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WAGNER IZUMI SAWADA GERMINIANI

**AVALIAÇÃO DAS PROPRIEDADES ÓPTICAS DE COR E TRANSLUCIDEZ DO
DISSILICATO DE LÍTIO CAD/CAM APÓS CICLOS DE QUEIMAS**

**PONTA GROSSA
2024**

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Tese apresentada ao Programa de Pós-Graduação strictu sensu em Odontologia como requisito parcial para obtenção do título de Doutor em Odontologia pela Universidade Estadual de Ponta Grossa. Área de concentração em Dentística Restauradora. Linha de Pesquisa em Propriedades Físico-Químicas e Biológicas dos Materiais.

Orientador: Prof. Dr. João Carlos Gomes.
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Tese apresentada para obtenção do título de Doutor em Odontologia no Programa de Pós-Graduação Strictu Sensu da Universidade Estadual de Ponta Grossa- Área de Concentração Dentística Restauradora. Linha de Pesquisa: Propriedades Físico-Químicas e Biológicas dos Materiais.

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*“A pessoa humana tem uma necessidade
que é ainda mais profunda, uma fome que
é maior que aquela que o pão pode saciar:
é a fome que possui o coração humano
da imensidade de Deus.”*

Papa João Paulo II

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RESUMO

GERMINIANI, Wagner Izumi Sawada. **Avaliação das propriedades ópticas de cor e translucidez das variações do dissilicato de lítio CAD/CAM após ciclos de queimas.** 2024. Tese (Doutorado em Odontologia) - Universidade Estadual de Ponta Grossa, Ponta Grossa, 2024.

Objetivo. Avaliar as propriedades ópticas de cor e na translucidez após ciclos de queima e aplicação da pasta de glase em 3 variações do dissilicato de lítio CAD. **Material e métodos.** Foram obtidos 180 espécimes retangulares de dissilicato de lítio CAD (5 x 6 x 1 mm) com $1,0 \pm 0,1$ mm de espessura, dividido em 18 subgrupos de acordo com as variações do fabricante (HT, MT, LT), a quantidade de queimas submetidas e se receberam a aplicação de pasta glase. O estudo I (n=90) avaliou os espécimes após ciclos de queimas sem aplicação de pasta glase. O estudo II (n=180) comparou espécimes com e sem a aplicação de pasta de glase após ciclos de queimas. Cada subgrupo de n=10 cada foi classificado de acordo com a quantidade de queimas aos quais foram submetidos (1,2 ou 5 queimas). Os parâmetros de cor do sistema Cie*Lab foram aferidos para cada subgrupo sobrepostos em fundo preto e branco. Os dados foram aplicados em fórmulas matemáticas para obtenção de $\Delta E/\Delta E_{00}$ e $\Delta TP/\Delta TP_{00}$. Utilizou-se a análise de variância (ANOVA) e o teste de Tukey para análise estatística. Os resultados foram determinados em nível de significância de 95% ($p < 0,05$). Os espécimes passaram por análise de microscopia eletrônica de varredura (MEV) e espectroscopia por dispersão de elétrons (EDS). **Resultados.** Foram verificadas diferenças estatisticamente significantes nos parâmetros *L, *a e *b para HT, MT e LT em todos os períodos de queima. Comparando os subgrupos quanto a cor (ΔE), os valores mais altos de ΔE foram encontrados em HTNG5x ($\Delta E=3,7/\Delta E_{00}=3,0$), seguido por HTNG1x para fundo preto e os mais baixos em LTGZ2x ($\Delta E=0,6/\Delta E_{00}=0,4$). Comparando as diferenças entre espécimes com e sem glase, quanto ao número de queimas, o subgrupo com maiores variações foram para MT com 1 queima ($\Delta E=8,1/\Delta E_{00}=5,9$) e HT com 2 queimas ($\Delta E=3,5/\Delta E_{00}=3,5$). Os valores de ΔE de todos os subgrupos com glase mostraram valores acima do limite de perceptibilidade, exceto para MTGZ5x ($\Delta E=0,4$ e $\Delta E_{00}=0,3$) e LTGZ2x ($\Delta E=0,6$ e $\Delta E_{00}=0,4$). Na comparação da translucidez ΔPT os valores médios mais baixos foram encontrados em MTGZ2x ($\Delta PT/\Delta PT_{00}=-0,2$) e LTGZ2x ($\Delta PT=0,2/\Delta PT_{00}=0,4$). Exceto para os espécimes com glase após 2 queimas (HTGZ2x, MTGZ2x, LTGZ2x) todos os demais subgrupos tiveram variações na translucidez acima do limite de percepção ($\Delta PT=1,33/\Delta PT_{00}=0,62$) mas ainda dentro do limite de aceitação. **Conclusões:** Os resultados mostraram que os parâmetros de cor e translucidez do dissilicato de lítio CAD foram afetados tanto pela pasta de glase quanto pelas queimas repetidas. Para os espécimes que se submeteram até duas queimas, o grupo LT apresentou a menor variação de cor, seguido pelo grupo MT. O grupo HT revelou a maior variação diante de múltiplas queimas; portanto, seu uso deve preceder cautela adicional porque sua cor e translucidez apresentam uma alteração significativa após queimas repetidas.

Palavras-chave: Facetas dentárias. CAD/CAM. Estética dentária. Prótese dentária

*Em acordo com os Descritores em Ciências da Saúde (DeCS) disponível em <http://decs.bvsalud.org>

ABSTRACT

GERMINIANI, Wagner Izumi Sawada. **Evaluation of the optical properties of color and translucency of CAD/CAM lithium disilicate variations after firing cycles.**

2024. Thesis (Doctorate in Dentistry) - State University of Ponta Grossa, Ponta Grossa, 2024.

Objective: To evaluate the optical properties of color and translucency after firing cycles and the application of glaze paste to 3 variations of CAD lithium disilicate. **Material and methods.** 180 rectangular CAD lithium disilicate specimens (5 x 6 x 1 mm) with a thickness of 1.0 ± 0.1 mm were obtained and divided into 18 subgroups according to the manufacturer's variations (HT, MT, LT), the number of firings they underwent and whether they received glaze paste. Study I (n=90) evaluated the specimens after firing cycles without the application of glaze paste. Study II (n=180) compared specimens with and without the application of glaze paste after firing cycles. Each subgroup of n=10 was classified according to the number of firings they had undergone (1, 2 or 5 firings). The color parameters of the Cie*Lab system were measured for each subgroup superimposed on a black and white background. The data was applied to mathematical formulas to obtain $\Delta E / \Delta E_{00}$ and $\Delta TP / \Delta TP_{00}$. Analysis of variance (ANOVA) and Tukey's test were used for statistical analysis. The results were determined at a significance level of 95% ($p < 0.05$). The specimens were analyzed using scanning electron microscopy (SEM) and electron dispersion spectroscopy (EDS). **Results.** Statistically significant differences were found in the *L, *a and *b parameters for HT, MT and LT in all firing periods. Comparing the subgroups in terms of color (ΔE), the highest ΔE values were found in HTNG5x ($\Delta E = 3.7 / \Delta E_{00} = 3.0$), followed by HTNG1x for black background and the lowest in LTGZ2x ($\Delta E = 0.6 / \Delta E_{00} = 0.4$). Comparing the differences between specimens with and without glaze in terms of the number of firings, the subgroup with the greatest variations was MT with 1 firing ($\Delta E = 8.1 / \Delta E_{00} = 5.9$) and HT with 2 burns ($\Delta E = 3.5 / \Delta E_{00} = 3.5$). The ΔE values of all the subgroups with glaze showed values above the perceptibility threshold, except for MTGZ5x ($\Delta E = 0.4$ and $\Delta E_{00} = 0.3$) and LTGZ2x ($\Delta E = 0.6$ and $\Delta E_{00} = 0.4$). When comparing ΔPT translucency, the lowest average values were found in MTGZ2x ($\Delta PT / \Delta PT_{00} = -0.2$) and LTGZ2x ($\Delta PT = 0.2 / \Delta PT_{00} = 0.4$). Except for the specimens with glaze after 2 firings (HTGZ2x, MTGZ2x, LTGZ2x) all the other subgroups had variations in translucency above the perception limit ($\Delta PT = 1.33 \Delta PT_{00} = 0.62$) but still within the acceptance limit. **Conclusions:** The results showed that the color and translucency parameters of CAD lithium disilicate were affected by both the glaze paste and repeated firings. For specimens that underwent up to two firings, the LT group showed the least variation in color, followed by the MT group. The HT group showed the greatest variation after multiple firings; therefore, its use should be preceded by additional caution because its color and translucency show a significant change after repeated firings.

Keywords: Dental Venners. CAD-CAM. Dental Esthetics. Dental Prosthodontics.

*In accordance with the Medical Subject Headings (MeSH) available at: <http://meshb.nlm.nih.gov>

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LISTA DE ABREVIATURAS E SIGLAS

μm	Micrômetro
ANOVA	Análise de variância
CAD	Computer-aided design
CAM	Computer-aided manufacturing
Kv	Quilovolt
Min	Minuto
HT	Alta translucidez
MT	Média translucidez
LT	Baixa translucidez
s	Segundo
L	Luminosidade
a	Parâmetro : vermelho ao verde
b	Parâmetro : amarelo ao azul
CIE	Comissão internacional de iluminação
LP	Limite de percepção
LA	Limite de aceitação

LISTA DE SÍMBOLOS

=	Igual
+	Mais
±	Mais ou menos
%	Porcentagem
&	E (conjunção de adição)
<	Menor
>	Maior
x	Veze
α	Alfa (nível de significância)
°C	Graus Celsius
nº	número
P	Significância estatística
®	Registrado
™	Marca registrada
Δ	Delta

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1 INTRODUÇÃO

A Odontologia moderna tem presenciado um momento de grande avanço em materiais dentários e isso se confirma com mais veemência na especialidade da prótese dentária, onde a aplicação da tecnologia e o aprimoramento dos materiais são muito evidentes (Miyazaki, 2007; Christensen, 2014). Cada vez mais o processo de confecção de uma prótese dentária, outrora feito quase todo manualmente tem dado espaço a um outro mais moderno, que envolve o uso de uma alta tecnologia de desenho (CAD) e uma usinagem conduzida por computação (CAM). (Guyer *et al.*, 1988; Suganna *et al.*, 2022). O uso do CAD/CAM na área de restaurações dentárias em cerâmica aumentou exponencialmente nos últimos anos (Davidowitz; Kotick, 2011; Suganna *et al.*, 2022), e um dos motivos certamente está relacionado ao fato de permitir a fabricação de restaurações de alta qualidade com mais precisão, eficiência, rapidez e menos erros em comparação com os métodos convencionais. (Nejatidanesh *et al.*, 2018; Tabesh *et al.*, 2018; Yin *et al.*, 2019). Outro ponto que também justifica esse crescimento é que o uso da tecnologia CAD/CAM permite que os clínicos realizem restaurações cerâmicas de forma muito rápida e em apenas uma única consulta. Esse processo economiza tempo e esforço consideráveis em comparação com os métodos tradicionais. (Suganna *et al.*, 2022).

Um dos materiais cerâmicos mais utilizados pelos dentistas nessa nova era da prótese digital é o dissilicato de lítio- DL (Christensen, 2014). Ele está classificado entre as três principais escolhas para coroas anteriores, correspondendo à preferência majoritária de 54% dos dentistas nos EUA (Makhija *et al.*, 2016). O DL está disponível para sistemas CAD/CAM desde 2006, na forma de blocos pré-cristalizados (fase azul) sob a marca IPS e.maxCAD (Ivoclar Vivadent e Schaan de Liechtenstein) e são ofertados para uso digital em diversos tamanhos e tonalidades em três versões de acordo com os níveis de translucidez (alta, média e baixa translucidez) sendo que a nomenclatura adotada pelo fabricante (HT, MT e LT) vem da abreviatura dos termos da língua inglesa – high translucency, medium translucency e low translucency, respectivamente. Os blocos, na fase azul, podem ser usinados com maior facilidade na fresadora, no entanto, após o processamento, a restauração necessita obrigatoriamente passar por um ciclo térmico no forno cerâmico para ser cristalizada, a fim de se atingir as propriedades físicas finais, como a resistência e as propriedades

ópticas correspondentes, que são obtidas por meio da transformação da microestrutura do material (Zhang *et al.*, 2022).

Uma das grandes qualidades do DL é a combinação de uma excelente estética com resistência -em média de 380 MPa, o que certamente torna atraente a escolha dos profissionais por este material (Alessandretti *et al.*, 2019). Outra característica que o diferencia é que a matriz vítrea do DL pode ser condicionada com ácido fluorídrico e quimicamente unida à estrutura dental com um primer de silano e cimento resinoso adesivo (Aboushelib; Sleem, 2014), sendo indicada com segurança para realização de facetas, coroas anteriores e posteriores, peças indiretas tipo in lay/on lay e pontes fixas de até 3 elementos (Zhang *et al.*, 2022), o que lhe confere uma vantagem adicional em relação a zircônia, por exemplo. Além disso, a adaptação marginal das restaurações de DL CAD parece ter qualidade suficiente para contribuir para a longevidade das mesmas na cavidade oral.(Bresser *et al.*, 2023; Sanches *et al.*, 2023)

Apesar da revisão de literatura indicar alguns estudos sobre o efeito de queimas repetidas em variados tipos de cerâmica (Abdel Sadek *et al.*, 2022; Campanelli De Moraes *et al.*, 2021; Fouda *et al.*, 2022; Jurado *et al.*, 2022; Magalhães *et al.*, 2023; Miranda *et al.*, 2020; Nejatidanesh *et al.*, 2020; Ozdogan; Ozdemir, 2021; Wang; Yu; Chen, 2020), a literatura científica ainda é limitada de estudos de mesma natureza sobre o DL CAD, principalmente em trabalhos que evidenciem (em seus 3 principais níveis de translucidez -HT,MT,LT) a dinâmica do comportamento das propriedades ópticas de cor e translucidez do DL CAD quando são submetidos a queimas repetidas. Por isso alguns trabalhos científicos apontam a necessidade de estudos adicionais nesta área assim como mais estudos que abordem a influência da aplicação da pasta glase em tais propriedades do DL CAD e sua correlação com mais ciclos de queimas (Aurélio; Dorneles; May, 2017; Zaniboni *et al.*, 2022; Magalhães *et al.*, 2023).

A obtenção de restaurações cerâmicas com características de cor e translucidez desejáveis, muito próximas ao natural e previsíveis quanto ao resultado esperado depende, entre outros fatores, das características do material (Paravina *et al.*, 2007) e é um desafio compartilhado pela indústria com os clínicos e técnicos de prótese dentária. Para isso se faz necessário compreender melhor a dinâmica das propriedades ópticas do dissilicato de lítio CAD quando o material é submetido a vários ciclos de queimas (aquecimento a altas temperaturas e resfriamento). Portanto, o objetivo deste estudo é investigar o comportamento das propriedades ópticas de cor

e translucidez das principais variações de translucidez do DL CAD após subsequentes ciclos de queimas e a influência do uso da pasta glase.

2 REVISÃO DA LITERATURA

2.1 Seleção e aferição de cores em odontologia

O uso cotidiano de restaurações monolíticas com dissilicato de lítio envolve inicialmente a escolha de uma cor dominante, mas na maioria das vezes é necessária uma etapa final de personalização da cor, com a aplicação de pigmentos coloridos na superfície externa da cerâmica. Essa fase de caracterização costuma ser obrigatória para uma melhor correspondência de cores. Esses pigmentos são apresentados na forma de pastas e podem ser queimados juntos ou após a cristalização da cerâmica de dissilicato de lítio.(Fouda *et al.*, 2022; Pecho *et al.*, 2012).

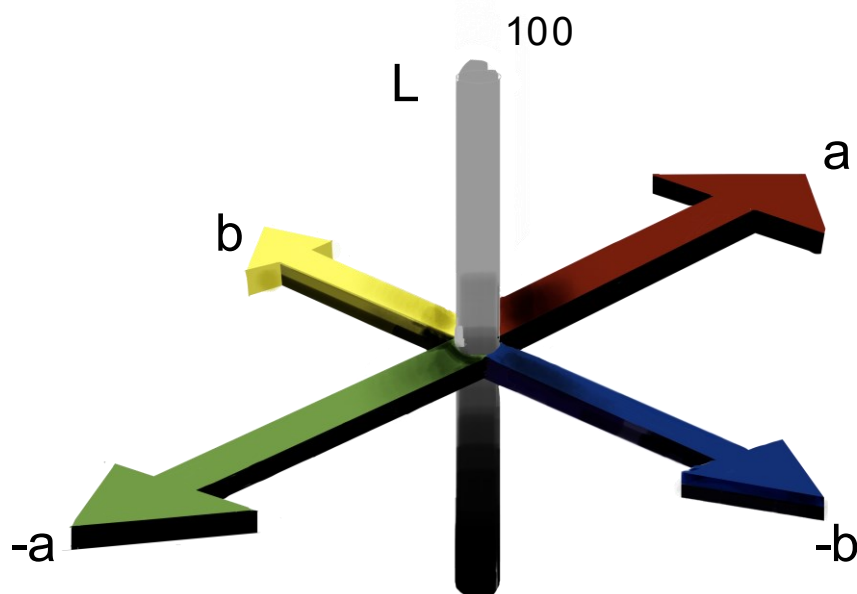
Tradicionalmente, os dentistas utilizam escalas de cores análogas às cerâmicas como referência para tomar a cor dos dentes a fim de prosseguir com a execução da prótese, buscando a melhor qualidade possível de naturalidade do tratamento (Paravina *et al.*, 2007). Alguns estudos confirmaram a hipótese de que os resultados da correspondência visual de cores exibem um nível alto a moderado de inconsistência, além disso o guia de cores VITA Classical não foi projetado para cerâmicas monolíticas (Iguel *et al.*, 2017). No entanto, o uso da medição digital de cores tem aumentado em popularidade ao longo dos anos para avaliação e seleção de cores(Czigola *et al.*, 2021). O aparelho digital mais conhecido e utilizado para esse fim é o Easy Shade (Vita® Zahn Fabrik), um espectrofotômetro portátil e compacto (Floriani *et al.*, 2024). A medição com auxílio de um dispositivo digital fornece dados objetivos e quantitativos, reduzindo o viés da subjetividade visual. Por esse motivo, hoje em dia o dentista pode obter as coordenadas de cor do sistema de cores Cie*L*a*b com mais precisão para selecionar a melhor opção que corresponderá à restauração, o mais próximo da cor original do dente (Chu; Trushkowsky; Paravina, 2010; Iguel *et al.*, 2017; Kose *et al.*, 2023).

2.2 A ciência das cores: o sistema de coordenadas Cie*L*a*b

Na ciência das cores, o sistema de coordenadas Cie*L*a*b é usado rotineiramente como referência na medição de cores (Luo; Cui; Rigg, 2001). O eixo L* simboliza a escuro e o claro, variando do preto ao branco perfeito. O eixo a* simboliza o verde em coordenadas negativas e o vermelho em coordenadas positivas. O eixo b* simboliza o amarelo em coordenadas positivas e o azul em coordenadas negativas.

Esses parâmetros de coordenadas incluem 3 valores ($L^*a^*b^*$) em um espaço de cores tridimensional- vide Figura 1.

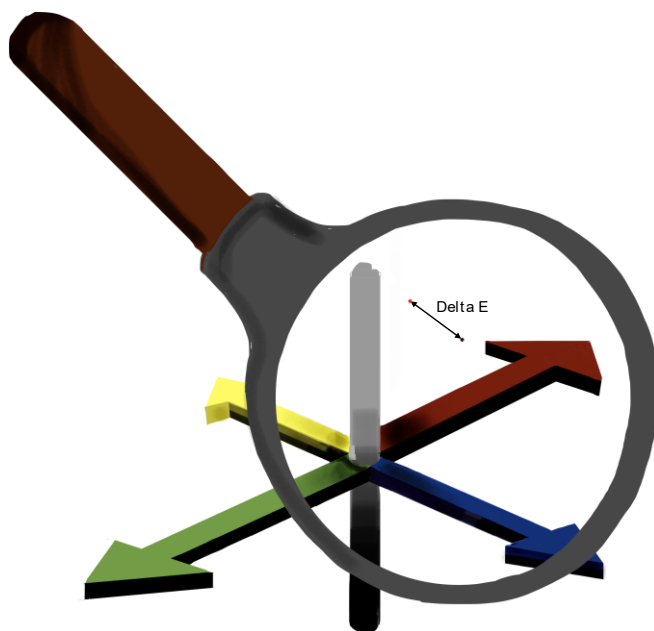
Figura 1- Eixos de coordenadas do sistema de coordenadas $Cie^*L^*a^*b$



Fonte: Ilustração por Amanda Germiniani

A distância numérica entre as coordenadas $L^*a^*b^*$ de duas cores ou no mesmo objeto antes e depois de diferentes condições é representada por valor delta (ΔE) - vide Figura 2. Essa fórmula de diferença de cor (ΔE) foi projetada para fornecer uma representação quantitativa da diferença de cor percebida entre dois objetos coloridos (Johnston, 2009)

Figura 2- Representação da distância entre 2 cores (ΔE)



Fonte: Ilustração por Amanda Germiniani

Dessa forma, a qualidade da correspondência de cores entre a restauração dentária e um objeto natural adjacente pode ser expressa e aferida numericamente e se correlaciona principalmente com a magnitude e a direção da diferença de cores.(Czigola *et al.*, 2021)

Quanto a translucidez há três tipos de indicadores usados no campo da prótese estética: transmitância (T), a relação de contraste (RC) e o parâmetro de translucidez (PT). Entre esses três indicadores, o valor do PT é geralmente considerado mais aplicável à avaliação visual da translucidez que pode ser entendida como a propriedade de permitir mais ou menos a passagem de luz através de um objeto. Esta é calculada como a diferença de cor de um fundo branco e preto em uma espessura uniforme de uma substância. Ela pode determinar a intensidade percebida da cor (Johnston, 2014; Salas *et al.*, 2018).

2.3 Efeitos das queimas repetidas nas propriedades ópticas das cerâmicas

Quando o assunto é material cerâmico torna-se natural o entendimento de que existe obrigatoriamente o envolvimento de uma etapa de queima deste material para que ele possa ser utilizado na função restauradora e para se atingir um nível

elevado de mimetismo a estrutura natural dos dentes é comum a utilização pigmentos coloridos que personalizem a peça protética. Tal personalização obriga o profissional a submeter esta peça a um ciclo de queima. Muito provavelmente tal fato justifica o porquê a relação dos ciclos de queimas com as propriedades físicas e ópticas das cerâmicas foi e ainda é tema de investigação em trabalhos científicos. Isto posto, para facilitar a visualização das publicações ao longo do tempo e a compreensão do escopo de cada estudo, optou-se por organizar as informações de forma resumida em dois quadros. O Quadro 1 envolve trabalhos que avaliaram as queimas em cerâmicas produzidas essencialmente de modo analógico (com exceção da zircônia que pode ser CAD/CAM), e o Quadro 2 elencou trabalhos que envolvem comparativos do dissilicato de lítio CAD/CAM que apresentaram algum nível de relação das queimas com as propriedades ópticas ou mecânicas deste material (ver Quadro 1 e 2).

