

UNIVERSIDADE FEDERAL DE PERNAMBUCO
CENTRO DE CIÊNCIAS DA SAÚDE
MESTRADO EM ODONTOLOGIA
ÁREA DE CONCENTRAÇÃO EM CLÍNICA INTEGRADA

SINARA CUNHA LIMA

**INFLUÊNCIA DA ESPESSURA E TRANSLUCIDEZ DA CERÂMICA DE
DISSILICATO DE LÍTIO NA TAXA DE CONVERSÃO DE CIMENTOS
RESINOSOS COM DIFERENTES INICIADORES**

Recife

2021

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Dissertação apresentada ao programa de Pós-graduação em Odontologia do Centro de Saúde da Universidade Federal de Pernambuco como requisito parcial para obtenção do título de mestre em Odontologia com área de concentração em Clínica Integrada.

Orientadora: Prof^a Dr^a Bruna de Carvalho Farias Vajgel
Coorientadora: Prof^a Dr^a Renata Cimões

Recife

2021

Catálogo na fonte:
Bibliotecária: Elaine Freitas, CRB4:1790

L732i	Lima, Sinara Cunha Influência da espessura e translucidez da cerâmica de dissilicato de lítio na taxa de conversão de cimentos resinosos com diferentes iniciadores / Sinara Cunha Lima. – 2021. 56 f. ; il. Orientadora: Bruna de Carvalho Farias Vajgel. Dissertação (Mestrado) – Universidade Federal de Pernambuco, Centro de Ciências da Saúde. Programa de Pós-graduação em Odontologia. Recife, 2021. Inclui referências e anexo. 1. Cerâmica. 2. Cimentos de resina. 3. Fotoiniciadores dentários. I. Vajgel, Bruna de Carvalho Farias (orientadora). II. Título. 617.6 CDD (23.ed.) UFPE (CCS 2021 - 167)
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da Saúde, como requisito para a obtenção do
título de Mestre em Odontologia. Área de
concentração: Clínica Integrada

Aprovado em: 30/08/2021

Orientador:

Prof.^a Dr.^a Bruna de Carvalho Farias Vajgel

BANCA EXAMINADORA

Prof.^a Dr.^a Joel Ferreira Santiago Junior (Examinador Externo)
Universidade de São Paulo, Campus Bauru

Prof.^a Dr.^a Cátia Maria Fonseca Guerra (Examinadora Externa)
Universidade Federal de Pernambuco

Prof.^a Dr.^a Juliana Raposo Souto Maior (Presidenta)
Universidade Federal de Pernambuco

AGRADECIMENTOS

Agradeço primeiramente aos meus pais, Monica da Cunha e Joselito Lima por terem me concebido e criado com tanto amor e carinho. Agradeço por todo o suporte e incentivo dado para que eu pudesse estudar.

À minha irmã, Mariana Cunha, por ser companheira em todos os momentos. Obrigada por sempre ter uma palavra amiga e uma boa história para contar.

Ao meu esposo, Carlos Eduardo Sá, que é o meu companheiro do dia-a-dia a apenas 10 meses. Agradeço pelo empréstimo do carro para ir à UFPE, pelas horas dedicadas me ajudando com as planilhas do excel e tentando entender as análises estatísticas junto comigo, e pelo café quente nas noites de estudo.

À toda minha família que sempre esteve presente, em especial à minha tia e madrinha Vera Lúcia que como professora vibrou junto comigo a aprovação no vestibular e foi a responsável por me presentear com o primeiro jaleco.

À professora Bruna Farias pela orientação na monitoria de PPR, na iniciação científica e agora no mestrado. Agradeço pelo suporte concedido para realização dessa pesquisa. Obrigada pela confiança, conselhos, pelos puxões de orelha, por acreditar em mim e por me presentear com desafios cada dia maiores. A senhora foi peça-chave na construção deste trabalho e na minha formação acadêmica.

À professora Renata Cimões pela co-orientação no trabalho e na vida. Agradeço pelas palavras sinceras e pela generosidade.

À todos os amigos do grupo de pesquisa Perio-Implante UFPE, em especial as alunas da graduação Andreza Amaral e Giovanna Bione, e a colega do doutorado Jéssyca França que me ajudaram ativamente na construção desta dissertação.

À todos da turma de mestrado 2019. Agradeço pelas conversas descontraídas e pelo suporte e esforço para sanar as dúvidas.

Ao Junior Lima, técnico em prótese dentária, que construiu junto comigo toda a metodologia para obter os discos de cerâmica e executou com maestria a confecção dos discos em seu laboratório Junior Lima-atelier dental. Agradeço pelas inúmeras vezes que me recebeu em seu laboratório.

Ao servidor João Rangel, gerente do Laboratório de Combustíveis da UFPE, e ao Douglas, técnico do mesmo laboratório, por terem me recebido e ensinado todo o processo de aquisição dos espectros de absorbância no FTIR.

Ao Laboratório de Combustíveis (LAC) que é parte do Laboratório Integrado de Tecnologia em Petróleo, Gás e Biocombustíveis (LITPEG – UFPE) por permitir a utilização do equipamento de espectroscopia FTIR.

Ao estatístico Jansen Campos, pelas análises estatísticas apresentadas neste trabalho.

Aos professores Hilcia Mezzalira e Alexandre Nascimento por fornecerem o radiômetro para as leituras e por me receberem na sala da Disciplina de Dentística da UFPE.

À todos os professores que fazem parte do corpo docente da graduação e da Pós-graduação em Odontologia da UFPE. Agradeço por todos os ensinamentos adquiridos.

Aos amigos Dennis Cunha e Janaína Câmara da Texas A&M University pelo suporte a distância com artigos difíceis de acessar.

À todos os meus amigos e amigas que são ponto de apoio e que estão sempre prontos para uma conversa.

À CAPES pela concessão da bolsa de estudos, possibilitando a realização desta dissertação de mestrado.

Minha eterna gratidão a todos que não foram mencionados, mas que participaram direta ou indiretamente para a construção deste trabalho.

Muito obrigada!

RESUMO

A taxa de conversão (TC) dos cimentos resinosos pode ser influenciada pela espessura e translucidez das restaurações indiretas, assim como pelo tipo de cimento empregado. Portanto, o objetivo foi avaliar a influência da espessura e translucidez da cerâmica de dissilicato de lítio na TC de cimentos resinosos com diferentes iniciadores, sendo dois fotopolimerizáveis (Variolink® Esthetic LC e NX3® LC) e um dual (NX3® DC). Foram confeccionados discos de cerâmica IPS e.max® Press em quatro espessuras (0,3, 0,5, 1,0, e 1,5 mm) na cor A2, e em três translucidez: HT (alta translucidez), LT (baixa translucidez), e MO (média opacidade). Em seguida, 234 amostras de cimento resinoso com 5mm de diâmetro e 1mm de espessura foram fotopolimerizados com a interposição dos respectivos discos de cerâmica. Após, a TC das amostras foi mensurada pela Espectroscopia no Infravermelho por Transformada de Fourier (FTIR). Os dados TC (%) foram avaliados pelos testes Mann-Whitney e Kruskal Wallis ($p < 0,05$). Observou-se diferença significativa entre todos os cimentos estudados ($p < 0,05$), onde o Variolink obteve as melhores médias de TC ($80,62 \pm 5,51\%$), e o NX3 DC apresentou as menores TC ($38,36 \pm 3,82\%$). Quanto à influência das espessuras na TC, não houve diferença significativa ($p > 0,05$), exceto para as espessuras do grupo HT do NX3 DC ($p = 0,005$). Para translucidez, a MO interferiu na TC do Variolink ($78,32 \pm 7,36\%$; $p=0,018$), e o NX3 DC apresentou menores TC com diferença significativa para as diferentes translucidezes dos discos cerâmicos ($p=0,001$). Portanto, conclui-se que a maioria das espessuras e translucidezes da cerâmica não afetou a TC dos cimentos resinosos fotopolimerizáveis, com exceção do cimento dual que foi negativamente influenciado pelas espessuras dentro do grupo HT e pelas translucidezes. O Variolink (Ivocerin®) quando comparado com o NX3 LC e DC (REDOX®) obteve melhores TC, mesmo com cerâmicas mais espessas e opacas, sugerindo uma ampla aplicação clínica.

Palavras-chave: cerâmica; cimentos de resina; fotoiniciadores dentários.

ABSTRACT

The degree of conversion (DC) of resin cements might be influenced by the thickness and translucency of indirect restorations, as well as by the type of resin cement. Therefore, the study aimed to evaluate the influence of the thickness and translucency of lithium disilicate ceramic on the DC of resin cements with different initiators: two light-cured (Variolink® Esthetic LC and NX3® Light), and one dual (NX3® Dual). IPS e.max® Press ceramic discs were prepared in four thicknesses (0.3, 0.5, 1.0, and 1.5 mm), color A2, and in three translucency: HT (high translucency), LT (low translucency), and MO (medium opacity). Subsequently, 234 samples of resin cement, with 5mm diameter and 1mm height, were photopolymerized through those ceramic discs. The DC of the samples was assessed by Fourier Transform Infrared Spectroscopy (FTIR), and evaluated by Mann-Whitney and Kruskal Wallis. There was statistical difference between all cements ($p \leq 0.05$), where Variolink had the highest DC mean ($80,62 \pm 5,51\%$), and NX3 Dual the lowest ($38,36 \pm 3,82\%$). Among thicknesses, there were no differences ($p > 0.05$), except for NX3 Dual HT group ($p = 0,005$). For translucency, MO type affected Variolink DC ($78.32 \pm 7.36\%$; $p=0.018$), and NX3® Dual showed a significant difference in DC among translucencies ($p=0.001$). To conclude, thickness and translucency do not affect the DC of light-cured resin cements; however, the DC of the dual-cured resin cement was significantly affected by translucencies. Variolink (Ivocerin®) when compared to NX3 Light and Dual (REDOX®) reached higher DC, even with thicker and more opaque ceramics, suggesting a wide clinical application.

Keywords: ceramic; resin cement; photoinitiators, dental.

