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Influência de diferentes protocolos de polimento na rugosidade e adesão bacteriana em cerâmicas de dissilicato de lítio e silicato de lítio reforçadas com zircônia

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“O correr da vida embrulha tudo, a vida é assim: esquenta e esfria, aperta e daí afrouxa, sossega e depois desinquieta. O que ela quer da gente é coragem.” (ROSA, 1965, p. 448)

RESUMO

As restaurações cerâmicas necessitam de ajustes antes ou após a cimentação. Para devolver lisura de superfície é necessário realizar o reglazing ou polimento manual, no entanto existem controvérsias quanto ao melhor método. Sendo assim, o objetivo do estudo foi comparar a rugosidade e adesão bacteriana em cerâmicas de dissilicato de lítio e silicato de lítio reforçado com zircônia após diferentes protocolos de polimento. Foram confeccionadas 72 amostras retangulares, de cada grupo cerâmico: Dissilicato de lítio (LD), silicato de lítio reforçado com zircônia - Vita Suprinity (VS), silicato de lítio reforçado com zircônia - Celtra Duo com queima (CD-AF) e silicato de lítio reforçado zircônia - Celtra duo sem queima (CD). As amostras foram divididas em seis grupos aleatórios de acordo com o protocolo: Glaze (GL), Exacerapol (EX), Ceramisté (CR), Pk 5.1 Ceram (PK), Optragloss (OP) e Controle (CO). Os protocolos de polimento manuais foram realizados com pontas de borrachas abrasivas com mesmo formato, de duas ou três etapas, de diferentes marcas comerciais. A rugosidade foi avaliada antes e depois do protocolo. Duas amostras representativas de cada grupo foram avaliadas por microscopia eletrônica de varredura. A adesão do biofilme *Streptococcus mutans* foi determinada pela contagem de Unidades Formadoras de Colônias por mililitro (UFC/ml). A análise estatística foi realizada com o software Jamovi, utilizando ANOVA de duas vias, seguida pelo teste post hoc de Bonferroni para identificar diferenças significativas entre os grupos. Também foi realizado o teste de correlação de Pearson, para avaliar a correlação entre adesão bacteriana e rugosidade em cada grupo cerâmico. O nível de significância foi estabelecido em $P = 0,05$. Foi observada interação significativa entre as cerâmicas e protocolos na alteração de rugosidade ($(F(12,220) = 19,7, P < 0,006, \eta^2_{\text{partial}} = 0,517)$ e adesão bacteriana ($F(3,216) = .234, P < 0,872, \eta^2_{\text{partial}} = 0,003$). A cerâmica LD apresentou menor alteração de rugosidade, enquanto CD a maior. Ao avaliar somente protocolos houve diferenças significativas entre protocolos de polimento manual e glaze. Houve uma grande correlação positiva entre adesão e rugosidade em todos os grupos LD ($r = 0,589, P < 0,001$), VS ($r = 0,6, P < 0,001$), CD ($r = 0,649, P < 0,001$), CD-AF ($r = 0,727, P < 0,001$). Para LD e VS o protocolo mais eficaz foi OP, enquanto que para CD-AF e CD foi o protocolo PK. Todas as cerâmicas apresentaram menores alterações de rugosidade com os protocolos EX e CR. Para adesão bacteriana só houve diferença significativa entre as

cerâmicas no protocolo GL. Para alteração de rugosidade com exceção do GL, todos os outros protocolos geraram diferenças significativas entre as cerâmicas. A análise em MEV confirmou os resultados de rugosidade. Foi possível concluir que todas as cerâmicas apresentaram diminuição da rugosidade e da adesão bacteriana após os diferentes protocolos de polimento, mas demonstraram comportamentos distintos ao receberem um mesmo protocolo de polimento.

Palavras-chave: cerâmicas vítreas; polimento; rugosidade; adesão bacteriana.

ABSTRACT

Ceramic restorations require adjustments before or after cementation. To restore surface smoothness, reglazing or manual polishing is necessary; however, there is controversy regarding the best method. Therefore, the aim of this study was to compare surface roughness and bacterial adhesion on lithium disilicate and zirconia-reinforced lithium silicate ceramics after different polishing protocols. Seventy-two rectangular samples were fabricated for each ceramic group: Lithium disilicate (LD), zirconia-reinforced lithium silicate - Vita Suprinity (VS), zirconia-reinforced lithium silicate - Celtra Duo with firing (CD-AF), and zirconia-reinforced lithium silicate - Celtra Duo without firing (CD). The samples were divided into six randomized groups according to the protocol: Glaze (GL), Exacerapol (EX), Ceramisté (CR), Pk 5.1 Ceram (PK), Optragloss (OP), and Control (CO). Manual polishing protocols were performed using abrasive rubber points with the same shape, in two- or three-step processes, from different commercial brands. Roughness was assessed before and after each protocol. Two representative samples from each group were evaluated using scanning electron microscopy. Biofilm adhesion of *Streptococcus mutans* was determined by colony-forming units per milliliter (CFU/ml). Statistical analysis was performed using Jamovi software, employing two-way ANOVA followed by Bonferroni post hoc test to identify significant differences between groups. A Pearson correlation test was also conducted to evaluate the correlation between bacterial adhesion and roughness in each ceramic group. The significance level was set at $P = 0.05$. A significant interaction between ceramics and protocols was observed in terms of roughness change ($F(12,220) = 19.7$, $P < 0.006$, $\eta^2_{\text{partial}} = 0.517$) and bacterial adhesion ($F(3,216) = 0.234$, $P < 0.872$, $\eta^2_{\text{partial}} = 0.003$). The LD ceramic showed the least roughness alteration, while CD had the highest. When evaluating only protocols, there were significant differences between manual polishing protocols and glaze. A large positive correlation was found between adhesion and roughness in all groups: LD ($r = 0.589$, $P < 0.001$), VS ($r = 0.6$, $P < 0.001$), CD ($r = 0.649$, $P < 0.001$), and CD-AF ($r = 0.727$, $P < 0.001$). For LD and VS, the most effective protocol was OP, while for CD-AF and CD, it was PK. All ceramics showed less roughness alteration with EX and CR protocols. For bacterial adhesion, significant differences were only observed between ceramics under the GL protocol. Regarding roughness alteration, all protocols except GL generated significant differences between

ceramics. The SEM analysis confirmed the roughness results. It was concluded that all ceramics showed decreased roughness and bacterial adhesion after the different polishing protocols but exhibited distinct behaviors when subjected to the same polishing protocol.

Keywords: glass ceramic; polishing; roughness; bacterial adhesion.

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1 INTRODUÇÃO

O design auxiliado por computador (CAD) e a fabricação auxiliada por computador (CAM), começaram a ser utilizados na odontologia na década de 1970, com a finalidade de reproduzir restaurações resistentes, de aparência natural, de forma rápida e precisa (Davidowitz, Kotick, 2011). Atualmente, esse procedimento digital pode ser realizado pelos técnicos de laboratório com um fluxo de trabalho tradicional, alternativo ou inteiramente nos consultórios odontológicos (Vichi et al., 2018). Com a popularidade crescente desse sistema (Davidowitz, Kotick, 2011), uma ampla variedade de materiais está disponível para uso clínico, apresentando diferenças na composição e indicação (Fouda et al, 2022).

Entre os materiais existentes, as vitrocerâmicas desempenham um papel significativo na odontologia, sendo classificadas como bioativas e bioinertes (Montazerian et al., 2023). Esses materiais têm sido amplamente utilizados para confecção de inlays, onlays, facetas ou coroas anteriores e posteriores. (Banh et al., 2021; Borges et al, 2021; Vo et al; 2015; Zarone et al., 2019).

O dissilicato de lítio IPS e.max CAD (Ivoclar,Vivadent) foi introduzido em 2006. Esse material é composto por uma matriz de vidro de silicato de lítio com cristais de dissilicato de lítio de tamanho micrométrico intercalados, apresentando alto teor de cristal, cerca de setenta por cento (Vo et al., 2015). Possui boas propriedades mecânicas resistência à flexão até valores de 262 ± 88 MPa, juntamente com uma tenacidade à fratura de $2,5 \text{ MPa}\cdot\text{m}^{1/2}$ (Abdulrahman et al., 2021, ref comentarios) e características ópticas apropriadas para restauração da cor do dente (Zarone et al., 2019).

Outro material importante é a vitrocerâmica de silicato de lítio reforçado com zircônia (VITA Suprinity, VITA Zahnfabrik; Celtra Duo, Dentsply-Sirona), introduzida mais recentemente (Matzinger et al., 2019). Com composição diferenciada, apresenta grãos de zircônia tetragonal adicionados a uma matriz vítrea homogênea que consiste em grãos alongados redondos e submicrométricos de metassilicatos de lítio e ortofosfatos de lítio (Sorrentino et al., 2021). A adição de zircônia tem o intuito de melhorar as propriedades mecânicas desses materiais (Matzinger et al., 2019).

Os blocos monolíticos Suprinity são fornecidos em um estágio metassinterizado com o intuito de facilitar a moagem, posteriormente a peça é

submetida a uma queima de cristalização final. Enquanto os blocos Celtra Duo estão disponíveis na forma sinterizada (Spitznagel, Boldt, Gierthmuehlen 2018), com a possibilidade de uma nova queima após a fresagem (Corado et al., 2022).

