PAULO SÉRGIO BORELLA

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Orientador: Prof. Dr. Paulo César de Freitas Santos Filho

Co-orientador: Luís Henrique Araújo Raposo

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Prof. Dr. Paulo César de Freitas Santos Filho

Prof. Dr. Flávio Domingues das Neves

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Título do Trabalho ***Influência do desgaste das pontas diamantadas em CAD/CAM na adaptação marginal de dois sistemas cerâmicos reforçados por dissilicato de lítio***
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Linha de pesquisa: Propriedades físicas e biológicas dos materiais odontológicos e das estruturas dentais

As **quatorze** horas do dia **vinte e oito de fevereiro do ano de 2018** no Anfiteatro do Bloco 4L, Campus Umuarama da Universidade Federal de Uberlândia, reuniu-se a Banca Examinadora, designada pelo Colegiado do Programa de Pós-graduação em janeiro 2018 , assim composta: Professores Doutores: Flávio Domingues das Neves (UFU); João Paulo Lyra e Silva (UNIEURO); e Paulo César de Freitas Santos-Filho (UFU) orientador(a) do(a) candidato(a) **Paulo Sérgio Borella.**

Iniciando os trabalhos o(a) presidente da mesa Dr. Paulo César de Freitas Santos-Filho apresentou a Comissão Examinadora e o candidato(a), agradeceu a presença do público, e concedeu ao Discente a palavra para a exposição do seu trabalho. A duração da apresentação do Discente e o tempo de argüição e resposta foram conforme as normas do Programa.

A seguir o senhor (a) presidente concedeu a palavra, pela ordem sucessivamente, aos (às) examinadores (as), que passaram a argüir o (a) candidato (a). Após a argüição, que se desenvolveu dentro dos termos regimentais, a Banca, em sessão secreta, atribuiu os conceitos finais.

Em face do resultado obtido, a Banca Examinadora considerou o (a) candidato(a) a provado(a).

Esta defesa de Dissertação de Mestrado Acadêmico é parte dos requisitos necessários à obtenção do título de Mestre. O competente diploma será expedido após cumprimento dos demais requisitos, conforme as normas do Programa, a legislação pertinente e a regulamentação interna da UFU.

Nada mais havendo a tratar foram encerrados os trabalhos às 17 horas e 15 minutos. Foi lavrada a presente ata que após lida e achada conforme foi assinada pela Banca Examinadora.

Prof. Dr. Flávio Domingues das Neves (UFU)

Prof. Dr. João Paulo Lyra e Silva (UNIEURO)

Prof. Dr. Paulo César de Freitas Santos-Filho UFU

Orientador (a)

SUMÁRIO

RESUMO

Objetivo. Este estudo in vitro teve como objetivo avaliar o efeito do desgaste das pontas diamantadas na adaptação marginal em sucessivas fresagens de coroas de duas cerâmicas reforçadas por dissilicato de lítio em CAD/CAM.

Material e métodos. Inicialmente, 36 troqueis de resina composta padronizadas foram prototipadas a partir de um projeto tridimensional de um primeiro molar mandibular direito com um preparo para coroa total gerada no software de CAD. Foram obtidas 36 coroas cerâmicas em CEREC CAD/CAM para cada troquel e divididos pelos dois sistemas cerâmicos (IPS e.max CAD e Rosetta SM) (n = 18). Foram utilizadas dois conjuntos de pontas diamantadas, um conjunto para cada grupo e a cada 3 coroas fresadas, microscopia eletrônica de varredura (MEV) foi feita. A adaptação marginal das coroas foi medida através de seccionamento coronal e sagital por microtomografia computadorizada (micro-CT), na direção vertical e horizontal das coroas fixadas em seus respectivos troqueis, simulando uma situação clínica. Os dados foram tabulados e submetidos a Analise de Variância em dois fatores e teste Tukey (HSD) com alfa=0,05.

Resultados. Imagens de MEV mostraram que as pontas diamantadas usadas na fresagem das coroas apresentaram mudanças em sua morfologia após as coroas fresadas para cada sistema cerâmico. Houve diferença significativa entre a adaptação marginal das coroas entre as direções (vertical e horizontal) ($p<0,001$). Diferenças significativas também foram verificadas entre os sistemas cerâmicos na direção horizontal ($p<0,041$), mas não na direção vertical ($p<0,465$). Também foram detectadas diferenças significativas na adaptação marginal das coroas nos diferentes períodos de fresagem entre os subgrupos (T1-T18) ($p<0,001$).

Conclusão. As pontas diamantadas são deterioradas por usos sucessivos. A desadaptação marginal das coroas de ambos os sistemas cerâmicos aumentou com o uso sucessivo das pontas diamantadas usadas em CAD/CAM CEREC. IPS e.max CAD apresentou maiores valores de desadaptação marginal na direção horizontal, mas ambos os sistemas foram semelhantes na direção vertical. Além disso, torna-se inadequado fresar novas restaurações após 6 fresagens para Roseta SM e 8 fresagens para IPS e.max CAD.