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LISTA DE ABREVIATURAS, SIGLAS E SÍMBOLOS

Ø	Diâmetro
ATR	Reflectância total atenuada
BAPO	2,4,6-Trimetilbenzofenona
Bis-EMA	Bisfenol A dimetacrilato etoxilado
Bis-GMA	Bisfenol A glicol dimetacrilato
CQ	Canforoquinona
CRO	Registro no conselho regional de odontologia
D3MA	1,10-decanodiol dimetacrilato
DC	Dual-cured (cura dual)
DP	Desvio padrão
EDMAB	Etil 4-dimetil aminobenzoato
FTIR	Espectroscopia no Infravermelho com Transformada de Fourier
HEMA	Metacrilato de 2-hidroxietila
HT	Alta translucidez
LC	Light-cured (fotopolimerizável)
LT	Baixa translucidez
MEMO	metacriloxipropiltrimetoxisilano
MO	Média opacidade
mW/cm ²	Miliwatt por centímetro quadrado
N e n	Número
NX3	Terceira geração do cimento resinoso Nexus
SLA	estereolitografia
TC	Taxa de conversão
TEGDMA	Trietileno glicol dimetacrilato
TPO	Óxido de 2,4,6-trimetil benzoildifenil fosfina
UDMA	Uretano dimetacrilato
UFPE	Universidade Federal de Pernambuco
Variolink E	Variolink Esthetic LC

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1 INTRODUÇÃO

A busca atual por restaurações estéticas tem como resultado um aumento no uso de facetas de cerâmica na Odontologia. As facetas possuem ampla aplicação clínica e dependendo da indicação podem ter de 1 mm a menos de 0,5 mm de espessura, enquanto coroas totais de cerâmica possuem espessura a partir de 1,0 mm (1, 2). Para o sucesso deste procedimento, a qualidade do material restaurador indireto não é o único critério a ser considerado. O sucesso a longo prazo dessas restaurações é determinado em parte, pela durabilidade da união adesiva que pode ser influenciada pela espessura e translucidez da restauração indireta, assim como pelo tipo de cimento e sistema adesivo empregado. A cimentação adesiva das restaurações cerâmicas oferece diversas vantagens, dentre elas a união química com a estrutura dentária, onde os cimentos resinosos proporcionam esta união (3).

Outro fator importante quanto ao sucesso da adesão, é a influência da cerâmica na conversão dos monômeros dos cimentos resinosos em polímeros (4). Os parâmetros inerentes a cerâmica que podem influenciar na TC estão relacionadas com o tipo da cerâmica, translucidez do material e espessura das restaurações (5), assim como as propriedades físicas de reflexão, absorção e refração da luz do fotopolimerizador quando entra em contato com o disco de cerâmica também influenciam na TC (6). Consequentemente, baixas TC estão relacionadas com um excesso de monômero residual que é citotóxico para a polpa e tecidos orais, assim como lixiviação desses monômeros por difusão da água, afetando diretamente na força e estabilidade da união adesiva, aumentando também a porosidade do cimento e levando a um acúmulo de bactérias, por fim, comprometendo a integridade da estrutura dentária e longevidade da restauração indireta (1, 7-9).

A translucidez dos materiais cerâmicos pode variar de acordo com os fatores: saturação da cor, estrutura cristalina, espessura, número de ciclos de queima, tamanho das partículas cristalinas e pigmentos. Já a espessura da cerâmica pode influenciar a transmissão e qualidade da luz do fotopolimerizador que atinge a camada de cimento subjacente (6, 10-12). Portanto, a escolha do tipo de cerâmica, espessura, cor e opacidade (translucidez) reflete diretamente na TC dos cimentos resinosos. Dessa forma, alguns estudos têm proposto que quanto maior a espessura da faceta, maior deve ser o tempo de exposição à luz para aumentar a energia

radiante que atinge o cimento resinoso e assim obter melhores propriedades mecânicas (1, 13-17).

Os cimentos resinosos são compostos por diferentes tipos de monômeros e iniciadores que quando ativados, reagem formando cadeias poliméricas e atingindo um estado sólido (18, 19). Consequentemente, as características e propriedades desses cimentos dependem diretamente da TC dos monômeros em polímeros (20). Estes são classificados de acordo com o tamanho das partículas (micro e nano), tipo de adesão (convencional e auto condicionante), e pelo tipo de cura (química, dual ou fotoativado) (7, 8, 21).

Os cimentos duais dependem da exposição à luz e de reações químicas de cura para produzir quantidades suficientes de radicais livres capazes de aumentar a TC do monômero em polímero, assim melhorando suas propriedades físicas e mecânicas (22). Porém, tais cimentos possuem aminas terciárias em sua composição que atuam como co-iniciadores do processo de polimerização, e estão associados a um comprometimento da estabilidade da cor a longo prazo (7, 23).

A etapa de manipulação dos cimentos duais, faz com que a incorporação de bolhas de ar seja inevitável, e esta interação com o oxigênio atmosférico pode enfraquecer algumas propriedades, como dureza e rugosidade. Para minimizar esta reação com oxigênio, vários fabricantes desenvolveram pontas de automistura (20, 24).

Já os cimentos fotopolimerizáveis possuem iniciadores que dependem da luz azul para iniciar a polimerização. A CQ é um fotoiniciador Norrish tipo II, onde ela depende de uma molécula doadora de hidrogênio, normalmente uma amina terciária, para desencadear a formação de radicais livres. Esses radicais reagem com os monômeros metacrilatos e dão início ao processo de polimerização. Por outro lado, a amina terciária presente em materiais com a CQ provoca um amarelamento do material a longo prazo devido a uma reação de oxidação, desfavorecendo o fator estabilidade de cor (24). Atualmente, alguns cimentos têm utilizado fotoiniciadores Norrish tipo I (Ivocerin®, TPO, BAPO) em sua formulação, os quais não necessitam de componentes químicos adicionais para a formação de radicais (18, 19, 25). Estes quando expostos a luz sofrem uma clivagem, a molécula se divide em dois ou mais radicais que reagem com os monômeros para formar a cadeia polimérica, um exemplo são os derivados do benzoil germânio (Ivocerin) que clivam em radicais germila e benzoíla (7, 8, 14, 26). Os fotoiniciadores tipo I

possuem um espectro mais amplo de absorção com ondas curtas do espectro violeta (380 a 420 nm) quando comparados a CQ, reduzindo tempo de fotoativação e aumentando a profundidade de cura, esses também apresentam menor solubilidade em água e citotoxicidade (24, 26, 27).

Existe poucos dados na literatura atual avaliando a TC de cimentos resinosos com fotoiniciadores Norrish tipo I quando fotopolimerizados através de diferentes translucidezes e espessuras de cerâmica, assim como existem poucos estudos comparando a TC desses com outros sistemas de iniciação, principalmente comparando com cimentos duais (8, 18, 19, 25).

Portanto, o presente estudo teve como objetivo principal avaliar a influência da espessura e translucidez da cerâmica de dissilicato de lítio na TC de cimentos resinosos com diferentes iniciadores, sendo dois fotopolimerizáveis (Variolink® Esthetic LC e NX3® LC) e um dual (NX3® DC). As hipóteses nulas do estudo foram: a) a espessura e translucidez da cerâmica de dissilicato de lítio não afeta a TC dos cimentos resinosos; b) Não houve diferença entre a TC dos cimentos fotopolimerizáveis e dual.

2 OBJETIVOS

2.1 Objetivo geral

Avaliar a influência da espessura e translucidez da cerâmica de dissilicato de lítio na TC de cimentos resinosos com diferentes iniciadores, sendo dois fotopolimerizáveis (Variolink® Esthetic LC e NX3® LC) e um dual (NX3® DC).

2.2 Objetivo específico

- Avaliar a influência das espessuras (0,3, 0,5, 1,0 e 1,5 mm) na TC dos cimentos resinosos Variolink® Esthetic LC, NX3® LC e NX3® DC;
- Verificar a influência das translucidezes (HT, LT e MO) na TC dos cimentos resinosos Variolink® Esthetic LC, NX3® LC e NX3® DC;
- Comparar a TC de cimentos resinosos com diferentes iniciadores, sendo dois fotopolimerizáveis (Variolink® Esthetic LC e NX3® LC) e um dual (NX3® DC);

3 METODOLOGIA

3.1 Localização do estudo

O presente estudo foi realizado no Laboratório da pós-graduação em Odontologia e no Laboratório de combustíveis (LAC) da Universidade Federal de Pernambuco, e em parceria com o Laboratório Junior Lima Atelier Dental/ CRO-PE: 440, localizado na cidade do Recife-PE.

3.2 Tipo de estudo

Este estudo é do tipo experimental laboratorial.

3.3 Hipóteses

H0: a) a espessura e translucidez da cerâmica de dissilicato de lítio não afeta a TC dos cimentos resinosos; b) Não houve diferença entre a TC dos cimentos fotopolimerizáveis e dual.

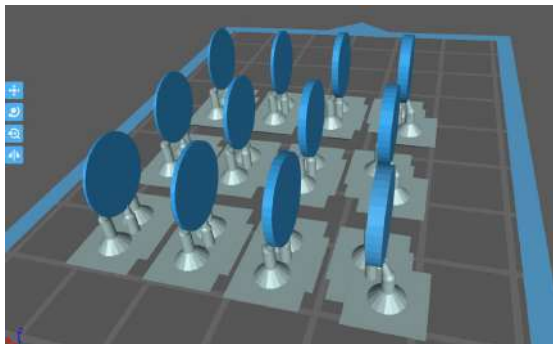
H1: a) a espessura e translucidez da cerâmica de dissilicato de lítio afeta a TC dos cimentos resinosos; b) Houve diferença entre a TC dos cimentos fotopolimerizáveis e dual.

3.4 Confeccção dos discos de cerâmica

Inicialmente foram confeccionados discos de cerâmica IPS e.max® Press (Ivoclar Vivadent) com $\varnothing = 10$ mm, em quatro espessuras (0,3 mm, 0,5 mm, 1,0 mm, 1,5 mm) na cor A2, e em três translucidezes: HT (alta translucidez), LT (baixa translucidez), e MO (média opacidade) de acordo com as especificações do fabricante (n=3 discos para cada espessura/translucidez, totalizando 36 discos cerâmicos), pelo laboratório Junior Lima – atelier dental (tabela 2) (28-30).