Quadro 1- Estudos de revisão de literatura sobre o efeito dos ciclos de queimas em propriedades ópticas das cerâmicas

(continua)

Autores/Ano	Tipos da cerâmica	Objeto de estudo	Grupos	Conclusões	Método para aferição da cor
BARGHI; GOLDBERG, 1977	Cerâmica feldspática com folha de platina (metalocerâmica)	Os efeitos do uso do vácuo durante as queimas das cerâmicas	80 espécimes n=40 queimas presença de ar n=40 queimas no vácuo 1,2,3,4... até 10 queimas	Até 5 queimas não houve diferença, mas entre 6 e 10 houve. O vácuo parece colaborar para menores alterações	Avaliação visual de participantes
O'BRIEN <i>et al.</i> , 1991	Cerâmica feldspática 4 marcas comerciais aplicada sobre metal com opaco (metalocerâmica)	Avaliar o efeito na cor das cerâmicas: entre os lotes de mesma marca, entre lotes de marcas diferentes e após várias queimas	216 espécimes 3 lotes de 4 marcas comerciais, sendo n=18 para cada lote Medições feitas após 3 e 6 queimas	Houve diferença de cores nas cerâmicas entre os lotes de algumas marcas. As alterações na cor pelas queimas não ficaram acima do nível de aceitação. Algumas marcas variam mais do que outras.	Espectrofotômetro com geometria de esfera- Marca Color Eye modelo M2020PL

(continuação)

Autores/Ano	Tipos da cerâmica	Objeto de estudo	Grupos	Conclusões	Método para aferição da cor
CELIK <i>et al.</i> , 2008	Zircônia com cerâmica feldspática	Avaliar as alterações de cor após queimas repetidas em 2 tipos de cores aplicada sobre a zircônia	20 espécimes discos de zircônia sendo n=10 para cor A1 e n=10 para A3 submetidos a queimas 3,5,7 e 9 queimas	Houve diferença nas cores tanto entre os espécimes de cores diferentes quanto em relação ao número de queimas. Porém o estudo aponta que as alterações foram clinicamente aceitáveis.	Vita Easysshade Bad Säckingen, Alemanha contra fundo preto
PANZERI PIRES-DE-SOUZA <i>et al.</i> , 2009	cerâmica feldspática pura e metalocerâmica	Avaliar a influência na cor das cerâmicas do número de queimas de acordo com o tipo do substrato e o efeito de envelhecimento	60 espécimes 3 grupos de n=20 De acordo com o número de 2,3 e 4 queimas Metade metalocerâmica e cerâmica pura	O número de queimas afetou a cor dos espécimes. Houve diferença na cor entre o tipo dos substratos. O envelhecimento também parece ter influenciado na cor, porém em nível aceitável.	Espectrofotômetro Byk Gardner PCB 6807 Alemanha contra fundo branco

(continuação)

Autores/Ano	Tipos da cerâmica	Objeto de estudo	Grupos	Conclusões	Método para aferição da cor
GONULDAS; YILMAZ; OZTURK, 2014	metalocerâmica	Avaliar o efeito das queimas em diferentes espessuras de coroas metalocerâmicas	21 espécimes n=7 de acordo com as espessuras cerâmicas 1.4; 1.7 e 2mm 1,3,5 e 7 queimas	A medida que o número de queimas aumentou a cor da cerâmica foi alterada e a superfície se deteriorou.	Colorímetro Minolta CR 321 Tokyo, Japan
YILMAZ; GONULDAS; OZTURK, 2014	3 tipos de cerâmicas sendo 1 tipo de cerâmica a base de leucita 1 tipo de cerâmica de matriz de vidro cristalina 1 tipo de metalocerâmica	Avaliar as alterações da cor de acordo com o tipo de material, o método de glase e o número de queimas	35 espécimes n=14 para metalocerâmica n=14 para base de leucita n=7 para matriz de vidro cristalina 1,3,5 e 7 queimas	Houve alteração na cor das cerâmicas com as queimas repetidas, especialmente nas cerâmicas sem o metal. Múltiplas queimas devem ser evitadas. O glase natural não trouxe uma superfície suave o suficiente E que o glase químico deveria ser utilizado nas cerâmicas de vidro.	Colorímetro Minolta CR 321 Tokyo, Japan

(continuação)

Autores/Ano	Tipos da cerâmica	Objeto de estudo	Grupos	Conclusões	Método para aferição da cor
ZAID <i>et al.</i> , 2016	1 tipo de Zircônia + cerâmica feldspática 1 tipo de Copping de Dissilicato de lítio para prensagem + cerâmica feldspática 1 tipo de metalocerâmica	Avaliar a alteração da cor final da cerâmica em variados tipos de espessuras em materiais diferentes	72 espécimes 3 grupos cada um com 3 subgrupos com espessuras de cerâmica de 0,5, 1 e 2mm 3,5 e 7 queimas	A cor final foi afetada nas variadas espessuras de acordo com o aumento do número de queimas, especialmente após a quinta queima.	Vita Easysshade Bad Säckingen, Alemanha contra fundo branco.
FEHMI; ERSAN; CANER, 2018	1 tipo de Zircônia 1 tipo de Dissilicato de lítio para prensagem	Avaliar os efeitos das queimas repetidas em 2 tipos de cerâmicas puras.	20 espécimes n=10 para cada material mesma espessura houve aplicação de glase 1,3 e 5 queimas	Os valores de ΔE com as queimas ficaram acima dos níveis de percepção para zircônia e dissilicato. Os parâmetros *L e *a foram alterados no dissilicato de lítio e por isso evitar queimas repetidas	Colorímetro Minolta CR 321 Tokyo, Japan

(conclusão)

Autores/Ano	Tipos da cerâmica	Objeto de estudo	Grupos	Conclusões	Método para aferição da cor
ELBASUNY <i>et al.</i> , 2021	1 tipo de zircônia, 1 tipo de Dissilicato de Lítio para prensagem prensado e 1 tipo de metalocerâmica	Avaliar a alteração de cor das cerâmicas após queimas repetidas de acordo com diferentes materiais	30 espécimes n=10 para cada grupo	DL prensado foi aquele altamente afetado pelas queimas repetidas, seguido pela zircônia e metalocerâmicas	Espectrofotômetro *não mencionado modelo
ABDELMONIEM; EL-ETREBY; SALAH, 2022	1 tipo de Dissilicato de Lítio para prensagem	Avaliar a influência na cor e translucidez de queimas múltiplas e do envelhecimento em dissilicato para prensagem submetido a reprensagens.	42 espécimes Divididos em 3 grupos n=14 de acordo com o número de reprensagens Subdivididos em 2 grupos de acordo com os ciclos de queimas-2x e 4x	O número de queimas e o envelhecimento com a termociclagem afetou a cor e translucidez dos espécimes.	Espectrofotômetro Agilent Cary 5000 UV-Vis-NIR

Quadro 2 - Estudos da revisão de literatura relacionados as propriedades ópticas do dissilicato de lítio CAD/CAM

(continua)

Autores/Ano	Tipos da cerâmica	Objeto de estudo	Grupos	Conclusões	Método para aferição da cor
DELLA BONA <i>et al.</i> , 2015	2 variações do Dissilicato de Lítio CAD 4 variações da cerâmica vítrea com reforço de leucita (2 marcas diferentes) 1 cerâmica feldspática	Avaliar as diferenças de cor entre as cerâmicas com a escala Vita e entre os sistemas	60 espécimes 4 grupos 12 subgrupos (n=5 cada) Espessura de 1.0 mm	Nenhum sistema foi capaz de corresponder a cor da cerâmica com a escala Vita, embora todas dentro do limite de aceitabilidade. Algumas cerâmicas tiveram diferenças entre A1-A2 e A2-A3, mas não significantes.	Espectroradiômetro Spectra Scan PR-704 Chatsworth, EUA
KANG <i>et al.</i> , 2017	1 tipo de dissilicato de lítio CAD 1 tipo de cerâmica vítrea com reforço de leucita (ambos de baixa translucidez)	Avaliar os efeitos na variação da espessura de copings e da camada de cerâmica na cor do dissilicato de lítio.	42 espécimes 2 grupos de n=21	A cor da cerâmica é influenciada pela espessura do coping e da camada de cerâmica	Espectrofotômetro CM-3600 Konica Minolta

(continuação)

Autores/Ano	Tipos da cerâmica	Objeto de estudo	Grupos	Conclusões	Método para aferição da cor
WANG; YU; CHEN, 2020	2 tipos de Dissilicato de lítio CAD (Média opacidade/Alta translucidez) 3 tipos Dissilicato de lítio para prensagem (Alta e média opacidade) (Baixa translucidez) 1 dissilicato de lítio novo para prensagem 1 tipo de Zircônia	Avaliar a resistência flexural e comparar as características de translucidez de materiais com diferentes níveis de translucidez	80 espécimes n=10 para cada grupo 2 espessuras 0.5 e 1.0 mm	Os valores obtidos das aferições dos parâmetros de translucidez confirmam diferenças entre os subgrupos de acordo com o que se esperava exceto para dissilicato de lítio para prensagem de alta e baixa translucidez	Colorímetro Minolta CR 321 Tokyo, Japan
NEJATIDANESH <i>et al.</i> , 2020	2 tipos de Dissilicato de lítio CAD (alta translucidez) (baixa translucidez) zircônia reforçada por silicato de lítio	Avaliar as alterações do dissilicato de lítio e da zircônia após as queimas de cristalização, correção e glase.	80 espécimes n=10 espessuras diferentes (0.6 e 1mm) 1,2 e 3 queimas	Queimas repetidas afetaram significativamente os espécimes de 0.6 mm, mas 1.0mm não afetou. Dissilicato alterou mais que a zircônia	Espectrofotômetro de reflexão Degudent-Rodenbacher.

(continuação)

Autores/Ano	Tipos da cerâmica	Objeto de estudo	Grupos	Conclusões	Método para aferição da cor
MIRANDA <i>et al.</i> , 2020	1 tipo de Dissilicato de Lítio CAD (baixa translucidez)	Avaliar a resistência flexural, a composição e comparar técnicas diferentes de caracterização do material.	270 espécimes Divididos em 3 grupos + 3 subgrupos cada Com n=30 Espessura de 1.2 mm 2, 4 e 6 queimas	Os grupos que receberam a caracterização apresentaram menores valores de fadiga a medida que passaram por mais queimas. O maior tolerância a fadiga foi para o grupo que recebeu apenas 1 queima.	EDS XRD Teste flexural *não mencionam marcas
CAMPANELLI DE MORAIS <i>et al.</i> , 2021	Zircônia + Silicato de Lítio 1 tipo de Dissilicato de Lítio CAD	Avaliar as propriedades de cor e resistência flexural de 2 tipos diferentes de material após as queimas repetidas.	45 espécimes Divididos em 3 grupos de n=15 2,5 e 7 queimas	Houve alteração de cor para ambos os materiais estudados, mas ainda dentro de níveis de aceitação clínica. O dissilicato apresentou maior resistência flexural.	Optical stereomicroscopy Stereo Discovery V12; Carl Zeiss, Göttingen, Alemanha
OZDOGAN; OZDEMIR, 2021	1 tipo de Dissilicato de Lítio para prensagem 1 tipo de Dissilicato de Lítio CAD	Avaliar o efeito das queimas repetidas nas propriedades mecânicas e superfície do dissilicato de lítio produzido por 2 técnicas diferentes	80 espécimes 4 grupos de cada tipo 2 subgrupos n=10 cada 1,2,3,4 queimas	Um número maior de queimas não alterou a resistência flexural dos materiais, porém alterou a resistência a fratura e a dureza da superfície.	Máquina de ensaio universal Instron model 2519-106

(continuação)

Autores/Ano	Tipos da cerâmica	Objeto de estudo	Grupos	Conclusões	Método para aferição da cor
ABDEL SADEK <i>et al.</i> , 2022	Um novo Dissilicato de lítio para prensagem Um novo Dissilicato de lítio CAD	Avaliar os impactos de queimas repetidas na cor, translucidez e resistência flexural de um novo dissilicato de lítio produzido por 2 técnicas diferentes	60 espécimes 2 grupos de n=30 1,3 e 5 queimas	O aumento do número de queimas aumentou a alteração da cor e translucidez do material Aumento do número de queimas levou a uma diminuição da resistência flexural	Espectrofotômetro Vis-NIR Agilent Cary 5000 Agilent, EUA
JURADO <i>et al.</i> , 2022	1 tipo de dissilicato de lítio (alta translucidez) 1 tipo de silicato de lítio pré-cristalizado 1 tipo de novo dissilicato de lítio	Avaliar as alterações de cor e translucidez de 2 tipos de cerâmicas pré-cristalizadas e de 1 novo dissilicato de lítio e 1 dissilicato de lítio pioneiro no mercado.	105 espécimes 7 grupos n=15 1 e 2 queimas 1 grupo sem queima alguma(controle)	A realização de queimas para o material pré-cristalizado e o novo dissilicato de lítio provocou alterações na cor e diminuiu a translucidez. O material pioneiro no mercado aumentou a translucidez	Color imaging spectrophotometer Spectroshade Micro II Oxnard, EUA

(conclusão)

Autores/Ano	Tipos da cerâmica	Objeto de estudo	Grupos	Conclusões	Método para aferição da cor
KELMA PALACIO GOMES MAGALHÃES <i>et al.</i> , 2023	1 tipo de dissilicato de lítio para prensagem	Avaliar o efeito na cor do dissilicato de lítio com a aplicação de 1 ou 2 queimas de glase com envelhecimento	80 espécimes 2 grupos 4 subgrupos n=10	Apenas 1 queima de glase teve um resultado melhor de cor, rugosidade e microdureza.	• Informação não localizada
OZDOGAN; TOSUN, 2023	Coping de zircônia + feldspática Zircônia monolítica Zircônia + silicato de lítio Apenas 1 tipo de Dissilicato de lítio CAD	Avaliar e comparar os efeitos de queimas repetidas na cor e propriedades mecânicas das cerâmicas do estudo	160 espécimes divididos em n=40 para cada material Seleção aleatória de 1 a 4 queimas	Como conclusões obtiveram que o número de queimas afetou a cor final das cerâmicas, a dureza e rugosidade. No entanto não houve diferença na resistência flexural para os grupos após as queimas.	Colorímetro Minolta CR 321 Tokyo, Japão
LU <i>et al.</i> , 2023	1 tipo de novo dissilicato de lítio pré-cristalizado CAD 1 tipo de dissilicato de lítio CAD	Avaliar os efeitos do glase na rugosidade e resistência flexural de um novo dissilicato de lítio pré-cristalizado	160 espécimes 8 grupos n=20 1 e 2 queimas	Realizar 2 queimas aumentou a resistência flexural do novo dissilicato de lítio	Perfilômetro e máquina de ensaio de flexão

3 PROPOSIÇÃO

3.1 Proposição geral

Avaliar as propriedades ópticas de cor e translucidez do dissilicato de lítio CAD após subseqüentes ciclos de queimas avaliado por meio de espectrofotômetro em interação com fundos branco e preto, com e sem a aplicação da pasta glase.

3.2 Proposições específicas

- Avaliar as **propriedades de cor** com a interação em fundo branco e preto de espécimes das 3 principais variações do dissilicato de lítio pré-fabricados tipo CAD/CAM (HT, MT, LT) após ciclos de queimas repetidas (1x, 2x e 5x).
- Avaliar as **propriedades de translucidez** com a interação em fundo branco e preto de espécimes das 3 principais variações do dissilicato de lítio pré-fabricados tipo CAD/CAM (HT, MT, LT) após queimas repetidas (1x, 2x e 5x).
- Avaliar as **propriedades de cor** com a interação em fundo branco e preto de espécimes das 3 principais variações do dissilicato de lítio pré-fabricados tipo CAD/CAM (HT, MT, LT) após queimas repetidas (1x, 2x e 5x) **com a aplicação da pasta glase**.
- Avaliar as **propriedades de translucidez** com a interação em fundo branco e preto de espécimes das 3 principais variações do dissilicato de lítio pré-fabricados tipo CAD/CAM (HT, MT, LT) após queimas repetidas (1x, 2x e 5x) **com a aplicação da pasta glase**.

4 MATERIAIS E MÉTODOS

4.1 Caracterização da amostra

Nove blocos de dissilicato de lítio (DL) cor A2 (Figura 3) foram usados neste estudo sendo três de cada variação de translucidez disponíveis comercialmente pelo fabricante para uso em sistema CAD/CAM - 3 blocos de alta translucidez (HT) IPS e.max® CAD; 3 blocos de média translucidez (MT) IPS e.max® CAD e 3 blocos de baixa translucidez (LT) IPS e.max® CAD (Ivoclar, Vivadent Schann, Liechtenstein) de tamanho C14 -12x14x18 mm - conforme mostrado na Figura 2. A composição dos blocos de DL tipo CAD informada nas instruções está no Quadro 3.

Figura 3 – Bloco de dissilicato de lítio IPS e.max® CAD HT A2 tamanho C14



Fonte: website www.ivoclar.com/pt_br

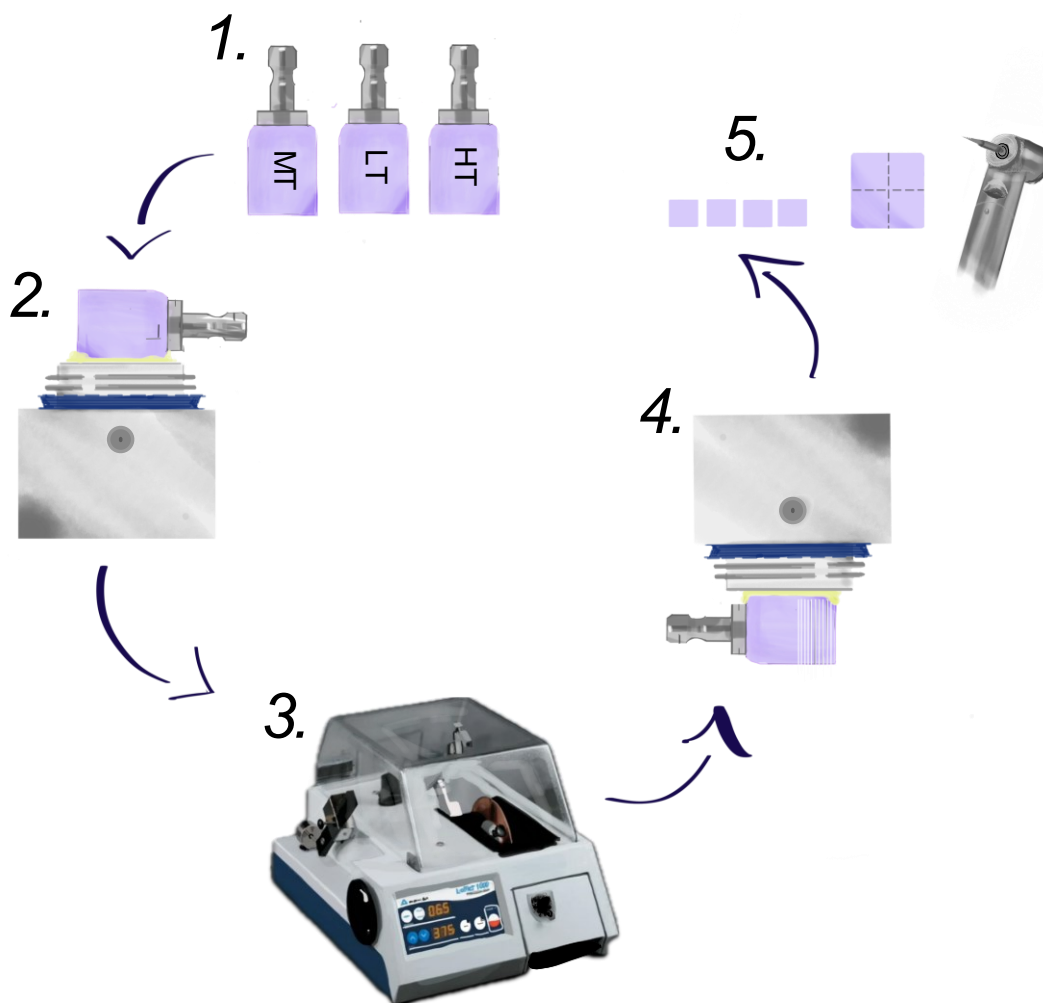
Quadro 3- Composição do dissilicato de lítio (IPS emax® CAD Ivoclar Vivadent)

Technical specifications	
Chemical composition	
SiO ₂	57.0 – 80.0 %
Li ₂ O	11.0 – 19.0 %
K ₂ O	0.0 – 13.0 %
Other oxides	0–8 %
Physical material data	
Coefficient of expansion (100 – 400°C)	$10.15 \pm 0.4 \cdot 10^{-6} \text{ K}^{-1}$
Coefficient of thermal expansion (100 – 500°C)	$10.45 \pm 0.4 \cdot 10^{-6} \text{ K}^{-1}$
Flexural strength (biaxial)	$\geq 360 \text{ MPa}$
Density	$2.5 \pm 0.1 \text{ g/cm}^3$

Cada bloco CAD/CAM foi inicialmente cortado em fatias de tamanho 12 × 14 × 1 mm por meio de uma máquina de corte de baixa velocidade (Isomet® Buehler, EUA). Para isso, os espécimes foram previamente embutidos em cloreto de polivinil (PVC)

fixados e preenchidos com cera pegajosa (Asfer, SP, Brasil), deixando o longo eixo da superfície do material perpendicular a serra (vide Figura 4).

Figura 4 - Esquema representativo das etapas da sequência de trabalho para obtenção dos espécimes: 1. Blocos de DL CAD; 2. representação da fixação do bloco CAD com cera pegajosa para levar a máquina de corte; 3- Máquina de corte de baixa rotação Isomet®; 4. representação do bloco com o fatiamento; 5. Fatia obtida e novamente cortada em 4 partes menores obtendo assim os espécimes para o estudo.



Fonte: ilustração de Amanda Germiniani

Assim, cada fatia foi dividida em 4 pedaços menores de 5 x 6 x 1 mm com $1,0 \pm 0,1$ mm de espessura, após delimitação centralizada procedeu-se a separação final da fatia obtida em partes menores por meio de uso do alta rotação com ponta diamantada 2200 (KG Sorensen, Serra, Brasil) com irrigação de água ativa (vide Figura 4). Portanto, um total de 180 espécimes foram obtidos com este processo e selecionados para as aferições de cor e demais testes (vide Figura 4). Todos os espécimes foram polidos manualmente em apenas um lado, usando lixas d'água (grão

320, 400 e 600, 3M - Brasil) com uma fina película de pasta de polimento (Universal Polishing paste, Ivoclar Vivadent) por 10 segundos de atrito suave para cada gramatura de lixa usada (Figura 5). A espessura de cada espécime foi controlada com um paquímetro digital (Mitutoyo, Kawasaki, Japão)- Figura 6. Todos os espécimes de DL foram limpos e lavados em água destilada, imersos em um limpador ultrassônico por 10 minutos e secos com papel absorvente (vide Figura 7).