PALAVRAS CHAVE: Desadaptação marginal; CAD/CAM; Desgaste das pontas diamantadas.

ABSTRACT

Purpose. This in vitro study aimed to assess the effect of successive milling in CAD/CAM diamond burs in the marginal misfit of two lithium disilicate ceramic crowns.

Material and methods. Initially, 36 standardized composite resin dies were prototyped from a three-dimensional design of a right mandibular first molar with a full-crown preparation generated in CAD software. Ceramic crowns were obtained in CEREC CAD/CAM for each composite resin die and divide according to ceramic system (IPS e.max CAD and Rosetta SM) (n=18). Two diamond burs as a set were used, one set for each group and each 3 total crown millings scanning electron microscopy (SEM) was made them. Crowns marginal misfit was assessed through coronal and sagittal micro-tomographic sectioning, in the vertical and horizontal of crows directions seated in their respective dies, simulating a clinical situation. The data was tabulated and submitted to Two-Way ANOVA and Tukey honestly significant difference (HSD) test with alpha=.05.

Results. SEM shows that diamond burs wearing used for milling the crowns presented changes on the superficial morphology after crowns milled for each ceramic system. There was significant difference between the marginal misfit of the crowns for both directions (vertical and horizontal) ($p<.001$). Significant differences were also verified between ceramic systems in horizontal direction ($p<.041$) but not in the vertical direction ($p<. 465$). Also significant differences were detected in the marginal misfit of the crowns at the different milling periods among subgroups (T1-T18) ($p<.001$)

Conclusion. Diamond set burs are deteriorated by successive uses. The crowns marginal misfit of both ceramic systems increased with successive use of the CAD/CAM diamond set burs weariness. IPS e.max CAD showed higher marginal misfit values in horizontal direction, but both systems were similar in vertical direction. In addition, it becoming inappropriate to mill new restorations after 6 milling for Roseta SM and 8 for IPS e.max CAD total ceramic crowns.

KEYWORDS: Marginal misfit; CAD/CAM; Diamond burs wear.

INTRODUÇÃO FUNDAMENTADA

Atualmente, os sistemas cerâmicos possuem grande popularidade para restaurações dentárias pelo o aumento da demanda de pacientes para restaurações dentais estéticas [1] e a melhora de suas propriedades físicas. [2] Isso é possível devido às restaurações cerâmicas oferecem melhor transmissão de luz, o que leva a reprodução melhorada da cor e translucidez dos recursos naturais dos dentes. [3]

Uma restauração dentária ideal em cerâmica pura deve apresentar excelentes características estéticas como translucidez, cor natural, transmissão de luz e ao mesmo tempo excelentes propriedades mecânicas como resistência à flexão, fratura, tenacidade e propagação limitada de trincas em condições de carga parafuncionais, a fim de assegurar a longevidade. Entretanto, hoje, nenhuma dos sistemas cerâmicos odontológicos consegue satisfazer todos esses requisitos ao mesmo tempo. [4]

Uma melhoria significativa no desempenho clínico das restaurações cerâmicas foi obtido com a introdução da cerâmica vítrea reforçada por dissilicato de lítio, recoberta com cerâmica feldspática à base de fluoroapatita, como em IPS Empress 2 (Ivoclar Vivadent, Liechtenstein), mostrando resistência à flexão superior (~350MPa) aos sistemas vítreos precedentes e, ao mesmo tempo, translucidez adequada. Nos últimos anos, tanto as propriedades mecânicas e ópticas desse sistema cerâmico foram implementadas com o desenvolvimento do IPS e.max Press (Ivoclar Vivadent, Liechtenstein), graças às melhorias técnicas no processo de produção. [5]

Avanços na área da informática possibilitaram o desenvolvimento da tecnologia CAD/CAM (Computer Assisted Design/ Computer Aided Manufacturing). Os sistemas CAD/CAM odontológicos são empregados para projetar restaurações cerâmicas de forma eletrônica e fabricar as mesmas utilizando unidade fresadora computadorizada. Usando estes sistemas, o profissional pode fabricar uma restauração sem a necessidade de assistência de laboratório protético, com a vantagem de poder não empregar moldagens convencionais e restaurações provisórias por realizar todos os passos para uma restauração indireta em seção única. [6]

O sistema CEREC é um dos vários sistemas de fresagem computadorizada disponíveis comercialmente, sendo o primeiro sistema CAD/CAM criado especificamente para ser usado no consultório odontológico. [7] As coroas são fabricadas com base no modelo digital gerado por digitalização óptica da boca, impressão regular ou modelos de gesso, que é diretamente controlado pelo operador. Após a digitalização, a restauração é projetada em software específico usando o modelo virtual, por meio do qual blocos de cerâmica são fresados. [8]