Após a fresagem desses materiais, a superfície se torna áspera, sendo necessário finalizar a restauração antes da entrega (Siddanna et al., 2021). Além disso, em muitos casos são necessários ajustes antes ou após a cimentação, exigindo um novo tratamento para garantir a lisura de superfície (Camacho et al., 2006; Sagsoz et al., 2016).

Manter a superfície cerâmica lisa é importante para garantir o sucesso a longo prazo da restauração, uma vez que uma maior rugosidade é responsável por alteração de cor (Nascimento et al., 2023), redução das resistências a flexão (Lohbauer, Müller, Petschelt, 2007) e desgaste no dente antagonista e do próprio material (Fouda et al., 2022; Steiner et al., 2015). Além disso, há uma correlação entre rugosidade e adesão bacteriana (Vo et al., 2015; Abdalla et al., 2021). Estudo indica que uma rugosidade acima de 0,2 μm favorece o acúmulo de placa bacteriana (Bollen, Lambrechts, Quirynen, 1997). A adesão bacteriana na superfície cerâmica pode causar micro infiltração, cárie secundária na interface cerâmica-dente, o que pode resultar na falha da restauração (Haralur, Shibani, Alqahtani, 2023; Hahnel et al., 2009).

O *Streptococcus Mutans* é um importante agente etiológico da cárie dentária (Dal Piva et al., 2018). Esse microrganismo tem um grande potencial cariogênico devido a capacidade de converter a sacarose em um polímero celular, o glucano, que permite a adesão e o acúmulo de biofilmes em superfícies lisas como esmalte ou restauração (Al-Marzok, Al-Azzawi, 2009; Bowen, Koo, 2011). Além disso, o *S. mutans* consegue transportar e metabolizar uma ampla gama de carboidratos em ácidos orgânicos (acidogenicidade) e crescer sob condições de estresse ambiental, especialmente em pH baixo (aciduricidade) (Lemos, Burne, 2008).

Com o objetivo de reduzir a rugosidade e obter a lisura superficial adequada para os materiais cerâmicos, podem ser realizados tratamentos de superfície, como o glaze (Camacho et al., 2006; Sagsoz et al., 2016) ou polimentos manuais (Vichi et al., 2018). Os polimentos manuais podem ser executados de várias formas, utilizando polidores diamantados, discos flexíveis com revestimento de óxido de alumínio, polidores de silicone ou pasta de polimento diamantada (Canceill et al., 2023; Carrabba et al., 2017). Nesses procedimentos, alguns fatores como habilidades do

profissional e do técnico, pressão aplicada, velocidade de rotação, tipo de polidor, tempo de polimento, tamanho do grão e espessura da camada de glaze podem influenciar o resultado final (Canceill et al.,2023; Vichi et al.,2018).

Apesar das diferentes possibilidades para obtenção da lisura, não existe um protocolo definido para o polimento de cerâmicas. Um estudo comparou protocolos de polimento mecânico com o glaze em dissilicato de lítio e silicato de lítio reforçado com zircônia. Demonstrou que, para o dissilicato de lítio o glaze é mais eficaz na redução da rugosidade, enquanto, para o silicato de lítio reforçado com zircônia o polimento mecânico é mais efetivo (Kurt et al., 2020).

Alguns estudos apontam que o glaze é o método mais eficiente ao avaliar estabilidade de cor ou propriedades superficiais após desafios ácidos (Abu-Obaid et al., 2020; Hjerppe et al., 2023; Kanat-Ertürk,2019;). No entanto, essa técnica apresenta algumas limitações práticas, uma vez que exige o retorno da peça ao laboratório, aumentando o tempo de tratamento e demandando uma sessão clínica adicional para o paciente (Carrabba et al., 2017). Além disso, o processo de glaze pode alterar as microestruturas cerâmicas, comprometendo a estabilidade do material (Haralur, Shibani, Alqahtani,2023; Scherrer et al. 2020). Outro ponto relevante é que o glaze tem se mostrado suscetível ao desgaste causado pela mastigação cíclica, o que pode resultar na perda da camada superficial ao longo do tempo e no aumento da rugosidade (Kaizer et al., 2019).

Por outro lado, alguns estudos sugerem que o polimento manual pode ser uma alternativa tão eficaz quanto o glaze (Canceill et al.,2023; Vichi et al.,2018). A vantagem do polimento manual é que ele pode ser realizado diretamente no consultório, eliminando a necessidade de etapas laboratoriais e proporcionando mais conveniência ao clínico e ao paciente.

Diante do exposto, o presente estudo tem o objetivo de avaliar a influência de diferentes protocolos de polimento, em cerâmicas vítreas que competem pela mesma indicação clínica, dissilicato de lítio e silicato de lítio reforçado com zircônia, considerando seus efeitos na rugosidade e adesão bacteriana.

2 ARTIGO CIENTÍFICO

Artigo científico a ser enviado para publicação no periódico *The Journal of Prosthetic Dentistry*, qualis CAPES Interdisciplinar A1. A estruturação do artigo baseou-se nas instruções aos autores preconizadas pelo periódico (ANEXO A).

Influence of different polishing protocols on surface roughness and bacterial adhesion in lithium disilicate and zirconia-reinforced lithium silicate ceramics

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ABSTRACT

Statement of Problem: Ceramic surfaces often become rough after adjustments, necessitating re-glazing or manual polishing. However, the ideal polishing protocol remains a topic of debate.

Purpose: To compare the surface roughness and bacterial adhesion of lithium disilicate and zirconia-reinforced lithium silicate ceramics after different polishing protocols.

Materials and Methods: Seventy-two samples were prepared for each ceramic group: lithium disilicate (LD), zirconia-reinforced lithium silicate Vita Suprinity (VS), Celtra Duo - additionally fired (CD-AF), and Celtra Duo (CD). The samples were divided into six groups according to polishing protocol: Control (CO), Glaze (GL), Exacerapol (EX), Ceramisté (CR), Pk 5.1 Ceram (PK), and Optragloss (OP). Manual polishing utilized was performed using abrasive rubber points. Surface roughness was measured before and after polishing. Scanning electron microscopy (SEM) was performed used to examine two samples per group. *Streptococcus mutans* biofilm adhesion was quantified as CFU/mL. Statistical analysis was conducted using two-way ANOVA, Bonferroni post hoc tests, and Pearson correlation to examine the relationship between bacterial adhesion and surface roughness ($P = .05$).

Results: A significant interaction was observed between ceramics and polishing protocols for changes in roughness ($P < .006$), roughness values ($P < .001$), and bacterial adhesion ($P < .001$). Upon evaluating protocols, manual polishing protocols was found to be as effective as or more effective than glazing. Specifically for CD and CD-AF, CD-AF exhibited higher roughness values. A large correlation was noted between bacterial adhesion and surface roughness for LD ($r = .589$, $P < .001$), VS ($r = .6$, $P < .001$), CD ($r = .649$, $P < .001$), and CD-AF ($r = .727$, $P < .001$).

Conclusion: Different polishing protocols effectively reduced roughness and bacterial adhesion in all ceramics. However, each ceramic type exhibited distinct behaviors when subjected to the same protocol.

Keywords: Glass ceramics, polishing, roughness, bacterial adhesion.

CLINICAL IMPLICATION

Polishing after clinical adjustment is essential for restoring surface smoothness and minimizing biofilm adhesion. Both manual polishing and glazing are effective; however, the choice of protocol should be tailored to the composition of the ceramic material, as different compositions respond variably to the same polishing protocol.

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INTRODUCTION

Dental ceramics are commonly used to replace missing parts of dental structures.¹ The computer-aided design and manufacturing (CAD/CAM) system has revolutionized the fabrication of ceramic prostheses.² This technology has led to the development of a wide range of ceramic materials with minimal milling defects and high durability resulting in esthetic and resistant dental restorations.³

Among the various available ceramic materials, lithium disilicate and zirconia-reinforced lithium silicate ceramics are particularly noteworthy. Although these materials have different chemical compositions,⁴ they share similar clinical applications and can be used for inlays, onlays, veneers, and anterior or posterior crowns.^{1,5-8}

Lithium Disilicate ceramic is composed of a lithium silicate glass matrix with micrometer-sized lithium disilicate crystals interspersed, providing a high crystal content of approximately 70%.⁵ This material offers high mechanical strength (flexural strength and fracture toughness),⁹ coupled with translucency characteristics, making it suitable for tooth-colored restorations.⁶ Consequently, lithium disilicate is valued for its aesthetic appeal and fracture resistance.^{1,5,10}

Zirconia-reinforced lithium silicate ceramics are available in the precrystallized form, Vita Suprinity (Vita Zahnfabrik, Bad Säckingen, Germany) or the crystallized form: Celtra Duo (Dentsply Sirona, Hanau-Wolfgang, Germany). The Celtra Duo offers the option for additional firing after milling.^{2,11} Both materials have a similar microstructural configuration, incorporating tetragonal zirconia grains to a homogeneous glassy matrix comprising elongated, round, and submicrometer-sized grains of lithium metasilicates and lithium orthophosphates.¹²

Ceramic surfaces are generally treated to reduce surface roughness, with glazing being the most common approach.^{13,14} However, in clinical practice, most restorations require

adjustment before or after cementation to improve contour and achieve optimal occlusion .¹⁵ These adjustments often result in the loss of the glaze layer and an increase in surface roughness.^{15–17}