Figura 5- Lixas para polimento (3M, Brasil) e pasta de polimento universal (Ivoclar Vivadent, Alemanha)



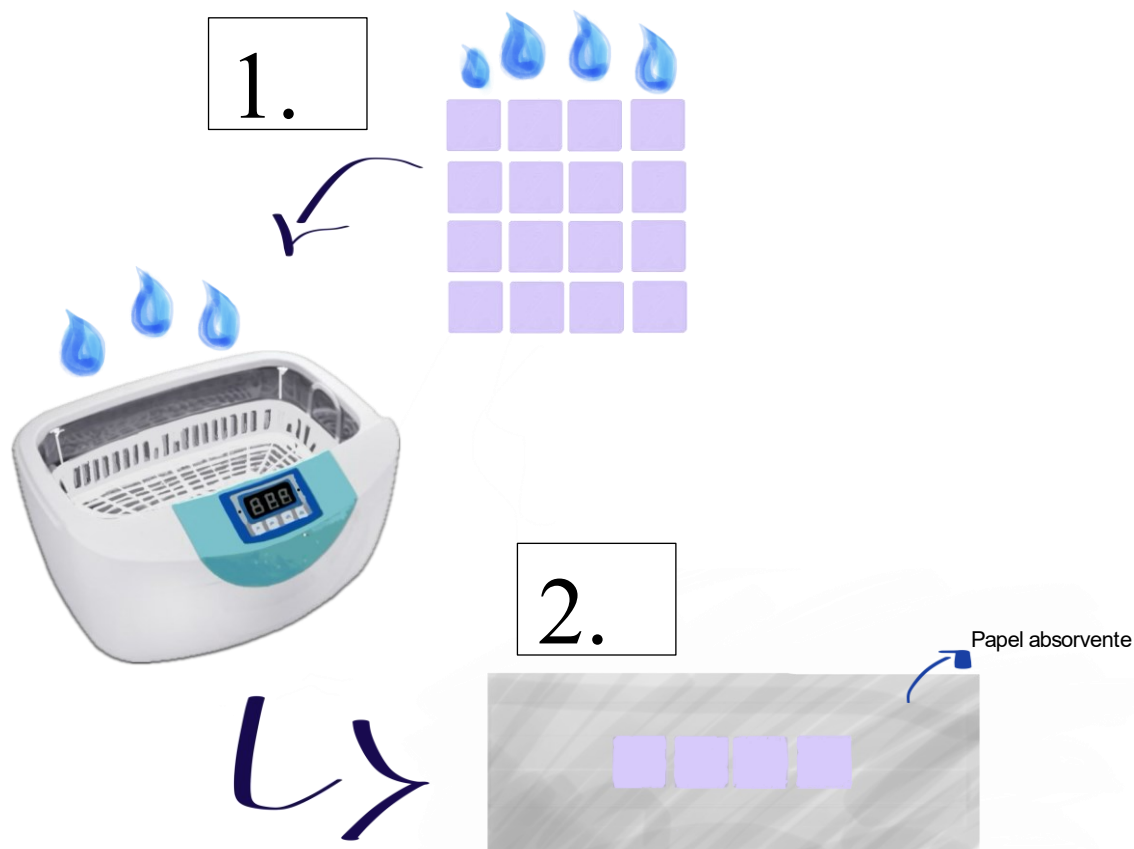
Fonte websites: www.3mbrasil.com.br & www.ivoclar.com/pt_br

Figura 6- Paquímetro digital Mitutoyo (Miyazaki, Japão)



Fonte website: www.mitutoyo.com.br

Figura 7- Sequência para limpeza dos espécimes antes da aferição; 1-Lavagem dos espécimes em cuba ultrassônica com água destilada. 2- Secagem em papel absorvente



Fonte: ilustração de Amanda Germiniani

4.2 Distribuição dos grupos experimentais do estudo

Os espécimes foram igualmente distribuídos em subgrupos experimentais. No estudo 1 (n=90) a divisão dos espécimes em subgrupos ocorreu de acordo com o grau de translucidez informado pelo fabricante (HT, MT, LT) e de acordo com o número de queimas realizadas (1,2 ou 5) como representado no *flow-chart* do desenho experimental na Figura 8.

No estudo 2 (n=180) a divisão dos espécimes em subgrupos também ocorreu de acordo com o grau de translucidez informado pelo fabricante (HT, MT, LT), de acordo com o número de queimas realizadas (1,2 ou 5) e se receberam a aplicação da pasta glase ou não, como representado no *flow-chart* do desenho experimental na Figura 9.

O tamanho da amostra para cada subgrupo do estudo com 10 amostras ($n=10$) foi calculado e confirmado usando um software de análise (G*Power v3.1.9; Heinrich-Hein- Universität Dusseldorf), considerando um α igual a 0,05, tamanho do efeito de 0,50 e poder de 80%. Isso vai de encontro ao que foi utilizado em outros estudos

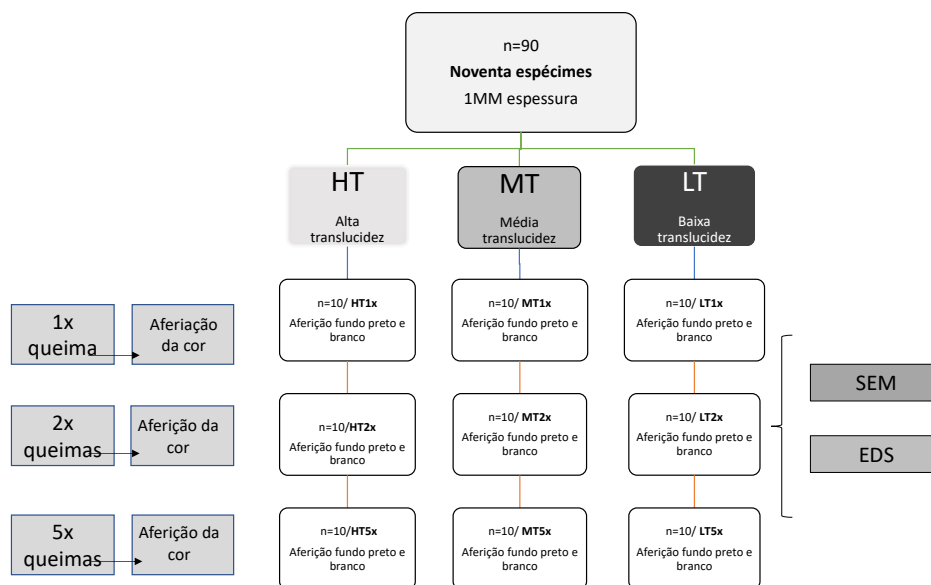
O forno de cerâmica utilizado para as etapas de queima foi o EP3000 (Ivoclar Vivadent, Schaan, Liechtenstein) vide Figura 9, de acordo com os programas configurados de fábrica ajustadas pelo fabricante, sendo um programa para cristalização e outro para etapa de glase e/ou caracterização) – vide tabelas 1 e 2.

Figura 8



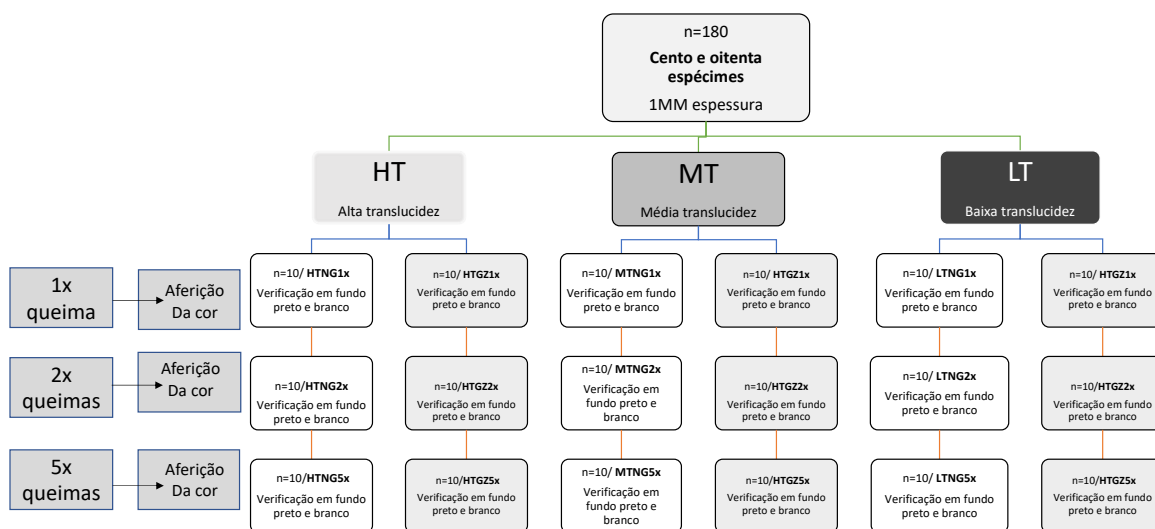
Fonte: [website ivoclar.com/pt_br](http://website.ivoclar.com/pt_br)

Figura 9 - Forno Cerâmico EP3000 -Ivoclar Vivadent®, Schaan, Liechtenstein



Fonte: o autor

Figura 10- Flow-chart do delineamento experimental do estudo 1



Fonte: o Autor

Tabela 1- Programação de temperaturas e tempos para cristalização do dissilicato de lítio

Tempo Fechamento	Temperatura espera	Taxa aquecimento	Temperatura queima	Tempo espera	Taxa aquecimento	Temperatura queima	Tempo manutenção	Temperatura resfriamento	Vácuo 1	Vácuo 2
6:00	403°C	60 °C/min	820 °C	0:10	30 °C/min	850 °C	10:00	700 °C	550	770

Fonte: website www.ivoclar.com

Tabela 2- Programação de temperaturas e tempos para glase e caracterização do dissilicato de lítio

Tempo Fechamento	Temperatura espera	Taxa aquecimento	Temperatura queima	Tempo espera	Taxa aquecimento	Temperatura queima	Tempo manutenção	Temperatura resfriamento	Vácuo 1	Vácuo 2
6:00	403°C	90 °C/min	820 °C	0:10	30 °C/min	840 °C	7:00	700 °C	550	820

Fonte: website www.ivoclar.com

A aferição de cor de cada amostra foi executada em duplicata para fundo branco e fundo preto usando o espectrofotômetro Vita Easyshade (ES) (Vident, Brea, CA, EUA) (vide Figura 11):

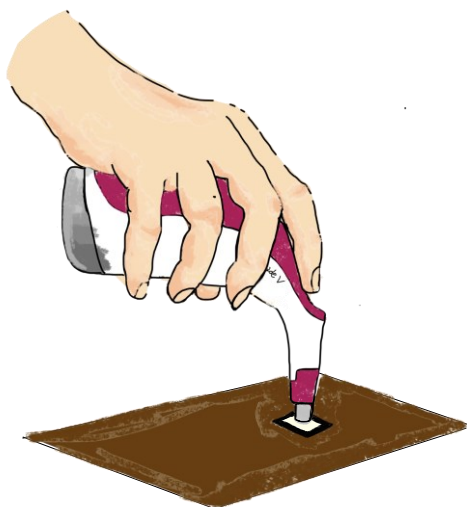
Figura 11- Aparelho de espectrofotômetro digital portátil (Vident, Bad Säckingen, Alemanha)



Fonte website: vita-zahnfabrik.com

O contato óptico entre a amostra e os fundos foi melhorado com o uso de uma camada de interface de uma solução de polietilenoglicol (Amanda Farmácia de Manipulação, Brasil) aplicado com pincel tipo *microbrush*. A área de medição de interesse para a correspondência de tonalidade foi o centro da amostra. Como o espécime era de pequeno tamanho e a área de laterais remanescentes eram muito pequenas, optou-se por seguir com bastante atenção a posição do aparelho em relação a superfície no momento das aferições, não sendo necessário para este caso desenvolver algum tipo de posicionador como suportado pelo estudo de (Fernández Millán; Gallas Torreira; Alonso De La Peña, 2020). Para fins de busca de uma forma de calibração, as aferições foram realizadas pela mesma pessoa usando o ES (ver Figura 12). Os valores CIE L^* , a^* e b^* são uma medida de cor discutida e apresentada pela Commission Internationale de l'Eclairage -CIELAB color, em que L^* indica a luminosidade (0 a 100) e a^* e b^* indicam os níveis de vermelho ($+a^*$), verde ($-a^*$), amarelo ($+b^*$) e azul ($-b^*$) -vide Figura 11. Os valores de L^* , a^* e b^* dos fundos utilizados neste estudo em sobreposição as cerâmicas foram $L^*=2,95$, $a^*=0,27$ e $b^*=1,28$ para o fundo preto, e $L^*=92,84$, $a^*=-0,13$ e $b^*=1,59$ para o fundo branco. A comparação de cores dos espécimes de cada grupo, ou seja, do antes e depois das etapas de queimas foi avaliada por meio das diferenças matemáticas tipo delta sendo que a nomenclatura para o delta da cor é ΔE .

Figura 12- Representação da aferição realizada em fundo branco e fundo preto



Fonte: ilustração de Amanda Germiniani

Essas diferenças matemáticas obtidas entre os subgrupos foram calculadas para identificação das diferenças com as seguintes fórmulas:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{\frac{1}{2}} \text{ e}$$

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C}\right) \left(\frac{\Delta H'}{K_H S_H}\right)}.$$

Dois estudos (Paravina *et al.*, 2015; Paravina; Pérez; Ghinea, 2019) trouxeram os referenciais matemáticos utilizados neste estudo para as variações consideradas perceptíveis (ΔE LP) e aquelas consideradas ainda dentro de aceitação (ΔE LA) mesmo sendo perceptíveis. Os valores para ΔE e ΔE_{00} de LP considerados nos comparativos foram de 1.2 e 0.8 respectivamente e para LA de 2.7 e 1.8 respectivamente.

As variações tipo delta nos parâmetros de translucidez (ΔPT e ΔPT_{00}) foram comparadas com os limiares de diferença de translucidez de 50:50% onde há um limite da percepção de variação da translucidez (LPT) e um limite de aceitação da variação da translucidez (LPAT). Esses limiares de translucidez foram estabelecidos recentemente com base em estudos (Johnston, 2014; Salas *et al.*, 2018). Os níveis de translucidez foram calculados usando a fórmula para o parâmetro de translucidez conforme a equação

$$TP_{ab} = [(L^*_B - L^*_W)^2 + (a^*_B - a^*_W)^2 + (b^*_B - b^*_W)^2]^{1/2}$$

Em que W e B são coordenadas de cor dos espécimes nos fundos branco e preto respectivamente. Além disso, a fórmula de diferença de cor CIEDE2000 (1:1:1) também foi usada para calcular o parâmetro de translucidez (TP_{00}):

$$TP_{00} = \left[\left(\frac{L'_B - L'_W}{K_L S_L} \right)^2 + \left(\frac{C'_B - C'_W}{K_C S_C} \right)^2 + \left(\frac{H'_B - H'_W}{K_H S_H} \right)^2 + R_T \left(\frac{C'_B - C'_W}{K_C S_C} \right) \left(\frac{H'_B - H'_W}{K_H S_H} \right) \right]^{1/2}$$

onde os subscritos "B" e "W" se referem à luminosidade (L^*), croma (C^*) e matiz (H^*) dos espécimes sobre os fundos preto e branco, respectivamente. R_T é a função de rotação que leva em conta a interação entre as diferenças de croma e matiz na região azul. As funções de ponderação S_L , S_C e S_H ajustam a diferença total de cor para a variação na localização da amostra de diferença de cor.

O uso da fórmula de diferenças de cor CIEDE2000 é recomendado pela Comissão Internationale de l'Éclairage (Comissão Internacional de Iluminação) como um aprimoramento da fórmula CIELAB sendo uma forma de correção entre as diferenças de cores percebidas visualmente e as diferenças de cores anotadas no computador (Luo; Cui; Rigg, 2001; Gómez-Polo *et al.*, 2016). No entanto, no momento, na maioria dos estudos revisados que envolvem cores na literatura odontológica, principalmente a translucidez ainda é quantificada usando o espaço das cores CIELAB e sua fórmula de cor associada (E^*_{ab}) (Lindsey; Wee, 2007; Tejada-Casado *et al.*, 2024). Por isso neste estudo optou-se por apontar resultados com as 2 formas de cálculo.

4.3 Análise estatística

Os dados coletados dos parâmetros L^* , a^* , b^* foram anotados em planilha do Microsoft™ Excel para então serem submetidos a análise de variância ANOVA e pós teste de Tukey ($\alpha=0,05$) em software gratuito de estatística - Jasp Team (Versão 0.18.3- 2024), Jasp Computer softwares.

4.4 Microscopia eletrônica de varredura (MEV)

No estudo 1, alguns espécimes de cada grupo foram selecionados aleatoriamente para a avaliação em microscopia eletrônica de varredura. Estes foram preparados passando por um novo polimento por meio de sequência de lixas (320,400,600,1000) 3M -Brasil; após isso os espécimes passaram por limpeza em cuba ultrassônica com água destilada por 5 min e então apenas um lado de cada superfície foi condicionada com ácido fluorídrico a 5% por 60 segundos. Após isso eles foram secos com papel absorvente e somente então passaram para recobrimento por uma camada nanométrica de ouro de aproximadamente 10-12 nm em aparelho específico para esta finalidade EMITECH SC7620 (East Sussex, United Kingdom); este processo durou em torno de 3 minutos. O aparelho de microscópio eletrônico de varredura utilizado foi o Mira 3 (TESCAN ®- Czech Republic) -vide Figura 13; com 10kv de tensão, altura de 10mm e área com aproximadamente 5 a 10 μm . As leituras eram realizadas em 100s em tempo real e para uma área de 1mm². As imagens coletadas passaram por uma análise qualitativa.

Figura 13- Ilustração digital do aparelho de microscopia eletrônica de varredura e espectroscopia de energia dispersiva de raios X- MIRA3 Tescan®



Fonte: website www.tescan.com

4.5 EDS – Espectroscopia de energia dispersiva de raios

No estudo 1, o uso da espectroscopia de energia dispersiva de raios-X (EDS) ocorreu no mesmo aparelho logo imediatamente após as tomadas realizadas pelo MEV com o intuito de se verificar e analisar a composição química dos espécimes selecionados para posterior análise a fim de se conferir a composição do material aferida com a bula do material – vide Figura 13.

5 RESULTADOS

5.1 Artigo 1 (Artigo submetido THE JOURNAL OF PROSTHETIC DENTISTRY em 22/05/2024)

- Does repeated firings change lithium disilicate CAD color and translucency parameters?

This article is based on a thesis submitted to the postgraduate program in dentistry of the State University of Ponta Grossa in partial fulfillment of the requirement for the Doctor of Science degree.

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ABSTRACT

Statement of problem. Repeated firings cause materials to be exposed to additional heat treatments. The effect of these additional firings on optical properties of all levels of translucency of lithium disilicate CAD ceramic is not fully known. **Purpose.** The purpose of this in vitro study was to determine the effects of repeated firing on the color and translucency of lithium disilicate glass ceramic milled in 1mm thickness commonly indicated for veneers. The null hypothesis is that there is no significant difference in color and translucency properties for all specimens after repeated firings. **Material and Methods.** A total of 90 rectangular lithium disilicate specimens (5 x 6 x 1 mm) with 1.0 ± 0.1 mm thickness were used in this study, divided in 3 groups according to manufacturer three levels of translucency (HT, MT, LT) and each group in 9 subgroups (n=10) according to a different number of firings (1x,2x,5x). After firings, the Cie*Lab color parameters were checked and a ΔE and ΔTP was calculated. The specimens were analyzed with scanning electron micrograph (SEM). Data were computed and analyzed with analysis of variance (ANOVA) and Tukey test were used for statistical analysis. The results were determined at significance level of 95% ($p < 0.05$). **Results.** There were significant differences in *L, *a and *b parameters for HT, MT, and LT at all firings periods ($p < 0.05$). The highest ΔE values were found after 5th firing in the comparison of HT1x/HT5x and the lowest in LT1x/LT5x. The MT specimens from 1st to 2nd firing (MT1x/MT2x) was the lowest ΔE values found comparing all groups. The ΔTP comparison after 5th firings, the MT and LT showed no significant differences with almost identical optical behavior ($p > 0.05$). The ΔTP of HT5x hit the highest values. All specimens of HT, MT and LT ΔE values were over perceptibility threshold (PT >1.2) after 5th firing(5x). However, the ΔE values of MT and LT did not exceed the acceptability threshold (AT >2.7) after 5th firing. The HT ΔTP values also were higher than the parameters set for AT. **Conclusions:** The results showed that the color and translucency parameters of IPS E. maxCAD CAD were affected by repeated firings. For monolithic veneers with 1mm thickness requiring up to two firings, MT group had the lowest color variation. Comparing 1x to 5x firings, LT group had the smallest color variation. HT group should be used with caution for more than one firing because its color has a markable alteration after it.

CLINICAL IMPLICATIONS

This study will provide more information about the influence of subsequent firings on the optical properties of the monolithic lithium disilicate ceramic in the three main CAD manufacturer variations of translucency -HT, MT and LT.

Certainly, this research work will bring greater subsidies for professional to be aware of possible changes that material could suffer after firings in daily use thus corroborating for a better resolution of treatments. It can be helpful for future development of computer algorithm models of predicting the final color of lithium disilicate after repeated firings.

INTRODUCTION

In recent decades, the materials used in general dentistry have advanced greatly, but this is even more true especially in the field of prosthodontics where the application of technology and improvement of materials is clear.^{1,2,3} Over the last few years, the almost total manual craftsmanship involved in making a dental prosthesis.⁴ has given way to a process involving milling technology. The use of computer aided and manufacturing technology (CAD/CAM) in dental restoration area has strongly increased³ because it allows the professionals to fabricate high-quality restorations from ceramic blocks with more accuracy, efficiency, rapidly and with less errors comparing to the conventional methods.^{5,6,7}

Presently, clinicians have access to numerous chairside CAD-CAM technology iterations, enabling the swift creation of precise ceramic restorations during a single appointment. This process saves considerable time and effort compared to traditional methods.³

One of the most widely used ceramic materials among dentists in this new era of digital prosthodontics is the lithium disilicate (LD)¹. It is ranked among the top 3 choices for anterior crowns corresponding to majority preference with 54% of dentists in USA⁸. It's been available for CAD-CAM systems since 2006, in the form of pre-crystallized ceramic blocks (the blue phase) under the brand name IPS e.maxCAD (Ivoclar Vivadent, and Schaan of Liechtenstein) and they are offered for digital use in diverse sizes and shades on three versions HT, MT and LT according to levels of translucency (high, medium and low translucency). In the blue phase - a crystalline

intermediate stage- the e.maxCAD CAD blocks can be processed very easily in a milling machine, though after they are milled the restoration needs to be crystallized in ceramic furnace to achieve the final physical properties, such as the strength of 380 MPa (typical average value) and the corresponding optical properties that are achieved through the transformation of the microstructure.

One of the great qualities of the LD is the great esthetics combined to strength of the monolithic restorations around 360 MPa that certainly makes it a preferred choice among professionals⁹. Another one, is that the glass matrix of lithium disilicate can be etched with hydrofluoric acid and chemically bonded to tooth structure with a silane primer and adhesive resin cement¹⁰, giving to it an extra advantage compared to other ceramics because it can be indicated safely for veneers¹¹. Besides that, the marginal adaptation of lithium disilicate restorations seems to be efficient enough to contribute to longevity^{12,13}

The day-to-day use of monolithic restorations with LD, it initially involves choosing a dominant color¹⁴, but most of the time a final stage of personalized staining is required (external characterization) with the application of colored pigments on the ceramic surface. This phase of characterization should be mandatory for better color match.^{15,16} Those pigments are presented as pastes, and they can be fired together or after the crystallization of the lithium disilicate ceramic.

