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Influence of Computer-aided Design/Computer-aided Manufacturing Diamond Bur Wear on Marginal Misfit of Two Lithium Disilicate Ceramic Systems

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Clinical Relevance

Marginal misfit of monolithic lithium disilicate ceramic crowns obtained from a chairside computer-aided design/computer-aided manufacturing system is affected after successive millings using a single diamond bur set. This fact can be critical for the longevity of indirect restorations.

SUMMARY

Objectives: This laboratory study aimed to assess the effect of successive crown millings on the marginal misfit of monolithic full-ceramic restorations obtained from two lithium disilicate systems, with a single diamond bur set used for each material in a chairside computer-aided design/computer-aided manufacturing (CAD/CAM) unit.

Methods and Materials: Initially, 36 standardized composite resin dies were produced by additive manufacturing from a three-dimensional model of a right mandibular first molar with full-crown preparation generated in CAD software. Individual ceramic crowns were obtained in a chairside CAD/CAM unit (CEREC MC XL) for each composite resin die according to the ceramic system (IPS e.max CAD and Rosetta SM; n=18). Two new diamond burs were used as a set for obtaining the crowns in each experimental group (ceramic systems),

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and the milling periods were defined after three crown millings (T0-T6), when the diamond bur set of each system was removed for morphologic characterization using scanning electron microscopy (SEM). The marginal misfit of the crowns was assessed through coronal and sagittal micro-tomographic sectioning, in the vertical and horizontal directions of the ceramic crowns seated on their respective resin dies. The collected data were tabulated and subjected to one-way analysis of variance and Tukey's honestly significant difference test (α=0.05).

Results: SEM images showed changes in the superficial morphology of the diamond bur sets, with progressive loss of the diamond granules after the successive millings of crowns for both experimental groups. Significant differences were detected in the marginal misfit of the crowns from both ceramic systems at the different milling periods ($p<0.001$).

Conclusions: Diamond burs deteriorated after successive crown millings for both lithium disilicate ceramic systems. The marginal misfit of the crowns obtained increased with the successive use of the CAD/CAM diamond bur set employed for milling each ceramic material. In addition, new milling of full lithium disilicate ceramic crowns can be inappropriate after 11 successive millings for IPS e.max CAD and 12 for Rosetta SM, due to the increased marginal misfit observed under the parameters tested.

INTRODUCTION

Advances in the field of computer sciences have led to the development and improvement of computer-aided design/computer-aided manufacturing (CAD/CAM) technology. Dental CAD/CAM systems are used for the digital design and manufacture of indirect restorations in computerized milling units with prefabricated blocks or discs of different materials.[1,2] Chairside CAD/CAM systems allow indirect restorations to be manufactured in the office by the practitioner, without the need for prosthetic laboratory assistance. These systems have the advantage of not necessarily requiring conventional impressions and temporary restorations when all the steps for an indirect restoration can be performed in a single clinical session. Also, restorations with satisfactory esthetics and acceptable marginal accuracy can be obtained with chairside CAD/CAM systems.[1–3]

Most popular dental CAD/CAM milling units use diamond burs at high speed to mill distinct materials into indirect restorations.[4] The diamond burs from CAD/CAM systems are frequently used under water cooling, and the performance of these instruments is expected to decline when they are used successively.[5,6] Little is known about how CAD/CAM systems are capable of defining the number of milling cycles after which the diamond bur set needs to be replaced.[7–9] In other words, can the CAD/CAM milling units really have adequate control over the number of times the diamond burs can be securely used for milling the different restorative materials available without causing damage to the restorations?

Several types of dental ceramics are currently available, but the materials most commonly used in chairside CAD/CAM systems are blocks/discs from glass ceramics (feldspathic, leucite reinforced, and lithium disilicate reinforced).[10,11] Lithium disilicate–reinforced ceramic was first presented in 1998 as the IPS Empress 2 system (Ivoclar Vivadent, Schaan, Liechtenstein) for use in the heat-pressed technique.[12] Further, a new version of the material was released as IPS e.max Press in 2005, with improved mechanical and optical properties in relation to the first-generation system.[13] The lithium disilicate family of products was patent protected when introduced into the market, and after the patent's expiration, different manufacturers released alternative versions of this material,[11] some of which have different structural properties, sometimes showing behavior distinctly different from that of the original material.[14,15]