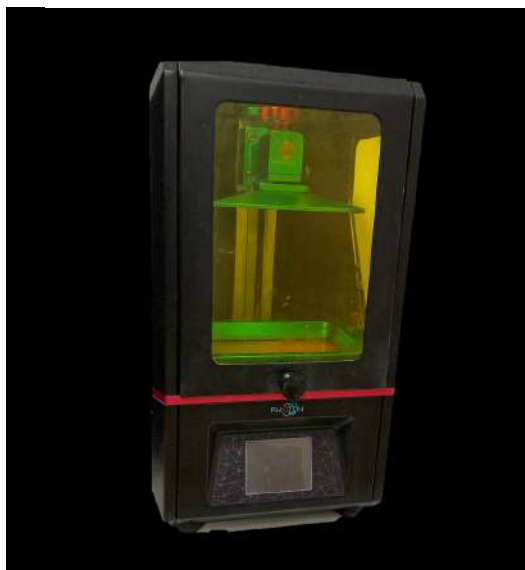
Primeiramente, um protótipo dos discos de cerâmica foi projetado no programa exocad GmbH® seguindo o diâmetro e espessuras estabelecidos. O projeto foi salvo no formato STL para ser impresso em uma impressora 3D com resina (Anycubic Photon LCD-based SLA 3D Printer, Shenzhen, China) (Figuras 1 e 2).

Figura 1: Projeto exocad.



Fonte: A autora.

Figura 2: Impressora 3D.



Fonte: A autora.

Os protótipos foram impressos por SLA usando uma resina específica para o equipamento (priZma 3D CM-450 CASTING DLP/LCD UV, Makertech Labs, São Paulo, Brasil). Após impressão, os discos foram destacados da base e preparados para o anel para injeção. Foi necessário 2 conectores de injeção (fios sprues 2/5mm, Kota®) para os discos mais finos e um conector para os discos mais grossos. Quatro discos de resina foram posicionados em um anel de fundição de 100 gramas de revestimento (Figura 3). Um agente redutor de tensão superficial (Surface, Polidental, São Paulo) foi aplicado com pincel antes da inclusão do revestimento para injeção (Gilvest HS®, Bradent, São Paulo), e após a cura completa do revestimento seguindo os parâmetros do fabricante, a resina foi eliminada em forno automático a temperatura de 850°C por 60 min, utilizando a técnica de cera perdida. Os lingotes de cerâmica IPS e.max® Press foram injetados nos moldes de revestimento em um forno de prensagem automática (EP 600, Ivoclar Vivadent) para obter a estrutura final em cerâmica após remoção do material de revestimento (2, 28, 30, 31) (Figura 4).

Figura 3: Discos de resina no anel de injeção.



Fonte: A autora.

Figura 4: Discos de cerâmica após injeção (4 espessuras).



Fonte: A autora.

Aleatoriamente, um dos lados do disco de cerâmica foi submetido a acabamento e polimento com pedras e borrachas (DT01, DT08 diamante - Diaturbo, Ribeirão Preto, Brasil) para simular o processo que o técnico em prótese dental realiza nas restaurações indiretas de cerâmica (32). O outro lado do disco não foi submetido a polimento. Todos os discos foram limpos em cubas ultrassônicas em água deionizada (Ultrasonic Cleaner 1440 D) por 10 min e secas com jatos de ar comprimido.

As espessuras finais foram confirmadas com um especímetro (Golgran) e um paquímetro digital (Zaas precision; 0,01 mm). Duas camadas de pasta *glaze* (IPS e.max Ceram Glaze, Ivoclar-Vivadent) foram aplicadas na superfície da cerâmica polida com movimentos em direção única. Cada camada de pasta *glaze* queimou no forno de sinterização (P710 Programat; Ivoclar-Vivadent) por 15 min, segundo orientações do fabricante. Após, os discos foram condicionados em recipientes específicos e separados por translucidez e espessura (Figura 5) de acordo com a tabela 2.

Figura 5: Aspecto final dos discos de cerâmica.



Fonte: A autora.

3.5 Mensuração da irradiância transmitida (mW/cm^2)

O aparelho emissor de luz LED através dos discos de cerâmica utilizado foi o fotopolimerizador VALO (Ultradent Inc, South Jordan, UT, USA), na potência standard (20s), onde, de acordo com o fabricante, alcança uma irradiância de até $1000 \text{ mW}/\text{cm}^2$ neste modo (1). Um radiômetro (Hilux Ledmax Dental Curing Light Meter, Benlioğlu Dental Inc.) foi utilizado para confirmar e mensurar a irradiância que atravessou os discos de cerâmica (33) (Figura 6). Para isto, os discos de cerâmica foram posicionados sobre a área fotossensível do radiômetro e a ponta LED do fotopolimerizador foi posicionada em contato e perpendicular ao disco (32).

Primeiramente, o aparelho foi acionado por 60 segundos, completando três ciclos de 20 segundos. Esta etapa teve por objetivo padronizar a temperatura da lâmpada (34). Para obter uma irradiância estável, todas as mensurações foram registradas após 10 segundos de ativação (32). Posteriormente, foi realizada uma leitura controle, onde a ponta fotopolimerizadora foi colocada perpendicular e em contato com a porção central da superfície fotossensível do radiômetro. As mensurações foram realizadas com todos os discos de cerâmica, seguindo o protocolo descrito anteriormente (30, 35).

Figura 6: Radiômetro.



Fonte: A autora.

3.6 Confeção das amostras de cimento resinoso

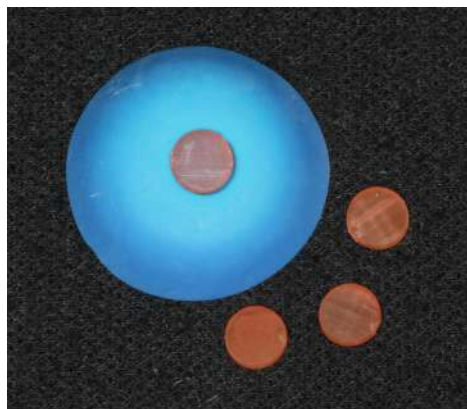
As amostras dos cimentos resinosos (tabela 1) foram confeccionadas a partir de uma matriz de polivinilsiloxano (Virtual®, Ivoclar Vivadent AG, Schaan, Liechtenstein) com 5 mm de diâmetro e 1 mm de profundidade, confeccionada a partir de um molde de discos impressos na impressora 3D SLA Anycubic Photon LCD-based SLA (Figura 7 e 8). A matriz em polivinilsiloxano foi utilizada para confecção das amostras de cimentos após 1h de sua confecção, devido às características do material empregado. Tal metodologia foi adaptada de alguns estudos presentes na literatura (7, 8, 25, 36-38).

Tabela 1: Cimentos resinosos utilizados na pesquisa.

Produto	Lote	Fabricante	Cor	Iniciador	Componentes*
Variolink® E	Y43728 Z014KC	Ivoclar Vivadent; Schaan, Liechtenstein	Light	Ivocerin® (benzoil germânio)	Trifluoreto de itérbio, UDMA, D3MA.
NX3® LC	7441520 7558135 8016077	Kerr Corp, Orange, CA, USA	White	Sistema REDOX® (livre de amina terciária e peróxido de benzoíla)	Bis-EMA, Bis-GMA, Dimetacrilato de diuretano e isômeros, TEGDMA, HEMA, UDMA, MEMO, trifluoreto de itérbio.
NX3® DC	7927410 7452376	Kerr Corp, Orange, CA, USA	White	Sistema REDOX® <u>Co-iniciador:</u> EDMAB	<u>Base:</u> Bis-EMA, Bis-GMA, UDMA, TEGDMA, HEMA, EDMAB, MEMO, partículas de vidro de aluminoborosilicato de bário, trifluoreto de itérbio. <u>Catalizador:</u> TEGDMA, Bis-EMA, Bis-GMA, UDMA; HEMA, partículas de vidro de aluminoborosilicato de bário, trifluoreto de itérbio, MEMO, Hidroperóxido de Cumeno, óleo de hortelã.

*Assim como descrito pelo fabricante (Safety data sheets (SDS)).
Fonte: A autora.

Figura 7: Matriz com discos de resina 3D.



Fonte: A autora.

Figura 8: Matriz de polivinilsiloxano.



Fonte: A autora.

Para cada disco de cerâmica foram confeccionadas 2 amostras de cada cimento avaliado, resultando em 6 amostras de cimento por grupo investigado de acordo com o tipo de cimento, espessura e translucidez da cerâmica, conforme tabela 2. Adicionalmente, grupos controle com 6 corpos de prova de cada cimento foram confeccionados pela fotopolimerização direta sem a interposição do disco de cerâmica. Ao total foram confeccionadas 234 amostras de cimento, sendo 78 amostras para cada tipo de cimento avaliado.

Tabela 2: Distribuição dos grupos de acordo com os cimentos resinosos e quantidade de amostras.

Cimento	Cerâmica		N de amostras de cimento		
	Translucidez	Espessura (mm)			
Variolink Esthetic LC	Controle		6		
	HT	0,3	3	6	
		0,5	3	6	
		1,0	3	6	
		1,5	3	6	
	LT	0,3	3	6	
		0,5	3	6	
		1,0	3	6	
		1,5	3	6	
	MO	0,3	3	6	
		0,5	3	6	
		1,0	3	6	
		1,5	3	6	
	NX3 LC	Controle		6	
		HT	0,3	3	6
			0,5	3	6
1,0			3	6	
1,5			3	6	
LT		0,3	3	6	
		0,5	3	6	
		1,0	3	6	
		1,5	3	6	
MO		0,3	3	6	
		0,5	3	6	
		1,0	3	6	
		1,5	3	6	
NX3 DC		Controle		6	
		HT	0,3	3	6
			0,5	3	6
	1,0		3	6	
	1,5		3	6	
	LT	0,3	3	6	
		0,5	3	6	
		1,0	3	6	
		1,5	3	6	
	MO	0,3	3	6	
		0,5	3	6	
		1,0	3	6	
		1,5	3	6	
	Total		36	234	

N: número; LC: light cure; DC: dual cure; *N=12 discos de cerâmica para cada translucidez.