Traditionally, dentists use ceramic analog color scales as a reference to take the color of the teeth to proceed with the execution of the prosthesis, seeking the best possible quality of naturalness of the treatment. Some studies confirmed the hypothesis that the results for visual shade matching exhibits a high to moderate level of inconsistency, and the VITA Classical shade guide was not designed for monolithic ceramics.^{17,18} However the use of digital color measurement has increased in popularity over the years in dentistry for shade evaluation and selection.¹⁹ It provides objective and quantitative data, reducing the bias of visual subjectivity. For this reason, nowadays the dentist can take the L^* , a^* , b^* coordinates with more accuracy in order to select the best ceramic shade that will match to restore as much as natural the original color of the tooth.^{17,20,21} The most known and used appliance for this purpose is named Easy Shade (Vita Zahn Fabrik)- a portable and compact spectrophotometer.¹⁹

In color science, the Cie L a b coordinate system is routinely used in color measurement as a reference. The L^* axis symbolizes darkness and lightness ranging from black and perfect white. The a^* axis symbolizes green in negative coordinates

and red in positive coordinates. The b^* axis symbolizes yellow in positive coordinates and blue in negative coordinates²². These coordinates parameters include 3 values ($L^*a^*b^*$) in a 3-dimensional color space. The numerical distance between $L^*a^*b^*$ coordinates of 2 colors or in the same object before and after different conditions is represented by ΔE . This color difference formula (ΔE) is designed to give a quantitative representation of the perceived color difference between a pair of colored specimens. Thus, the quality of color match between dental restoration and an adjacent natural tooth correlates mostly with the magnitude and direction of color difference. Translucency in esthetic restorative materials influences color harmonization with the surrounding or adjacent teeth and restorations. There are three kinds of translucency indicators commonly used in the field of esthetic prosthodontics, transmittance (T), the contrast ratio (CR), and the translucency parameter (TP). Among these three indicators, the TP value is generally considered to be more applicable to the visual evaluation of translucency²³, and is calculated as the color difference from a white and black background in a uniform thickness of a substance. Although monolithic restorations of lithium disilicate have a big popularity in dental applications, there are some answers that have not been fully answered. The concern about the interference and impact of firings on ceramics has been around for decades^{24,25}. Despite of this, there are few numbers of studies on the effect of repeated firings on the final color and translucency of those LD restorations.^{26,27,28,29,30} If there is any influence on that, it could have a negative impact on the expected clinical results in esthetic terms and also bringing frustration to clinicians and patients. In the same way, it's not totally clear the behavior of LD facing the burning process, according to translucency levels (HT, MT, LT)^{31,32,33,34}.

The aim of this study is to evaluate the optical properties stability of CAD-CAM lithium disilicate after required sintering processes and additional firings.

The first null hypothesis is that CAD-CAM lithium disilicate will show no difference on its color after repeated firings among the three groups and subgroups of study.

The second null hypothesis is that CAD-CAM lithium disilicate will show stable values on its translucency reference parameters, still inside the Translucency Perceptibility Thresholds -TPT and Translucency Acceptability Thresholds- TAT after repeated firings between the three subgroups of study(1x-2x-5x).

MATERIALS AND METHODS

Sample characterization and distribution of experimental Groups of the Study

Six A2 shaded lithium disilicate blocks (LD) were used in this study, two of each translucency manufacturer variation of IPS e. maxCAD: 2 blocks of high translucency (HT); 2 blocks of medium translucency (MT) and 2 blocks of low translucency (LT); size C14 -12x14x18 mm (Ivoclar Vivadent)- as shown in Figure 1. The composition of the LD CAD block is displayed in Table 1. Each CAD/CAM block were primarily cut into slices (12 × 14 × 1 mm) using a low speed cutting machine (Isomet® Buehler, USA). To do that, the blocks were embedded in polyvinyl chloride (PVC) filled with sticky wax (Asfer, SP, Brazil), leaving the long axis of the material surface as shown in Figure 2. So, each slice was divided to compose the specimens as symmetrical as possible into 4 small pieces (5 x 6 x 1 mm) with 1.0 ± 0.1 mm thickness. A total of 90 specimens were obtained and selected for color tests measurement and SEM-EDS Analysis. The study selected the thickness value of 1mm based on previous studies³⁵ and according to the manufacturer's instructions and indication for a conservative and safety thickness for veneers. Besides that, there were studies^{36,37,38,39} that showed that the thickness of the ceramic restoration affected the final color, therefore, since it would not be the focus to investigate this variable, it was decided to use that single value in this study. All specimens were manually polished on one side only, using water sandpaper (320,400,600 grit, 3M -Brazil) with a thin film of polishing paste (Universal Polishing paste, Ivoclar Vivadent) for 10 seconds of smooth friction for each sandpaper grit used. The thickness of each specimen was controlled with a digital pachymeter (Mitutoyo, Kawasaki, Japan). Those 90 lithium disilicate specimens were cleaned and washed in distilled water immersed in ultrasonic cleaner for 10 minutes and dried out using absorbent papers (coffee cloth). Then they were equally distributed first in 3 experimental groups according to their manufacturer informed degree of translucency (HT, MT, LT) and afterwards in three subgroups as it follows: Group 1 (n=10) only 1 firing; Group 2 (n=10) - 2 firings and Group 3(n=10)- 5 firings. For all groups, no glaze paste was applied at any stage of the study. The specimens of each group were subjected to the firings using a ceramic furnace- EP3000 -Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer's preset programs (for IPS e. maxCAD for crystallization and IPS e. maxCAD glaze and

characterization) -Table 2 and 3. The color of each specimen was checked twice on white and black backgrounds using the Vita Easy shade spectrophotometer (ES) - Vident, Brea, CA, USA. Optical contact between the specimen and the backgrounds was improved by using an interfacing layer of a polyethylene glycol solution (Amanda Handling Pharmacy, Brazil). The measurement area of interest for shade matching was the middle of the specimen.

For calibration purposes the same person took the color measures using the ES. Those measures are according to the CIE L^* , a^* , and b^* parameters of color coordinated by the Commission Internationale de l'Eclairage -CIELAB color, where L^* indicates lightness (0 to 100), and a^* and b^* indicate the levels of red ($+a^*$), green ($-a^*$), yellow ($+b^*$), and blue ($-b^*$). Figure 2. The L^* , a^* , and b^* values of the black and white background employed in this study were $L^*=2.95$, $a^*=0.27$, and $b^*=1.28$ for the black background, and $L^*=92.84$, $a^*=-0.13$, $b^*=1.59$ for the white background. The color comparison before and after the repeated firings of specimens was assessed through the differences (ΔE and ΔE_{00}) that were observed between the two colors. Such differences were calculated with the formula: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ and the variations in Translucency Parameters (ΔTP and ΔTP_{00}) were compared with recently

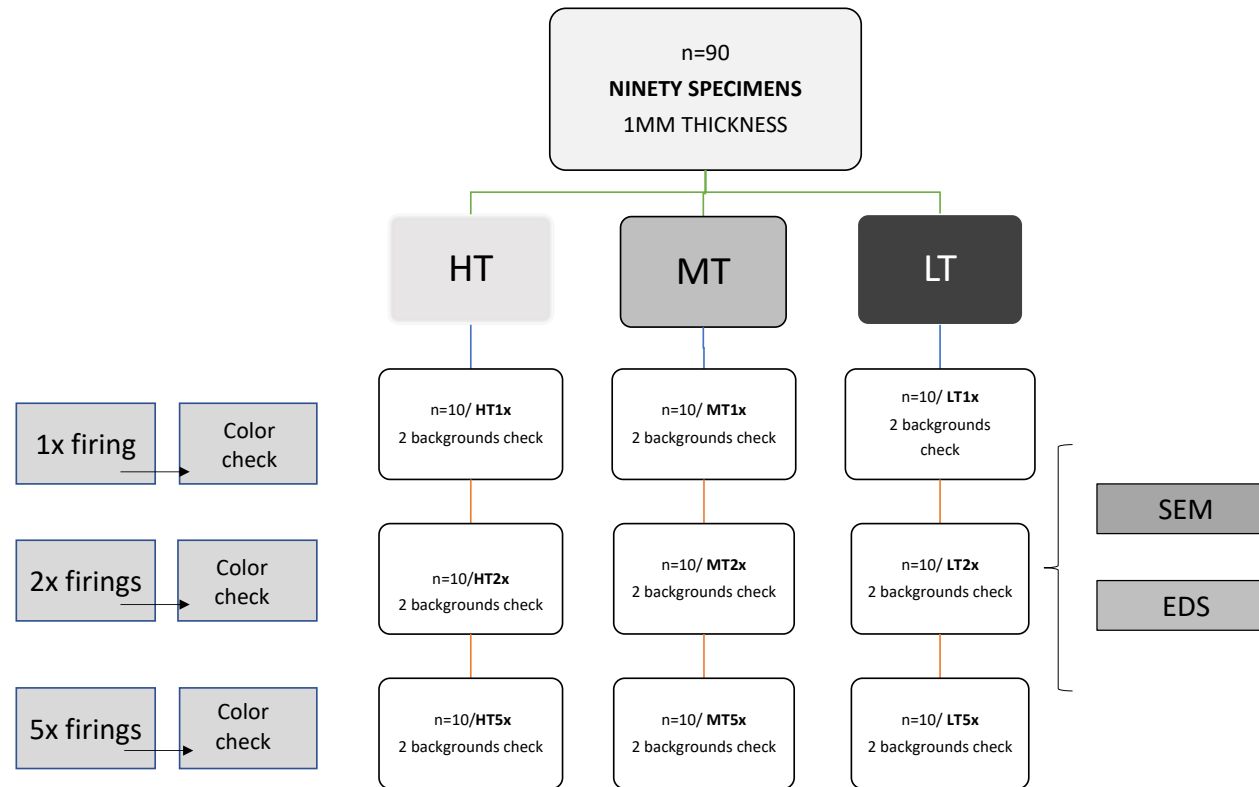
$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C}\right) \left(\frac{\Delta H'}{K_H S_H}\right)}.$$

reported 50:50% translucency difference thresholds Translucency Perceptibility Threshold (TPT) and Translucency Acceptability Threshold (TAT). Reliable translucency thresholds have been recently determined based on a study (SALAS *et al.*, 2018). The translucency levels was calculated using the formula for translucency parameter as follows the equation $TP = ([L^*_B - L^*_w]^2 + [a^*_B - a^*_w]^2 + [b^*_B - a^*_w]^2)^{1/2}$. Where w and B are color coordinates of the specimens on the white and black backgrounds. In addition, CIEDE2000 (1:1:1) color difference formula was also used to calculate the translucency parameter (TP_{00}) (Salas *et al.*, 2018) :

$$TP_{00} = \left[\left(\frac{L'_B - L'_W}{K_L S_L} \right)^2 + \left(\frac{C'_B - C'_W}{K_C S_C} \right)^2 + \left(\frac{H'_B - H'_W}{K_H S_H} \right)^2 + R_T \left(\frac{C'_B - C'_W}{K_C S_C} \right) \left(\frac{H'_B - H'_W}{K_H S_H} \right) \right]^{1/2}$$

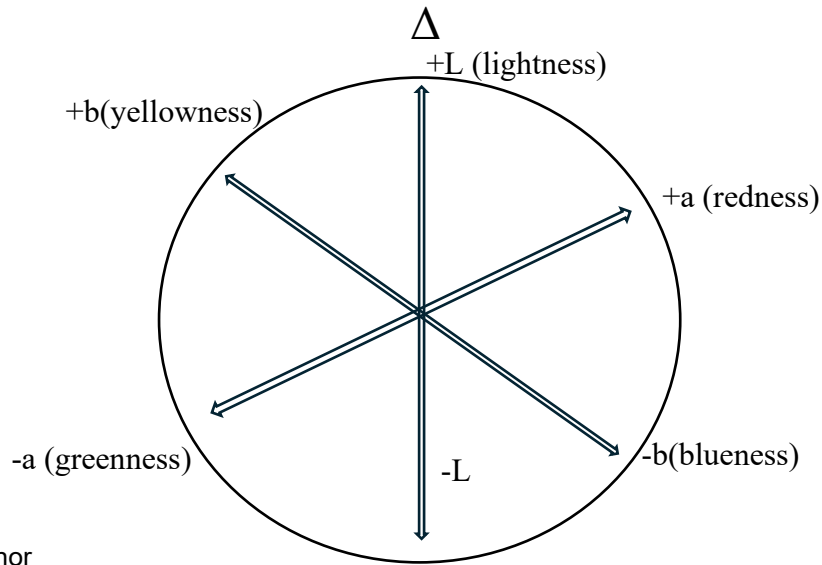
where the subscripts “B” and “W” refer to lightness (L^*), chroma (C^*) and hue (H^*) of the specimens over the black and the white backgrounds, respectively. R_T is the rotation function that accounts for the interaction between chroma and hue differences in the blue region. Weighting functions, S_L , S_C , S_H adjust the total color difference for variation in the location of the color difference specimen over the B and W backgrounds in L^* , a^* , b^* coordinates and the parametric factors, K_L , K_C , K_H , are correction terms for experimental conditions. To calculate using the CIEDE2000 color difference formula, discontinuities due to mean hue computation and hue difference computation were considered.⁴⁰ Higher TP values represent higher translucency (transparent), and low values represent lower translucency (opaque). Based on previous studies, at least 8 specimens in each group were required for this study.^{36,41,42} Therefore the sample size for each subgroup with 10 specimens was calculated and confirmed using an analysis power software (G*Power v3.1.9; HeinrichHein- Universität Dusseldorf), considering an α equal 0.05, effect size of 0.50 and power of 80% according to ANOVA test and Tukey posttest was used to determine whether the differences originated by conjunction. The data were analyzed by using a statistical software program -Jasp Team (2024), Jasp (Version 0.18.3- Computer software)

Figure 1 - Study Design for high-translucency (HT), medium translucency (MT) and low translucency (LT) ceramics.



Source: The Author

Figure 2 - A simple diagram of the CIE L*a*b* system. The color is in the conjunction of the three axis



Source: The author

Table 3. Composition of lithium disilicate (IPS e.maxCAD Ivoclar Vivadent)

Technical specifications	
Chemical composition	
SiO ₂	57.0 – 80.0 %
Li ₂ O	11.0 – 19.0 %
K ₂ O	0.0 – 13.0 %
Other oxides	0–8 %
Physical material data	
Coefficient of expansion (100 – 400°C)	$10.15 \pm 0.4 \cdot 10^{-6} \text{ K}^{-1}$
Coefficient of thermal expansion (100 – 500°C)	$10.45 \pm 0.4 \cdot 10^{-6} \text{ K}^{-1}$
Flexural strength (biaxial)	$\geq 360 \text{ MPa}$
Density	$2.5 \pm 0.1 \text{ g/cm}^3$

Source: The author

RESULTS

Cie*Lab parameters

Tables 2 shows the lightness (***L**) **color parameter values** on the black and white backgrounds after the firing cycles. The highest mean values for the parameter of lightness on the black background were found after the 2nd firing cycle in LT2x and the lowest mean values in HT5x. As for the white background, the MT specimens didn't

modify the mean values after all firing cycles and the lowest average value obtained was also found in subgroup after 2 firings but in LT2x. There was a statistically significant difference in *L mean values from the first to the second firing ($HT1x \neq HT2x$; $MT1x \neq MT2x$; $LT1x \neq LT2x$, $p \leq 0.05$) among HT, MT, LT on the black background, which only occurred for the HT specimens on the white background ($HT1x \neq HT2x$ $p \leq 0.05$).

Table 4 : Mean $\pm$ standard deviation of CIE*L*A*B parameters values on black and white backgrounds after one firing (1x), two firings (2x) and five firings (5x). Capital letters means statistically differences in columns and small letters means significant differences in rows, comparing black and white backgrounds individually.

BACKGROUND BLACK/WHITE	HIGH TRANSLUCENCY		MEDIUM TRANSLUCENCY		LOW TRANSLUCENCY	
Cie *L*a* b Firings Comparisons						
	black	white	black	white	black	white
*L (HT1x,MT1x,LT1x)	76.15 ± 2.07 Aa	99.92 ± 0.13 Cc	72.90 ± 0.8 Ab	100 ± 0.0 Cc	75.19 ± 2.09 Aa	99.43 ± 0.57 Cc
*L (HT2x MT2x,LT2x)	73.56 ± 1.18 Ba	99.31± 0.59 Dc	74.80 ± 1.09 Bb	100 ± 0.0 Cd	77.90 ± 0.80 Ba	97.44± 0.70 Ce
*L (HT5x MT5x,LT5x)	72.87 ± 1.24 Ba	99.98 ± 0.71 Dc	76.63 ± 1.10 Cb	100± 0.0 Cd	77.14 ± 1.35 Cc	100 ± 0.0 Cd
*a (HT1x,MT1x,LT1x)	-1,32 ± 0.61 Aa	-0.70 ± 0.61 Cc	-2,16 ± 0.14 Ab	-0,42 ± 0.24 Cc	-1,92 ± 0.25 Ab	-0,70 ± 0.24 Cc
*a (HT2x MT2x,LT2x)	-3,65 ± 0.75 Ba	-1.91± 0.14 Dc	-1,44 ± 0.32 Bb	-0,84 ± 0.18 Dd	-2,16 ± 0.14 Bc	-0,95 ± 0.14 Cd
*a (HT5x MT5x,LT5x)	-2,20 ± 0.16 Ca	-1.84 ± 0.14 Dc	-1,91 ± 0.09 Cb	-1,30± 0.11 Ed	-2,56 ± 0.16 Bc	-0,22 ± 0.04 De
*b (HT1x,MT1x,LT1x)	2.12 ± 0.98 Aa	10.69 ± 1.01 Cc	12.36 ± 0.6 Ab	14.23 ± 0.75 Cd	11.42 ± 1.48 Ab	23.56 ± 1.34 Ce
*b (HT2x MT2x,LT2x)	4.04 ± 0.85 Ba	13.97 ± 0.77 Dc	4.89 ± 1.16 Ba	14.96 ± 1.04 Cc	12.36 ±0.61 Ab	25.07 ± 0.60 Dd
*b (HT5x MT5x,LT5x)	3.65± 0.75 Ba	13.61 ± 0.58 Dc	6.63 ± 0.57 Cb	17.10± 0.64 Dd	9.57 ±0.26 Bc	21.38 ± 1.04 Ee

Table 2 shows the redness- greenness (***a**) **color parameter values** on the black and white backgrounds after the firing cycles. The HT specimens showed no significant statistical difference among 1x, 2x and 5x on the black background. The MT specimens showed significant statistical difference after 5th firings cycles on 5x (MT5x $\neq$ MT2x; MT5x $\neq$ MT1x). The same occurred to LT but after 2nd firing on LT2x $\neq$ LT1x. On the white background, the *a parameter showed significant statistical difference between HT1x $\neq$ HT2x) but showed no difference between the 2nd and 5th firings cycles, HT2x=HT5x), the MT specimens showed significant statistical differences in all groups (MT1x $\neq$ MT2x $\neq$ MT5x) and LT showed difference LT1x $\neq$ LT5x, LT2x $\neq$ LT5x).

Table 2 shows the yellowness-blueness (***b**) **color parameter values** on the black and white backgrounds after the firing cycles. There was no statistical difference in all groups for the HT on black background. In the MT specimens the subgroup after 2x firings showed significant statistical difference compared to 1x and 5x firings (MT1x $\neq$ MT2x/ MT2x $\neq$ MT5x), and in the LT, it occurred in 5x compared to 1x and 2x firings (LT5x $\neq$ LT2x / LT5x $\neq$ LT1x). On the white background, different from what occurred on the black background, in HT the HT1x showed a significant statistical difference compared to 2x and 5x firings (HT1x $\neq$ HT2x/ HT1x $\neq$ HT5x). In the MT specimens, 5x firings showed significant statistical difference compared to 1x and 2x (MT5x $\neq$ MT1x/ MT5x $\neq$ MT2x) and in the LT, it occurred in 2x firings compared to 1x and 5x (LT2x $\neq$ LT1x / LT2x $\neq$ LT5x).

ΔE and ΔE_{00} values comparison

Table 3 shows the ΔE and ΔE_{00} values on the black background for HT, MT and LT specimens. The highest values were found in the HT on HT1x/HT2x and HT1x/HT5x comparison ($\Delta E= 3.4$ / $\Delta E_{00} =2.8$ - $\Delta E= 3.7$ / $\Delta E_{00} =3.0$ respectively). In contrast, HT showed the least variation between the 2nd and 5th firings ($\Delta E= 0.5$ / ΔE_{00}

=0.3- white background). The lowest values were found in the MT specimens from 1st to 2nd firings (MT1x/MT2x- $\Delta E = 0.3$ / $\Delta E_{00} = 0.3$). When comparing the 1st with 5th firings, the lowest ΔE and ΔE_{00} values were found in the LT specimens (LT1x/LT5x - $\Delta E = 1.3$ / $\Delta E_{00} = 0.9$).

Table 3 shows the ΔE values on the white background for HT, MT and LT specimens. The optical behavior had similarities among the three Groups compared to black background, which means that the highest values were also found in the HT1x/HT2x and HT1x/HT5x ($\Delta E = 4.5$ / $\Delta E_{00} = 3.1$ - $\Delta E = 4.1$ / $\Delta E_{00} = 2.9$ respectively). The lowest ΔE and ΔE_{00} values comparing the 1st to 5th firings-LT1x/LT5x-were found in the LT specimens ($\Delta E = 1.3$ / $\Delta E_{00} = 0.9$). MT specimens had a minor change from the 1st and 2nd firings, as well ($\Delta E = 0.8$ / $\Delta E_{00} = 0.6$).

ΔTP and ΔTP_{00} values comparison

Table 4 shows the ΔTP and ΔTP_{00} values comparison. The highest values were found in the HT, specifically after 5th firings in HT5x ($TP = 28.9$ / ($TP_{00} = 19.1$). In comparison after 5th firings, the MT and LT had practically identical results ($TP = 25.6$ / $TP_{00} = 16.5$ - $TP = 25.8$ / $TP_{00} = 16.4$, respectively). However, LT showed the minor ΔTP values after 2 firings in LT2x ($TP = 23.3$ / $TP_{00} = 14.4$).

Table 5 - Mean $\pm$ standard deviation of ΔE values on black and white backgrounds after firings and the perceptibility threshold (PT) and acceptability threshold (AT) as references.

BACKGROUND BLACK & WHITE	HIGH TRANSLUCENCY				MEDIUM TRANSLUCENCY				LOW TRANSLUCENCY			
	Black		White		Black		White		Black		White	
Comparison	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}
1 st to 2 nd	3.4	2.8	4.5	3.1	0.3	0.3	0.8	0.6	2.8	2.0	2.8	2.0
2 nd to 5 th	0.8	0.6	0.5	0.3	2.6	2.0	2.2	1.4	1.9	1.4	1.9	1.4
1 st to 5 th	3.7	3.0	4.1	2.9	2.3	1.8	3.0	1.9	1.3	0.9	1.3	0.9
PT	1.2	0.8	1.2	0.8	1.2	0.8	1.2	0.8	1.2	0.8	1.2	0.8
AT	2.7	1.8	2.7	1.8	2.7	1.8	2.7	1.8	2.7	1.8	2.7	1.8

PT: Perceptibility threshold; AT: Acceptability threshold

Table 6 - ΔTP and ΔTP_{00} values after comparison of subgroups (1x, 2x, 5x firings) on black and white backgrounds of high translucency, medium translucency and low translucency lithium disilicate specimens.

BACKGROUND BLACK & WHITE	HIGH TRANSLUCENCY		MEDIUM TRANSLUCENCY		LOW TRANSLUCENCY	
Comparison	TP	TP ₀₀	TP	TP ₀₀	TP	TP ₀₀
1x	25.3	16.6	27.2	17.8	27.1	17.1
2x	27.7	18.4	27.1	17.7	23.3	14.4
5x	28.9	19.1	25.6	16.5	25.8	16.4
1 st to 2 nd	2.4	1.8	-0.1	-0.1	-3.8	-2.7
2 nd to 5 th	1.2	0.7	-1.5	-1.2	2.5	2
1 st to 5 th	3.6	2.5	-1.6	-1.3	-1.3	-0.7
TPT* references	1.33	0.62	1.33	0.62	1.33	0.62
TAT** references	4.43	2.62	4.43	2.62	4.43	2.62

* TPT : translucency perceptibility threshold / **TAT: translucency acceptability threshold

Scanning electron microscopy (SEM) and Energy-Dispersive Spectroscopy (EDS) analyses.