In 2006, IPS e.max CAD was introduced for use in CAD/CAM systems,[16] and recently, another lithium disilicate ceramic block became available (Rosetta SM, Hass, Gangneung, Gangwon, Korea).[11,17] The lithium disilicate ceramic blocks available on the market are partially crystallized and contain both lithium metasilicate (Li_2SiO_3) and lithium disilicate ($Li_2Si_2O_5$) crystal nuclei. In this state, the diamond burs of the CAD/CAM systems can be used for milling the blocks into restorations with reduced wear.[10,11]

The cervical adaptation of indirect ceramic restorations plays a key role in its clinical success,[18] since failure to provide good marginal adaptation can lead to plaque accumulation and periodontal destruction, recurrent caries, and, finally, failure of the restorations.[19] The marginal misfit size of an indirect restoration is dependent on the various steps involved in clinical and laboratory processing during the traditional manufacturing process.[14,20–25] Also, while the marginal misfit of CAD/CAM restorations can be affected by several factors, the scanning quality and successive use of diamond burs in the milling unit for extended periods can be decisive in their adaptation.[1,2] It has been shown that the use of an opacifier powder before intraoral digital scanning can improve the marginal adaptation of full-ceramic crowns,[2] and because of severe use, CAD/CAM diamond burs must be used with caution, to reduce disturbances over the ceramic surface and cervical region, with consequent negative effects on final restoration strength.[15]

As has been seen, many factors can influence the quality of indirect restorations produced in chairside CAD/CAM systems. Thus, the purpose of this in vitro study was to assess the effects of successive crown millings on the marginal misfit of monolithic full-ceramic restorations obtained from two lithium disilicate systems with a single diamond bur set used for each material in a chairside CAD/CAM unit. Two null hypotheses were tested: 1) the monolithic full-ceramic crowns obtained would not show differences in marginal adaptation at the different milling periods for both ceramic systems and 2) the CAD/CAM diamond bur sets used for milling the monolithic full-ceramic crowns would not show differences in morphology at the different milling periods for both ceramic systems.

METHODS AND MATERIALS

Die Manufacturing

Thirty-six standardized composite resin dies were obtained and used for production of the ceramic crowns and evaluation of their adaptation. The die base drawing was obtained from a three-dimensional model of a right mandibular first molar with full-crown preparation with rounded axiogingival angles and shoulder termination,[20] which was created with CAD software (Rhinoceros 4.0, McNeel North America, Seattle, WA, USA) and nonuniform rational basis splines lines to generate the solid surfaces and volumes (Figure 1).[26,27]

Subsequently, the three-dimensional model was used for producing the standardized dies with additive manufacturing (Objet Connex350, Stratasys, Eden Prairie, MN, USA) with light-curing composite resin (Veroblack FullCure850, Objet Geometries, Rehovot, Central District, Israel). The dies obtained were checked for any defects and substituted when necessary. Then the dies were assigned to the experimental groups by simple randomization according to the ceramic system (n=18), IPS e.max