The increased roughness promotes bacterial adhesion .^{16,18} *Streptococcus mutans* (*S. mutans*), an early colonizer and cariogenic bacterium, synthesizes adhesive glucans, allowing it to adhere even to smooth surfaces, such as enamel or restorations.^{19,20} Bacterial adhesion on ceramic surfaces can lead to microleakage and development of caries around restorations, ultimately compromising them.^{21,22}

After adjustment, reglazing or in-office polishing can be performed²³ to reduce surface roughness to values below 0.2 μm .^{16,24} However, disagreements exist among researchers regarding the best method. Some studies indicate that reglazing is the most effective approach,^{25–27} although it requires returning the restored component to the laboratory and scheduling an additional clinical session.²⁸ Moreover, the glazing process can affect ceramic microstructures,^{21,29} making the restorations susceptible to wear during cyclic mastication (rendering the surface rough).³⁰ Conversely, other studies have concluded that manual polishing can be as effective as glazing.^{4,31,32}

Therefore, this study aimed to evaluate and compare the surface roughness and bacterial adhesion of lithium disilicate and zirconia-reinforced lithium silicate ceramics following different manual polishing and glazing protocols. The null hypotheses were that the different polishing protocols would cause no changes in surface roughness or bacterial adhesion of the ceramics, , roughness alterations between glazing and manual polishing protocols would not be different, and roughness or bacterial adhesion values would not be different among different ceramic types.

MATERIALS AND METHODS

Sample Preparation

Three different types of ceramic blocks were used to fabricate the specimens: Lithium Disilicate (IPS e.max CAD, Ivoclar Vivadent) A3 low translucency (LT)/C14, Zirconia-Reinforced Lithium Silicate, VS (Vita Zahnfabrik), A3 translucent (T)/C14, and Celtra Duo (Dentsply Sirona), with and without additional firing A3 LT/C14. The characteristics of the materials are summarized in Table 1.

A sample size analysis was conducted for the factorial analysis of variance (ANOVA) using software (G*Power 3.1.9.7).³³ With a significance level of 0.05, a power of 80%, and an expected effect size of 0.3,³⁴ the required sample size was calculated to be 10 samples per group. Two additional samples were prepared from each subgroup for scanning electron microscopy (SEM) analysis.

The ceramic blocks were sectioned with a diamond disk under water cooling ((Isomet, CutMaster) in a rectangular shape (dimensions: 14 mm × 8 mm × 1.5 mm). After milling, the specimens were polished on a variable-speed polisher (Teclago, SP, Brazil) with a 400-grit silicon carbide abrasive paper (Norton) for 30 seconds. The thickness of each specimen was measured using a gauge (Iwanson, Golgran). Subsequently, samples of Lithium Disilicate (LD), Vita Suprinity (VS), and Celtra Duo with additional firing (CD-AF) were sintered according to the manufacturer's instructions. The samples of all ceramic groups were then roughened to simulate the necessary adjustments. The four ceramic groups were randomly divided (<https://www.random.org/>)³⁵ into the following six groups ($n = 12$) based on different polishing protocols (Fig 1). Os grupos o Glaze (GL), Exacerapol (EX), Ceramisté (CR), PK 5.1 Ceram (PK), OptraGloss (OP), and Control (CO). The selected manual polishing kits consisted of flame-shaped abrasive rubber points from different commercial brands, and polishing was performed in two or three steps. (Fig. 1).

Roughening was performed by a single operator, whereas polishing of the specimens was performed by four calibrated operators.. For roughening, a conical diamond bur (PM95F, 45- μm grit; American Burs) was used under refrigeration. The burr was positioned parallel to the surface of the specimens and moved across it for 20 seconds,³⁶ applying a force of 1 N³⁷ at a speed of 14000 rpm. The burs were replaced after working on every five samples to maintain the same amount of diamond grit.^{36,38} After roughening, the samples were polished according to their respective groups. The specimens in group GL received a glaze layer (IPS Ivocolor Glaze Paste, Ivoclar) on one surface, followed by firing based on the manufacturer's instructions. Polishing was standardized across all groups, conducted at a low speed under constant refrigeration for 60 seconds, coupled with intermittent, unidirectional movements, and a constant pressure of 500 grams, at a speed of 10000 rpm. A polishing kit was used for each ceramic group.

Surface Roughness Analysis

The surface roughness evaluation of the ceramic specimens was measured using a roughness tester (Surftest SJ-401, Mitutoyo, Japan) at two different stages: post-roughening and post-polishing. The evaluation length was set to 3 mm, with the measurement interval adjusted to 800 μm (range 800). Three measurements were taken for each sample at the central point, 90 degrees to the right, and 180 degrees to the right, in a counterclockwise direction. The mean roughness values for each group were then calculated.

SEM Analysis

Two specimens from each group, following different polishing protocols, were prepared for SEM (INSPECT S50, FEI). The samples were cleaned with isopropyl alcohol for 3 min, dried with absorbent paper, mounted on a stub, and coated with a thin layer of gold before analysis at 500 $\times$ magnification.

Bacterial Adhesion

Ten specimens from each group were sterilized with ethylene oxide (Oxiecto Industrial Sterilization) before the bacterial adhesion test to prevent contamination of the culture media. *S. mutans* (UA159) was cultivated in brain heart infusion (BHI) broth with 1% sucrose in an anaerobic jar and streaked onto a Petri dish containing Mueller–Hinton agar (IONLAB). The culture was then incubated in an oven at 37 °C for 24 hours .^{5,18}

In a laminar flow chamber, using sterile clinical tweezers, the specimens were placed in 12-well culture plates (KA-12012, KASVI), one specimen per well, with the treated surface facing upward. On the surface of each sample, 50 µL of the *S. mutans* inoculum was deposited. The samples were then immersed in 4 mL BHI broth containing 1% sucrose .The inoculum was prepared using sterile saline solution, and *S. mutans* was adjusted to a turbidity standard of 0.5 McFarland.³⁹ Subsequently, the plates were incubated at 37 °C in a microaerophilic environment.

After 24 hours of incubation, the samples were washed once with sterile distilled water (Dal Paiva, 2018), immersed in wells containing 4 mL BHI broth with 1% sucrose, and incubated for an additional 24 hours .⁴⁰

Following 48 hours of incubation, the samples were washed with sterile distilled water, and the biofilm was removed using a 10-µL polypropylene loop. Two standardized “X” strokes were made across the sample: the first from the lower left to the upper right, and the second from the lower right to the upper left. This procedure was standardized to ensure consistency in measurement.

The loop was inserted into an Eppendorf tube containing 1100 µL of sterile saline solution, and the content was vortexed for 1 minute. From this initial sample, serial dilutions were prepared by transferring 100 µL into a second Eppendorf tube containing 1000 µL of sterile saline solution, followed by vortexing for 1 minute. This step was repeated,

transferring 100 μL from the first Eppendorf tube to the second Eppendorf and vortexed again. This procedure was repeated for third, fourth, and fifth Eppendorf tubes.

For plating, dilutions from 10^{-1} to 10^{-5} were used. Each Petri dish was divided into five sections, and two drops of 25 μL each from the corresponding dilution dispensed into each section. The plates were then incubated for 48 hours. Colony-forming unit (CFU) counting was performed at the 10^{-3} dilution, where counts between 30 and 300 colonies were observed.¹⁹ The average colony count per sample was calculated, and the mean values of CFU (CFU/mL) were obtained.^{39,41}

Statistical Analysis

Data on roughness, roughness change ΔRa (calculated by subtracting the mean roughness values before and after polishing individually), and bacterial adhesion were evaluated for normal distribution and homogeneity of variances. The Kolmogorov–Smirnov test confirmed normal distribution, and Levene’s test verified the homogeneity of variances. Factorial ANOVA (specifically, two-way ANOVA) and Bonferroni post hoc tests were employed to compare the changes in roughness (sample roughness values after abrasion subtracted by roughness values after polishing), and differences in bacterial adhesion, considering the interaction between the ceramic groups (LD, VS, CD, and CD-AF) and different polishing protocols (GL, EX, CR, PK, OP, and CO).). Additionally, Pearson correlation test was performed to assess the relationship between roughness and bacterial adhesion within each ceramic group, based on CFU/mL and roughness values after polishing., the results were interpreted according to Cohen's classification. Statistical analysis was conducted using statistical software (Jamovi, Version 2.5.3),⁴² with an α of .05.

RESULTS

A significant difference was observed between ceramics types ($P < .001$), protocol ($P < .001$), and the ceramic-protocol interaction ($P < .001$) (Table 2). The post hoc analysis of

the interaction showed a significant difference between the control group and other protocols (Table 3). The post hoc analysis revealed that all polishing groups differed statistically from the control group. Furthermore, the GL group differed from the other groups. PK and OP showed lower roughness compared to GL, whereas the EX, CR, and CO protocols presented higher Ra values. An additional analysis was conducted on the CD and CD-AF ceramics, showing significant differences between ceramics types ($F(1,132) = 40.87$, $P < .001$, $\eta^2_{\text{partial}} = 0.038$), protocols ($F(5,132) = 170.98$, $P < .001$, $\eta^2_{\text{partial}} = 0.866$), and the ceramic-protocol interaction ($F(5,132) = 9.01$, $P < .001$, $\eta^2_{\text{partial}} = 0.254$). In the post hoc analysis of the interaction, the CO group, which exhibited the highest roughness, significantly differed from the other groups (Fig. 2). When evaluating protocols independently, CO had the highest roughness and differed from all protocols, whereas GL differed only from PK, OP, and CO. The PK and OP protocols showed the lowest roughness values compared to GL.