Fonte: A autora.

Um operador (S. C. L) depositou o cimento resinoso diretamente no interior da matriz e para inibir o contato com o oxigênio atmosférico e facilitar o posicionamento do disco de cerâmica, uma tira transparente de poliéster foi posicionada sobre o conjunto matriz/cimento (7, 8) (Figura 9 e 10). Para regularizar a espessura extravasando o excesso de cimento, a tira de poliéster

foi pressionada manualmente por uma espátula reta número 24 (Golgran). Após, o disco de cerâmica foi posicionado sobre o conjunto matriz/ cimento resinoso/ tira de poliéster (Figura 11). Posteriormente, foi feita a fotoativação do cimento resinoso LC e DC com o VALO LED de alta potência, por 20 segundos, no modo Standard, com a ponta do LED em íntimo contato com o disco de cerâmica (1, 31) (Figura 12 e 13). As etapas aconteceram em uma sala sem a interferência de luz artificial e as amostras foram condicionadas em estufa biológica a 37°C por 24h no laboratório da pós-graduação em Odontologia da UFPE, antes da mensuração da taxa de conversão (25, 28, 29, 38).

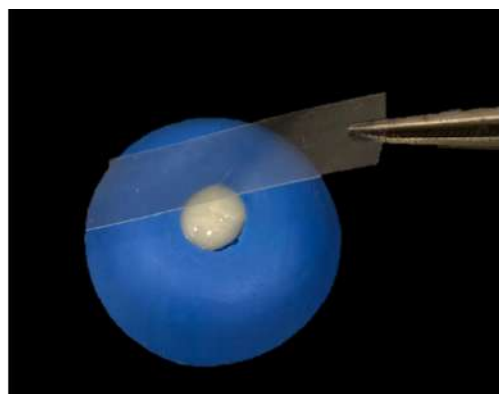
A manipulação dos cimentos resinoso seguiram as orientações dos fabricantes, sendo o cimento dual misturado através da ponta automix fornecida pelo próprio fabricante.

Figura 9: Inserção do cimento na matriz.



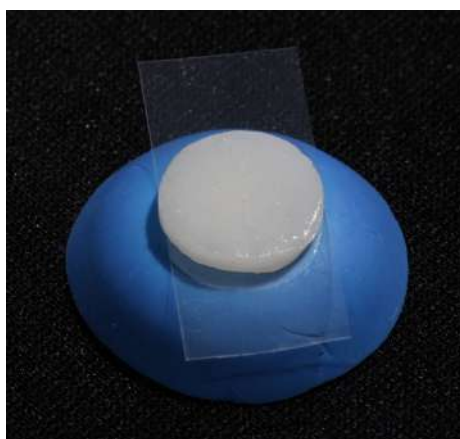
Fonte: A autora.

Figura 10: Tira de poliéster sobre o cimento.



Fonte: A autora.

Figura 11: Disco de cerâmica sobre a matriz.



Fonte: A autora.

Figura 12: VALO sobre o disco de cerâmica.



Fonte: A autora.

Figura 13: Amostra de cimento 5 x 1 mm.



Fonte: A autora.

3.7 Mensuração da taxa de conversão do cimento resinoso

As análises da TC das amostras de cimento foram realizadas por dois operadores e feitas através da Espectroscopia no Infravermelho com Transformada de Fourier (FTIR) associada com reflectância total atenuada (ATR) (PerkinElmer® FT-IR/FT-NIR Spectrometer, modelo: spectrum 400; Miracle accessory ATR unit, spectrum 100, diamante/ZnSe Ø 1mm) (Figura 14 e 15), realizadas no LAC-UFPE.

Figura 14: FTIR com a unidade ATR acoplada.



Fonte: A autora.

Figura 15: Amostra de cimento posicionada sobre o cristal da ATR.



Fonte: A autora.

Primeiramente, foi realizada uma leitura preliminar do cimento resinoso na sua forma líquida para obter o espectro de absorvância inicial

(antes da polimerização) das ligações químicas. Cada amostra foi escaneada 32 vezes com uma faixa de variação de comprimento de onda de 4.000 a 400 cm^{-1} e resolução de 4 cm^{-1} (28, 33). Todas as leituras foram realizadas no centro da amostra com a face que estava em contato com a tira de poliéster em contato com o diamante da unidade ATR. A razão entre a ligação dupla carbono-carbono alifática e o grupo aromático para amostras não polimerizadas e polimerizadas respectivamente, foi usada para calcular a TC de acordo com a seguinte equação (7, 8, 28-30, 32, 33):

$$TC (\%) = 1 - \frac{\left[\frac{abs(C=C_{alifática})}{abs(C=C_{aromática})} \right]_{polímero}}{\left[\frac{abs(C=C_{alifática})}{abs(C=C_{aromática})} \right]_{monômero}} \times 100$$

Onde, TC é a taxa de conversão, $abs(C=C_{alifática})$ é a quantidade máxima de ligações alifáticas C=C que atinge o pico de absorbância no comprimento de onda 1637 cm^{-1} , e $abs(C=C_{aromática})$ é o pico de absorbância das ligações aromáticas em 1609 cm^{-1} para todos os tipos de cimento estudados. Tal equação resume-se na razão entre a absorbância do cimento polimerizado (polímero) e não polimerizado (monômero).

3.8 Análise estatística

O delineamento experimental do estudo apresenta 3 fatores de estudo que são variáveis independentes (cimento resinoso, translucidez e espessura da cerâmica), subdivididas nos níveis: a) Variolink E, NX3 LC e NX3 DC; b) controle; HT, LT e MO; c) controle; 0,3, 0,5, 1,0 e 1,5 mm. E a taxa de conversão (%) como variável dependente.

Os dados obtidos para cada variável avaliada foram registrados, tabulados e calculados em planilha no software SPSS versão 20.0 para Windows. O teste de normalidade de Shapiro-Wilk mostrou distribuição não normal para TC ($p < 0,05$). Para a análise de comparação, foram adotados os testes não paramétricos de Mann-Whitney para duas categorias independentes e o teste de Kruskal Wallis para mais de duas categorias independentes. Os dados foram expressos em média $\pm$ desvio-padrão, mínimo e máximo ($\alpha=0,05$).

4 RESULTADOS

4.1 ARTIGO: Influence of thickness and translucency of lithium disilicate ceramic on the degree of conversion of resin cements with different initiators

Sinara C. Lima¹ | Andreza C. A. da Silva² | Renata Cimões³ | Bruna C. F. Vajgel³

Author's affiliations:

¹ Master student, Federal University of Pernambuco (UFPE), Recife, Pernambuco, Brazil

² Undergraduate student, Federal University of Pernambuco (UFPE), Recife, Pernambuco, Brazil

³ Professor, Federal University of Pernambuco (UFPE), Recife, Pernambuco, Brazil

Key words: dental veneers; degree of conversion; resin cement.

Corresponding author:

Bruna de Carvalho Farias Vajgel

Av. Prof. Moraes Rego, 1235 – Cidade Universitária, Recife-PE, Brazil

508670-901

Tel: +55 (81) 2126-8817

e-mail: bruna.farias@ufpe.br

ABSTRACT

Statement of the problem: The degree of conversion (DC) of resin cements might be affected by the thickness and translucency of indirect restorations, and by the type of resin cement.

Objective: To evaluate the influence of the thickness and translucency of lithium disilicate ceramic on the DC of resin cements with different initiators: two light-cured (Variolink Esthetic Light and NX3 Light), and one dual-cured (NX3 Dual).

Materials and methods: IPS e.max Press ceramic discs were prepared in four thicknesses (0.3, 0.5, 1.0, and 1.5 mm), color A2, and in three translucency: HT (high translucency), LT (low translucency), and MO (medium opacity). Subsequently, 234 samples of resin cement, with 5mm diameter and 1mm height, were photopolymerized through those ceramic discs. The DC of the samples was assessed by Fourier Transform Infrared Spectroscopy (FTIR), and evaluated by Mann-Whitney and Kruskal Wallis.

Results: There was statistical difference between all cements ($p < 0.05$), where Variolink had the highest DC mean ($80,62 \pm 5,51\%$), and NX3 Dual the lowest ($38,36 \pm 3,82\%$). Among thicknesses, there were no differences ($p > 0.05$), except for NX3 Dual HT group ($p = 0,005$). For translucency, MO affected Variolink DC ($p = 0.018$), and NX3 Dual showed a significant difference in DC among translucencies ($p = 0.001$).

Conclusion: Thickness and translucency do not affect the DC of light-cured resin cements; however, the DC of the dual-cured resin cement was significantly affected by translucencies. Variolink (Ivocerin) when compared to NX3 Light and Dual (REDOX) reached higher DC, even with thicker and more opaque ceramics, suggesting a wide clinical application.

CLINICAL IMPLICATIONS

Despite the influence of thickness and translucency of ceramics restorations on the DC, light-cured resin cements showed satisfactory and higher DC even beneath thicker and opaquer ceramics, demonstrating a wide applicability with veneers (<1 mm thick) and crowns (>1,0 mm thick). Conversely, the dual-cured resin cement showed the lowest DC, compromising its clinical application by considering that an inadequate photopolymerization lead to a low DC, and affects mechanical strength, bond stability, pulpal integrity, and restoration longevity.