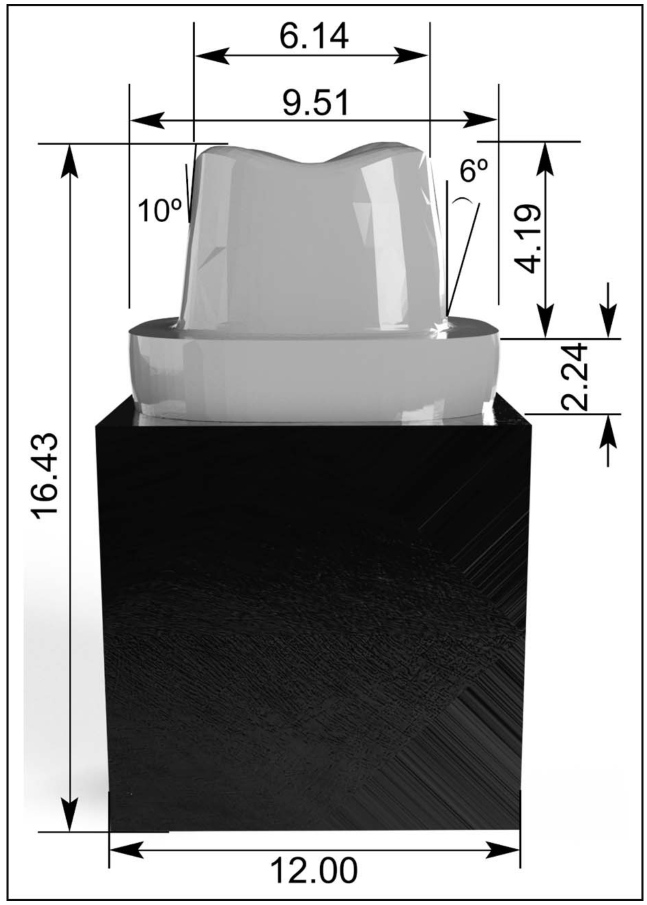
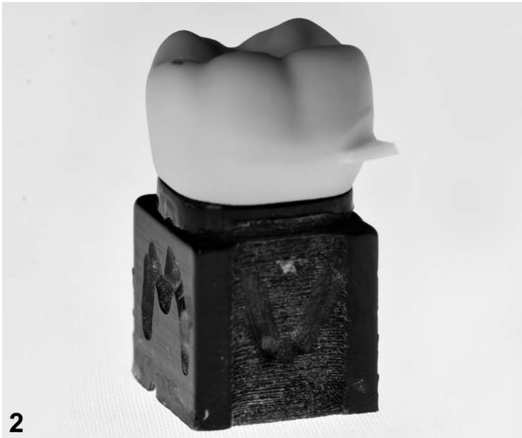


Figure 1. *Three-dimensional CAD model of a right mandibular first molar with full-crown preparation (mm).*

CAD (LT A2, Ivoclar Vivadent), and Rosetta SM (LT A2, Hass) and subdivided according to the milling period (n=3).

CAD/CAM Milling Process

To produce the ceramic crowns by means of the chairside CAD/CAM technique, all the composite resin dies were sprayed with a thin layer of an opacifier powder (CEREC Optispray; Dentsply Sirona, York, PA, USA), indicated for improving the vertical fit, being considered in this study as an option for reducing the need for internal surface adjustments of the crowns.[2] The die scanning was performed with a device formed by a custom stable base and a rotating platform developed for this study, to simplify image acquisition by the scanner. A digital camera (CEREC Omnicam; Dentsply Sirona) was positioned perpendicularly and as close as possible to the specimen, rather than at a 45° angle, and operated in dry conditions, and the scanning procedure was performed by a single experienced operator who had been previously



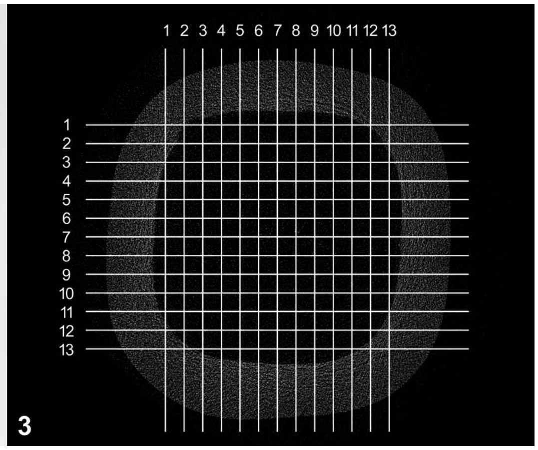


Figure 2. *Full monolithic lithium disilicate ceramic crown seated on its respective resin die.*

Figure 3. *Micro-CT sagittal and coronal cuts of the specimens.*

trained for this purpose.[28] After each resin die had been digitized, full-crown restorations were individually designed in the CAD software for the respective abutments, according to the standard occlusal anatomy of a mandibular first molar crown available in 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 teeth was disabled. A new set of CAD/CAM diamond burs (CEREC Step Bur 12 and Cylinder Pointed Bur 12S; Dentsply Sirona) was selected 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 in groups of three restorations per period. The milling periods for each ceramic material were defined after the completion of three crown millings per group (T0-T6), when the diamond bur set of each ceramic system was removed from the CAM unit for morphologic characterization. The accuracy of milling was ±25 μm, as described by the manufacturer. No polishing, glazing, or internal adjustments were made for any of the milled crowns before the marginal misfit measurements, to avoid additional interference.