The roughness change results indicated statistically significant differences between the ceramic type ($P < .001$), polishing protocol ($P < .001$), and the interaction between these two variables ($P < .006$) (Table 4). Except for the GL protocol, significant differences were observed between the ceramics types for the same polishing protocol. Furthermore, considerable differences were detected between the polishing protocols when each ceramic was evaluated individually (Table 5). The evaluation of the protocols showed that PK and OP differed from GL, EX, and CR, presenting higher ΔRa values. PK also differed from OP, exhibiting higher ΔRa values. The other protocols did not present significant differences. For the CD and CD-AF ceramics, significant differences were observed between ceramics ($F(1,21) = 84.11$, $P < .001$, $\eta^2_{\text{partial}} = 0.155$), protocol ($F(4,121) = 82.95$, $P < .001$, $\eta^2_{\text{partial}} = 0.613$), and the ceramic-protocol interaction ($F(1,132) = 3.85$, $P < .001$, $\eta^2_{\text{partial}} = 0.028$). The post hoc analysis revealed that PK had the highest ΔRa value, differing from EX, CR,

and OP (Fig.3). Upon considering polishing alone, GL differed from the other manual protocols, presenting the lowest ΔRa value.

The CFU/mL count was lower for all the ceramics type after the polishing protocols were applied. No significant difference in bacterial adhesion was observed between the ceramics ($P < .872$). However, significant differences were observed among the polishing protocols ($P < .001$) and in the interaction between the ceramic*protocol ($P < .001$) (Table 6). In all ceramic groups (LD, VS, CD, and CD-AF), statistically significant differences were found between the CO protocol and other polishing protocols, with the CO group exhibiting the highest mean bacterial adhesion (Table 7). Additionally, CO exhibited the highest CFU/mL and differed from the other protocols. PK differed from GL, EX, and OP, showing lower CFU/mL, and OP presented lower CFU/mL compared to CR. No difference was observed among the other groups. For the CD and CD-AF ceramics, significant differences were observed among protocols ($F(5,108) = 54.769$, $P < .001$, $\eta^2_{\text{partial}} = 0.717$) and in the ceramic-protocol interaction ($F(5,108) = 6.51$, $P < .001$, $\eta^2_{\text{partial}} = 0.232$), but not between the ceramics ($F(1,108) = 0.320$, $P = .573$, $\eta^2_{\text{partial}} = 0.003$). The post hoc analysis revealed differences between CO and the other protocols (Fig. 4). When considering protocols alone, CO differed from all other protocols, while GL showed no significant difference compared to other manual polishing protocols. Furthermore, OP presented the lowest CFU/mL, differing from the EX, CR, and PK protocols

A large positive correlation was observed between adhesion and roughness in all groups: LD ($r = 0.589$, $P < .001$), VS ($r = 0.6$, $P < .001$), CD ($r = 0.649$, $P < .001$), and CD-AF ($r = 0.727$, $P < .001$).

The SEM images qualitatively illustrate the results obtained from the roughness and bacterial adhesion tests (Fig. 5). The CO group demonstrated greater surface irregularity across all the ceramics types analyzed. In the LD group, the OP protocol led to fewer surface

irregularities. In the VS group, the most regular surface was observed with the OP protocol. For the CD and CD-AF ceramics, the PK protocol resulted in the least irregular surfaces.

DISCUSSION

The present study demonstrated the differences in roughness and bacterial adhesion values among ceramics, considering the interaction between the applied polishing protocol and ceramic type, furthermore, there were differences between the glaze and the manual polishing protocols. Therefore, the null hypothesis were rejected.

Several factors, such as composition, manufacturing method, and surface treatment, can influence the polishability of a material.^{31,38} The LD and VS ceramics exhibited the smallest changes in roughness but the highest roughness values after polishing. The roughness values observed in LD align with those demonstrated in previous studies.^{4,22,38} A review indicated that zirconia-reinforced lithium silicate ceramics have greater polishability than LD,³¹ likely due to differences in their microstructures. LD contains larger crystals and a higher percentage of crystalline content, which may contribute to its lower polishability.^{32,38}

The ΔRa values of VS and LD ceramics were similar across all the protocols, with no significant differences. The same was observed when comparing the interaction between ceramic type and polishing protocol in roughness values after polishing, except for the OP protocol. Vichi et al.⁴ found significant differences, with VS exhibiting lower roughness; however, each ceramic type was polished with different kits, which may explain the discrepancies between the results. Nevertheless, this finding aligns with that of a previous study which demonstrated similar roughness between these VS and LD after polishing.¹⁷

Celtra Duo ceramics were tested both with additional firing (CD-AF) and without it (CD). Although additional firing is an optional step,^{2,11} studies have indicated that additional crystallization and glazing affect the ceramic microstructure and failure load.^{11,43} Therefore,

whether additional firing would influence surface changes in the ceramic after polishing was evaluated. Considerable differences were found in the changes in roughness after applying the manual polishing protocols, with the CD-AF group exhibiting smaller surface changes (ΔRa) and higher roughness values after polishing. This may be attributed to the increased crystalline content promoted by firing,⁴⁴ as a higher crystalline phase content typically reduces the polishability of ceramics.¹⁶

In manual polishing, all ceramics displayed fewer roughness changes with the EX and CR protocols. However, manual polishing protocols resulted in greater roughness alterations than glazing. For the VS and LD ceramics, the two-step OP protocol promoted a greater alteration, whereas for the CD and CD-AF ceramics, the three-step PK protocol was more effective. This finding contrasts with that of a study in which no significant differences were observed between two- and three-step kits for polishing LD and zirconia ceramics.²⁹ The differences found in the present study may be related to the interaction between the polishing kits and ceramic materials rather than the number of steps.

Another important factor is the abrasive particle size in polishing systems, which affects the surface characteristics of ceramics.⁴⁵ A study showed that roughness reduction is greater when the grit size of the polishing bur is larger than the crystalline structure of the ceramic.³⁸ In the PK kit, the first two steps consisted of silicon carbide, while the third comprised diamond grit; in contrast, in the OP kit, both steps comprised diamond grit. However, the lack of data on the grit size limits further discussion on this matter.

Another critical aspect to consider is time and pressure, both of which were standardized in this study. Previous research demonstrated that 60 seconds of polishing effectively reduced roughness, with further improvements plateauing as the polishing time increased.³¹ The pressure applied in this study was 500 g, differing from that in Yu et al.'s study,²³ which found that a force of 2N (~203 g) was needed to achieve effective polishing in

polymer-infiltrated ceramics. The differences in the type of material evaluated, the use of alumina disks, and extended polishing time in Yu et al.'s study should be considered.

This study also evaluated bacterial adhesion to ceramics with different polishing protocols. Bacterial adhesion was observed across all ceramics types and polishing protocols, aligning with a previous study,²⁴ which highlighted that surface roughness above 0.2 μm promotes bacterial adhesion. A large positive correlation between roughness and bacterial adhesion was observed across all ceramic groups analyzed, a relationship also described in other studies.^{5,16,20} These findings reinforce the importance of selecting a polishing protocol that ensures surface smoothness and minimizes the consequences of plaque accumulation, given the causal link between roughness and adhesion.

Studies suggest that manual polishing can be as effective as glazing.^{4,31} In the present study, regarding roughness after polishing and ΔRa , some manual protocols were observed to be more efficient in reducing roughness compared to glazing. When evaluating the protocols specifically for CD and CD-AF ceramics, all manual polishing protocols were more effective than glazing in terms of ΔRa reduction. However, when comparing bacterial adhesion results, only one of the manual polishing protocols resulted in lower CFU/mL than glazing. For CD and CD-AF ceramics, no significant differences were found between glazing and the other protocols. These results are clinically relevant as they suggest that manual polishing can be an efficient alternative to glazing, providing equal or better results.

According to Paiva et al.,¹⁹ vitrified ceramics exhibit greater roughness and tend to accumulate more biofilms. In all tested ceramics, the lowest CFU/mL count was observed in one of the manual polishing protocols, except for CD. However, this difference was not significant for most polishing protocols. Additionally, a lower CFU/mL count did not consistently correspond to the protocol showcasing the least roughness alteration, although these CFU/mL variations were not statistically significant. This outcome may be attributed to

the standardized roughness measurements taken at specific points on each sample; nonetheless, the ceramic sample/restoration surfaces are not perfectly smooth and uniform.¹⁶ SEM analysis further confirmed the observed trends in roughness and bacterial adhesion data.

This study has certain limitations, notably, bacterial adhesion and roughness were not tested under aging conditions (such as thermocycling). Additionally, the exclusive use of *S. mutans* does not capture the full microbial diversity found in the oral environment.

All ceramic groups exhibited reduce roughness and bacterial adhesion after polishing and glazing, underscoring the importance of these step following adjustments. The selection of a polishing protocol should consider the ceramic material being used: while VS and LD ceramics showed comparable outcomes for both polishing and glazing, CD and CD-AF achieved better results with manual polishing when evaluating the interaction between ceramics type and protocol.