INTRODUCTION

The current search for esthetic restorations has increased the use of ceramic veneers in dentistry. Veneers have a wide clinical application and, depending on the indication, they can measure from 1 mm to less than 0.5 mm in thickness, while all-ceramic crowns have a thickness from 1.5 mm.^{1,2} The long-term success of these restorations is determined in part by the durability of the adhesive bond, which can be influenced by the thickness and translucency of the indirect restoration, as well as the type of cement and adhesive system employed. The adhesive cementation of ceramic restorations with resin cements offers several advantages, including the chemical bond with the tooth structure.³

Another important factor regarding the success of adhesive bonding is the influence of ceramics on the conversion of resin cement monomers into polymers.^{4,5} Therefore, the characteristics inherent to ceramics that might influence DC are related to the type of ceramic, translucency of the material, and thickness of restorations.⁶⁻⁸ Consequently, low TC is associated with an excess of residual monomers that is cytotoxic to pulp and oral tissues, as well as leaching of these monomers by water

diffusion, directly affecting the strength and stability of the adhesive bond, also increasing the porosity of the cement and leading to an accumulation of bacteria, finally compromising the integrity of the tooth structure and longevity of the indirect restoration.^{1, 9-12}

The translucency of ceramic materials can vary according to color saturation, crystal structure, thickness, number of firing cycles, size of crystalline particles, and pigments. These characteristics and ceramic thickness might affect the transmission and quality of light from the light-curing unit that reaches the resin cement layer.^{3, 7, 13, 14} Therefore, the choice of ceramic type, thickness, color, and opacity (translucency) directly affect the DC of resin cements.^{1, 8, 14-17}

Therefore, the characteristics and properties of resin cements depend directly on the DC of monomers in polymers.^{5, 18} Cements are classified according to filler particle size (micro and nano), method of bonding (total-etch and self-etch), and type of cure (chemical, dual or photoactivated).^{9, 10, 19}

Dual-cured resin cements depend on exposure to light and chemical curing reactions to produce sufficient amounts of free radicals capable of converting monomer to polymer; thus, improving its physical and mechanical properties⁽¹⁹⁻²¹⁾. However, those cements usually have tertiary amines in their composition, that act as co-initiators of the polymerization process, and compromise the long-term color stability.^{9, 22-25}

The manipulation of dual cements makes the incorporation of air bubbles inevitable, and this interaction with oxygen can affect some properties, such as hardness and roughness. Then, to minimize this reaction with oxygen, several manufacturers have developed self-mixing tips.^{5, 18}

Otherwise, light-cured resin cements have initiators that depend only on light to initiate polymerization. Camphorquinone (CQ) is a Norrish type II

photoinitiator that needs an electron donor molecule, usually a tertiary amine, to trigger the formation of free radicals. These radicals react with the methacrylate monomers and start the polymerization process. However, the tertiary amine present in CQ materials compromises color stability.^{18, 25, 26} Currently, some cements have been using Norrish type I photoinitiators, such as Ivocerin, TPO (2,4,6-trimethylbenzoyl diphenylphosphine oxide), and BAPO (2,4,6-Trimethylbenzophenone) in their formulation, which does not require co-initiators to form free radicals. Those, when exposed to light, undergo a cleavage, and the molecule splits into two or more radicals that lead to a polymer chain reaction, an example is the benzoyl germanium derivatives (Ivocerin) that cleave into germyl and benzoyl radicals.^{9, 10, 23, 25} Additionally, type I photoinitiators have a broader absorption spectrum with short wavelengths of the violet spectrum (380 to 420 nm) when compared to CQ, reducing photoactivation time, water-solubility, cytotoxicity, and increasing the depth of cure.^{18, 23, 27, 25}

There are a short number of studies evaluating the DC of resin cements with Norrish type I photoinitiators when light-cured through different ceramic translucencies and thicknesses, as well as comparing the DC of type I with other initiation systems, mainly with dual cements.^{9, 10, 25, 26}

For that reason, the main objective of the present study was to evaluate the influence of thickness and translucency of lithium disilicate ceramic on resin cements DC with different initiators, using two light-cure (Variolink Esthetic Light and NX3 Light) and one dual-cure (NX3 Dual). Then, the null hypotheses tested were: a) thickness and translucency of lithium disilicate ceramics does not affect the DC of resin cements; b) There was no difference between the DC of light-cure and dual-cure resin cements.

MATERIALS AND METHODS

Primarily, IPS e.max Press ceramic discs (Ivoclar Vivadent) with 10 mm in diameter were made, in four thicknesses (0.3 mm, 0.5 mm, 1.0 mm, 1.5 mm), color A2, and in three translucency: HT (high translucency), LT (low translucency), and MO (medium opacity) according to manufacturer specifications (n=3 discs for each thickness/translucency, totaling 36 ceramic discs) (table 1). A prototype of the discs was designed in exocad GmbH and printed in a 3D printer, and then these discs were included in the injection ring, and heat-pressed using the lost-wax technique, according to manufacturer specifications by a prosthetics technician (Figure 1A and 1B).^{2, 28-30}

A radiometer (Hilux Ledmax Dental Curing Light Meter, Benlioğlu Dental Inc.) was used to confirm and measure the irradiance of the VALO curing light (Ultradent Inc.), at standard power (20s), where, according to the manufacturer, it achieves an irradiance of up to 1000 mW/cm² in this mode.^{1,14}

For each ceramic disc, two samples of each evaluated resin cement were made. Then, it results in 6 resin cement samples per investigated group according to the type of resin cement, thickness, and translucency of the ceramic disc, as shown in table 1. Additionally, a control group with 6 samples of each resin cement were made without the interposition of the ceramic disc, totaling 234 resin cement samples, 78 samples for each type of resin cement.

The resin cement samples (table 2) were shaped from a polyvinylsiloxane matrix (Virtual, Ivoclar Vivadent) with 5 mm in diameter and 1 mm in depth. Due to the characteristics of the material, the matrix was used after 1 hour of its making.^{9, 10, 22, 24, 31-}

33

The resin cement was deposited directly inside the matrix, and a transparent polyester strip was placed over the matrix/cement set to inhibit contact with

atmospheric oxygen and facilitate the positioning of the ceramic disc.^{9, 10, 33} Then, to regularize sample thickness, the polyester strip was pressed manually by a straight spatula number 24 (Golgran). Afterward, the ceramic disc was placed on the matrix/ resin cement/ polyester strip set (Figure 1). Subsequently, the resin cement was light-activated with the high power VALO LED, for 20 s, in Standard mode, with the LED tip in intimate contact with the ceramic disc (Figure 1C, 1D, 1E and 1F).^{1, 7, 15}

The steps were conducted in a room without the interference of artificial light. Before measuring the DC, the samples were stored under dry and dark conditions at 37°C for 24h.^{24-26, 28, 29, 32} The handling of resin cements followed the instructions provided by the manufacturer, and the dual-cured resin cement was mixed through the automix tip supplied by the manufacturer. Further, the resin cement samples were obtained by one operator (L. S.).

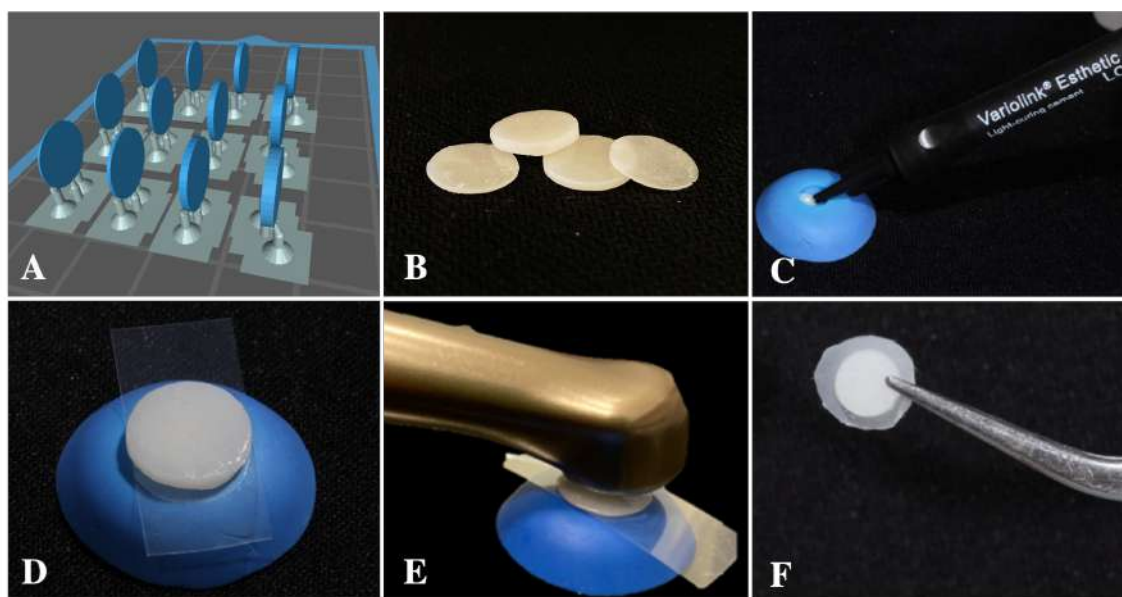


Figure 1: steps to produce resin cement samples. A: exocad GmbH project; B: ceramic discs after polishing; C: resin cement on the vinisiloxane matrix; D: ceramic disc placed over the matrix; E: VALO positioned; F: resin cement sample (5x1cm).

The DC analyzes of resin cement samples were performed by two operators (L.S and S. A.) using Fourier Transform Infrared Spectroscopy (FTIR) associated with attenuated total reflectance (ATR) (PerkinElmer FT-IR/FT-NIR Spectrometer, model: spectrum 400; Miracle accessory ATR unit, spectrum 100, diamond/ZnSe).

First, a reading of the resin cement in its liquid form was performed to obtain the initial absorbance spectrum (before polymerization). Subsequently, each sample was scanned 32 times with a wavelength range of 4,000 to 400 cm^{-1} and a resolution of 4 cm^{-1} .^{25, 30} Moreover, the side of the sample that was in contact with the polyester strip was placed toward the diamond of the ATR unit. Then, all readings happened at the center of the sample. Further, the ratio between the aliphatic carbon-carbon double bond and the aromatic group for uncured and polymerized samples, respectively, was used to calculate the DC according to the following equation:^{9, 10, 14 28-30,}

34

$$DC (\%) = 1 - \frac{\left[\frac{abs(C=C_{aliphatic})}{abs(C=C_{aromatic})} \right]_{polymer}}{\left[\frac{abs(C=C_{aliphatic})}{abs(C=C_{aromatic})} \right]_{monomer}} \times 100$$

Where DC is the degree of conversion, $abs(C=C_{aliphatic})$ is the maximum amount of C=C aliphatic bonds that reach the peak absorbance at wavelength 1637 cm^{-1} , and $abs(C=C_{aromatic})$ is the absorbance peak of aromatic bonds at 1609 cm^{-1} for all types of cement studied. Moreover, being the ratio between the absorbance of the polymerized cement (polymer) and uncured cement (monomer).