Marginal Misfit Evaluation

The placement and adaptation of the ceramic crowns were individually checked with fluid vinylpolysiloxane material (Fit Checker, GC Dental Industrial Corp, Tokyo, Japan),[1,2] on the respective composite resin dies used for scanning and obtaining the restorations, to ensure passive adaptation was obtained. The vinylpolysiloxane material was also used for maintaining the crowns in position (cementation) for marginal misfit evaluation (Figure 2). The material was manipulated for 20 seconds according to the manufacturer's instructions before insertion inside the restorations and placement of the crowns on the resin dies. The excess material was removed from the cervical region using scalpel blades after the setting time was completed (two minutes). After the crowns were seated on their respective resin dies, the sets were first examined under stereomicroscopy at 40× magnification (MZ6, Leica Microsystems GmbH, Wetzlar, Germany) to ensure correct placement and avoidance of any cementation interference caused by the vinylpolysiloxane material. If any dislocation, unseating, or misadjustment was detected during this assessment, the ceramic crown and cementation material were removed from the die followed by new seating. No ceramic crowns were discarded at this time, as the intention was to check the marginal adaptation from the restorations as they were produced by the CAD/CAM system.

The assessment of the marginal misfit of the crowns was performed in a high-resolution micro–computed tomographic (micro-CT) scanner (1272, SkyScan, Bruker, Kontich, Belgium).[1] 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° rotation steps to 180°. To reduce artifacts, an average of two frames was collected with 20-pixel random movements, resulting in a scanning time of 20 minutes per specimen for the tomographic sections to be obtained. The tomographic sections were combined in three-dimensional images with specific software (NRecon v1.6.8.0; SkyScan, Bruker) with the following parameters: smoothing of 3%, ring artifact correction of 5%, and beam-hardening correction of 10%. After image reconstruction, specific software (DataViewer v1.5.0.2; SkyScan, Bruker) was used to obtain image data sets of the sagittal and coronal planes. Next, 13 images from the sagittal set and 13 images from the coronal set were selected to illustrate specimen extension in these two different planes, according to previous studies (Figure 3).[1,2,29] The vertical and horizontal marginal fits were measured in all aspects of the crowns (buccal, lingual, mesial, and distal) considering absolute values, using previously described criteria,[1,2] with the maximum acceptable misfit being defined as 120 μm.[19]

The marginal misfits were evaluated in the images obtained with the measuring software (CTAN v1.12.0.0; SkyScan, Bruker). For each selected image, measurements were made for vertical and horizontal marginal misfits on each aspect of the crown-die set at 200× magnification (Figure 4). The linear distance from the cavosurface angle of the preparation to the margin of the restoration was defined as the marginal misfit, in the vertical and horizontal directions, which represents the maximum measurement of discrepancy at the margin.[1,2,30] Fifty-two measurements were made per specimen (two planes × 13 slices × two aspects), and the combined mean of all four locations for each specimen was calculated.[1,2] All equipment was calibrated, and the software parameters were the same for all specimens; an experienced operator conducted all the evaluations.

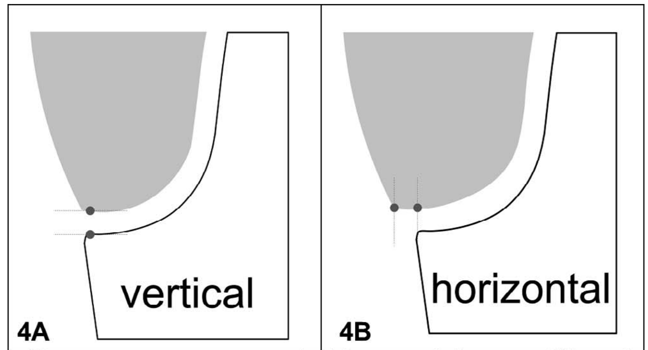


Figure 4. *Marginal misfit measurements. (A): Vertical misadjustment at the cervical region. (B): Horizontal misadjustment at the cervical region.*