CONCLUSIONS

Based on the findings and limitations of this study, the following conclusions can be drawn:

1. All ceramics types demonstrated a reduction in roughness and bacterial adhesion following the application of glazing and polishing protocols, though the results varied between protocols.
2. Among the polishing protocols, it the manual polishing protocols, PK and OP, were more effective than glazing in reducing roughness Additionally, all manual protocols outperformed glazing in the CD and CD-AF ceramics
3. Regarding bacterial adhesion, the PK protocol demonstrated lower bacterial adhesion compared to glazing. no differences were found between glazing and manual protocols for the CD and CD-AF ceramics

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TABLES

Tabela 1. Commercial name, collective name, manufacturer, and chemical composition of the ceramics in the study.

Material	Collective name	Manufacturer	Composition
Celtra Duo	Zirconia-reinforced lithium silicate	Dentsply-Sirona	SiO ₂ , P ₂ O ₅ , Al ₂ O ₃ , Li ₂ O, K ₂ O, ZrO ₂ , CeO ₂ , Na ₂ O, Tb ₄ O ₇ , V ₂ O ₅ , Pr ₆ O ₁₁ , Cr, Cu, Fe, Mg, Mn, Si, Zn, Ti, Zr, and Al
IPS e.max CAD	Lithium Disilicate	Ivoclar Vivadent	57%–80% SiO ₂ , 11%–19% Li ₂ O, 0%–13% K ₂ O, 0%–11% P ₂ O ₅ , 0%–8% ZrO ₂ , 0%–8% ZnO, 0%–5% Al ₂ O ₃ e 0%–5% MgO
Vita Suprinity	Zirconia-reinforced lithium silicate	VITA Zahnfabrik	56%-64% SiO ₂ , 8-12% ZrO ₂ , 15%-21% Li ₂ O, , <10% pigments, <10% other componentes.

Table 2. Two-way ANOVA results roughness after polishing treatments between ceramic materials and different polishing protocols

	Sum of Squares	df	Mean Square	F	<i>P</i>	η^2p
Ceramic	0.573	3	0.19096	27.8	<.001	0.240
Protocol	7.406	5	1.48130	215.7	<.001	0.803
Ceramic*Protocol	1.059	15	0.07058	10.3	<.001	0.369
Residuals	1.813	264	0.00687			

Table 3. Mean and standard deviation of roughness after polishing treatments

Ceramic	Mean roughness (Ra) ± standard deviation					
	GL	EX	CR	PK	OP	CO
LD	0.830±0.0873 ^{Cc}	1.05±0.102 ^{Ba}	1.04±0.0783 ^{Bab}	0.875±0.0966 ^{Cab}	0.802±0.0546 ^{Cc}	1.20±0.117 ^{Ab}
VS	0.934±0.105 ^{Bbc}	1.03±0.0731 ^{Ba}	1.01±0.0840 ^{Bab}	0.932±0.0687 ^{Ba}	0.933±0.0584 ^{Bab}	1.31±0.0842 ^{Abc}
CD	0.968±0.0898 ^{Bab}	0.991±0.114 ^{Ba}	0.924±0.0585 ^{Bb}	0.790±0.0736 ^{Cb}	0.864±0.0722 ^{BCbc}	1.49±0.107 ^{Aa}
CD-AF	1.08±0.0863 ^{Ba}	1.08±0.0620 ^{Ba}	1.12±0.0604 ^{Ba}	0.839±0.0723 ^{Cab}	1.01±0.0611 ^{Ba}	1.40±0.0753 ^{Aac}

Uppercase letters indicate significant differences ($P < .005$) between polishing protocols within each ceramic type; lowercase letters indicate significant differences between ceramics types within each polishing protocol. Legend LD: Lithium Disilicate, VS: Vita Suprinity; CD: Celtra Duo; CD-AF: Celtra Duo - Additional Firing; GL: Glaze; EX: Exacerapol; CR: Ceramisté; PK: Pk 5.1 Ceram; OP: Optragloss; CO: Control.

Table 4. Two-way ANOVA results analyzing the surface change value (ΔRa) between ceramic materials and different polishing protocols.

	Sum of	df	Mean	F	<i>P</i>	η^2p
	Squares		Square			
Ceramic	2.152	3	0.71721	174.9	<.001	.705
Protocol	1.026	4	0.25642	62.5	<.001	.532
Ceramic*Protocol	0.967	12	0.08060	19.7	<.001	.517
Residuals	0.902	220	0.00410			

Table 5. Mean $\pm$ standard deviation of the roughness change value (ΔRa) for each material with different polishing protocols.

Cerâmica	$\Delta Ra \pm$ standard deviation (μm)				
	GL	EX	CR	PK	OP
LD	0.358 $\pm$ 0.0528 ^{ABa}	0.301 $\pm$ 0.0556 ^{Ba}	0.277 $\pm$ 0.0787 ^{Bbc}	0.329 $\pm$ 0.0639 ^{ABa}	0.403 $\pm$ 0.0520 ^{Abc}
VS	0.331 $\pm$ 0.0383 ^{ABa}	0.283 $\pm$ 0.0595 ^{ABa}	0.238 $\pm$ 0.0428 ^{Bc}	0.336 $\pm$ 0.0477 ^{Ba}	0.379 $\pm$ 0.0635 ^{Abc}
CD	0.362 $\pm$ 0.0373 ^{Ca}	0.505 $\pm$ 0.0737 ^{Bb}	0.563 $\pm$ 0.0950 ^{Ba}	0.761 $\pm$ 0.101 ^{Ab}	0.568 $\pm$ 0.0367 ^{Ba}
CD-AF	0.318 $\pm$ 0.0615 ^{Ca}	0.401 $\pm$ 0.0682 ^{ABc}	0.361 $\pm$ 0.0658 ^{ABb}	0.640 $\pm$ 0.0804 ^{Ac}	0.448 $\pm$ 0.0581 ^{Bc}

Uppercase letters indicate significant differences ($P < .005$) between polishing protocols within each ceramic type; lowercase letters indicate significant differences between ceramics types within each polishing protocol. Legend: LD: Lithium Disilicate, VS: Vita Suprinity; CD: Celtra Duo; CD-AF: Celtra Duo - Additional Firing; GL: Glaze; EX: Exacerapol; CR: Ceramisté; PK: Pk 5.1 Ceram; OP: Optragloss.

Table 6. Two-way ANOVA results analyzing bacterial adhesion (CFU/ml) between ceramic materials and different polishing protocols

	Sum of	df	Mean	F	P	η^2p
	Squares		Square			
Ceramic	18.1	3	6.05	.234	.872	.003
Protocol	14202.4	5	2840.28	110.115	<.001	.718
Ceramic*Protocol	1473.7	15	98.25	3.809	<.001	.209
Residuals	5571.8	216	25.80			

Table 7. Mean $\pm$ standard deviation of bacterial adhesion (CFU/ml) for each material with different polishing protocols.

Ceramic	CFU/ml (10^5) $\pm$ standard deviation					
	GL	EX	CR	PK	OP	CO
LD	23.6 $\pm$ 4.09 ^{BCab}	28.5 $\pm$ 4.59 ^{Ba}	23.2 $\pm$ 4.99 ^{BCa}	18.8 $\pm$ 3.49 ^{Ca}	26.1 $\pm$ 6.49 ^{BCa}	44.0 $\pm$ 4.39 ^{Aa}
VS	27.8 $\pm$ 5.0 ^{Bb}	25.6 $\pm$ 5.04 ^{Ba}	20.1 $\pm$ 5.09 ^{Ba}	22.1 $\pm$ 5.20 ^{Ba}	26.2 $\pm$ 2.49 ^{Ba}	42.5 $\pm$ 5.70 ^{Aa}
CD	19.1 $\pm$ 3.62 ^{Ca}	20.5 $\pm$ 4.25 ^{Ca}	23.3 $\pm$ 5.20 ^{BCa}	22.9 $\pm$ 3.76 ^{BCa}	30.7 $\pm$ 5.90 ^{Ba}	43.8 $\pm$ 7.77 ^{Aa}
CD-AF	29.5 $\pm$ 6.26 ^{Bb}	24.3 $\pm$ 4.66 ^{BCa}	22.9 $\pm$ 6.78 ^{BCa}	17.0 $\pm$ 4.11 ^{Ca}	25.5 $\pm$ 4.10 ^{BCa}	44.4 $\pm$ 5.66 ^{Aa}

Uppercase letters indicate significant differences ($P < .005$) between polishing protocols within each ceramic type; lowercase letters indicate significant differences between ceramics types within each polishing protocol. Legend: LD: Lithium Disilicate, VS: Vita Suprinity; CD: Celtra Duo; CD-AF: Celtra Duo - Additional Firing; GL: Glaze; EX: Exacerapol; CR: Ceramisté; PK: Pk 5.1 Ceram; OP: Optragloss; CO: Control.

LEGENDA DE FIGURAS

Fig. 1. Study design outline.