The data obtained for each variable evaluated were registered, tabulated, and calculated in a spreadsheet using SPSS software version 20.0 for Windows. The

Shapiro-Wilk normality test showed non-normal distribution for DC ($p < 0,05$). Further, to perform comparison tests, the nonparametric Mann-Whitney tests were used for two independent categories and the Kruskal Wallis test for more than two independent categories. Data were reported by mean $\pm$ standard deviation, minimum and maximum ($\alpha=0,05$).

RESULTS

The DC in percentage values was obtained by analyzing the absorbance spectrum of the specimens and applying the DC(%) equation. With the data obtained, descriptive graphs were constructed to compare the absorbance spectrum, highlighting the absorbance peaks of the aliphatic (1637 cm^{-1}) and aromatic (1609 cm^{-1}) carbon bonds between a cured and uncured sample (Figures 3, 4, and 5).

Figura 2: Graph of the absorbance spectrum of Variolink E Light.

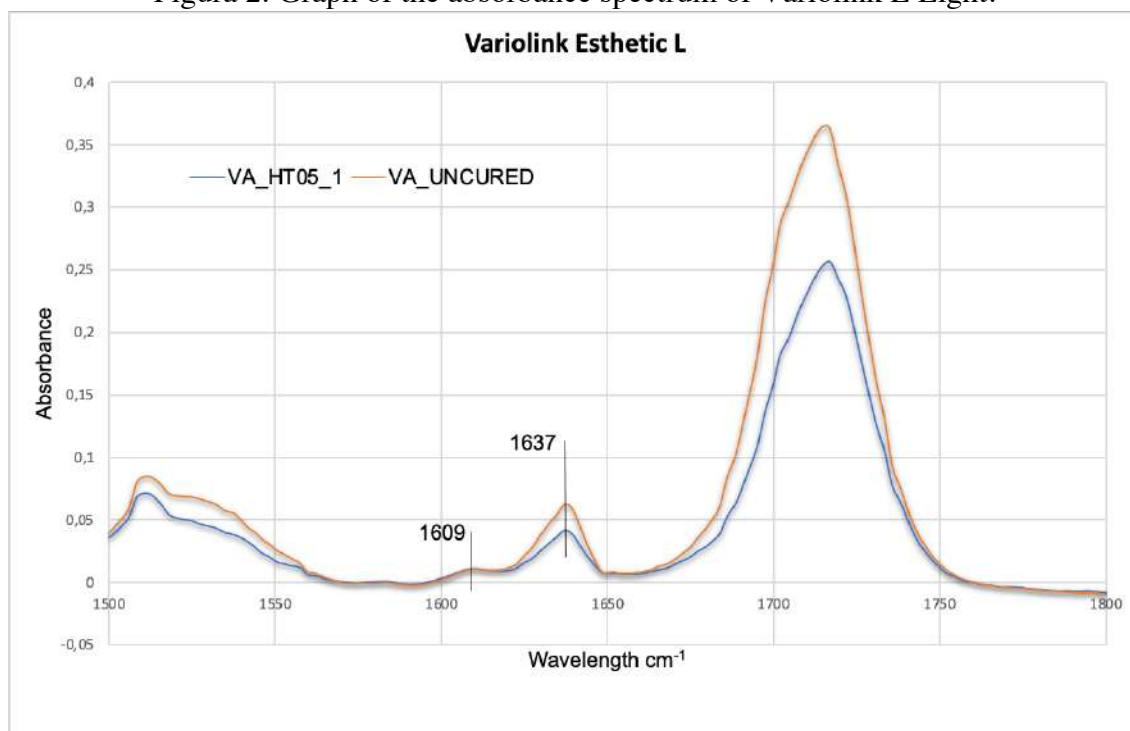


Figura 3: Graph of the absorbance spectrum of NX3 Light.

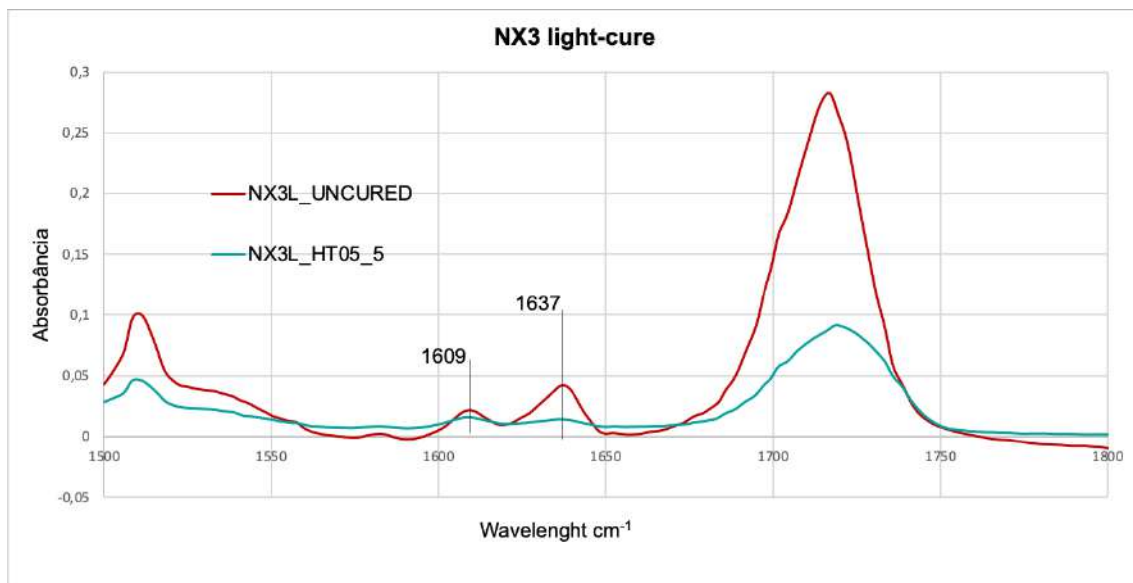
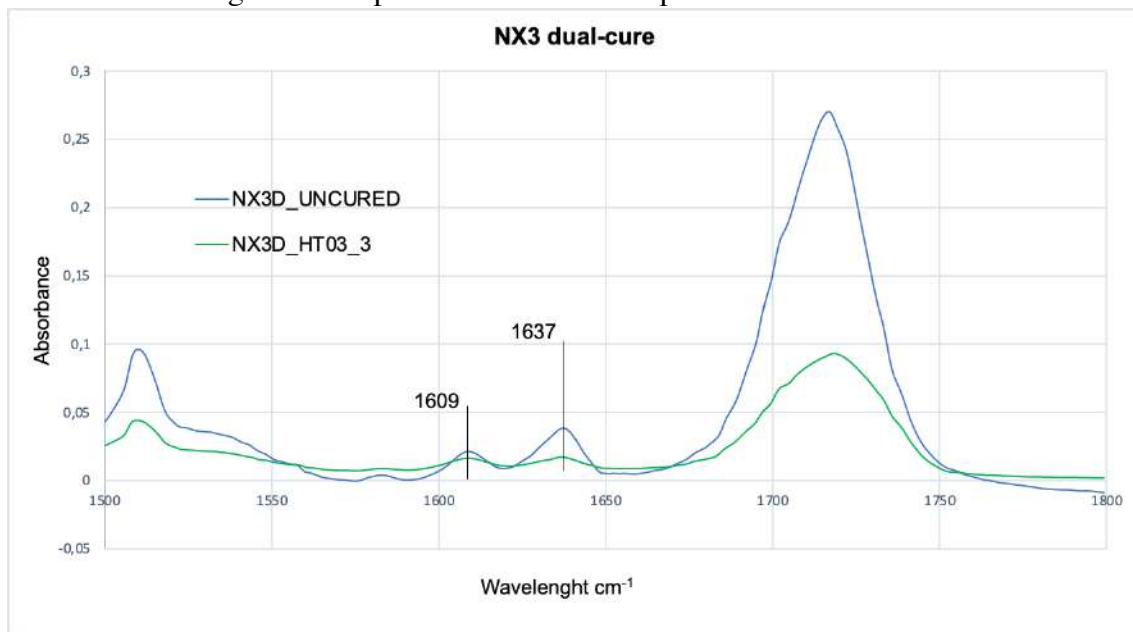


Figure 4: Graph of the absorbance spectrum of NX3 Dual.



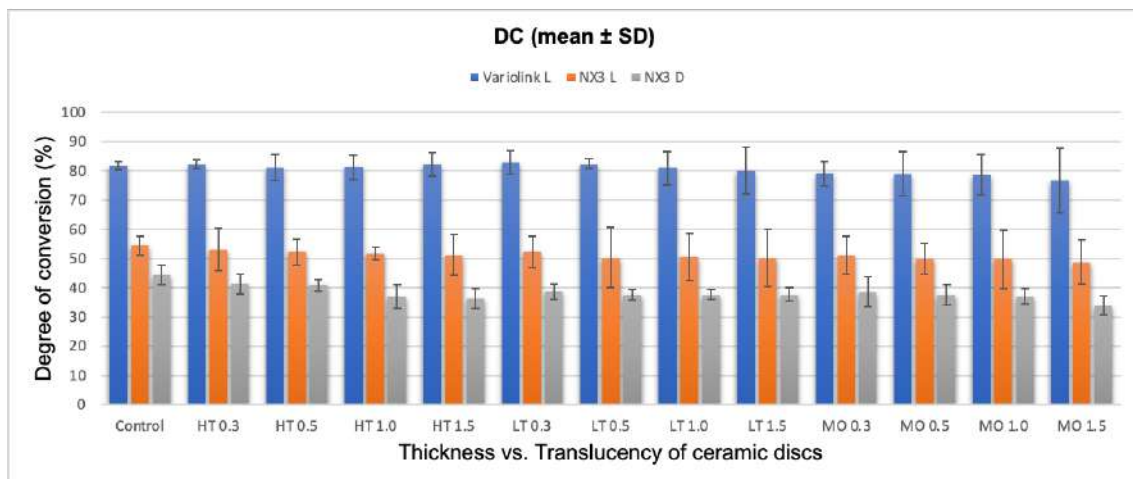
The statistical analysis presented in table 3 shows that between thicknesses, within each translucency group, there were no significant differences ($p > 0.05$), except for the HT translucency group of NX3 Dual ($p^3 = 0.005$), where the thicknesses 0.3 and 0.5 mm were different from 1.0 and 1.5 mm.