Although the SEM images are qualitative biased, it is not difficult to realize that (figures 3,4,5,6 and 7) there is a slight difference in the accommodation of the disilicate crystals in the glass matrix among the groups (HT, MT, LT). Mainly, after several firings, it is possible to observe in the HT group an image with a kind of melting of layer of the glass matrix. The MT specimens seemed almost unaltered after the firings. The HT specimens seemed to have more spaces opened in the glass matrix after several firings. The LT group showed a well compacted network of glassy matrix with nearly no gaps between the crystals and the matrix.

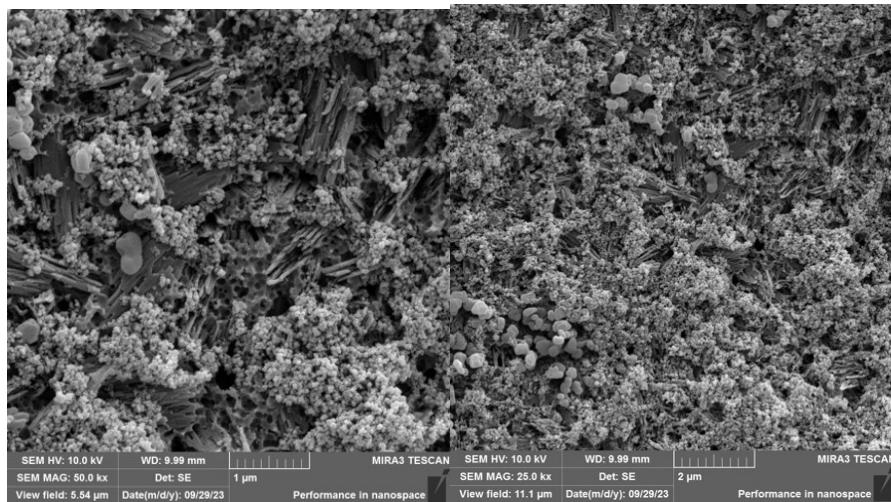
The energy dispersive spectroscopy (EDS) technique is mostly used for qualitative analysis of materials but can provide semi-quantitative results as well.

The data of EDS confirmed the manufacturer information about composition of LD- Figure 8,9 and 10. It was found a discreet difference in composition of the LT specimen. Lithium was not detected. It is the lightest solid element, with atomic number of 3. As a result, it can't be detected by conventional EDS detectors. Although lithium

atoms also emit characteristic X-rays when excited, these are so low energy that they cannot be detected. Consequently, when creating an EDS map of a sample containing lithium, only the other elements are mapped, but lithium itself is "invisible." Although alternative methods have been proposed in the scientific literature to quantify lithium as well, these require special equipment and are therefore very complex and expensive.

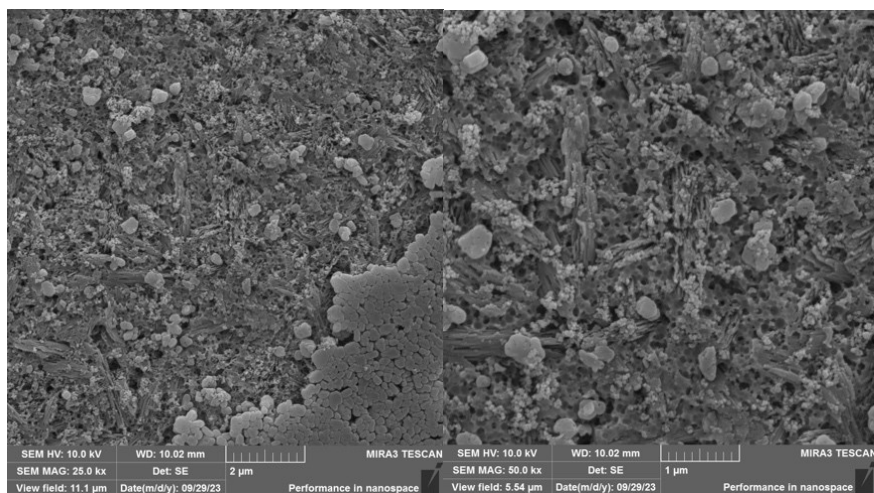
Scanning Electron Microscopy- SEM images

Figure 3 - HT specimen after 1st firing



Source: The author

Figure 4 - HT specimen after 5th firing



Source: The author

Figure 5 - MT specimen after 1st firing

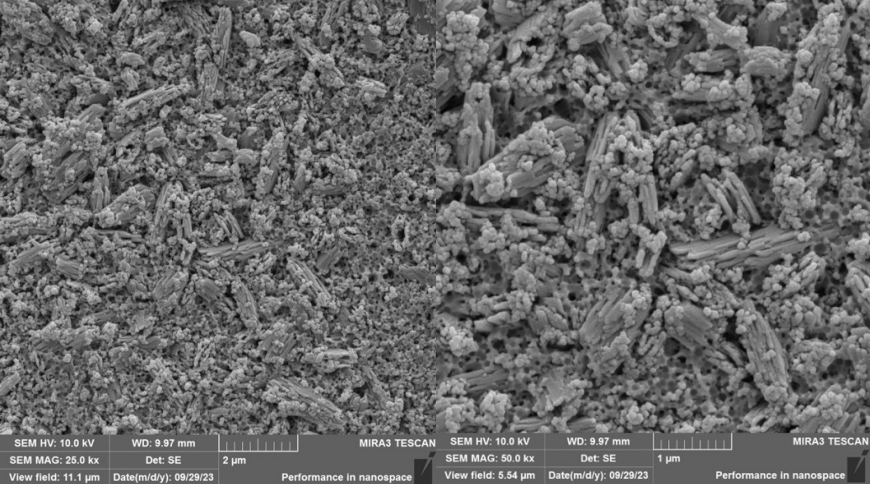
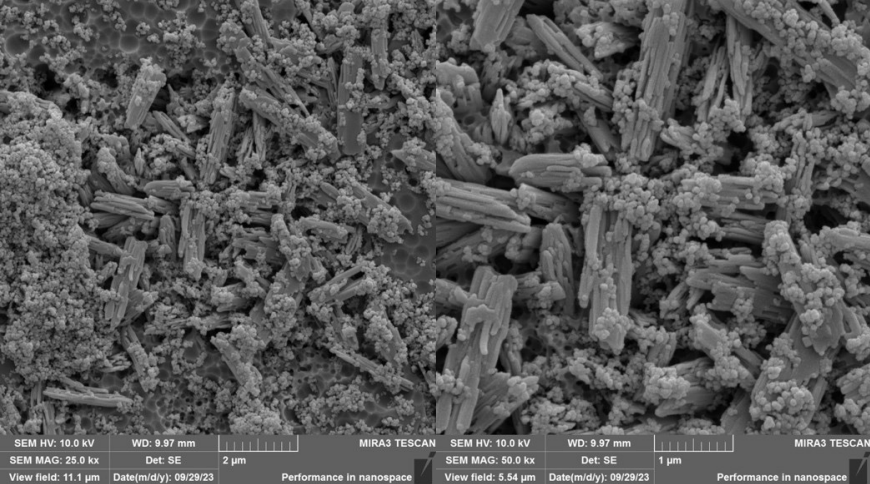
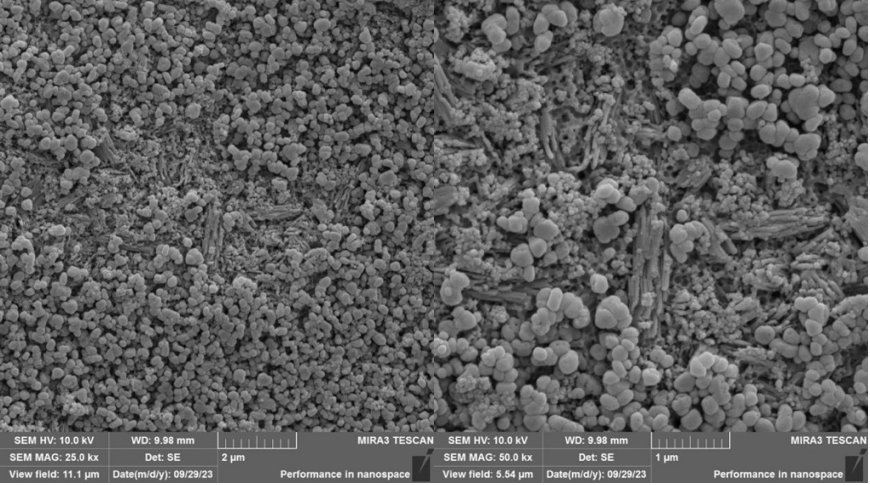


Figure 6 - MT specimen after 5th firing



Source: The author

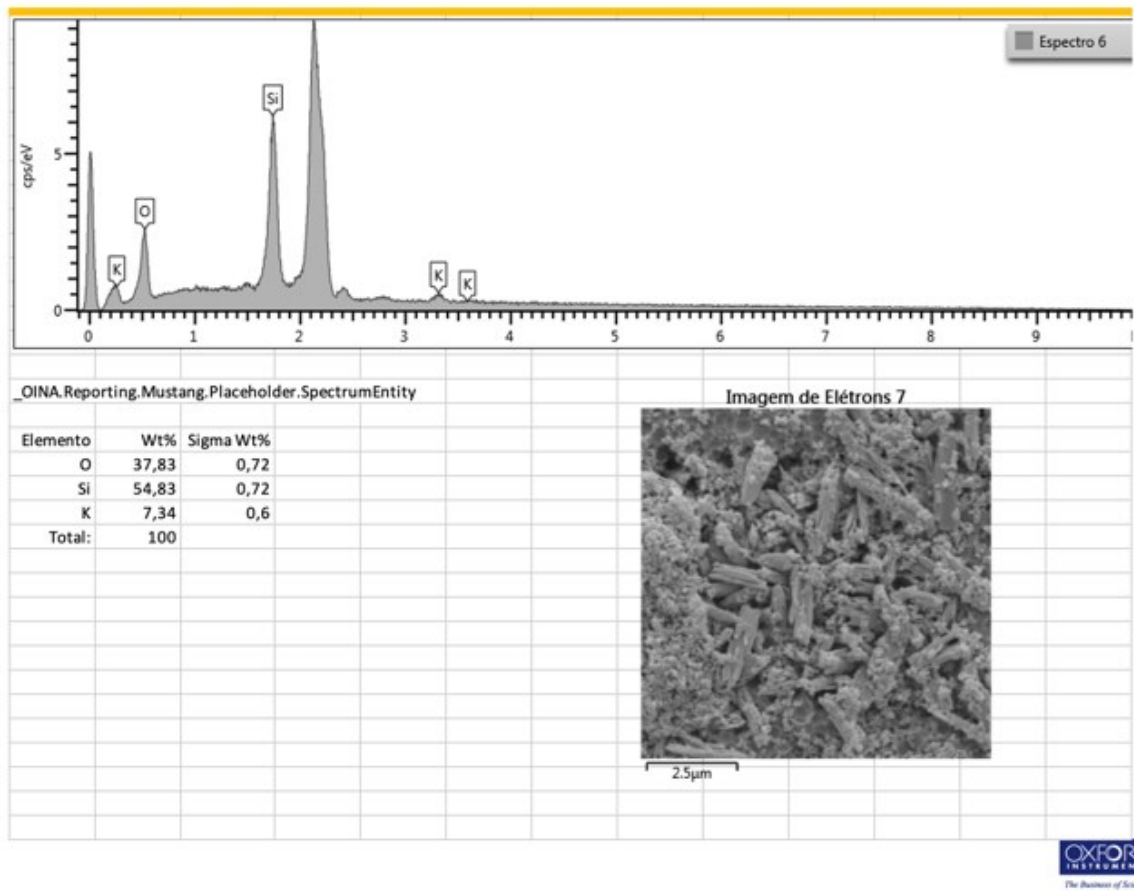
Figure 7 - LT specimen after 5th firing



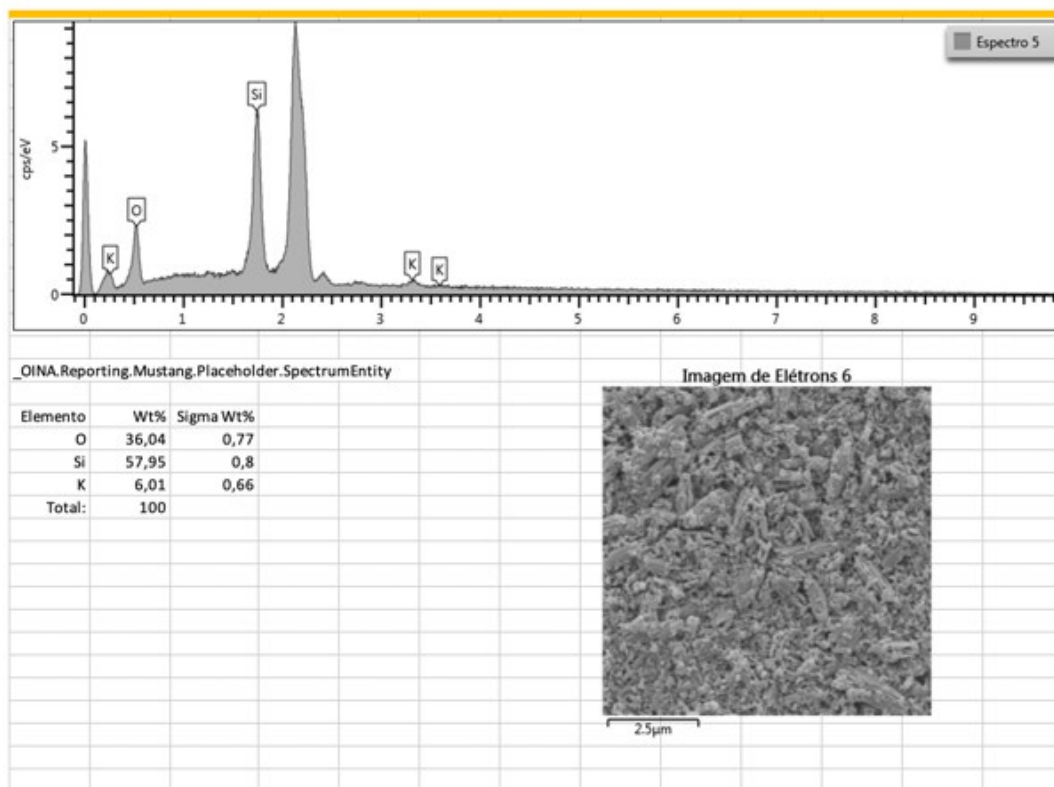
Source: The author

Energy dispersive X-ray spectroscopy (EDS) analyses

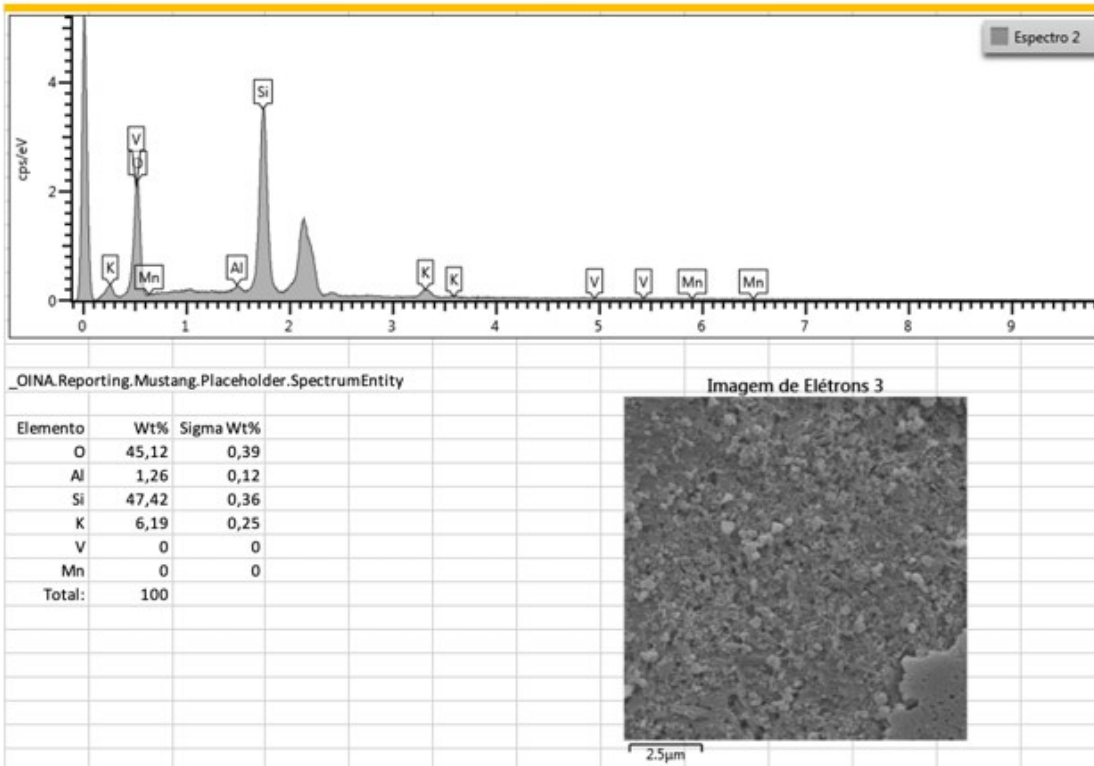
Figure 8 - HT group specimen after 5th firing



Source: The author

Figure 9 - MT group specimen after 5th firing

Source: The author

Figure 10 - LT group specimen after 5th firing

Source: The author

DISCUSSION

The first null hypothesis of this study was rejected. Some changes in the color parameters for lithium disilicate were significantly affected by repeated firings. Although the white and black backgrounds were used mainly to calculate the TP²³, the presentation of the results in separate tables can be important in this study due to have a better comprehension of the data. The results for each type of background are relevant for better comprehension of the optical behavior of disilicate specimens when confronted with these 2 opposing colors (black and white). This could be seen as a situation that normally occurs in the day-to-day life of the dental professionals when faced with lighter and darker dental remnant substrates, where the ceramic veneers are fitted.

As results showed the lightness *L parameter was affected by subsequent firing cycles, especially after two and five firings. When interacting with black background, LT specimens after 2nd firing became lighter with the values increasing and HT became more grayish. After 5th firing, there were no significant statistically difference between HT and MT specimens, but there was a difference comparing to LT. In previous studies, it was demonstrated that *L values decreased due to repeated firings.^{42,43} There were studies that differed from those results^{23,25,44} Interestingly, it is important to mention that not all of studies used lithium disilicate in their tests.⁴³ Nevertheless there have also been studies where it was verified a significant change in the *L parameter after three firings when the material studied was lithium disilicate pressable ingots form (for injection technique)²⁶ and others using alumina and powder ceramics after seven firings^{42,44}. This difference found in the results among studies could be attributed to the process of manufacturing the LD and the fact that in the present study, standard blocks of pre-crystallized matrix (e. maxCAD) were used, and that meta disilicate form should promote a different arrangement of crystals in the glassmatrix,⁴⁵ which could impact on this *L parameter evolution after firings.

The *a parameter had no significant statistical difference in 1x firing subgroups comparing HT, MT, LT. But after 5th firings, this difference between those three sort of specimens could be observed. In interaction with the black background, the HT and LT had the mean values increased, became greener but MT tended towards red. When interacting with the white background, the HT and MT became greener, and LT tended towards red. These results are also corroborated by previous studies.^{42,43}

The a^* parameter showed no significant statistical difference in 1x firing subgroups comparing HT, MT, LT on black background but on white background, this level of subgroup showed differences among the groups ($HTG1 \neq MTG1 \neq LTG1$). The values measured on white were higher than black background. On white background the specimens became more yellow and on black background they tended to be bluer after repeated firings.

The color changes after repeated firings may be associated with the color stability of metal oxides which are used as coloring agents. Some researchers have claimed that metal oxides cannot keep color stability after being exposed to firing process. It was still related that repeated firings break down metal oxides bond easily^{42,46}. Another related issue was in evidence back in the 1980s, where a experimental study⁴⁷ stated that the changes in color parameters of porcelain normally is caused by the filtering effects of translucent material over a backing result from interaction, at every wavelength, of optical scattering and absorption coefficients, the thickness of the translucent material, and the reflectance of the backing.

It's imperative that dental materials need to match and reproduce the color appearance of natural teeth to achieve desired esthetic outcome in an efficient manner. In this in vitro study, the results showed that there is a significant statistical difference in the parameters (Cie^* Lab) after repeated firings. The color changed among (HT, MT, LT) variations of LD. To the dentists, dental ceramists and dental technicians, the knowledge of this optical behavior makes it possible to be alert to this and it takes on a position of great importance in clinical dentistry and dental research as well.

The color difference values ΔE showed a discrepancy between the types of specimens (HT, MT, LT) and between the different firing subgroups 1x,2x,5x. The ΔE represents the numerical distance measured between the L^* a^* b^* coordinates of 2 colors. Under ideal observation conditions, a color match between two colors cannot be judged when the ΔE value of colors is less than 1 ($\Delta E < 1$). When the measured color differences are within 1 to 2 ΔE range, correct judgments are frequently done by observers. When ΔE values are greater than 2 ($\Delta E > 2$), all observers can detect a color difference between the two colors. The smallest perceptible color difference- a perceptibility threshold (PT)- refers to the smallest difference that can be detected by a casual observer. A classic article of color differences for discriminating mismatch between composite and tooth color⁴⁸ was reported a AT parameters (acceptability

thresholds) which was $\Delta E = 2.18$ for dentists; $\Delta E = 1.78$ for dental auxiliaries; $\Delta E = 2.52$ for scientists and 2.69 for patients. In dentistry, the acceptability threshold for color difference is greater than the perceptibility threshold 49,50,51,52,53

Some studies have shown that color differences greater than one unit can be visually perceived only by 50% of human observers.^{54,55} Although there are studies suggesting different values for PT and AT^{39,52} the parameters of the color difference value considered in this study is supported by others research, which is PT/AT $\Delta E_{00} = 0.8/1.8$ and $\Delta E = 1.2/2.7$ respectively^{20,56}. In this study, a considerable alteration of color occurred in specimens. The results of ΔE on the black and white background in HT revealed values much higher than the reference for PT and AT after the first to second firings (G1/G2) and from the 1st to 5th firings G1/G3. From the 2nd firing to 5th firing the results were in the range of PT. It was found also in other study in which results revealed higher ΔE_{00} values with greater translucency ceramics, resulting in a lower quality shade match.

Although the MT specimens on the black and white background showed results above the perceptibility level (MT2x/MT5x- MT1x/MT5x); it is worth noting that they showed the lowest color change values for MT1x/MT2x, which means that there was no significant difference even after the second firing. This is a positive point because many professionals can carry out ceramic veneers with up to two firings.

The LT specimens in both backgrounds were those with the least color change between the first and fifth firing (LT1x/LT5x). It was found in other studies too⁵⁷. Those data can indicate an advantage in terms of the predictability of color results of veneers, especially if the professional foresees the need for multiple firings in the initial planning stage.