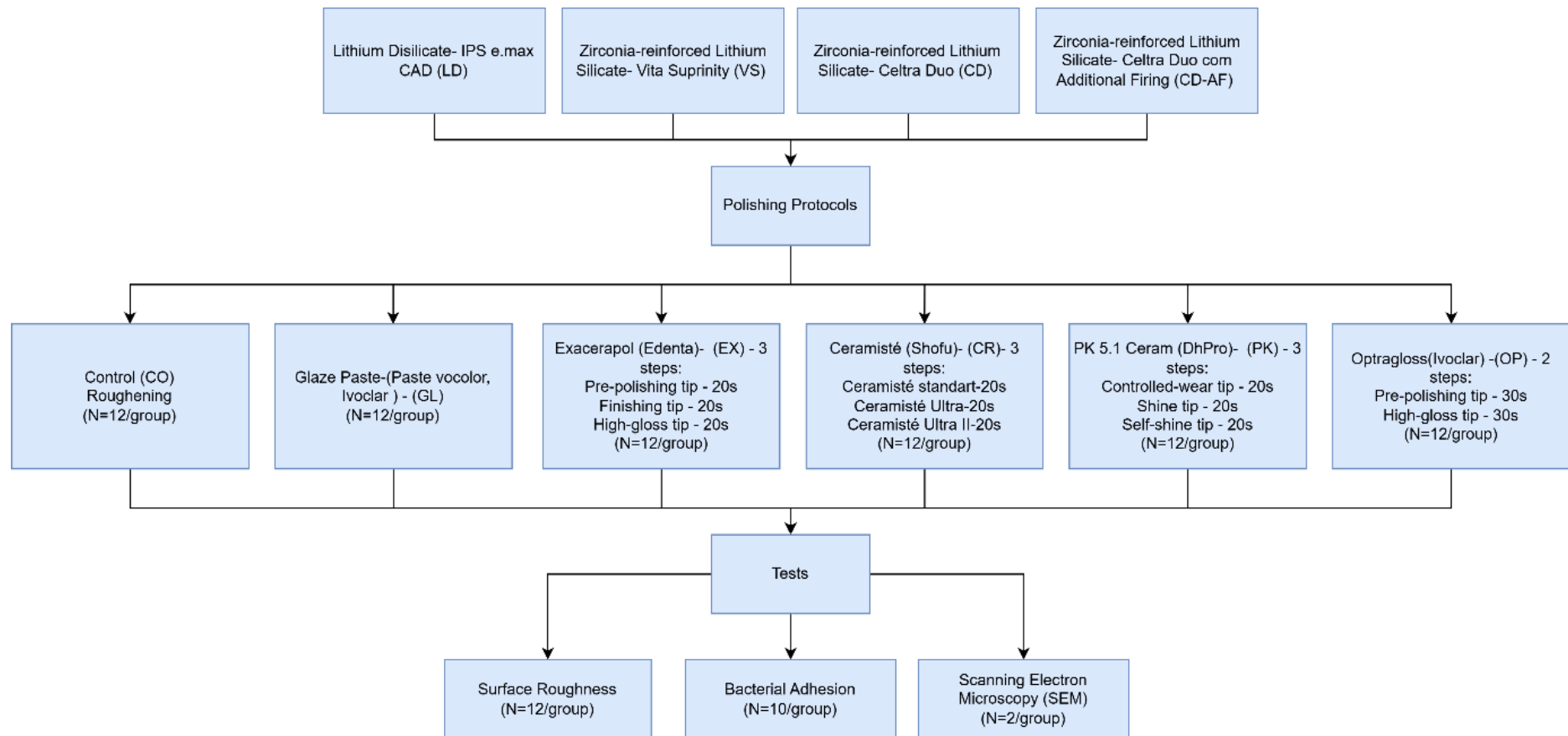


Fig. 2. Graph of the surface roughness of Celtra Duo ceramics and Celtra Duo with additional firing. Uppercase letters indicate significant differences ($P < .005$) between polishing protocols within each ceramic type; lowercase letters indicate significant differences between ceramics types within each polishing protocol. CD: Celtra Duo; CD-AF: Celtra Duo - Additional Firing; GL: Glaze; EX: Exacerapol; CR: Ceramisté; PK: Pk 5.1 Ceram; OP: Optragloss; CO: Control.

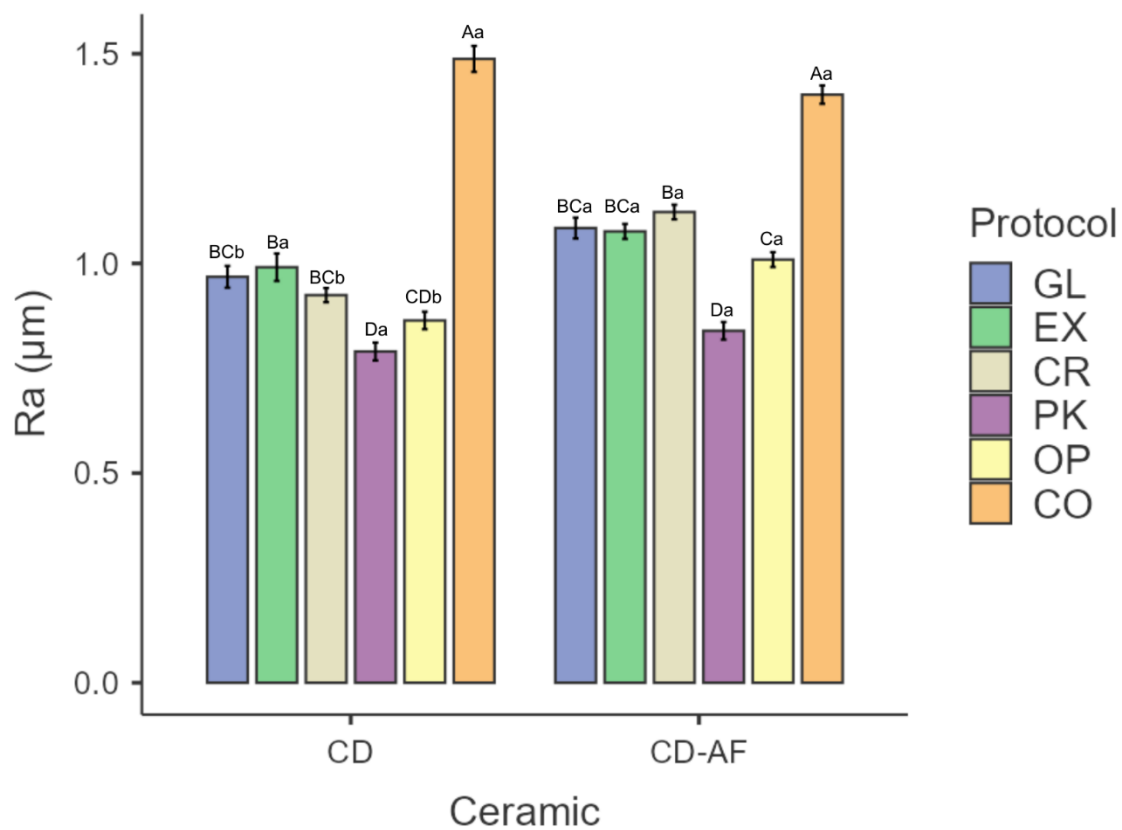


Fig. 3. Graph of the surface roughness change (ΔRa) of Celtra Duo ceramics and Celtra Duo with additional firing. Uppercase letters indicate significant differences ($P < .005$) between polishing protocols within each ceramic type; lowercase letters indicate significant differences between ceramics types within each polishing protocol. CD: Celtra Duo; CD-AF:

Celtra Duo - Additional Firing; GL: Glaze; EX: Exacerapol; CR: Ceramisté; PK: Pk 5.1

Ceram; OP: Optragloss..