A adaptação cervical das restaurações cerâmicas possui um papel chave no seu sucesso, pois o não fornecimento de boa adaptação marginal pode levar ao acúmulo de placa bacteriana e destruição periodontal, cárie recorrentes, e, finalmente, o fracasso das restaurações. [3] Isso ocorre pelo fato da dimensão de desadaptação marginal das restaurações fixas é dependente dos diversos passos envolvidos nos processos clínicos e laboratoriais e da sua correta aplicação pelo profissional. [9]

Vários estudos têm relatado que o ajuste cervical de restaurações CAD/CAM é dependente de diferentes fatores que incluem a configuração de margem, espessura do desgaste, do tipo de cimento utilizado, e a técnica de cimentação. [3] Usando uma fórmula de previsão de regressão linear, [10] descobriu que uma desadaptação cervical aceitável estaria entre 34-119 µm. Autores [10] também sugeriram que restaurações com fendas marginais inferiores a 120 mm apresentaram maiores índices de sucesso. [11] Essa determinação da fenda marginal é feita pela mensuração perpendicular a partir da superfície interna da coroa para a margem do dente preparado.

Os atuais sistemas CAD/CAM odontológicos utilizam, em sua maioria, pontas diamantadas especiais de diferentes formas e granulações para fresagem dos variados blocos cerâmicos disponíveis. Essas podem apresentar alterações na impregnação dos diamantes na ponta ativa, o que pode resultar um prejuízo à qualidade dos instrumentos e do trabalho executado. Além disso, é imprescindível que pontas diamantadas tenham elevada eficiência de corte, [12,]

[13] sendo necessário determinar um limite de uso desta para que a mesma exerça corte adequado.

É possível classificar uma perda de até ¼ dos grânulos de diamantes em pontas diamantadas para alta rotação após a primeira etapa de desgastes em restaurações de resina composta. [12, 13] Como as pontas diamantadas utilizadas para fresagem de restaurações cerâmicas em sistemas CAD/CAM são submetidas à regimes mais intensos de utilização por conta da alta dureza dos materiais fresados, é plausível presumir que as mesmas possam perder parte dos grânulos de diamante durante o uso. Esse fato levaria a uma menor capacidade de desgaste dos blocos cerâmicos, o que poderia resultar em maior número de falhas e pior qualidade de adaptação cervical das restaurações fresadas por pontas diamantadas empregadas por maiores períodos.

CAPITULO 1

ARTIGO 1

Escrito de acordo com as normas da revista Journal of Prosthetic Dentistry.

Influence of CAD/CAM Diamond burs wear on marginal misfit of two lithium disilicate systems

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ABSTRACT

Statement of problem. Small number of studies have compared the marginal misfit of monolithic ceramic crowns obtained by CAD/CAM systems made from different lithium disilicate systems after successive millings.

Purpose. This in vitro study aimed to assess the effect of successive milling in CAD/CAM diamond burs in the marginal misfit of two lithium disilicate ceramic crowns.

Material and methods. Initially, 36 standardized composite resin dies were prototyped from a three-dimensional design of a right mandibular first molar with a full-crown preparation generated in CAD software. Ceramic crowns were obtained in CEREC CAD/CAM for each composite resin die and divide according to ceramic system (IPS e.max CAD and Rosetta SM) (n=18). Two diamond burs as a set were used, one set for each group and each 3 total crown millings scanning electron microscopy (SEM) was made them. Crowns marginal misfit was assessed through coronal and sagittal micro-tomographic sectioning, in the vertical and horizontal of crows directions seated in their respective dies, simulating a clinical situation. The data was tabulated and submitted to Two-Way ANOVA and Tukey honestly significant difference (HSD) test with alpha=.05.

Results. SEM shows that diamond burs wearing used for milling the crowns presented changes on the superficial morphology after crowns milled for each ceramic system. There was significant difference between the marginal misfit of the crowns for both directions (vertical and horizontal) ($p<.001$). Significant differences were also verified between ceramic systems in horizontal direction ($p<.041$) but not in the vertical direction ($p<. 465$). Also significant differences were detected in the marginal misfit of the crowns at the different milling periods among subgroups (T1-T18) ($p<.001$)

Conclusion. Diamond set burs are deteriorated by successive uses. The crowns marginal misfit of both ceramic systems increased with successive use of the CAD/CAM diamond set burs weariness. IPS e.max CAD showed higher marginal misfit values in horizontal direction, but both systems were similar in vertical direction. In addition, it becoming inappropriate to mill new restorations after 6 milling for Roseta SM and 8 for IPS e.max CAD total ceramic crowns.

Clinical Implications: How many successive mills diamonds burs on CEREC CAD/CAM system can be made without result in increased marginal misfit for milled crowns?

