenstein
RelyX Ultimate	Conventional resin cement	3M ESPE, United States
RelyX U200	Self-adhesive resin cement	3M ESPE, United States
Sett PP	Self-adhesive resin cement	SDI, Australia

5 CONSIDERAÇÕES FINAIS

A cimentação é um passo operatório muito importante, sendo responsável pela união entre substrato dental e material restaurador, prevendo um bom selamento marginal e transmissão de forças mastigatórias aos tecidos dentais. Cimentos resinosos duais são indicados em situações onde não é possível apenas a fotoativação. Apresentam um bom grau de conversão de monômeros e boas propriedades físicas e mecânicas. Ainda sim, é imprescindível a luz no processo de polimerização desses cimentos.

Materiais resinosos ainda continuarão a evoluir. Novas misturas, partículas de carga e mecanismo de presa em meio ácido são possibilidades concretas que veem sendo aperfeiçoadas. Consequentemente, o assunto cimentação em Odontologia nunca deixará de ser revistado com, seja com abordagens ou metodologias diferentes, ou em razão da existência de novos materiais cerâmicos, resinosos e/ou sistemas adesivos.

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