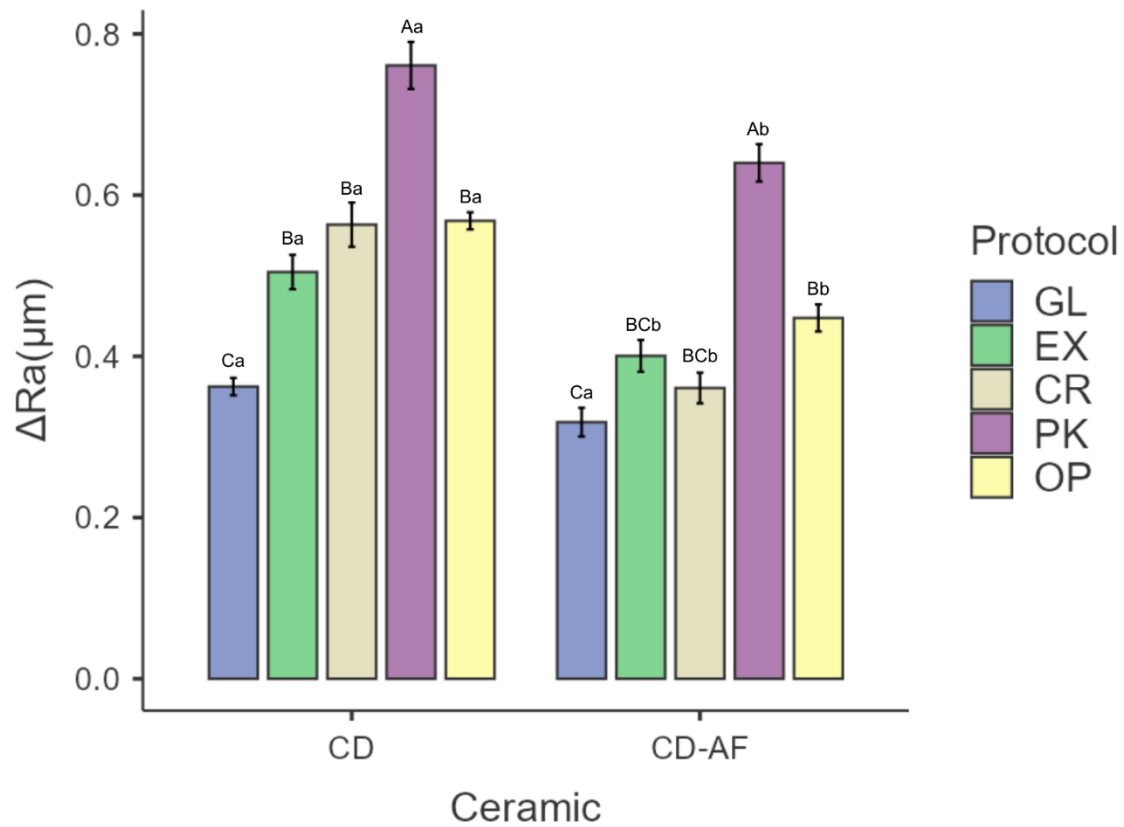


Fig. 4. Graph of bacterial adhesion (CFU/ml) of Celtra Duo ceramics and Celtra Duo with additional firing. Uppercase letters indicate significant differences ($P < .005$) between polishing protocols within each ceramic type; lowercase letters indicate significant differences between ceramics types within each polishing protocol. CD: Celtra Duo; CD-AF: Celtra Duo - Additional Firing; GL: Glaze; EX: Exacerapol; CR: Ceramisté; PK: Pk 5.1 Ceram; OP: Optragloss..

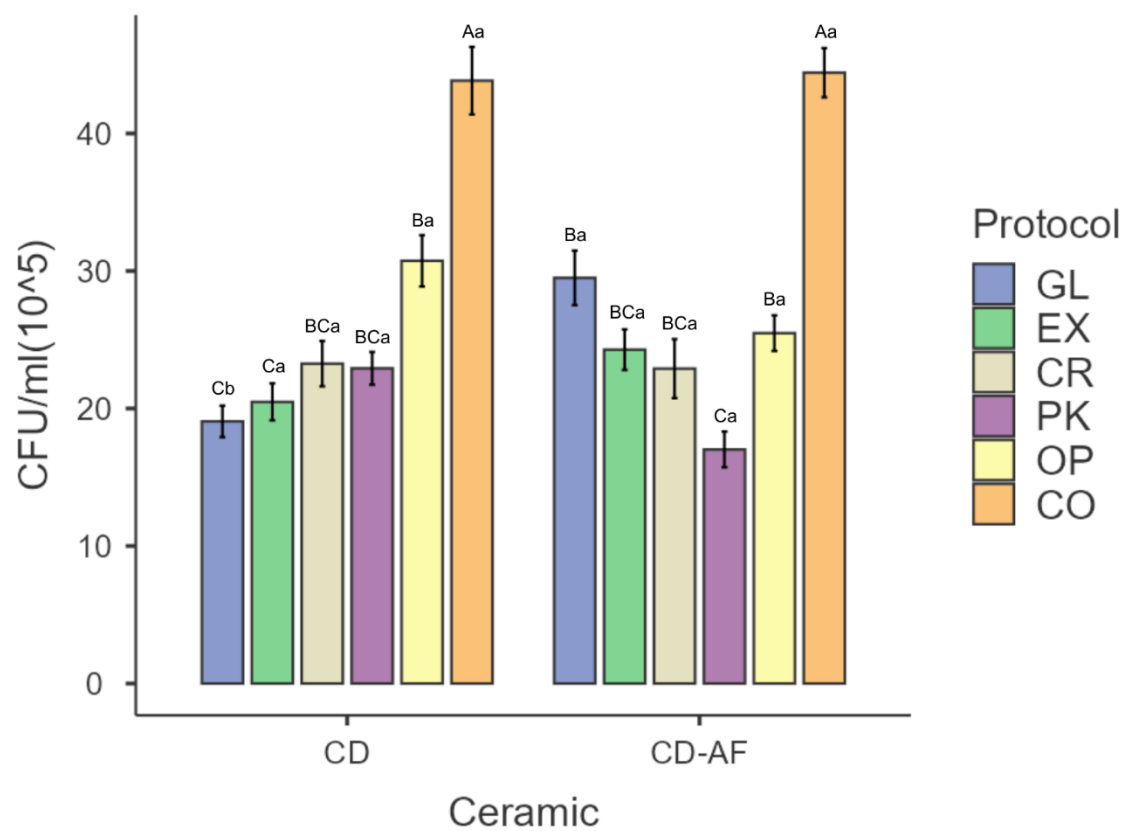
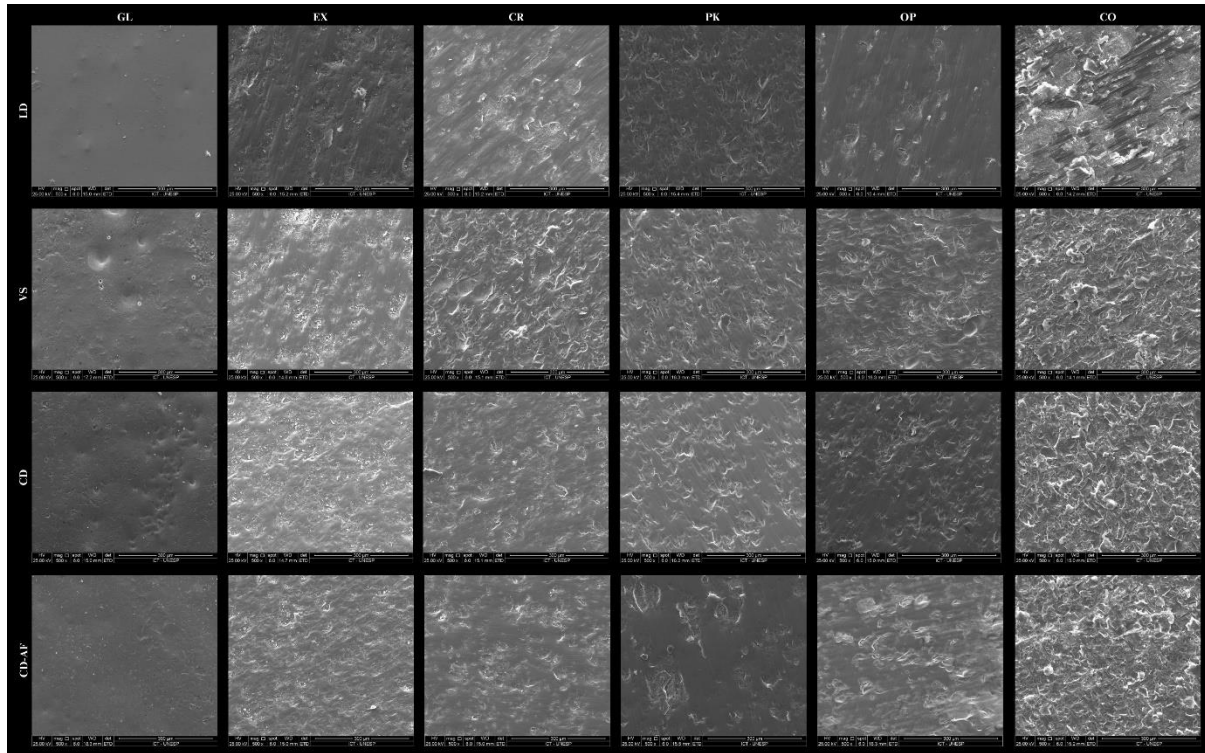


Fig. 5. SEM images of ceramic surfaces after polishing protocols. LD: Lithium Disilicate, VS: Vita Suprinity; CD: Celtra Duo; CD-AF: Celtra Duo - Additional Firing; GL: Glaze; EX: Exacerapol; CR: Ceramisté; PK: Pk 5.1 Ceram; OP: Optragloss; CO: Control.



3 CONCLUSÃO

Conclui-se que o glaze e o polimento manual contribui para a redução da rugosidade e da adesão bacteriana em todas as cerâmicas testadas, uma vez que todos os protocolos de polimento apresentaram diferenças significativas com o grupo controle em todas as cerâmicas. Observou-se que as cerâmicas de disilicato de lítio apresentaram menor alteração de rugosidade, enquanto a cerâmica Celtra Duo exibiu a maior alteração de superfície com os diferentes protocolos de polimento. Ademais, foi identificada uma grande correlação entre rugosidade e adesão bacteriana, reforçando a importância de tratamentos que garantam uma superfície mais lisa para minimizar o acúmulo bacteriano.

Em relação ao efeito dos protocolos de polimento e cerâmicas, verificou-se que, nas cerâmicas Dissilicato de lítio e Vita Suprinity, não houve diferença significativa entre o polimento manual, que gerou maiores alterações de superfície, e o glaze, tanto na alteração da rugosidade quanto na adesão bacteriana. Já para as cerâmicas Celtra Duo e Celtra Duo com queima adicional, o polimento manual resultou em uma superfície significativamente mais lisa que o glaze. Embora essa diferença tenha sido significativa para a adesão bacteriana apenas no grupo Celtra Duo com queima adicional. Ao analisar somente protocolos, foram identificados protocolos de polimento manuais similares ou mais efetivos que o glaze em todas as cerâmicas.