Regarding translucency within each thickness, there were no significant differences, except for Variolink E Light under 0.3 mm thickness where the translucency MO was statistically different from HT and LT ($p^5 = 0.017$) (table 4).

The mean DC for Variolink E Light differed statistically in terms of translucency, in which the MO ceramic obtained significantly lower values ($78.32 \pm 7.36\%$) when compared to HT and LT (81.69 ± 3.52 and 81.57 ± 5.15 , respectively) ($p = 0.018$). For NX3 Light, no difference was observed between the ceramic discs with different translucencies ($p = 0.659$), while for NX3 Dual, the control group ($44.42 \pm 3.37\%$) presented a significant DC result differing from others translucencies ($p = 0.001$), as shown in table 5.

DC differ significantly between the types of cement ($p\text{-value}^4 < 0.05$). Variolink E had the highest DC means $\pm$ SD for LT 0.3 ($82.92 \pm 3.93\%$) and HT 0.3 ($82.3 \pm 1.53\%$) groups, and NX3 Dual presented the lower DC mean in the MO 1.5 group ($33.92 \pm 3.22\%$). In general, the DC means of the groups were closer to the control group. Further, comparing the DC among light-cured resin cements, the Variolink E (Ivocerin) had a higher DC than NX3 Light (REDOX) (Figure 6).

Figure 5: Barplot with the DC means of each resin cement according to thickness and translucency of the ceramic disc.



DISCUSSION

The thickness and translucency of the ceramic do not seem to affect the DC of light-cure resin cements. However, the translucency affected the DC of the dual-cure cement. Therefore, the first null hypothesis was partially accepted, no statistically significant difference was identified in DC between thicknesses for each ceramic translucency, except for HT translucency groups with thickness 1.0 and 1.5 mm from the NX3 DC, where they presented statistical difference when compared with 0.3 and 0.5 mm thickness. That hypothesis is in accordance with the findings of the systematic review by Martins et al.¹⁷, where the authors assessed through meta-analysis that the ceramic thicknesses (1.0, 1.5, 2.0, and 3.0 mm) affected DC ($p < 0.05$).

Several studies have reported the influence of thickness, translucency, type, and shade of ceramics on the DC of resin cements.^{7, 12, 13, 17, 19, 22, 28, 31, 34} Therefore, the different types of resin cements reported in the literature showed reduced DC when thickness and opacity of the indirect restoration increased.^{5-8, 31} These findings agree with the present research, where thicknesses compatible with ceramic laminates (0.3 and 0.5 mm) provided higher DC to the resin cements, and thicknesses compatible with all-ceramic crowns (1.0 and 1.5 mm) provided a lower DC. However, few studies have correlated the influence of different ceramic thicknesses and translucencies in the DC of resin cements with Norrish type I photoinitiators when light-cured by high-power light-curing units.^{10, 25, 26} The study by Alkhudhairy⁽¹⁰⁾, for example, used a 1mm-thick ceramic disc interposed over the Variolink E, yet they did not describe the translucency of this disc in their study. Further, other studies have been using Ivocerin in experimental resin cement formulations.^{25, 26}

Regarding ceramic translucency, the DC of Variolink E was affected by the MO translucency. Moreover, NX3 Dual reached statistically different DC values from

the control group for all translucencies. Such results are in agreement with other studies that demonstrate the inversely proportional relationship between translucency and DC.^{6,}

7, 18, 31

The second null hypothesis was rejected, the DC of all studied cements, when compared to each other, showed a significant difference. Variolink E showed significantly higher DC when compared to NX3 Light and NX3 Dual. Therefore, the DC is affected by the properties of the materials that compose the organic and inorganic cement matrix.^{24-26, 32, 33} The findings observed by this research for the superior behavior of Variolink E can be justified due to the presence of Ivocerin. It is already known that the incorporation of Ivocerin in the composition of experimental resin cements leads to an increase in DC, cure depth, and decreases yellowing; thus, being indicated as a substitute for CQ.^{23, 25, 26} Other studies comparing Variolink E (Ivocerin) and NX3 Light also report significantly higher DC for Variolink E.^{9, 10}

Ivocerin (Ivoclar Vivadent), as a Norrish type I initiator, does not need another molecule acting as a co-initiator. Thus, favoring DC, color stability, and decreasing solubility and cytotoxicity.^{2, 9, 10} Evidence states that type I photoinitiators such as TPO and BAPO may have significantly reduced DC because they rely much more on the violet spectrum (380 to 420 nm) than on blue light (420 to 495 nm).^{24, 25} As the wavelength of the violet spectrum is short, it can be easily attenuated by the thickness and translucency of the indirect restoration.²⁴ However, such interference was not observed in the present study, where Ivocerin promoted high DC for Variolink E, even with thicker and more opaque ceramics.

There were not enough reports regarding the composition and mechanism of the REDOX system (Kerr Corp.) present in NX3 Light and Dual, and some authors reported a lack of information provided by the manufacturer.^{10, 30} Studies have reported

that NX3 Light and Dual have higher DC values when compared to cements based on QC, yet they have lower DC values when compared to Variolink E, which contains Ivocerin.^{9, 10, 15} Likewise, those findings are in agreement with the present study, where Variolink E obtained mean DC values higher than NX3 Light and Dual.

The dual-cure resin cement studied presented a significantly lower DC when compared to light-cure resin cements. It is reported that the dual characteristic of resin cements favors DC since the self-and light-curing reactions might generate more free radicals.^{4, 15, 20, 29, 19} Consequently, to achieve an optimal DC, several manufacturers suggest the ideal self-cure time before light-curing. However, some authors report that the self-curing component of dual cements reduces shrinkage stress, but it does not increase DC and may take more than 5 minutes to polymerize.^{11, 16, 21} Based on these statements and on the lack of instructions from the manufacturer (Kerr Corp.) about the self-cure time for NX3 Dual, studies light-cured the NX3 Dual immediately after placement of the indirect restoration.^{15, 30} Despite the methodology used in previous studies,^{15, 30} and by the present study, immediate light curing of dual resin cements can delay or inhibit the self-curing polymerization, directly affecting the DC.^{5, 11, 15, 21} Some studies have evaluated DC at 48 and 72 hours and reported a gradual increase in DC with time.^{1, 21} Therefore, such inhibition of the self-cure reaction may have negatively influenced the DC results of NX3 Dual reported in the present study, mainly due to the time determined between light-curing and DC analysis.

Although some studies suggest that the DC is higher when the light-curing light irradiance is above 3200 mW/cm²,^{1, 17} the research by Faria-e-Silva & Pfeifer¹ when compared the DC of a light-cured resin cement by VALO in the Standard power 20s (1000 mW/cm²) with the Xtra power 3s (3200 mW/cm²) through the ceramic thicknesses 0.5, 1.0 and 2.0 mm, it reported higher DC for the Standard power during

20s. The study reported that irradiance of 3200 mW/cm² for a short period (3s) does not efficiently convert the light-cured resin cement monomers.¹ Therefore, the VALO irradiance at standard power for 20s (1186.3 ± 5.5 mW/cm²), used by the present research, was enough for the DC of Variolink E reach values that are in agreement with what has been reported in other studies, for the same thickness and ceramic translucency.^{9,10} Such results might be justified due to the polywave property of VALO, which reaches 3 peaks of radiant flux at 3 different wavelengths, being one of them between the violet spectrum wavelength (380 to 420 nm).^{1,24}

Regarding the NX3 Light, the study by Alkhudhairyet al.¹⁰ obtained higher DC values (75.9%) for ceramics with a thickness of 1mm. This result differs from the present study mainly due to the light-curing unit and the exposure time used by the researchers (2300 mW/cm²; 40s). It might suggest that NX3 Light needs a higher irradiance and/ or more light-curing time.

The evidence from the present study suggests that the thickness and translucency of lithium disilicate ceramics do not affect the DC of light-cure resin cements. However, the dual-cure resin cement was significantly affected by translucency, which could influence the mechanical and bond adhesion properties. Moreover, resin cements with type I photoinitiators, based on benzoyl germanium (Ivocerin), had high DC. Conversely, a higher DC is also related to increased polymerization shrinkage, elastic modulus, and material hardness.^{3,28,29}

Furthermore, further experimental studies are needed to evaluate bond strength and stability, shrinkage stress, and other mechanical properties of Variolink E Light with Ivocerin and of NX3 Light and Dual. Then, as a consequence of the limitations of an in vitro study, clinical studies are suggested to assess in vivo the integrity and longevity of indirect restorations cemented with the studied resin cements.

CONCLUSION

By the evidence of the present study, it was possible to conclude that:

- Thickness did not affect DC, except for NX3 Dual, where thicknesses of 0.3 and 0.5 mm were similar and different from 1.0 and 1.5 mm for HT translucency;
- Only MO translucency negatively affected the DC of Variolink E Light cement. As for NX3 Dual cement, all translucency had an influence when compared to the control;
- DC of all cements were statistically different from each other. Variolink E Light had the highest DC, followed by NX3 Light and NX3 Dual;
- Variolink E Light (Ivocerin) when compared to NX3 Light (REDOX) achieved significant superior performance beneath thicker and more opaque ceramics, suggesting a wide clinical application;
- The NX3 Dual achieved significantly lower DC when the control group was compared with the other translucencies. The dual-cure characteristic was not more advantageously than NX3 Light.