INTRODUCTION

Advances in the field of computer science have enabled the development of CAD/CAM (Computer Assisted Design/Computer Aided Manufacturing) technology. Dental CAD/CAM systems are employed to design digital ceramic restorations and fabricate them using computerized milling unit with a prefabricated blocks of different materials. Using these systems, the professional can fabricate a restoration without the need for prosthetic laboratory assistance, with the advantage of not necessarily employing conventional impressions and temporary restorations by performing all the steps for an indirect restoration in a single session. Currently, indirect restorations with satisfactory aesthetics and acceptable of marginal accuracy are possible using chairside CAD/CAM systems. [3, 8, 14-17] The most popular CAD/CAM milling unit (Cerec) uses diamond burs rotating fast speed to mill the ceramic block and to transform them in restorations. Diamond burs are a stainless steel rod and active part formed by micro granules of natural and synthetic diamonds elaborate in a metallic matrix and fixed by galvanic process. This diamonds burs are under wear and its performance can reduce when it is used.[13, 18] Few is known about how the CAD/CAM systems are capable to define after how many crowns milled the set diamond burs need to be changed and is an awareness about how many times can those diamond burs be used.

The cervical adaptation of ceramic restorations plays a key role in their success, since failure to provide good marginal adaptation can lead to plaque accumulation and periodontal destruction, recurrent caries, and, finally, failure of restorations. This is because the marginal misfit size of the fixed restorations is dependent on the various steps involved in the clinical, laboratory processes, and their correct application by the professional in the traditional procedure.[11, 14, 16, 17, 19-21] Marginal misfit of CAD/CAM restorations can be affected by several reasons, but the scanning quality and successive use of diamond burs for long periods can play a decisive role on the adaptation of the definitive restoration. It has been shown that the use of an opacifier powder before scanning can improve the marginal adaptation of crowns, and due to the severe regimen of use, CAD/CAM diamond burs must have limited use in order to reduce disturbs over the ceramic surface and strength.[18, 22]

There are many types of ceramics. The most commonly adapted to CAD/CAM systems are leucite reinforced, feldspatic and lithium disilicate reinforced. The lithium disilicate is introduced in market having many distinct manufactures. Some of them have different proprieties in their structure and sometimes showing different behaviors. Lithium disilicate glass ceramic maintains a relatively high strength, which is high enough for full-coverage crowns in the posterior area. The ceramic blocks are partially crystallized and contain both lithium metasilicate (Li2SiO3) and lithium disilicate (Li2Si2O5) crystal nuclei. In this state, the milling burs are readily applicable with minimized wear-out.[23, 24]

Under so many influences that can influence on the marginal misfit of monolithic ceramic crowns reinforced by lithium disilicate milled in CAD/CAM systems, the purpose of this in vitro study was to assess the influence of the successive uses of CAD/CAM diamond burs process in the marginal misfit of monolithic ceramic crowns produced with two lithium disilicate systems. The null-hypotheses tested were: 1) the CAD/CAM diamond burs used for milling the monolithic ceramic crowns would not show differences in their micromorphology at the different milling periods; and 2) the monolithic ceramic crowns obtained would not show differences in the marginal adaptation in the different milling periods for the both ceramic systems.

MATERIALS AND METHODS

Dies acquisition

Thirty-six standardized composite resin dies were obtained and used for producing and evaluating ceramic crowns adaptation. The drawing was obtained by a three-dimensional model of a right mandibular first molar with a full-crown preparation with beveled shoulder finish line was created in CAD software (Rhinoceros 4.0, Mcneel North America, Seattle, WA, USA) using NURBS lines to generate the surfaces and volumes of the solid (Fig. 1).[25]

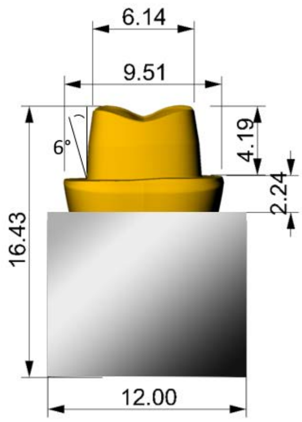

Figure 1- Three-dimensional model of right mandibular first molar knitting with preparation for total crown (mm).

Subsequently, the three-dimensional model was used for prototyping 36 dies models with light-curing composite resin (Veroblack FullCure850, Objet Geometries). The dies obtained were divided into two groups according to the ceramic system (n=18) IPS e.max CAD (LT A2; Ivoclar Vivadent) and Rosetta SM (LT A2, HASS CORP) and subdivided according to the milling period.

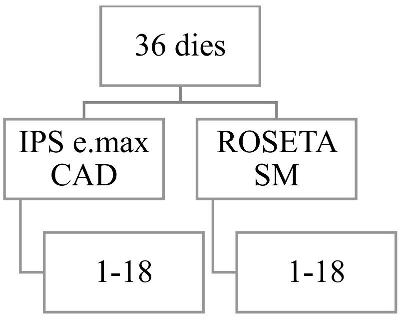

Figure 2 – Schematic group division.