Esses achados, demonstram a importância de realizar o polimento ou glaze após ajustes para garantir a longevidade da restauração. Além disso, demonstram que o polimento manual é uma alternativa eficaz ao glaze e que diferentes cerâmicas se comportam de forma diferente ao receberem um mesmo protocolo de polimento.

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Introduction: Explain the problem completely and accurately. Summarize relevant literature and identify any bias in previous studies. Clearly state the objective of the study and the research hypothesis at the end of the Introduction. Please note that, for a thorough review of the literature, most (if not all) references should first be cited in the Introduction and/or Material and Methods section.

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units of measure. List criteria for quantitative judgment. Describe the experimental design and variables, including defined criteria to control variables, standardization of testing, allocation of participants or specimens to groups (specify method of randomization), total sample size, controls, calibration of examiners, and reliability of instruments and examiners. State how sample sizes were determined (such as with power analysis). Avoid the use of group numbers to indicate groups. Instead, use codes or abbreviations that will more clearly indicate the characteristics of the groups and will therefore be more meaningful for the reader. Statistical tests and associated significance levels should be described at the end of this section.

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Discussion: Discuss the results of the study in relation to the hypothesis and to relevant literature. The Discussion section should begin by stating whether or not the data support rejecting the stated null hypothesis. If the results do not agree with other studies and/or with accepted opinions, state how and why the results differ. Agreement with other studies should also be stated. Identify the limitations of the present study and suggest areas for future research.

Conclusions: Concisely list conclusions that may be drawn from the research; do not simply restate the results. The conclusions must be pertinent to the objectives and justified by the data. In most situations, the conclusions are true for only the population of the experiment. All statements reported as conclusions should be accompanied by statistical analyses.

References: See Reference Guidelines and Sample References page.

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Clinical Report

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Discussion: Comment on the advantages and disadvantages of the chosen treatment and describe any contraindications for it. If the text will only be repetitive of previous sections, omit the Discussion.

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Tips are brief reports on helpful or timesaving procedures. They should be limited to 2 authors, no longer than 250 words, and include no more than 2 high quality illustrations. Describe the procedure in a numbered, step-by-step format; write the text in command rather than descriptive or passive form ("Scan the diagnostic cast" rather than "The diagnostic cast is scanned").

Contact Information

The Journal of Prosthetic Dentistry

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excessive claims of effectiveness. If the text will only be repetitive of previous sections, omit the Discussion.

Summary: Briefly summarize the technique presented and its chief advantages.

References: See Reference Guidelines and Sample References page

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This section describes the artwork for this journal.

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Some Elements of Effective Style

- Short words. Short words are preferable to long ones if shorter word is equally precise.
- Familiar words. Readers want information that they can grasp easily and quickly. Simple, familiar words provide clarity and impact.
- Specific rather than general words. Specific terms pinpoint meaning and create word pictures; general terms may be fuzzy and open to varied interpretations.
- Brisk opening. Plunge into your subject in the first paragraph of the article.
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- Paragraphs. Break up long sections into paragraphs but avoid the use of single sentence paragraphs.
- Restraint. Writers who use flamboyant words or overstate their proposition or conclusions discredit themselves. Facts speak for themselves.
- Clearly stated conclusions. Don't hedge. If you don't know something, say so.

Objectionable Terms

The following are selected objectionable terms and their proper substitutes. For a complete list of approved prosthodontic terminology, consult the eighth edition of the *Glossary of Prosthodontic Terms* (J Prosthet Dent 2005;94:10-92).

Or visit JPD <http://www.prosdent.org> and click on Collections/Glossary of Prosthodontic Terms.

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- The JPD uses the serial comma which is the comma that precedes the conjunction before the final item in a list of three or more items: The tooth was prepared with a diamond rotary instrument, carbide bur, and carbide finishing bur.
- We prefer the nonpossessive form for eponyms: the Tukey HSD test rather than Tukey's HSD test, Down syndrome rather than Down's syndrome and so on.
- Describe experimental procedures, treatments, and results in passive tense. All else should be written in an active voice.
- Describe teeth by name (eg, maxillary right first molar), not number.
- Hyphens are not used for common suffixes and prefixes, unless their use is critical to understanding the word. Some prefixes with which we do not use hyphens include: pre-, non-, anti-, multi-, auto-, inter-, intra-, peri-.
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- It is generally better to paraphrase information from a published source than to use direct quotations. Paraphrasing saves space. The exception is a direct quotation that is unusually pointed and concise.
- When long terms with standard abbreviations (as in TM) for *temporomandibular joint* are used frequently, spell out the full term upon first use and provide the abbreviation in parentheses. Use only the abbreviation thereafter. Even very common acronyms should still be defined at first mention.
- We do not italicize foreign words such as "in vivo", "in vitro."
- Abbreviate units of measurement without a period in the text and tables (g mm). Insert a nonbreaking space between all numbers and their units (100 mm, 25 MPa) except before % and °C. There should never be a hyphen between the number and the abbreviation or symbol except when in adjectival form (100-mm span).
- Spell out "degrees" for angles. Use the degree symbol only for temperature, include a space between the number and degree symbol (e.g., 37 °C).
- Contractions such as don't, it's, wouldn't, etc are not used in scientific writing.
- Avoid using the words "respectively" or "former/latter." Both force the reader to stop and backtrack.

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- Bite use Occlusion
- Bridge use Partial fixed dental prosthesis
- Case use Patient, situation, or treatment as appropriate
- Cure use Polymerize
- Final use Definitive
- Freeway space use Interocclusal distance
- Full denture use Complete denture
- Lower (teeth, arch) use Mandibular
- Model use Cast
- Modeling compound use Modeling plastic impression compound
- Muscle trimming use Border molding
- Overbite, overjet use Vertical overlap, horizontal overlap
- Periphery use Border
- Post dam, postpalatal seal use Posterior palatal seal
- Prematurity use Interceptive occlusal contact
- Saddle use Denture base
- Study model use Diagnostic cast
- Take impressions, photographs, radiographs use Make
- Upper (teeth, arch) use Maxillary
- X-ray, roentgenogram use Radiograph

In addition, *specimen* should be used rather than *sample* when referring to an example regarded as typical of its class.

Additional Terminology Guidelines

Acrylic

An adjective form that requires a noun, as in acrylic resin.

Affect, effect

Affect is a verb; effect is a noun.

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Spelled thus and preferred over **Negro** and **black** in both adjective (African American patients) and noun (... of whom 20% were African Americans) forms.

Average, mean, median

Mean and average are synonyms. Median refers to the midpoint in a range of items; the midpoint has many items above as below it.

Basic

Like fundamental, this word is often unnecessary. An example of unnecessary use: Dental implants consist of two basic types: subperiosteal and endosteal.

Between, among

Use between when 2 things are involved and among when there are more than 2.

Biopsy

This noun should NOT be used as a verb. A biopsy was performed on the Tissue, rather than: The tissue was biopsied.

Centric

An adjective that requires a noun, as in centric relation.

Currently, now, at present, etc.

These expressions are often unnecessary, as in: This technique is currently being used...

Data

Use as a plural, as in: The data were...

Employ

Should not become an elegant variation of use, as in This method is employed ...

Ensure

Preferred over insure in the sense of to make certain.

Fewer, less

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Use the percent sign in the text, as in The distribution of scores was as follows: adequate, 8%; oversized, 23%; and undersized, 69%. But spell out when the percent opens a sentence, as in Twenty percent of the castings ...

Prior to

Before is preferred.

Rare, infrequent, often not, etc.

Whenever possible, these vague terms should be backed up with a specific number.

Rather

Like very, this word should be avoided.

Regimen

A planned program for taking medication, dieting, exercising, etc. Not to be confused with regime, meaning a system of government or management.

Sex

Use "sex" rather than "gender" unless you are referring to the socially constructed roles, behaviors, activities, and attributes that a given society considers appropriate for men and women.

Symptomatology

The science or study of symptoms; this word is not a synonym for the word symptoms.

Technique

Preferred over technic.

Using

Avoid the dangling modifier in sentences such as "The impression was made using vinyl polysiloxane impression material." Write "with" or "by using" instead.

Utilize

Use is preferred.

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Following

After is preferred.

Imply, infer

The speaker implies; the listener infers.

Incidence

The rate at which a disease occurs in a given time; sometimes confused with prevalence (the total number of cases of a disease in a given region).

Majority

Means more than half; use most when you mean almost all. **Male, female**

For adult humans, use men and women. For children, use boys and girls.

Must, should

Must means that the course of action is essential. Should is less strong and means that the course of action is recommended.

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Spell out numbers used in titles or headings and numbers at the beginning of a sentence. The spelled version may also be preferable in a series of consecutive numbers that may confuse the reader (eg, 2 3.5-inch disks should be written two 3.5-inch disks). In all other cases, use Arabic numerals.

Orient

Proper form; avoid orientate.

Pathologic

Use instead of pathological. Other words in which the suffix -al has been dropped include biologic, histologic, and physiologic.

Pathology

The study of disease; often mistaken for pathosis (the condition of disease)

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Via

Use through, with, or by means of.

White

Preferred over Caucasian. This is true only if the patient is from the Caucasus region of Eastern Europe. If not, use the term, white to describe the patient.

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