Other study comparing HT to LT lithium disilicate CAD/CAM showed results of ΔE for HT higher than LT, this is the same found in this study⁵⁷ and an article comparing the effect of abutment tooth on color of lithium disilicate CAD/CAM showed that darker colors resulted in increased ΔE values⁵⁸.

Another authors²⁵ showed a color change after 3 and 6 firings on layering porcelain but according to them an average color difference obtained ($E = 1$) would not affect color stability. However, a 2007 study⁴³ revealed that there were substantial changes in $L^*a^*b^*$ color data as the number of firings increased (3,5,7 firings), which resulted in perceptual color changes in $L^*a^*b^*$ color parameter. A 2023 study⁵⁹ showed

that one additional firing process can considerably increase the translucency of the lithium disilicate furthermore for IPS Emax CAD, two sintering processes displayed an increase in translucency. And it was concluded that the translucency was significantly influenced by the brand of lithium disilicate and the number of sintering processes.

It is essential to mention that clinically perceptible color changes did not occur in all subgroups of HT, MT, LT groups. This was certainly due to the variation of the composition of blocks ⁶⁰, however the manufacturer does not specify in detail those differences for each type of block in the material guide and instructions. It was found in this study a significant statistical difference between ΔE and ΔE_{00} mean values ($p < 0.05$). This is consistent with the fact that the formulas for calculating Δ -delta variations apply different methodologies for calculating, and this difference does not imply that the results are different, but rather points to this difference in sensitivity in detecting the variations.⁵¹ The CIEDE2000 formula provides better adjustments in color difference evaluation which means in all the correlation between evaluated and perceived color differences detects small differences when CIEDE2000 formula was used (ΔE_{00}) instead of the CIELab formula (ΔE).^{51,52}

The ΔTP and ΔTP_{00} values shows that HT specimens increased the translucency level since after the 2nd firing, and it scored the highest level among the three groups comparing the 1st and 5th firing ($\Delta TP = 3.6$ and $\Delta TP_{00} = 2.5$), tending to be grayer. The MT specimens kept the translucency almost unchanged after the 2nd firing and they tended to be less translucent comparing 1st to 5th firing ($\Delta TP = -1.6$, $\Delta TP_{00} = -1.3$). The LT blocks exhibited a high translucency change getting opaquer after 2nd firing ($\Delta TP = -3.8$ and $\Delta TP_{00} = -2.7$) and comparing the 1st to 5th firing the specimens tended to become opaquer as well ($\Delta TP = -1.3$ and $\Delta TP_{00} = -0.7$). It would probably turn the shade more evident.

The present study confirmed the variations in the translucency parameters (TP) among the groups of each lithium disilicate glass ceramic as disclaimed by the manufacture. However, in practical daily use, it was observed that lithium disilicate showed a large variation in translucency after the 2nd firing, except for the MT specimens. These data indicate that MT appears to provide the most predictable final translucency results when the veneer is finished in up to two firings.

FINAL CONSIDERATIONS

In this study only one shade (A2) of LD was used but it was chosen the three translucency variations of LD (HT, MT, LT) and two background were used (black and white). Thus, more ceramic shades and background color variations should be considered in future studies. Based on the literature search, only a few studies have addressed the optical properties of lithium disilicate glass ceramics, and no one evaluated the effect of translucency comparing the three manufacturer variations. The fact is that due to small differences in experimental designs and methodological conditions, it is difficult to state an exact comparison of results between this study and previous studies. In addition, a standard *Lab** for all shades is not available yet. The use of different backgrounds may provide more knowledge and insight into the influence of translucency interacting to backgrounds colors on LD glass ceramic. Moreover, measurements of the color differences in the thickness of 1mm could provide valuable information for dental professionals. Future studies should also consider different thicknesses, different shades, and the tooth form (flat, convex, concave). The aim of implementing a color reference after repeated firings is to give the north for a desired color after milling and burning process on the daily routine. If the color of a product doesn't meet the standard, customer satisfaction is compromised, and the amount of rework and costs increase. Establishing color tolerances objectively within the color quality process is the most effective way to guarantee consistency and accuracy to material and improvements over the years.

CONCLUSIONS

Within the limitations of this study, it was concluded that:

1. All the null hypotheses were rejected. The optical properties of lithium disilicate were affected by the repeated firings.
2. Repeated firings affected the $*L^*a^*b$ parameters in the three groups -1x, 2x and 5x firings
3. It was found statistically significant differences between the interactions of groups (HT, MT, LT) and the subgroups of study (1x,2x,5x) $p \leq 0.05$.

4. ΔE and ΔE_{00} values were above perceptibility and acceptability thresholds for HT LD specimens after repeated firings
5. ΔE and ΔE_{00} values were under perceptibility and acceptability thresholds for LT LD specimens, after repeated firings
6. ΔE and ΔE_{00} values were at the limit of the perceptibility and acceptability thresholds for MT LD specimens, after repeated firings
7. ΔTP and ΔTP_{00} values of HT LD specimens increased the translucency, and it scored the highest level among the three groups. LT decreased the translucency getting opaquer. MT almost unchanged the ΔTP and ΔTP_{00} values, it can be considered the more predictable after repeated firings.

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5.2 Artigo 2 : JOURNAL OF COLOR AND APPEARANCE IN DENTISTRY Artigo Submetido em 22/05/2024

The influence of glazing in lithium disilicate CAD color and translucency

This article is based on a thesis submitted to the postgraduate program in dentistry of the State University of Ponta Grossa in partial fulfillment of the requirement for the Doctor of Science degree.

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ABSTRACT

Statement of problem. It is not fully known the effects of glaze paste on optical properties of lithium disilicate (LD) CAD/CAM in the three levels of translucency of the manufacturer (HT, medium – MT and low - LT) and also if the exposure of LD to repeated firings could cause any change effects as well. Purpose. To evaluate the effects of glaze paste and repeated firing on the color and translucency of lithium disilicate glass ceramic milled in 1mm thickness commonly indicated for veneers. The null hypothesis is that there is no significant difference in color and translucency properties for all specimens after glaze paste and also repeated firings. Material and Methods. A total of 180 rectangular lithium disilicate specimens (5 x 6 x 1 mm) with 1.0 ± 0.1 mm thickness were used in this study, divided according to manufacturer levels of translucency : (HT, MT and LT) , the use of glaze paste : no glaze(NG) and glazed(GZ) and number of firings: one(1x), two(2x) and 5 (5x) firings. After firings, the Cie*Lab color parameters were checked and a $\Delta E/ \Delta E_{00}$ and $\Delta TP/ \Delta TP_{00}$ was calculated. Data were submitted to analysis of variance (ANOVA) and Tukey test ($p < 0.05$). Results. There were significant differences in *L, *a and *b parameters for HT, MT and LT at all firings periods ($p < 0.05$). The highest ΔE values between the comparison of glazed and unglazed specimens were found in MT after 1x firing ($\Delta E = 8.1 / \Delta E_{00} = 5.9$) followed by HT after 2x firings on the black/white background ($\Delta E =$

3.5/ ΔE_{00} =3.5 and $\Delta E = 3.7/\Delta E_{00} = 2.6$). The lowest delta was found in LT after 1x firing ($\Delta E = 0.2/\Delta E_{00} = 0.1$). Comparing the subgroups of the glazed groups, the MT specimens from 1st to 5th firing cycle -GZMT1xGZMT5x- revealed the lowest ΔE values found comparing all groups. The ΔTP comparison after 5th firings, the MT and LT showed no significant differences with almost identical optical behavior ($p > 0.05$). The lowest mean values of ΔTP were found in GZLT5x. Although all specimens for HT, MT, LT ΔTP values were over perceptibility threshold ($\Delta TP = 1.33$ and $\Delta TP_{00} = 0.62$) comparing 2nd to 5th firing, they all were within TPAT. The ΔE values of all groups with glaze showed values over PT but they did not exceed the AT ($AT > 2.7$) after 5th firing. Conclusions: The results showed that the color and translucency parameters of IPS E.max CAD were affected by glaze paste and repeated firings. For monolithic veneers with 1mm thickness requiring up to two firings, LT group had the lowest color variation, followed by MT. The HT group revealed the highest variation face to multiple firings therefore it should be used with caution because its color has a markable alteration after it.

CLINICAL IMPLICATIONS

This study will provide more information about the influence of glaze paste on the optical properties of the monolithic lithium disilicate ceramic.

Certainly, this research work will bring better subsidies for professional to be aware of possible changes that material could suffer after applying glaze paste thus corroborating for a better resolution of treatments. It can be helpful for future development of computer algorithm models of predicting the final color of lithium disilicate.

INTRODUCTION

Dental ceramics industry has advanced rapidly both in materials and manufacturing technologies.^{1,2,3} The creation of new all ceramic materials can be cited as one of the greatest advances in the field of dental prosthesis in the last years.⁴ The use monolithic restorations made in computer aided and manufacturing(CAD/CAM) technology systems area has been increased and became popular among professionals due to high-quality restorations from ceramic blocks with accuracy, quality and speed and with minor errors comparing to the conventional artesian methods^{5,6,7}.

The introduction of glass ceramics, which combines highly esthetic and strong mechanical were a milestone in the evolution to the heights dentists see today.⁸ One

extraordinary material is the IPS e.MaxCAD, which is commercialized in several shades and in three main levels of translucency high (HT), medium (MT) and low (LT), thus enabling dentists to create precise ceramic restorations in just one consultation. This process saves time, money and efforts compared to the production in outsourced laboratories.³

The lithium disilicate (LD) is one of the most widely used all ceramic materials among dentists nowadays¹. It corresponds to the preference of 54% of dentists in USA and it is ranked among the 3 top choices for anterior esthetic crowns⁹. It's been available for CAD-CAM systems since 2006, under the brand name IPS e.max CAD (Ivoclar Vivadent, and Schaan of Liechtenstein). It can be processed very easily in a milling machine, though after the LD restoration needs to go into a ceramic furnace to achieve the final physical properties, such as the strength of 380 MPa (typical average value) and the corresponding optical properties.¹⁰

The marginal adaptation of LD restorations seems to be efficient enough to contribute to longevity.^{11,12} Besides that, the glass matrix of LD can be etched with hydrofluoric acid and chemically bonded to tooth structure with a silane primer and adhesive resin cement¹³, giving to it an extra advantage compared to other ceramics because it can be indicated safely for veneers.¹⁴

The day-to-day use of monolithic restorations with LD, it initially involves choosing a dominant color¹⁵, but most of the time a final stage of personalized staining is required (external characterization) with the application of colored pigments on the ceramic and a final glazing of the surface. This phase of characterization should be mandatory for better color match^{16,17}. Those pigments are presented as pastes and they can be fired together or after the crystallization of the LD ceramic¹⁶.

One primary factor that influences the esthetic is the translucency¹⁹. The stability of ceramics color over the lifetime of the restorations maybe is as important as the mechanical characteristics of materials. The longevity of a dental prosthesis can be reduced because of color change and the perceived quality by the patients is harmed when this occurs²⁰. The shade of LD ceramic restorations can be influenced by many factors like thickness²¹, surface texture and treatments²², material composition²³, transparency level²⁴, number of ceramic firings²⁵, brand and shade of cement²⁶, exposure and firing time²⁷ and glaze used.²⁸ It's been reported by authors that the final color of restorations is an interaction of all these factors.

The method of measuring shades can be subjectively and objectively. The ceramic analog color scales as a reference to take the color of the teeth is subjectively and some studies confirmed the hypothesis that the results for visual shade matching exhibits a high to moderate level of inconsistency.^{29,30} The most known and used appliance for objectively measure of color is named Easy Shade (Vita Zahn Fabrik)- a portable and compact spectrophotometer.³¹

The methods of measuring the shade objectively use the variations of color systems: the Munsell, red-green-blue (RGB), and Commission Internationale de l'Eclairage (CIELab). The most widely used color system for measuring color of dental materials is CIELab. It is expressed in terms of coordinates (L^* , a^* , b^* , C^* , h°). These coordinates parameters include 3 values ($L^*a^*b^*$) in a 3-dimensional color space. The L^* axis symbolizes darkness and lightness ranging from black and perfect white. The a^* axis symbolizes green in negative coordinates and red in positive coordinates. The b^* axis symbolizes yellow in positive coordinates and blue in negative coordinates.³² The numerical distance between $L^*a^*b^*$ coordinates of 2 colors or in the same object before and after different conditions is represented by ΔE . Also, there are also three kinds of translucency indicators commonly used in the field of esthetic prosthodontics, transmittance (T), the contrast ratio (CR), and the translucency parameter (TP). Among these three indicators, the TP value is generally considered to be more applicable to the visual evaluation of translucency.³³

The concern about the interference and impact of repeated firings on ceramics has been risen for decades.^{34,35} Despite of this, there are few numbers of studies on the effect of repeated firings on the final color and translucency of those LD restorations.^{23,36,38} In the same way, it's not totally clear the behavior of LD final color after applying the glaze paste.^{18,28}

If these 2 factors have any influence on that, it could have a negative impact on the expected clinical results in esthetic terms and the frustration of clinicians and patients could be frustrating.

So, the aim of this study was to evaluate the impact of glaze stage on the optical properties of CAD-CAM lithium disilicate after crystallization and repeated firings.

The first null hypothesis is that CAD-CAM lithium disilicate will show no difference on its color comparing glazed and unglazed LD. The second null hypothesis is that CAD-CAM lithium disilicate will show no difference on its color after repeated

firings being performed. The third null hypothesis is that CAD-CAM lithium disilicate will show no difference on its translucency reference parameters, after firings being performed and comparing glazed and unglazed LD. The fourth null hypothesis is that the of CAD-CAM lithium disilicate will show delta values within the limits of Translucency Perceptibility Thresholds -TPT and Translucency Acceptability Thresholds- TAT after firings and comparing glazed and unglazed LD.

MATERIALS AND METHODS

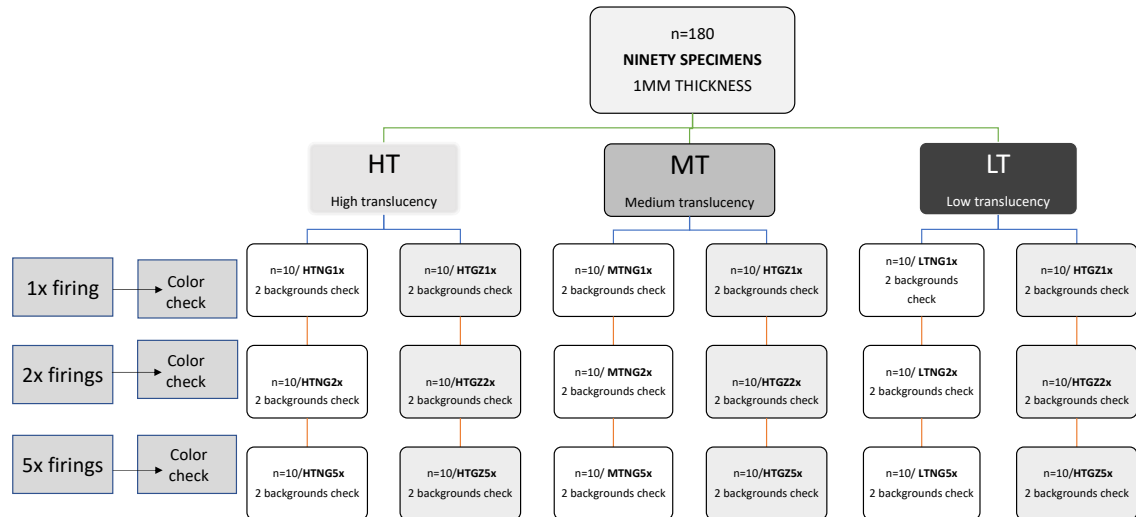
Sample characterization and distribution of experimental groups of the study

Nine A2 shaded lithium disilicate (LD) blocks were used in this study, three of each translucency manufacturer variations: 3 blocks of high translucency (HT); 3 blocks of medium translucency (MT) and 3 blocks of low translucency (LT); size C14 -12x14x18 mm (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein). The composition of the LD CAD block is displayed in Table 1. Each CAD/CAM block were primarily cut into slices ($12 \times 14 \times 1$ mm) using a low speed cutting machine (Isomet Buehler, USA). To do that, the specimens were embedded in polyvinyl chloride (PVC) filled with sticky wax (Asfer, SP, Brazil), leaving the long axis of the material surface. So each slice was divided symmetrically into 4 small pieces ($5 \times 6 \times 1$ mm) with 1.0 ± 0.1 mm thickness. A total of 180 specimens (60 from each translucency) were obtained and selected for color tests measurement and comparisons.⁴⁴ All specimens were manually polished on one side only, using water sandpaper (320,400,600 grit , 3M -Brazil) with a thin film of polishing paste (Universal Polishing paste, Ivoclar Vivadent) for 10 seconds of smooth friction for each sandpaper grit used. The thickness of each specimens was controlled with a digital pachymeter (Mitutoyo, Kawasaki, Japan). Those 180 LD specimens were cleaned and washed in distilled water immersed in ultrasonic cleaner for 10 minutes and dried out using absorbent papers (coffee cloth).

Then the specimens from each translucency (n=60) (HT, MT and LT) were equally divided in 6 subgroups (n=10) according to the following variables: the application of glaze paste: no glaze (NG) and glazed (GZ) and number of firings: one (1x), two (2x) and 5 (5x) firings. So, 18 subgroups were created as it follows : HTNG1x, HTNG2x, HTNG5x, HTGZ1x, HTGZ2x, HTGZ5x, MTNG1x, MTNG2x, MTNG5x,

MTGZ1x, MTGZ2x, MTGZ5x, LTNG1x, LTNG2x, LTNG5x, LTGZ1x, LTGZ2x, LTGZ5x. A flow-chart of experimental groups can be observed in Figure1.

Figure 1. A flow-chart of the experimental groups and subgroups : high-translucency (HT), medium translucency (MT) and low translucency (LT) ceramics.



Half of the specimens did not received glaze paste (Ivoclar glaze paste-Ivoclar Vivadent, Schaan, Liechtenstein), and the other half did; the glaze paste was gently applied on the surface of specimens using a brush as manufacturer recommendation. The specimens of each group were subjected to the firings using a ceramic furnace- EP3000 (Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer's preset programs (for crystallization and IPS emaxCAD glaze and characterization) -Tables 2 and 3. The color of each specimen was checked two times on white and two times on black backgrounds using the Vita Easyshade spectrophotometer (ES) (Vident, Brea, CA, USA). Optical contact between the specimen and the backgrounds was improved by using an interfacing layer of a polyethylene glycol solution (Amanda Handling Pharmacy, PR, Brazil). The measurement area of interest for shade matching was the middle of the specimen. For calibration purposes the same person took the color measures using the ES . The CIE L^* , a^* , and b^* values of LD is a measure of color coordinated by the Commission Internationale de l'Eclairage -CIELAB color, where L^* indicates lightness (0 to 100), and a^* and b^* indicate the levels of red ($+a^*$), green ($-a^*$), yellow ($+b^*$), and blue ($-b^*$) Figure 2. The L^* , a^* , and b^* values of the black and white background employed in this study were $L^*=2.95$, $a^*=0.27$, and $b^*=1.28$ for the black background, and $L^*=92.84$,

$a^* = -0.13$, $b^* = 1.59$ for the white background. The color comparison before and after the repeated firings of specimens was assessed through the differences (ΔE) that were observed between the two colors. Such differences were calculated with the formula: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ and

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C}\right) \left(\frac{\Delta H'}{K_H S_H}\right)}.$$

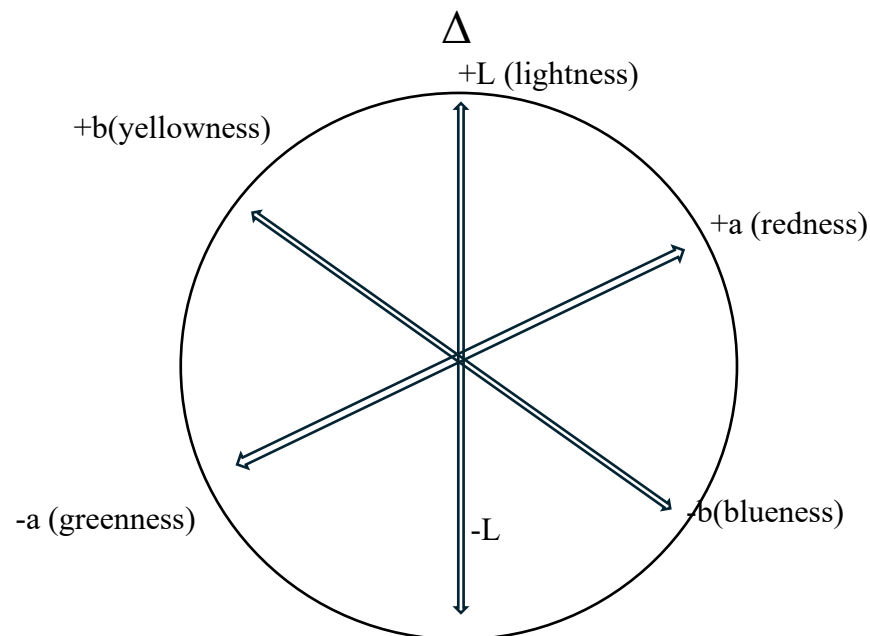
The variations in Translucency Parameters (ΔTP and ΔTP_{00}) were compared with recently reported 50:50% translucency difference thresholds Translucency Perceptibility Threshold (TPT) and Translucency Acceptability Threshold (TAT). Reliable translucency thresholds have been recently determined based on a study²⁴. The translucency levels was calculated using the formula for translucency parameter as follows the equation $TP = ([L^*_B - L^*_W]^2 + [a^*_B - a^*_W]^2 + [b^*_B - a^*_W]^2)^{1/2}$. Where w and B are color coordinates of the specimens on the white and black backgrounds. In addition, CIEDE2000 (1:1:1) color difference formula was also used to calculate the translucency parameter (TP_{00})(Salas *et al.*, 2018) :

$$TP_{00} = \left[\left(\frac{L'_B - L'_W}{K_L S_L} \right)^2 + \left(\frac{C'_B - C'_W}{K_C S_C} \right)^2 + \left(\frac{H'_B - H'_W}{K_H S_H} \right)^2 + R_T \left(\frac{C'_B - C'_W}{K_C S_C} \right) \left(\frac{H'_B - H'_W}{K_H S_H} \right) \right]^{1/2}$$

where the subscripts “B” and “W” refer to lightness (L^*), chroma (C^*) and hue (H^*) of the specimens over the black and the white backgrounds, respectively. R_T is the rotation function that accounts for the interaction between chroma and hue differences in the blue region. Weighting functions, S_L , S_C , S_H adjust the total color difference for variation in the location of the color difference specimen over the B and W backgrounds in L^* , a^* , b^* coordinates and the parametric factors, K_L , K_C , K_H , are correction terms for experimental conditions. To calculate using the CIEDE2000 color difference formula, discontinuities due to mean hue computation and hue difference computation were taken into account.³⁹ Higher TP values represent higher translucency (transparent) and

low values represent lower translucency (opaque). Based on previous studies, at least 8 specimens in each group were required for this study^{21,40,41}. Therefore the sample size of 10 specimens for each subgroup was calculated and confirmed using an analysis power software (G*Power v3.1.9; HeinrichHein-Universität Düsseldorf), considering an α equal 0.05, effect size of 0.50 and power of 80% according to ANOVA test and Tukey post test was used to determine whether the differences originated by conjunction. The data were analysed by using a statistical software program -Jasp Team (2024), Jasp (Version 0.18.3)[Computer software]

Figure 2 - A simple diagram of the CIE L*a*b* system



Source: The author

Table 1 - Composition of lithium disilicate (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein)

Technical specifications

Chemical composition

SiO ₂	57.0 – 80.0 %
Li ₂ O	11.0 – 19.0 %
K ₂ O	0.0 – 13.0 %
Other oxides	0–8 %

Physical material data

Coefficient of expansion (100 – 400°C)	$10.15 \pm 0.4 \cdot 10^{-6} \text{ K}^{-1}$
Coefficient of thermal expansion (100 – 500°C)	$10.45 \pm 0.4 \cdot 10^{-6} \text{ K}^{-1}$
Flexural strength (biaxial)	$\geq 360 \text{ MPa}$
Density	$2.5 \pm 0.1 \text{ g/cm}^3$

Source: website www.ivoclar.com/br

Table 2 - Crystallization parameters – IPS e.maxCAD

Closing time	Stand- by TEMP	Heating rate	Firing temp	Holding time	Heating rate	Firing temp	Holding time	Long term cooling	Cooling rate	Vacuum1	Vacuum 2
min	°C/°F	°C/°F	°C/°F	min	°C/min	°C/°F	min	°C/°F	°C/min	°C/°F	°C/°F
6:00	403/757	60/108	770/1418	5:00	30/54	850/1562	10:00	700/1292	20/36	550/1022	770/1418

Table 3 - Glaze,shades,stains,Add-on parameters – IPS e.maxCAD

Closing time	Stand- by TEMP	Heating rate	Firing temp	Holding time	Heating rate	Firing temp	Holding time	Long term cooling	Cooling rate	Vacuum1	Vacuum 2
min	°C/°F	°C/°F	°C/°F	min	°C/min	°C/°F	min	°C/°F	°C/min	°C/°F	°C/°F
6:00	403/757	90/162	820/1508	0:10	30/54	840/1544	7:00	700/1292	20/36	550/1022	820/1508

Source: website www.ivoclar.com/br

RESULTS

Cie*Lab parameters

Table 4 shows the comparison of CIELab color parameters values between the specimens (HT, MT, LT) with and without glaze paste on the black and white backgrounds after the firing cycles.