CAD/CAM milling process

For producing the 36 ceramic crowns by the CAD/CAM technique, the composite resin dies were sprayed with an opacifier powder (CEREC Optispray; Dentstply Sirona). The die scanning was performed with device helps. The device was form by a stable base and a gyratory platform, simplifying images capturing. The camera (Omnicam; Dentsply Sirona) was positioned perpendicularly and as closely as possible to the specimen, rather than at a 45-degree angle, and operated in dry conditions.[26] The full crown restorations were individually designed using the anatomy of a mandibular first molar crown from the digital impression of the composite resin dies using the software (CEREC v4.2.5; Dentsply Sirona). The luting space for adhesive cementation was set at 80 µm, according to the manufacturer's instructions and the parameter for young tooth was disable. A new set of CAD/CAM diamond burs (Step Bur 12 and Cylinder Pointed Bur 12S; Dentsply Sirona) was used for each ceramic system before the first milling. Subsequently, the ceramic blocks were positioned in the CAM unit (CEREC inLab MC XL; Dentsply Sirona) to be milled according to the contours and dimensions previously defined on the CAD software. No polishing, glazing or internal adjustments were made for any group before the marginal misfit measurements.

Marginal misfit evaluation

The settling and adaptation of the ceramic crowns were individually checked using fluid vinylpolysiloxane material (Fit Checker, GC America, Alsip, IL, USA) in the respective composite resin dies used to obtain the full ceramic crowns for ensuring passive adaptation. After seating the crowns on their respective composite resin dies, the sets were examined under stereomicroscope at 40× magnification (MZ6, Leica Microsystems GmbH, Wetzlar, Germany) to avoid any cementation interferences. Thus, vinylpolysiloxane (GC Fit Checker; GC Dental Industrial Corp) was used to maintain the indirect restorations in position.

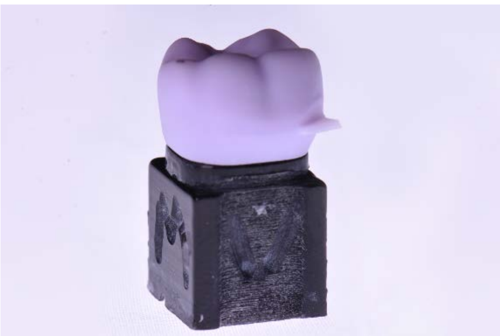

Figure 3 – The crown settled in resin die.

The assessment of the marginal misfit of the crowns was performed using high-resolution micro-computed tomographic scanner (Micro-CT) (1272 SkyScan, Bruker) at the CPBio Dental Research Center.[8] Micro-CT scanning was performed at 100 kV and 100 mA, with a pixel size of 12.0 µm, a filter Cu of 0.11 mm, and resolution of 1632×1092 pixels. The selected scanning was performed at 0.8-degree rotation steps to

180 degrees. To diminish artifacts, an average of 2 frames were collected with 20-pixel random movements, resulting in a scanning time of 20 minutes per specimen obtaining the tomographic sections. The tomographic sections were combined in three-dimensional images using specific software (NRecon v1.6.8.0; SkyScan) with the following parameters: smoothing of 3%, ring artifact correction of 5%, and beam hardening correction of 10%. After image reconstruction, software (DataViewer v1.5.0.2; SkyScan) was used to obtain datasets of sagittal and coronal images. Next, 13 images from the sagittal set and 13 images from the coronal set were selected to illustrate specimen extension in two different planes, according to previous studies (fig. 4).[8, 22, 27] Only was tabulated equally extended and overextended misfit situations. The maximum acceptable misfit was set in 120 μm according to previous study.[28]

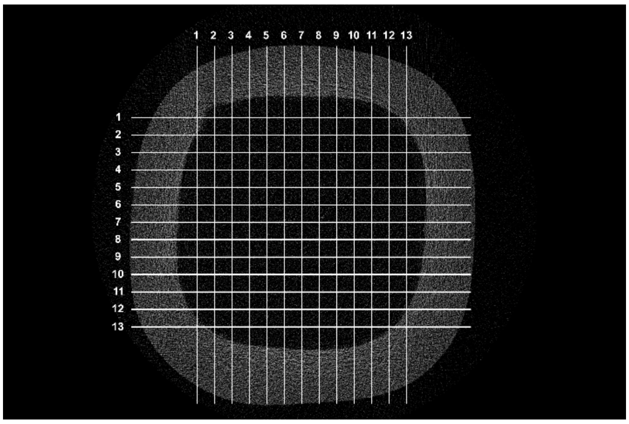

Figure 4 – Sagittal and coronal cuts.

Consecutive, the marginal misfit of the images obtained were evaluated using measuring software (CTAN v1.12.0.0; SkyScan). For each selected image, measurements were made for vertical and horizontal marginal mismatch on each side at ×200 magnification (fig.5). Fifty-two measurements per specimen were made (according to previous studies), and the means were calculated.[8, 22] All equipment were calibrated and operator got experience before the study and the software parameters were the same for all specimens of the both groups.