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TABLES

Table 1: Group distribution according to resin cements.

Resin cement	Ceramic			N cement samples
	Translucency	Thickness (mm)	N discs*	
Variolink Esthetic LC	Control			6
	HT	0.3	3	6
		0.5	3	6
		1.0	3	6
		1.5	3	6
	LT	0.3	3	6
		0.5	3	6
		1.0	3	6
		1.5	3	6
	MO	0.3	3	6
		0.5	3	6
		1.0	3	6
1.5		3	6	
NX3 LC	Control			6
	HT	0.3	3	6
		0.5	3	6
		1.0	3	6
		1.5	3	6
	LT	0.3	3	6
		0.5	3	6
		1.0	3	6
		1.5	3	6
	MO	0.3	3	6
		0.5	3	6
		1.0	3	6
1.5		3	6	
NX3 DC	Control			6
	HT	0.3	3	6
		0.5	3	6
		1.0	3	6
		1.5	3	6
	LT	0.3	3	6
		0.5	3	6
		1.0	3	6
		1.5	3	6
	MO	0.3	3	6
		0.5	3	6
		1.0	3	6
1.5		3	6	
Total			36	234

N: number; LC: light-cure; DC: dual-cure; *N=12 ceramic discs for each translucency.

Table 2: Resin cements.

Product	Lot	Manufacturer	Shade	Initiator	Content*
Variolink Esthetic Light	Y43728 Z014KC	Ivoclar Vivadent	Light	Ivocerin (benzoyl germanium)	ytterbium trifluoride, UDMA, D3MA.
NX3® Light	7441520 7558135 8016077	Kerr Corp.	White	REDOX system (free from thertiary amine and benzoyl peroxide)	Bis-EMA, Bis-GMA, TEGDMA, HEMA, UDMA, MEMO, ytterbium trifluoride.
NX3® Dual	7927410 7452376	Kerr Corp.	White	REDOX system <u>Co-initiator:</u> EDMAB	<u>Base:</u> Bis-EMA, Bis-GMA, UDMA, TEGDMA, HEMA, EDMAB, MEMO, Barium aluminoborosilicate glass, ytterbium trifluoride. <u>Catalyst:</u> TEGDMA, Bis-EMA, Bis-GMA, UDMA; HEMA, MEMO, Barium aluminoborosilicate glass, ytterbium trifluoride, Cumene Hydroperoxide, Peppermint oil.

*As described by the manufacturer (Safety data sheets (SDS)). UDMA: Urethane dimethacrylate; D3MA: 1,10-decandiol dimethacrylate; Bis-EMA: bisphenol A diglycidyl methacrylate ethoxylated; Bis-GMA: bisphenol A diglycidyl methacrylate; TEGDMA: triethylene glycol dimethacrylate; HEMA: Hydroxyethylmethacrylate; EDMAB: Ethyl 4-dimethyl aminobenzoate; MEMO: metacryloxipropyltrimetoxisilane.

Table 3: Comparative analysis of DC means according to the cement, and thickness and translucency of ceramic.

Translucency	Thickness	N	Resin Cement						p-value ⁴
			Variolink E		NX3 Light		NX3 Dual		
			Mean ± SD	P-value ¹	Mean ± SD	P-value ²	Mean ± SD	P-value ³	
Control	0.0	6	81.78 ± 1.49 a	-	54.40 ± 7.64 b	-	44.42 ± 3.37 c	-	0.001*
HT	0.3	6	82.30 ± 1.53 Aa	0.273	53.12 ± 3.22 Ab	0.419	41.26 ± 3.52 Ac	0.005*	0.001*
HT	0.5	6	81.13 ± 4.40 Aa		52.26 ± 7.18 Ab		40.84 ± 1.90 Ac		0.001*
HT	1.0	6	81.19 ± 4.22 Aa		51.77 ± 4.38 Ab		36.99 ± 3.96 Bc		0.001*
HT	1.5	6	82.15 ± 4.00 Aa		51.22 ± 2.05 Ab		36.30 ± 3.39 Bc		0.001*
LT	0.3	6	82.92 ± 3.93 Aa	0.419	52.25 ± 6.87 Ab	0.931	38.78 ± 2.60 Ac	0.686	0.001*
LT	0.5	6	82.37 ± 1.81 Aa		50.34 ± 5.43 Ab		37.58 ± 1.83 Ac		0.001*
LT	1.0	6	80.96 ± 5.64 Aa		50.53 ± 10.33 Ab		37.73 ± 1.66 Ac		0.001*
LT	1.5	6	80.05 ± 8.08 Aa		50.10 ± 7.96 Ab		37.70 ± 2.37 Ac		0.001*
MO	0.3	6	79.03 ± 4.07 Aa	0.773	51.08 ± 9.86 Ab	0.729	38.65 ± 4.97 Ac	0.100	0.001*
MO	0.5	6	78.87 ± 7.55 Aa		49.90 ± 6.55 Ab		37.49 ± 3.42 Ac		0.001*
MO	1.0	6	78.64 ± 6.99 Aa		49.80 ± 5.21 Ab		37.02 ± 2.67 Ac		0.001*
MO	1.5	6	76.75 ± 11.09 Aa		48.79 ± 9.91 Ab		33.92 ± 3.22 Ac		0.001*

* Statistically significant; 1- Kruskal Wallis test between Variolink E within each Translucency comparing the mean DC values between the types of thickness; 2- Kruskal Wallis Test between NX3 Light within each Translucency comparing the mean DC values between the types of thickness; 3- Kruskal Wallis test between NX3 Dual within each Translucency comparing the mean DC values between the types of thickness; Means (standard deviations) followed by different letters (upper case comparing thickness and lower case comparing cements) indicate a statistical difference ($p \leq 0.05$) using the Mann-Whitney test.

Table 4: Comparative analysis of DC means according to the cement, and thickness and translucency of ceramic.

Thickness	Translucency	N	Resin Cement						p-value ⁸
			Variolink E		NX3 Light		NX3 Dual		
			Mean ± SD	P-value ⁵	Mean ± SD	P-value ⁶	Mean ± SD	P-value ⁷	
Control		6	81.78 ± 1.49 a	-	54.40 ± 7.64 b	-	44.42 ± 3.37 c	-	0.001*
0.3	HT	6	82.30 ± 1.53 Aa		53.12 ± 3.22 Ab		41.26 ± 3.52 Ac		0.001*
	LT	6	82.92 ± 3.93 Aa	0.017*	52.25 ± 6.87 Ab	0.849	38.78 ± 2.60 Ac	0.366	0.001*
	MO	6	79.03 ± 4.07 Ba		51.08 ± 9.86 Ab		38.65 ± 4.97 Ac		0.001*
0.5	HT	6	81.13 ± 4.40 Aa		52.26 ± 7.18 Ab		40.84 ± 1.90 Ac		0.001*
	LT	6	82.37 ± 1.81 Aa	0.399	50.34 ± 5.43 Ab	0.644	37.58 ± 1.83 Ac	0.051	0.001*
	MO	6	78.87 ± 7.55 Aa		49.90 ± 6.55 Ab		37.49 ± 3.42 Ac		0.001*
1.0	HT	6	81.19 ± 4.22 Aa		51.77 ± 4.38 Ab		36.99 ± 3.96 Ac		0.001*
	LT	6	80.96 ± 5.64 Aa	0.854	50.53 ± 10.33 Ab	0.828	37.73 ± 1.66 Ac	0.895	0.001*
	MO	6	78.64 ± 6.99 Aa		49.80 ± 5.21 Ab		37.02 ± 2.67 Ac		0.001*
1.5	HT	6	82.15 ± 4.00 Aa		51.22 ± 2.05 Ab		36.30 ± 3.39 Ac		0.001*
	LT	6	80.05 ± 8.08 Aa	0.423	50.10 ± 7.96 Ab	0.895	37.70 ± 2.37 Ac	0.191	0.001*
	MO	6	76.75 ± 11.09 Aa		48.79 ± 9.91 Ab		33.92 ± 3.22 Ac		0.001*

* Statistically significant; 5- Kruskal Wallis test between Variolink E within each thickness comparing the mean DC values between the types of translucency; 6- Kruskal Wallis Test between NX3 Light within each thickness comparing the mean DC values between the types of translucency; 7- Kruskal Wallis test between NX3 Dual within each thickness comparing the mean DC values between the types of translucency; Means (standard deviations) followed by different letters (upper case comparing thickness and lower case comparing cements) indicate a statistical difference ($p \leq 0.05$) using the Mann-Whitney test

Table 5: Descriptive means of DC according to resin cement and ceramic translucency.

Translucency	N	Cement					
		Variolink E		NX3 Light		NX3 Dual	
		Mean $\pm$ SD	p-value ⁹	Mean $\pm$ SD	p-value ¹⁰	Mean $\pm$ SD	p-value ¹¹
Control	6	81.78 $\pm$ 1.49 A		54.40 $\pm$ 7.64 A		44.42 $\pm$ 3.37 A	
HT	24	81.69 $\pm$ 3.52 A	0.018*	52.09 $\pm$ 4.37 A	0.659	38.85 $\pm$ 3.81 B	0.001*
LT	24	81.57 $\pm$ 5.15 A		50.81 $\pm$ 7.38 A		37.95 $\pm$ 2.07 B	
MO	24	78.32 $\pm$ 7.36 B		49.89 $\pm$ 7.64 A		36.77 $\pm$ 3.86 B	
Total	78	80.62 $\pm$ 5.51		51.20 $\pm$ 6.69		38.36 $\pm$ 3.82	

* Statistically significant; 9- Kruskal Wallis test between Variolink E within each Translucency comparing the mean DC values between Translucency; 10- Kruskal Wallis Test between NX3 Light within each Translucency comparing the mean DC values between Translucency; 11- Kruskal Wallis test between NX3 Dual within each Translucency comparing the mean DC values between Translucency; Means (standard deviations) followed by different letters (upper case comparing thickness and lower case comparing cements) indicate a statistical difference ($p \leq 0.05$) using the Mann-Whitney test.

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