For the parameter of lightness (L^*), the highest mean values on the black background were found after the 2nd firing cycle in LT2x and lowest mean values in HT5x, both without glaze paste. Comparing the specimens with and without glaze paste at the same level of subgroups of firings, there were no significant differences among HTNG1x, LTNG1x, HTGZ1x, LTGZ1x, but there were between MT. It was found a significant difference between LTNG2x and LTGZ2x but not in HT and MT. There were no differences between HTNG5x and HTGZ5x; MTNG5x and MTGZ5x and LTNG5x and LTGZ5x. When the evaluation was at the same specimens but evaluating the subgroups of firings, it was noticed that there were significant changes among HTNG1x- HTNG2x; HTNG1x- HTNG5x; MTNG1x- MTNG2x; MTNG1x- MTNG5x; LTNG1x-LTNG2x; LTNG2x-LTNG5x; LTGZ1x-LTGZ2x; LTGZ1x and LTGZ5x subgroups.

For the parameter a^* , the highest mean values on the black background was found after the 2nd firing cycle in HTNG2x (without glaze) and lowest mean values in LTGZ5x (with glaze). Comparing the specimens with and without glaze paste at the same level of subgroups (see the rows in the table), there were no differences after 1st firing between HT and LT groups (HTNG1x-HTGZ1x and LTNG1x-LTGZ1x) but there was for MTNG1x and MTGZ1x. It was found a difference after 2x firings for HTNG2x-HTGZ2x and LTNG2x-LTGZ2x but not for MT group. After 5x firings cycles, there were statistical differences for all groups when comparing with and without glaze. Therefore the subsequent firings impacted the a^* parameter with glaze paste of LTGZ1x-LTGZ5x; LTNG1x-LTNG2x and LTNG2x-LTNG5x- $p < 0.05$); the HT and MT groups with glaze remained with no differences.

For the parameter b^* , the highest mean values on the black background was found after the 2nd firing cycle in LTNG2x and lowest mean values in HTNG5x, both without glaze. Comparing the specimens with and without glaze paste at the same level of subgroups (see the rows in the table), there were no differences after 1x firing

between HT and LT groups but there was for MT . It was found a difference after 2x firings for all groups. After 5x firings, there were differences for HT and MT groups but not for LT when comparing with and without glaze. Therefore the subsequent firings impacted the *b parameter with glaze paste only for LT group(LTGZ1x $\neq$ LTGZ2x and LTGZ1x $\neq$ LTGZ5x); the HT and MT groups with glaze remained with no differences.

ΔE and ΔE_{00} values for groups/subgroups with and without glaze

Tables 5 shows the ΔE and ΔE_{00} values on the black background and table 6 on the white background for HT, MT and LT specimens. The highest delta values were found in the HT without glaze between 1st to 2nd and 1st to 5th comparisons ($\Delta E= 3.4 / \Delta E_{00}=2.8$ - $\Delta E= 3.7 / \Delta E_{00}=3.0$ respectively). In contrast, HT without glaze showed small variations between the 2nd and 5th firing ($\Delta E= 0.8 / \Delta E_{00}=0.6$). The lowest values were found in the MT specimens without glaze from 1st to 2nd firings ($\Delta E= 0.3 / \Delta E_{00}=0.3$) and when comparing the MT specimens with glaze from the 1st to 5th firing ($\Delta E= 0.4 / \Delta E_{00}=0.3$).

Table 8 - Mean $\pm$ standard deviation lightness(*L) values on black background after one firing (1x), two firings (2x) and five firings (5x).

BACKGROUND BLACK/WHITE	HIGH TRANSLUCENCY				MEDIUM TRANSLUCENCY				LOW TRANSLUCENCY			
	NO GLAZE		GLAZE		NO GLAZE		GLAZE		NO GLAZE		GLAZE	
Firings Comparisons	black	white	black	white	black	white	black	white	black	white	black	white
*L (1x)	76.15 $\pm$ 2.07	99.92 $\pm$ 0.13	76.28 $\pm$ 1.64	99.59 $\pm$ 0.66	72.90 $\pm$ 0.8	100	76.40 $\pm$ 0.55	100	75.19 $\pm$ 2.09	99.43 $\pm$ 0.57	75.38 $\pm$ 2.09	98.56 $\pm$ 0.57
*L (2x)	73.56 $\pm$ 1.18	99.31 $\pm$ 0.59	74.49 $\pm$ 2.74	99.37 $\pm$ 1.34	74.80 $\pm$ 1.09	100	75.8 $\pm$ 1.31	100	77.90 $\pm$ 0.80	97.44 $\pm$ 0.70	77.02 $\pm$ 1.65	97.38 $\pm$ 0.72
*L (5x)	72.87 $\pm$ 1.24	99.98 $\pm$ 0.71	74.89 $\pm$ 1.50	99.38 $\pm$ 0.77	76.63 $\pm$ 1.10	100	76.41 $\pm$ 1.06	100	77.14 $\pm$ 1.35	100	77.22 $\pm$ 1.32	99.79 $\pm$ 0.28
*a (1x)	-1,32 $\pm$ 0.61	-0.70 $\pm$ 0.61	-1.37 $\pm$ 0.56	-0.80 $\pm$ 0.22	-2,16 $\pm$ 0.14	-0,42 $\pm$ 0.24	-1.37 $\pm$ 0,30	-0.47 $\pm$ 0.18	-1,92 $\pm$ 0.25	-0,70 $\pm$ 0.24	-1.94 $\pm$ 0.22	-0.79 $\pm$ 0.17
*a (2x)	-3,65 $\pm$ 0.75	-1.91 $\pm$ 0.14	-1.43 $\pm$ 0.14	-0.79 $\pm$ 0.11	-1,44 $\pm$ 0.32	-0,84 $\pm$ 0.18	-1.42 $\pm$ 0.09	-0.64 $\pm$ 0.12	-2,16 $\pm$ 0.14	-0,95 $\pm$ 0.14	-1.35 $\pm$ 0.30	-0.99 $\pm$ 0.16
*a (5x)	-2,20 $\pm$ 0.16	-1.84 $\pm$ 0.14	-1.43 $\pm$ 0.09	-1.21 $\pm$ 0.48	-1,91 $\pm$ 0.09	-1,30 $\pm$ 0.11	- 1.28 $\pm$ 0.16	-0.46 $\pm$ 0.09	-2,56 $\pm$ 0.16	-0,22 $\pm$ 0.04	-1.26 $\pm$ 0.11	-0.31 $\pm$ 0.12
*b(1x)	2.12 $\pm$ 0.98	10.69 $\pm$ 1.01	2.24 $\pm$ 0.76	10.78 $\pm$ 1.05	12.36 $\pm$ 0.6	14.23 $\pm$ 0.75	5.05 $\pm$ 0,72	14.18 $\pm$ 0.70	11.42 $\pm$ 1.48	23.56 $\pm$ 1.34	11.38 $\pm$ 1.22	24.24 $\pm$ 1.10
*b(2x)	4.04 $\pm$ 0.85	13.97 $\pm$ 0.77	1.47 $\pm$ 0.69	10.40 $\pm$ 0.96	4.89 $\pm$ 1.16	14.96 $\pm$ 1.04	3.47 $\pm$ 0.60	12.89 $\pm$ 0.61	12.36 $\pm$ 0.61	25.07 $\pm$ 0.60	10.24 $\pm$ 0.92	25.22 $\pm$ 0.65
*b(5x)	3.65 $\pm$ 0.75	13.61 $\pm$ 0.58	2.28 $\pm$ 1.08	11.51 $\pm$ 1.53	6.63 $\pm$ 0.57	17.10 $\pm$ 0.64	4.66 $\pm$ 0.65	14.18 $\pm$ 0.36	9.57 $\pm$ 0.26	21.38 $\pm$ 1.04	9.47 $\pm$ 0.81	21.27 $\pm$ 0.70

Table 5 - ΔE values after comparison of subgroups (1x,2x,5x) with and without glaze paste on black background for the different translucencies.

BACKGROUND BLACK	HIGH TRANSLUCENCY				MEDIUM TRANSLUCENCY				LOW TRANSLUCENCY			
	NO GLAZE		GLAZE		NO GLAZE		GLAZE		NO GLAZE		GLAZE	
Firings Comparisons	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}
1 st to 2 nd	3.4	2.8	1.8	1.4	0.3	0.3	1,7	1,4	2,8	2,0	2,3	1,7
2 nd to 5 th	0.8	0.6	0.9	0.9	2.6	2.0	1,3	1,1	1,9	1,4	0,6	0,4
1 st to 5 th	3.7	3.0	1.3	1.1	2.3	1.8	0,4	0,3	1,3	0,9	2,7	2,0
PT references	1.2	0.8	1.2	0.8	1.2	0.8	1.2	0.8	1.2	0.8	1.2	0.8
AT references	2.7	1.8	2.7	1.8	2.7	1.8	2.7	1.8	2.7	1.8	2.7	1.8

PT: Perceptibility threshold; AT: Acceptability threshold

Fonte: O autor

Table 6 - ΔE values after comparison of subgroups(1x,2x,5x) with and without glaze paste on white background for the different translucencies.

BACKGROUND WHITE	HIGH TRANSLUCENCY				MEDIUM TRANSLUCENCY				LOW TRANSLUCENCY			
	NO GLAZE		GLAZE		NO GLAZE		GLAZE		NO GLAZE		GLAZE	
Firings Comparisons	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}
1 st to 2 nd	3.5	2.5	2.1	1.6	4.5	3.1	1,3	0.8	2,8	2,0	2,4	1,4
2 nd to 5 th	0.8	0.4	0.8	0.6	0.5	0.3	1,3	0.8	1,9	1,4	4.7	2.5
1 st to 5 th	3.1	2.3	2.8	2.0	4.1	2.9	0,1	0,1	1,3	0,9	3.0	1.5
PT references	1.2	0.8	1.2	0.8	1.2	0.8	1.2	0.8	1.2	0.8	1.2	0.8
AT references	2.7	1.8	2.7	1.8	2.7	1.8	2.7	1.8	2.7	1.8	2.7	1.8

PT: Perceptibility threshold; AT: Acceptability threshold

Fonte: O autor

Comparing the HT specimens, with and without the glaze, and given the black and white backgrounds, it was noticed a decrease in delta values of glazed specimens from 1st to 2nd firing and 1st to 5th firing. Comparing the 2nd to 5th firing the delta values were quite similar.

Comparing the MT specimens with and without the glaze, the delta values did not followed a pattern given the 2 types of background, except in the comparison from 1st to 5th firing of glazed specimens where there was an decrease in delta values.

Comparing the LT specimens with and without the glaze, the delta values of glazed specimens had a discreet reduction from 1st to 2nd firing, but there was a great decrease from 2nd to 5th firing on the black background and in opposition an expressive increase on the white background. The LT delta values were still high for both types of background comparing 1st to 5th firings.

Tables 7 and 8 compared glazed and unglazed subgroups specimens at the same level of firings, and considering both types of background, the HT and LT specimens after 1st firing showed minor impact in delta values after the application of glaze paste. The MT specimens surprisingly in that same level revealed high values of delta $\Delta E = 8.2/\Delta E_{00} = 5.9$). After 2nd firing the MT specimens also revealed low values of delta. But after 5th firing, the LT exhibited the lowest values among the specimens $\Delta E = 0.9/\Delta E_{00} = 1.2$ on black background and $\Delta E = 0.3/\Delta E_{00} = 0.2$ on white background.

Table 7 – Comparison on black background of the specimens after the same level of firings with and without glaze and the ΔE values of color change

BACKGROUND BLACK	HIGH TRANSLUCENCY		MEDIUM TRANSLUCENCY		LOW TRANSLUCENCY	
	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}
Comparison						
1x	0.2	0.2	8.1	5.9	0.2	0.1
2x	3.5	3.5	1.7	1.4	2.4	1.8
5x	2.6	2.1	2.1	1.7	0.9	1.2
PT references	1.2	0.8	1.2	0.8	1.2	0.8
AT references	2.7	1.8	2.7	1.8	2.7	1.8

PT: Perceptibility threshold; AT: Acceptability threshold

Table 8 – Comparison on white background of the specimens after the same level of firings with and without glaze and the ΔE values of color change

BACKGROUND WHITE	HIGH TRANSLUCENCY		MEDIUM TRANSLUCENCY		LOW TRANSLUCENCY	
	ΔE	ΔE_{00}	ΔE	ΔE_{00}	ΔE	ΔE_{00}
Comparison						
1x	0.4	0.2	0.1	0.1	1.1	0.6
2x	3.7	2.6	2.1	1.3	0.2	0.1
5x	2.3	1,5	3.0	1.9	0.3	0.2
PT references	1.2	0.8	1.2	0.8	1.2	0.8
AT references	2.7	1.8	2.7	1.8	2.7	1.8

PT: Perceptibility threshold; AT: Acceptability threshold

ΔTP and ΔTP_{00} values comparison

Table 9- Comparison of translucencies (ΔTP and ΔTP_{00}) values after firings, on black and white background for the different specimens (HT, MT, LT)

Background Black & White	High Translucency				Medium Translucency				Low Translucency			
	No Glaze		Glaze		No Glaze		Glaze		No Glaze		Glaze	
Comparison	TP	TP ₀₀	TP	TP ₀₀	TP	TP ₀₀	TP	TP ₀₀	TP	TP ₀₀	TP	TP ₀₀
1x	25.3	16.6	24.8	16.4	27.2	17.8	25.3	16.4	27.1	17.1	26.5	16.7
2x	27.7	18.4	26.4	17.6	27.1	17.7	28	18.6	23.3	14.4	25.3	15.6
5x	28.9	19.1	26,2	17,3	25.6	16.5	27.8	18.4	25.8	16.4	25.5	16.0
1 st to 2 nd	2.4	1.8	1,6	1,2	-0.1	-0.1	2.7	2.2	-3.8	-2.7	-1.2	-1.1
2 nd to 5 th	1.2	0.7	-0.2	-0,3	-1.5	-1.2	-0.2	-0.2	2.5	2	0,2	0,4
1 st to 5 th	3.6	2.5	1.4	0.9	-1.6	-1.3	2.5	2	-1.3	-0.7	-1.0	-0.7
TPT references	1.33	0.62	1.33	0.62	1.33	0.62	1.33	0.62	1.33	0.62	1.33	0.62
TAT references	4.43	2.62	4.43	2.62	4.43	2.62	4.43	2.62	4.43	2.62	4.43	2.62

TPT: Translucency Perceptibility threshold; TAT: Translucency Acceptability threshold

Table 9 shows the ΔTP and ΔTP_{00} values comparison. The highest value were found in the MT with glaze, specifically after 2nd firing ($TP_{00} = 18.6$). The LT with glaze showed the minor TP values also after 2 x firings ($TP_{00} = 15.6$). In comparison after 5th firings, LT had also the lower TP variation, practically an identical result obtained after 2 x firings ($TP_{00} = 16.0$). Comparing the glaze paste subgroups the MT from 1st to 2nd firings obtained an elevated delta of translucency ($TP=2.7/ TP_{00}=2.2$), followed by HT from 1st to 2nd and 1st to 5th firings, which also had elevated values. In those groups the specimens tended to become more translucent. The LT group tended to become opaquer.

DISCUSSION

The optical behavior had peculiarities comparing the values with and without glaze among the three type of blocks. While the highest values obtained without glaze were in the HTNG1x - $\Delta E = 3.4 / \Delta E_{00} = 2.8$, the results after the 1st to 2nd firing with glaze decreased expressively HTGZ1x - $\Delta E = 1.8 / \Delta E_{00} = 1.4$. Looking at the individually performance of subgroups, on the black background, the comparison of the specimens without glaze paste from the 2nd to 5th firing was over the perceptibility threshold (PT) in MTNG2x and LTNG5x, however in MTNG2x was the only one where values hit the acceptability threshold-AT ($\Delta E_{00} = 2.0$). For the subgroups with glaze the PT was over the limits in HTGZ1x and MTGZ1x; LTGZ1x; HTGZ2x; MTGZ2x but all subgroups with glaze were under the AT.

It can be seen that in the HT specimens the first two firings had influence on the color parameters. However, from the second to fifth firings, the delta values changed a little but comparing the 1st to 5th firings the delta values raised to the point of being above the levels of perceptibility and acceptability.

The application of the glaze paste in the MT specimens seems to have had an effect on the color delta from the 1st to 2nd firing, and also from the 2nd to the 5th firing, both at the limit of PT and under AT. Although the results without the glaze were high for MTNG5x ($\Delta E = 4.1$ / $\Delta E_{00} = 2.9$), to the point of breaking over the PT and AT, surprisingly, with the glaze paste the delta values obtained in MTGZ5x were tiny, which is within the range accepted ($\Delta E = 0.1$ / $\Delta E_{00} = 0.1$).

The first null hypothesis of this study was rejected. Some changes in the color parameters of LD were significantly affected by the glaze paste application. Although the white and black backgrounds were used mainly to calculate the TP³³, in this study the presentation of the both measures can make it easier to understand the data. The results for each type of background is relevant for better comprehension of the optical behavior of LD specimens when confronted with these 2 opposing colors (black and white). This could be seen as a situation that normally occurs in the day-to-day life of the dental professionals when faced with lighter and darker dental remnant substrates, or perhaps with the need to use an opacifier for the substrate where the ceramic veneers is fitted.

As results showed on the blackbackground the lightness *L parameter was affected by the application of glaze paste in MTGZ1x and in LTGZ2x, besides that if considering the alterations due to subsequent firing cycles, there were found differences in MTGZ1x $\neq$ MTGZ2x; MTGZ1x $\neq$ MTGZ5x and in LTGZ1x $\neq$ LTGZ2x; LTGZ2x $\neq$ LTGZ5x ($p > 0.05$). The HT specimens with glaze did not show any statistical differences as well as the results on white background. When interacting with black background, LT glazed specimens after 2nd and 5th firings became lighter with the values increasing compared to one firing cycle, and HT became more grayish. In

previous studies, it was demonstrated that *L values decreased due to repeated firings.^{41,42}

A study comparing the thickness and shades of ceramics concluded that color differences between shades were largely due to differences in *L and *b and semi translucent all ceramic porcelain systems were better at achieving shades matches in 1mm thickness.⁴³

There were studies that differed from those results.^{33,35,44} Interestingly, it is important to mention that not all of studies used lithium disilicate in their tests.⁴² Nevertheless there have also been studies where it was verified a significant change in the * L parameter after three firings when the material studied was lithium disilicate pressable ingots form (for injection technique)³⁶ and others using alumina and powder ceramics after seven firings.^{41,44} This difference found in the results among studies could be attributed to the process of manufacturing the LD and the fact that in the present study, standard blocks of pre-crystallized matrix (eMax. CAD) were used, and that meta disilicate form should promote a different arrangement of crystals in the glassmatrix⁴⁵, which could impact on this *L parameter evolution after firings.

The * a parameter had significant statistical difference comparing the specimens with and without glaze in the subgroups HTNG2x-HTGZ2x, HTNG5x-HTGZ5x, MTNG1x- MTGZ1x, MTNG5x- MTGZ5x, LTNG2x- LTGZ2x and LTNG5x-LTGZ5x. But after 5th firings, this difference among the three blocks could be observed. In interaction with the black background, the *a parameter mean values decreased in all types of specimens (HT,MT LT), but it continued tending to green. When interacting on the white background, the HT and MT with the glaze, decreasead the mean values compared to without glaze subgroups but LT had a discreet increase. These results are also corroborated by previous studies.^{41,42}

The a^* parameter with glaze showed a overall decrease in mean values for the three groups, on black and white background. HT showed statistical differences between the specimens with and without glaze in 2x and 5x firings; MT in 1x, 2x and 5x firings and LT only in 2x firings. The values measured on white were higher than black background. On white background the specimens also became more yellow and on black background they tended to be more blue after repeated firings.

The color stability of metal oxides which are used as coloring agents may be associated with the color changes after repeated firings. Some researchs have claimed that metal oxides does not keep color stability after being exposed to firing process. It was still related that repeated firings break down metal oxides bond easily ^{4,41} Another related issue was in evidence back in the 1980s, where a experimental study ⁴⁶ stated that the changes in color parameters of porcelain caused by the filtering effects of translucent material over a backing result from interaction, at every wavelength, of optical scattering and absorption coefficients, the thickness of the translucent material, and the reflectance of the backing.

It's imperative that dental materials need to match and reproduce the color appearance of natural teeth in order to achieve desired esthetic outcome in an efficient manner. In this in vitro study, the results showed that there is a significant statistical difference in the parameters (Cie*Lab) after the use of glaze paste and also repeated firings. The color changed among (HT, MT, LT) variations of LD. To the dentists, dental ceramists and dental technicians, the knowledge of this optical behavior makes it possible to be alert to this and it takes on a position of great importance in clinical dentistry and dental research as well.

The color difference values ΔE showed a discrepancy between the types of specimens (HT, MT, LT) and between the different firing subgroups 1x, 2x, 5x. The ΔE

represents the numerical distance measured between the *L *a *b coordinates of 2 colors. Under ideal observation conditions, a color match between two colors cannot be judged when the ΔE value of colors is less than 1 ($\Delta E < 1$). When the measured color differences are within 1 to 2 ΔE range, correct judgments are frequently done by observers. When ΔE values are greater than 2 ($\Delta E > 2$), all observers can detect a color difference between the two colors. The smallest perceptible color difference- a perceptibility threshold (PT)- refers to the smallest difference that can be detected by a casual observer. A classic article of color differences for discriminating mismatch between composite and tooth color⁴⁷ was reported a AT parameters (acceptability thresholds) which was $\Delta E = 2.18$ for dentists; $\Delta E = 1.78$ for dental auxiliaries; $\Delta E = 2.52$ for scientists and 2.69 for patients. In dentistry, the acceptability threshold for color difference is greater than the perceptibility threshold^{48,49,50}.