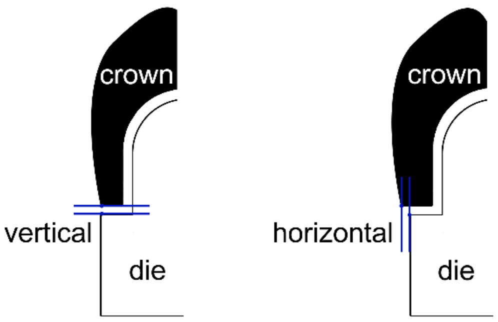

Figure 5 – Horizontal and vertical misfit examples.

Scanning electron microscopy

After milling each three crowns per subgroup, the diamond burs were examined under scanning electron microscopy (SEM) (VEGA 3, TESCAN Electron Microscopy). For this analysis, the distribution, morphology and size of the diamond granules were considered, as well as the presence of the matrix used in the diamond impregnation phase.

Statistical analysis

The marginal misfit (µm) verified in the coronal and sagittal sections selected for each specimen were tabulated, and the mean misfit values were calculated in the vertical and horizontal directions. Thus, Two-Way ANOVA was used to show the differences between the marginal misfits verified in the vertical and horizontal direction for the both groups, followed by the Tukey honestly significant difference (HSD) test with a confidence level of .05 to determine the mean differences. All tests were conducted in statistical software (SigmaPlot 12.0 for Windows, Systat Software Inc.)

RESULTS

The diamond burs wearing used for milling the crowns shown changes on the superficial morphology after the crowns milled for each ceramic system (Fig. 6).

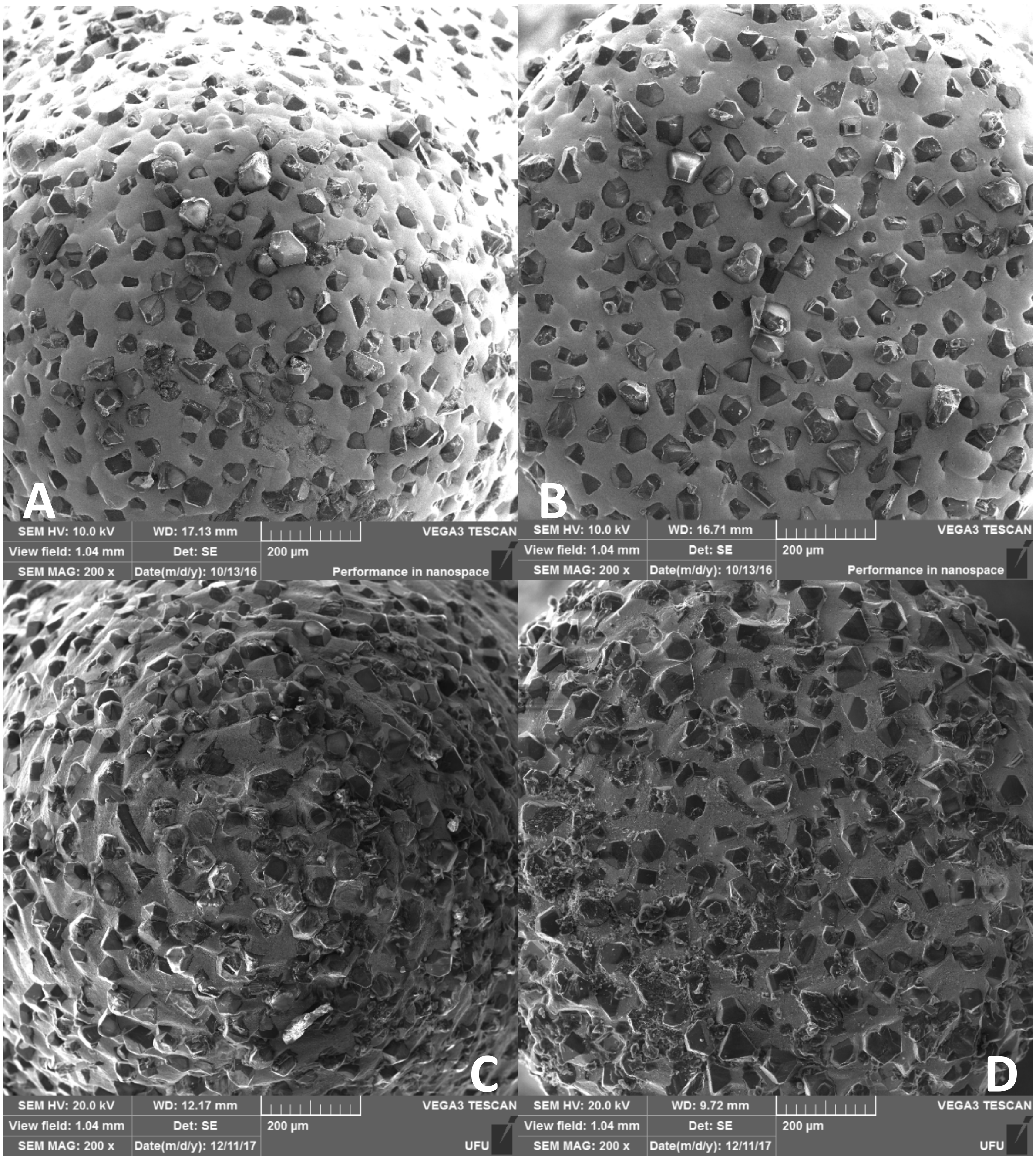

Figure 6 – A and B are SEM of diamond burs before first use – step bur and cylinder pointed bur respectively; C and D are SEM of diamond burs after successive use – step bur and cylinder pointed bur respectively.

The Normality Test (Shapiro-Wilk) passed (p=.165) and Equal Variance Test passed (p=1.0) presenting normal distribution of the data. Two-way Analysis of Variance shows there was significant difference between the marginal misfit of the crowns for both directions (vertical and horizontal) (p<.001). Significant differences were also verified between ceramic systems in horizontal direction (p<.041) but not in the vertical direction (p<. 465). The mean marginal misfit values are shown in Table I.

Table I. Mean of misfit in crystallized ceramic ± SD (n=18)

Groups	IPS e.max CAD	Roseta SM
Horizontal	164.16±53.8 Bb	125.71±49.4 Ba
Vertical	96.83±47.7 Aa	98.62±43.4 Aa

*Uppercase letters compare the direction in vertical; Lowercase letters compare the ceramic systems horizontal using the post hoc Tukey's HSD test (p<.05).

Inside groups significant differences were detected in the marginal misfit of the crowns at the different milling periods (T1-T18) (p<.001), as shown in Table II.

Table I. Mean of misfit in crystallized ceramic ± SD (n=18)

Group/ Specimen	IPS e.max CAD		Roseta SM	
	Horizontal	Vertical	Horizontal	Vertical
1	78.34±25.2 A	32.39±12.3 A	41.69±12.6 A	32.34±5.3 A
2	86.36±6.7 AB	35.15±12.6 AB	51.93±12.6 AB	35.03±6.5 AB
3	100.00±13.3 AB	37.42±9.0 AB	57.44±27.3 AB	36.23±7.8 AB
4	102.52±11.6 AB	39.83±4.5 AB	73.17±20.7 B	50.54±3.0 B
5	106.65±13 AB	41.64±12.6 AB	86.19±13.9 BC	67.91±5.2 BC
6	123.17±9.9 BC	45.11±14.3 BC	100.62±9.2 CD	72.13±4.6 CD
7	135.68±18.2 CD	80.19±14.0 CD	113.2±3.4 CDE	80.98±2.9 CDE
8	156.14±28.4 DE	88.66±18.3 DE	117.5±2.3 DEF	88.39±3.4 DEF
9	173.89±8.2 DEF	95.37±17.2 DEF	124.93±3.4 EF	92.42±1.8 EF
10	181.42±15.6 EFGH	107.51±20.2 EFGH	129.39±10.5 EFG	104.55±6.3 EFG
11	192.3±10.0 FGHI	121.03±7.5 FGHI	138.66±7.6 FGH	110.05±5.5 FGH
12	197.63±10.1 GHIJ	130.18±6.7 GHIJ	148.33±4.5 GH	120.82±2.6 GH
13	203.47±20.2 HIJK	135.16±16.0 HIJK	156.52±12.6 HI	130.19±2.5 HI
14	209.61±22.4 IJKL	143.52±7.0 IJKL	171.63±19.7 IJ	145.73±5.2 IJ
15	212.86±15.1 IJKL	147.85±9.0 IJKL	185.59±12.6 JK	146.95±5.9 JK
16	222.87±20.6 JKL	151.43±19.9 JKL	189.22±9.8 JK	152.50±13.8 JK
17	232.36±6.6KL	153.28±2.9 KL	192.14±5.8 JK	155.68±6.8 JK
18	239.68±8.0 L	157.35±3.9 L	194.77±16.9 K	158.89±2.4 K

*Different letters compare the milling periods in vertical using the post hoc Tukey's HSD test ($p<.05$).

DISCUSSION

According to the results of the present in vitro study, the first null hypothesis was rejected, as changes were observed in the micromorphology of the diamond burs after successive milling. The second null hypothesis was partially rejected, since significant differences were observed in the horizontal marginal fit for both ceramic systems. It was possible to determine that the behavior of the quality of diamond burs is related to crowns marginal misfit.

Since the form of tooth prepare influences in marginal misfit, the die configuration was standardized to avoid interferences on the scanning crowns and to ensure that its insertion in the die could be performed in an accurate and reproducible mode. Therefore, the literature corroborates on favoring of a termination in a straight shoulder that presents acceptable values of marginal misfit.[25] The composite resin material used for prototyping the standardized dies presents very distinct radiopacity properties when compared to dental ceramics, being useful when performing comparisons by tomographic assessments since it simplify readings between the different structures. The crowns tested were not luted to the composite resin dies in order to avoid any influence in the marginal adaptation caused by the luting materials due to factors such as cement type, viscosity, composition, radiopacity and fixation techniques.