Some studies have shown that color differences greater than one unit can be visually perceived only by 50% of human observers.^{51,52} Although there are studies suggesting different values for PT and AT ^{50,53} the parameters of the color difference value considered in this study is supported by others researches, which is PT/AT $\Delta E = 1.2/2.7$ and $\Delta E_{00} = 0.8/1.8$ respectively.^{54,55} In this study, a considerable alteration of color occurred in specimens. The HT specimens with and without glaze showed different averages when comparing the means side by side (table 8 and 14). The results of ΔE for both black and white background in HT revealed values much higher than the reference for PT and AT after the first to second firings (HTNG1x/HTGZ1x - HTNG2x/HTGZ2x) and from the 1st to 5th firings (HTNG1x-HTNG5x). From the 2nd firing to 5th firing the results were in the range of PT and AT. And this was seen in HT for specimens with and without glaze. It was found also in other study ^{56,57} in which results revealed higher ΔE_{00} values with greater translucency ceramics, resulting in a lower

quality shade match. A recent study of 2023⁵⁸ revealed that ceramics with 1 glaze firing showed greater color, roughness, and microhardness changes compared to those submitted to 2 firings. One of the most important comparisons in this study reveals the ΔE color variation between specimens with and without glaze at the same subgroup level, which means after the same firing stage. The HT specimens on the black background showed in HTNG1x and HTGZ1x a discreet variation ($\Delta E_{00} = 0.2$), HTNG2x and HTGZ2x exhibited such a high variation ($\Delta E_{00} = 3.5$), also perceived in HTNG5x and HTGZ5x ($\Delta E_{00} = 2.1$), which inserted those 2 groups in levels overcoming the PT and AT (0.8/1.8, respectively). On white background only HTNG5x and HTGZ5x pointed a delta over PT. A study that compared high translucency LD and zirconia-reinforced lithium silicate ceramic showed that the glaze procedure led to more color stability with respect to mechanical polishing and external staining and glaze⁵⁹. A recent systematic review⁶⁰ revealed that the glazed glass-ceramics have more color stability than resin-ceramics and other types of finishing procedures.

The MT specimens on the black and white background showed results above the perceptibility level with glaze (MTGZ1x-MTNG1x/ MTGZ5x-MTNG5x); however they showed the lowest color change values compared to HT, MT for MTNG2x-MTGZ2x ($\Delta E/\Delta E_{00} = 0.4$). When comparing the specimens with and without glaze, only MTNG1x and MTGZ1x almost had no changes after glaze application ($\Delta E = 0.1 \Delta E_{00} = 0.1$), moreover MTNG2x and MTGZ2x ($\Delta E = 2.1 \Delta E_{00} = 1.3$) and MTNG5x and MTGZ5x ($\Delta E = 3.0/\Delta E_{00} = 1.9$) also revealed delta values above PT and AT.

The LT specimens in both backgrounds revealed antagonist results from the 2nd to 5th firing. In black background the delta values in LTGZ2x were the lower obtained ($\Delta E = 0.6/\Delta E_{00} = 0.4$), and in the white background the opposite with the highest delta in LTGZ2x ($\Delta E = 4.7/\Delta E_{00} = 2.5$) It was found in other study too.⁶¹ Those

data can indicate warning in terms of the final results of veneers, especially if the professional is unaware of the color of substrate and the number of firings performed during the characterization.

Other study comparing HT to LT lithium disilicate CAD/CAM showed results of ΔE for HT higher than LT, this is the same found in this study⁶¹ and an article⁶² comparing the effect of abutment tooth on color of lithium disilicate CAD/CAM showed that darker colors resulted in increased ΔE values. The comparison between LT specimens with and without glaze showed the delta values for LTNG1x and LTGZ1x, inside the PT and AT, in addition after 2nd and 5th firing were above PT but still in the limit of AT.

The use of different backgrounds and ceramic fabrication techniques may provide more knowledge and insight into the influence of translucency and background colors on ceramics.⁴³

Another authors³⁵ showed a color change after 3 and 6 firings on layering porcelain but according to them an average color difference obtained ($E = 1$) would not affect color stability. However, a 2007 study revealed that there were substantial changes in $L^*a^*b^*$ color data as the number of firings increased (3,5,7 firings), which resulted in perceptual color changes in $L^*a^*b^*$ color parameter.⁴² A 2023 study⁶³ showed that one additional firing process can considerably increase the translucency of the lithium disilicate furthermore for IPS Emax CAD, two sintering processes displayed an increase in translucency. And it was concluded that the translucency was significantly influenced by the brand of lithium disilicate and the number of sintering processes.

It was found in this study a significant statistical difference between ΔE and ΔE_{00} mean values. This is consistent with the fact that the formulas for calculating Δ -

delta variations apply different methodologies for calculating, and this difference does not imply that the results are different, but rather points to this difference in sensitivity in detecting the variations.⁴⁹ The CIEDE2000 formula provides better adjustments in color difference evaluation which means in all the correlation between evaluated and perceived color differences detects small differences when CIEDE2000 formula was used (ΔE_{00}) instead of the CIELab formula (ΔE).^{49,50}

The ΔTP and ΔTP_{00} values shows that glazed specimens had very different results than the unglazed. The HT specimens with glaze decreased the translucency level compared to unglazed ones in all subgroups, and it scored the highest level comparing the 1st to 2nd firing ($\Delta TP=1.6$ and $\Delta TP_{00}=1.2$), tending to be grayer.

The MT specimens kept the translucency almost unchanged to subgroups from the 2nd to 5th firing and they tended to be less translucent. The results from the 1st to 2nd firing ($\Delta TP = 2.7/\Delta TP_{00}= 2.2$) and from 1st to 5th firing ($\Delta TP = 2.5/\Delta TP_{00}= 2.0$) indicated a moderate variation, both above the perceptibility threshold, but inside the acceptability threshold. The glazed MT specimens turned out to be very different from those not glazed. For those specimens the glaze paste seemed to increase the translucency parameters.

The LT blocks exhibited a high translucency change after the application of glaze paste taking the specimens to less opaque level in all subgroups .In practice it would probably turn the shade more evident.

The present study confirmed the variations in the translucency parameters (TP) among the groups of each lithium disilicate glass ceramic as disclaimed by the manufacture. However, it was observed that lithium disilicate showed a different variation in translucency comparing specimens with and without glaze. The LT specimens had the less variations. If the comparison extents to subgroups, it was

revealed that from the 1st to 5th firings, all groups (HT, MT, LT) presented mean values of delta above the PT. In addition, it's essential to mention that despite of those results, all subgroups were still inside the AT.

FINAL CONSIDERATIONS

In this study it was chosen the three translucency variations of LD (HT, MT, LT) and two backgrounds for comparison black and white but only one shade (A2) of LD was used. Thus, more ceramic shades and background color variations should be considered in future studies. Based on the literature search, only a few studies have addressed the optical properties of lithium disilicate glass ceramics and this extends to the influence and effects of the glaze paste on these properties. Future studies could check the use of different brands of glaze paste. There was no study that evaluated the effect of translucency comparing the three manufacturer variations with and without the application of glaze. An exact comparison of results between this study and previous studies is due to small differences in experimental designs and methodological conditions, it is difficult to state. In addition, a standard *Lab** for all shades with and without glaze is not available yet, but maybe in a close future it should be informed. The use of different backgrounds may provide more knowledge and insight into the influence of translucency interacting to background colors on LD glass ceramic. Moreover, measurements of the color differences in the thickness of 1mm could provide valuable information for dental professionals. Future studies should also consider different thicknesses, different shades and also the tooth form (flat, convex, concave). The aim of implementing a color reference after the use of glaze paste and repeated firings is to give the north for a desired color after milling and burning process on the daily routine. If the color of a product doesn't meet the standard, customer

satisfaction is compromised, and the amount of rework and costs increase. Establishing color tolerances objectively within the color quality process is the most effective way to guarantee consistency and accuracy to material and improvements over the years.

CONCLUSIONS

Within the limitations of this study it was concluded that :

8. All the null hypotheses were rejected. The color of lithium disilicate were affected by the use of glaze paste.
9. Repeated firings affected the $*L^*a^*b$ parameters in the three subgroups -1x, 2x and 5 x firings
10. It was found statistical significant differences between the interactions of groups (HT,MT,LT) and the subgroups of study (1x,2x,5x firings) $p<0.05$.
11. ΔE and ΔE_{00} values were above perceptibility and acceptability thresholds for HT specimens after 2x firings and 5x firings.
12. ΔE and ΔE_{00} values were under perceptibility and acceptability thresholds for LT specimens after repeated firings on white background but on blackbackground over the PT after 2x firings and 5x firings and at the limit of AT.
13. ΔE and ΔE_{00} values were over PT and AT for MT specimens after 1st firing on the black background, but above PT in after 2x and 5x firings. On the white blackground after 5x firings the delta values were over PT and AT.
14. ΔTP and ΔTP_{00} values of HT specimens tended to became grayer after repeated firings. The highest translucency level change among the three groups was in LT. The leves decresead getting more opaque. MT almost unchanged the ΔTP and ΔTP_{00} values, exhibiting a moderate variation however within the limits of AT.

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6 DISCUSSÃO GERAL

Nos parâmetros do sistema de cores CIE em todos os subgrupos pode-se constatar que existiram diferenças em $*L$, $*a$ e $*b$, de acordo com a quantidade de queimas, corroborando com resultados de outros estudos que também constataram alterações em tais parâmetros após variadas quantidades de queimas porém em cerâmicas diferentes do dissilicato de lítio CAD (Abdelmoniem; El-Etreby; Salah, 2022; Celik *et al.*, [s.d.]; Elbasuny *et al.*, 2021; Fehmi; Ersan; Caner, 2018; Gonuldas; Yilmaz; Ozturk, 2014; O'brien *et al.*, 1991a; Panzeri Pires-De-Souza *et al.*, 2009; Yilmaz; Gonuldas; Ozturk, 2014; Zaid *et al.*, 2016). Normalmente em uma variação do delta menor que 1 ($\Delta E < 1$), as duas cores podem ser consideradas equivalentes (Sharma; Wu; Dalal, 2005).

Embora as aferições das cerâmicas em fundos preto e branco tenham sido utilizadas principalmente para cálculo da variação da translucidez dos materiais (Johnston, 2014), ao invés de apresentar somente o resultado desta equação, optou-se neste estudo pela apresentação dos resultados em tabulação comparativa para cada um dos tipos de fundo (branco e preto) propiciando uma melhor compreensão dos resultados. Mesmo porque esta situação é enfrentada no cotidiano dos profissionais quando ao iniciar um trabalho protético de uma coroa pura ou uma faceta em porcelana, por exemplo, deparam-se com remanescentes dentais escurecidos ou mais claros (Azer *et al.*, 2011).

Uma avaliação dos resultados de $*L^*a^*b$ pode sinalizar quais as características que sofrem mais com as queimas repetidas. De acordo com Celik *et al.*, 2008, o $*L$ é uma medida de luminosidade, portanto quanto maior é o valor, mais claro é o espécime. Neste trabalho, os valores obtidos no parâmetro $*L$ com apenas 1 queima não apresentaram diferenças estatísticas para HT, MT e LT em fundo branco,

porém em fundo preto os espécimes de MTNG1x, MTNG2x e LTNG5x apresentaram diferença estatisticamente significativa em relação aos demais. No comparativo de Uludag *et al.*, 2007, houve diferença nos valores de $*L$ após 7 queimas quando comparado a 3 queimas, sendo valores muito menores, fato que não se encontrou neste estudo com tamanha variação. Embora o estudo de Della Bona *et al.*, 2015 não tenha avaliado o impacto na cor após queimas repetidas, a avaliação que foi realizada da correspondência de cores de alguns tipos de cerâmica pura com a escala Vita Classical pode constatar que os parâmetros $*L^*a^*b$, após a queima de cristalização do dissilicato de lítio CAD, ou seja, de apenas 1 queima foi diferente da referência da escala tanto para as versões HT quanto LT na cor A2, evidenciando de que estes parâmetros podem sofrer alterações. Em contraponto aos resultados do presente estudo, Nejatidanesh *et al.*, 2020 apontaram que para o DL CAD LT de 1.0mm de espessura o parâmetro $*L$ não sofreu alteração após 3 queimas nos fundos preto e branco.

No parâmetro $*a$, com apenas uma queima, não houve diferenças estatísticas entre HT, MT e LT para ambos os fundos, porém com 2 queimas houve diferença de LTNG2x com os demais e após 5 queimas houve diferença do HTNG5x com os demais. No estudo de Gozneli, Kazazoglu e Ozkan, 2013 o dissilicato de lítio para prensagem foi comparado em sua cor com outras cerâmicas após 7 ciclos de queimas, nos resultados o estudo revelou que os parâmetros $*L$ e $*a$ do DL para prensagem sofreu diferenças em todos os períodos avaliados. Os valores de $*a$ do DL para prensagem diferiram totalmente dos demais materiais daquele estudo, apresentando valores negativos, ou seja, com tendência ao verde. Esses dados corroboram o que foi encontrado no presente estudo, onde os valores do parâmetro $*a$ também foram negativos. Vale mencionar que no estudo citado não houve menção de qual cor e nem

qual variação de translucidez do DL para prensagem foi utilizada naquele estudo. Essas alterações dos parâmetros do sistema de cores CIE $*L^*a^*b$ foram encontradas no estudo de Uludag *et al.*, 2007 conforme aumentaram o número de queimas da cerâmica, porém os materiais daquele comparativo eram cerâmicas feldspáticas reforçadas por alumina e leucita. O estudo de Pires *et al.*, 2019 também constatou, para a cerâmica feldspática pura sem reforço, que após 4 queimas foram encontradas modificações nos parâmetros do CIE $*L^*a^*b$.

No parâmetro $*b$ com 1 queima também não foram encontradas diferenças estatísticas entre HT, MT e LT para fundo preto, porém em fundo branco houve para os 3 subgrupos (HTNG1x, MTNG1x e LTNG1x). Com 2 queimas houve diferença do LTNG2x com os demais para ambos os fundos e após 5 queimas foi MTNG5x que diferiu dos demais com fundo preto e em fundo branco todos os grupos apresentaram diferenças neste parâmetro (HTNG5x, MTNG5x e LTNG5x). Um estudo de KANG *et al.*, 2018 revelou que o parâmetro $*b$ também sofre alterações na cor com 1 queima, mas tal modificação foi atribuída de acordo com a variação da espessura da cerâmica, onde quanto maior a espessura maior os valores para aquele parâmetro. Da mesma forma que o estudo de OH e Kim, 2015 também atribuiu ao aumento da espessura uma alteração perceptível dos parâmetros $*a$ e $*b$. Num trabalho de revisão sistemática da literatura, No presente estudo não houve variação da espessura dos espécimes, para que não se tornasse uma variável a ser considerada.

Do mesmo modo que ocorre com outras cerâmicas, a cor do material dissilicato de lítio tipo CAD é determinado por íons que possam agregar cor, que ficam dispersos na matriz. Para o DL CAD utilizado neste estudo, um desses íons consiste no vanádio (V^{+3} -amarelado e V^{+4} - azul acinzentado); no Cério (Ce^{+4} -amarelado) e o

manganês (Mn^{+3}). Esses íons sofrem oxidação durante as queimas e isso resulta na alteração das cores (Williard; Gabriel; Chu, 2018).

A tabela de resultados com os deltas de cor e translucidez obtidos para HT, MT e LT foi reveladora e apontou alterações no comportamento óptico dos subgrupos deste estudo ao comparar não somente os níveis de queimas, mas também para as diferenças de valores com e sem a aplicação do glase. Observando o desempenho dos subgrupos, no plano de fundo preto, a comparação dos espécimes sem glase mostra que comparando os deltas de cor (ΔE e ΔE_{00}) da 2ª com a 1ª queima, os subgrupos HTNG1x e LTNG1x ultrapassaram os limites de percepção (LP) e aceitação (LA); da 2ª para a 5ª queima o LTNG2x ficou acima apenas do limite de perceptibilidade (LP) e comparando a 1ª com a 5ª queima, todos apresentaram deltas acima da percepção, porém apenas o HTNG5x ultrapassou o nível de aceitação. No fundo branco, ainda sem o glase, da 2ª com a 1ª queima todos os subgrupos ficaram acima do LP e LA, da 2ª para a 5ª queima, apenas LTNG2x ficou acima no LP, e comparando a 1ª com a 5ª queima, HTNG5x e MTNG5x ficaram acima de LP e LA e LTGZ5x ficou acima apenas de LP.

Para os subgrupos com glase em fundo preto, comparando a 2ª com a 1ª queima todos os subgrupos ficaram acima do LP, da 2ª para a 5ª queima, apenas MTGZ2x estava acima no LP, e comparando a 1ª com a 5ª queima, o MTGZ5x foi o único que ficou abaixo de LP e LA, sendo que LTGZ5x ficou acima de LP e LA. Já para os subgrupos com glase em fundo branco, da 2ª com a 1ª queima apenas o subgrupo MTGZ1x ficou abaixo do LP, os demais ficaram acima; da 2ª para a 5ª queima, apenas LTGZ2x ficou acima no LP e LA, e comparando a 1ª com a 5ª queima, o HTGZ5x e LTGZ5x ficaram acima de LP e LA, sendo que MTGZ5x ficou com uma variação mínima ($\Delta E = 0,1 / \Delta E_{00} = 0,1$).

Observando os dados numa objetiva mais aproximada, no comparativo dos espécimes, enquanto os maiores valores obtidos sem glase em fundo preto foram no HTNG1x- $\Delta E = 3,4 / \Delta E_{00} = 2,8$, e para fundo branco no MTNG1x- $\Delta E = 4,5 / \Delta E_{00} = 3,1$; os resultados do delta com glase diminuíram expressivamente HTGZ1x - $\Delta E = 1,8 / \Delta E_{00} = 1,4$ e $\Delta E = 1,3 / \Delta E_{00} = 0,8$ respectivamente. Essa diminuição também foi observada no LTNGZ1x. De um modo geral, com o uso da pasta glase, os valores de delta da cor se estabeleceram em patamares menores tanto para fundo preto quanto branco, exceto em MTGZ1x e LTGZ5x para fundo preto e em MTGZ2x, LTGZ2x e LTGZ5x para fundo branco, mesmo assim é nítido de que houve benefício. Idealmente para o clínico seria desejável que o ΔE sempre fosse zero ou que a variação de cor da cerâmica fosse mínima. O uso de pasta glase é reportado como opção preferível ao polimento para o dissilicato de lítio com base em outros estudos.(Alp *et al.* 2018 ; Mota *et al.*, 2017).

Comparando os espécimes com e sem glase com ênfase na quantidade de queimas para o fundo preto pode-se perceber que o MT sofreu uma variação excessiva com 1 queima, muito acima de LP e LA($\Delta E = 8,1 / \Delta E_{00} = 5,9$). Tanto para 2 quanto 5 queimas a maior variação observada foi do HT com valores acima de LP e LA, seguido pelo MT e LT, todos com variações acima dos limites de percepção. Em

Seguindo a comparação dos espécimes com e sem glase com ênfase na quantidade de queimas, porém no fundo branco pode-se perceber que para 1 queima HT, MT e LT mantiveram variações muito discretas. Para 2 e 5 queimas a maior variação observada foi do HT com valores acima de LP e LA ($\Delta E = 3,7 / \Delta E_{00} = 2,6$), seguido pelo MT com valores acima de LP e para 5 queimas foi o MT que exibiu valores acima de LP e LA ($\Delta E = 3,0 / \Delta E_{00} = 1,9$), seguido pelo HT com valores acima de LP. Em fundo branco o LT manteve variações sempre abaixo de LP e LA. O estudo

de IRAVANI *et al.*, 2020 corrobora com este resultado deste estudo, e embora tenha utilizado no comparativo o DL para prensagem na variação LT, aponta este como aquele que menos sofreu variação de cor, correspondendo ao que mais se assemelha ao A2 da escala Vita Classical. O Quadro 4 apresenta uma compilação de orientações sobre as variações do dissilicato de lítio CAD após variados ciclos de queimas.

Sobre as variações da translucidez, primeiramente com o enfoque sendo para a quantidade de queimas, tem-se que os maiores valores de delta obtidos sem o uso do glase foram do HT após 5 queimas ($\Delta PT = 28,9$ / $\Delta PT_{00} = 19,1$), seguido dos espécimes MT e LT com uma queima. É interessante que um estudo de Subasi e Alp, 2019 não apontou correlação da modificação da cor acompanhada da mesma proporção da translucidez no dissilicato de lítio onde se utilizou o glase em pasta, fato contrário ao que se constatou neste estudo onde o subgrupo HTGZ5x exibiu alta variação da cor e da translucidez. Após 2 queimas quem apresentou as menores variações foi o LT ($\Delta PT = 23,3$ / $\Delta PT = 14,4$). Corroborando com os resultados do LT, embora Abdelmoniem; EL-Etreby e Salah, 2022 não tenham realizado um comparativo do DL tipo CAD mas sim um DL para prensagem, na mesma variação LT (sem glase) citada anteriormente, constataram que em espécimes submetidos a reprensagens por 3 vezes com 4 ciclos de queimas a cada processo, que a translucidez diminuiu a medida que aumentam as queimas. Já com o uso do glase, no comparativo da translucidez intragrupos, as menores variações foram da 2ª para 5ª queima para todos, sendo na seguinte ordem MT, HT e LT mas que exibiu a maior variação foram os do MT entre 2 e 5 queimas ($\Delta PT = 28$ e $27,8$ / $\Delta PT_{00} = 18,6$ e $6,5$ respectivamente).

Quadro 4 – Esquema de orientação para escolha da variação do dissilicato de lítio CAD com tomando como referência o fundo utilizado, o tratamento de superfície e a quantidade de queimas previstas, com base nas variações do ΔE obtidos neste estudo

Fundo base	Tratamento de superfície	Quantidade de queimas	SIGA 	ATENÇÃO 	EVITAR 
preto	Com glase	2x		HT, MT, LT	
		3 e 4x	HT, LT	MT	
		5x	MT	HT	LT
branco	Sem glase	2x			HT, MT, LT
		3 e 4x	HT, MT	LT	
		5x		LT	HT, MT
branco	Com glase	2x	MT	HT,LT	
		3 e 4x	MT	HT	LT
		5x	MT		HT,LT
Fundo base	Tratamento de superfície	Quantidade de queimas	SIGA 	ATENÇÃO 	EVITAR 
preto	Sem glase	2x	MT		HT,LT
		3 e 4x	HT, MT	LT	
		5x		MT, LT	HT

Fonte: O autor

7 CONCLUSÃO

Os resultados mostraram que :

- 1) os parâmetros de cor e translucidez do DL CAD foram afetados pela pasta de glaze e pelas queimas repetidas.
- 2) Para restaurações monolíticas em DL CAD com 1 mm de espessura que requerem até duas queimas, o MT apresentou de um modo geral a menor variação de cor. Também apresentou menor variação após 5 queimas com uso da pasta glaze.
- 3) O grupo HT revelou a maior variação diante de múltiplas queimas, portanto deve ser usado com cautela em mais de uma queima porque apresenta uma alteração na cor e translucidez que ultrapassam níveis estabelecidos de aceitação após muitos ciclos de queimas.

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