The use of different cameras and the use of powder may also influence the marginal misfit values as demonstrated in previous studies.[22, 26] Therefore, in this study, the camera, opacifying powder and operator were standardized to perform the scanning of all dies avoiding other interferences. When the pilot tests were performed, it was seen the need to standardize the specimens scanning, since the scanning was difficult by the die instability, a device for die stabilization was created as describe before. This intercurrence resulted in accuracy scanning and small marginal misfit values and shows that the cast scanning in lab need to be more standardized.

The qualitative analysis of the images obtained by SEM showed partially loss of the diamond granules once present in the surface of the diamond burs. This finding is also in partially agreement with previously reported results about the progressive marginal misfit of ceramic crowns milled in CAD/CAM systems.[13] But, this study was performed with Y-TZP-based restorations showing that burs was similar after 30 millings, the mean surface roughness values were significantly different after 27 millings for Y-TZP-based restorations and 24 millings for veneered with a feldspathic porcelain. In this study, was not evaluate burs surface roughness, but SEM images showed changes in diamond granules morphology after first milling.

The efficiency of the diamond burs was reduced sequentially with the successive milling of the lithium disilicate crowns and a progressive increase of marginal misfit was seen as far as the ceramic crowns was milled for both experimental groups. Additionally, it can be assumed that the time required for milling monolithic lithium disilicate ceramic crowns in CAD/CAM systems depends on other factors than just the amount of diamond granules present on the diamond burs, such as a cooling system that must be in constant maintenance and the performance of the motors present in the CAM unit, what may require further studies. Related to this fact, this behavior may also be a result of a reduction in the cutting efficiency of the diamond burs, as it was possible to observe in this study. The literature supports that this fact occurs by the separation of the diamond particles at the beginning of the cut, in which it leaves a smaller amount of diamond particles and a large amount of diamond-shaped metal matrix.[12]

It is important to consider that the behavior of the diamond burs on the milling unit depends on the function performed by them, since the step bur in CEREC CAD/CAM system is used to mill the marginal adaptation area on indirect restorations, and the cylinder pointed bur is responsible for defining occlusal anatomy. In the present study, it was verified that the cylindrical pointed bur showed more wearing and loss/fracture in diamond granules on its surface than step bur. An explanation to this can be due to a higher activity of the diamond pointed bur because it is responsible for the definition of the occlusal anatomical contour.

Studies[8, 22, 29] validates the categorization of the Micro-CT as a technology slight used until then, for the measurement of the marginal adaptation and still a reliable technique, that allows 2D and 3D measurements from any angle or position. Previous study validate the hypothesis that there are significant differences in the marginal adaptation of restorations produced by different CAD/CAM systems.[25] Therefore, in this study, a single CAD/CAM system and software was used to assure the marginal misfit values of ceramic crowns was obtained in equivalent form.

A marginal gap inferior to 120 µm [28] is recommended in the literature as clinically acceptable. Although the previously mentioned misfit value of 120 µm is supported by the literature, recent studies indicate that the maximum level of vertical maladaptation should be 75 µm,[8, 22] which was smaller than those found in the present study were. Taking in considering the values of horizontal e vertical marginal misfit found in the present study, the maximum acceptable millings in vertical direction was 11 to IPS e.max CAD and 12 millings to Roseta SM. On the other hand, if to consider horizontal direction, only 6 mills to IPS e.max CAD and 8 to Roseta SM is the maximum acceptable numbers of total crowns milled per set burs. Any further milling with same set burs gave marginal misfit values greater than the acceptable in this study. IPS e.max CAD showed the highest values of horizontal misfit, that can be explained by the differences between the sizes of crystal in both ceramic systems.[24]

In the present study was found limitations as: the absence of adjacent and antagonist cast; was not a clinic study; and was not compared crystallization influence, building the necessity of further studies.

As far as the increase of the cut irregularity showed with successive uses in the marginal misfit produced by these instruments, more studies about surface roughness and resistance to fracture would be interesting to evaluate this relationship. Little information is provided by the manufacturer's website about the time it takes to replace the diamond burs. As known, the change of set burs it is CAD/CAM decision criterial and sometimes this decision is given to CAD/CAM's operator. More information is needed about those issues and a set burs replacement criterial is necessary to improve ceramic restorations quality.

On this way, considering the maximum acceptable misfit value for the marginal gap been 120 µm, it was observed that after 15 lithium disilicate crown milling, the diamond bur should no longer be used since the next milling will result in large misfit values that may put in risk the success of the restorative procedure.

CONCLUSION

Within the limitations of the present in vitro study, it can be concluded that the milling efficiency of the diamond burs installed in CEREC CAD/CAM reduces according to the sequential milling of ceramic crowns. IPS e.max CAD showed higher marginal misfit values in horizontal direction, but both systems were similar in vertical direction. This reduction in efficiency influence directly the cervical adaptation of the ceramic crowns, with a sequential increase in the mean marginal misfit, becoming inappropriate to mill new restorations after 6 milling for Roseta SM and 8 millings for IPS e.max CAD total ceramic crowns.

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