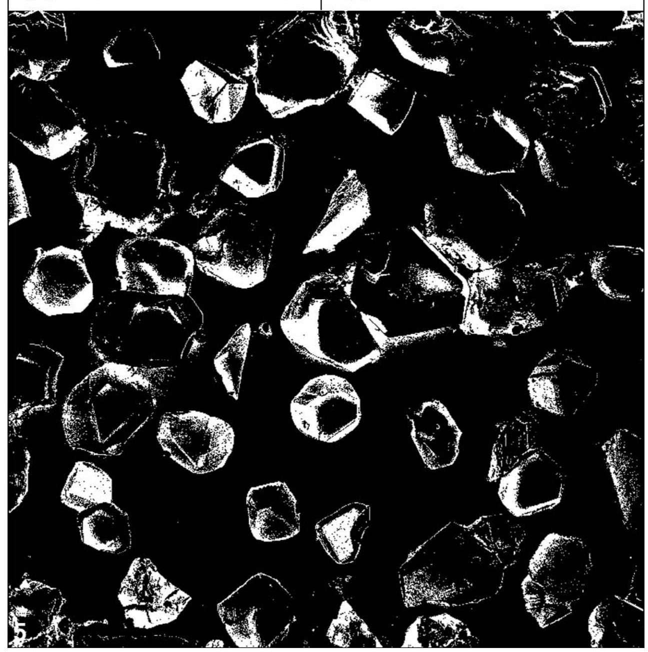


Figure 5. *SEM threshold of diamond grains.*

Morphologic Characterization of Burs

Before the first milling and after the completion of every milling period (three crown millings), the diamond bur set corresponding to each ceramic system was removed from the CAM unit, and the burs were cleaned in an ultrasonic bath with distilled water for five minutes and then dried. At that point, scanning electron microscopy (SEM; VEGA 3, TESCAN Electron Microscopy, Brno, Czech Republic) images were taken from the surfaces of the diamond burs at 100× to 200× magnification and 10.0 KV accelerating voltage. For this qualitative analysis, the distribution, morphology, and sizes of the diamond granules were considered, as well as the presence of exposed metallic matrix on the surfaces of the burs. The total area of the diamond burs in each image was measured with image processing and analysis software (ImageJ 1.52a, National Institutes of Health, Bethesda, MD, USA). The threshold of granules was determined (Figure 5) to define the granule count per area (GC), in addition to the mean area (μm^2) and percentage (%) of diamond granule distribution in the image for quantitative morphologic characterization of the burs.[7]

Statistical Analysis

The marginal misfits (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, one-way analysis of variance was used to show the differences between the marginal misfits verified isolated in the vertical direction and in the horizon-

Table 1: *Mean Marginal Misfit (μm) and Standard Deviation (±) for Lithium Disilicate Full-Ceramic Crowns According to the Ceramic Systems and Milling Periods (n=18)*[a]

Group/Milling Periods	IPS e.max CAD		Rosetta SM	
	Horizontal	Vertical	Horizontal	Vertical
T1 (crowns 1-3)				
1	78.3 ± 25.2 A	32.4 ± 12.3 A	41.7 ± 12.6 A	32.3 ± 5.3 A
2	86.4 ± 6.7 AB	35.1 ± 12.6 AB	51.9 ± 12.6 AB	35.0 ± 6.5 AB
3	100.0 ± 13.3 AB	37.4 ± 9.0 AB	57.4 ± 27.3 AB	36.2 ± 7.8 AB
T2 (crowns 4-6)				
4	102.5 ± 11.6 AB	39.8 ± 4.5 AB	73.2 ± 20.7 B	50.5 ± 3.0 B
5	106.6 ± 13 AB	41.6 ± 12.6 AB	86.2 ± 13.9 BC	67.9 ± 5.2 BC
6	123.2 ± 9.9 BC	45.1 ± 14.3 BC	100.6 ± 9.2 CD	72.1 ± 4.6 CD
T3 (crowns 7-9)				
7	135.7 ± 18.2 CD	80.2 ± 14.0 CD	113.2 ± 3.4 CDE	81.0 ± 2.9 CDE
8	156.1 ± 28.4 DE	88.7 ± 18.3 DE	117.5 ± 2.3 DEF	88.4 ± 3.4 DEF
9	173.9 ± 8.2 DEF	95.4 ± 17.2 DEF	124.9 ± 3.4 EF	92.4 ± 1.8 EF
T4 (crowns 10-12)				
10	181.4 ± 15.6 EFGH	107.5 ± 20.2 EFGH	129.4 ± 10.5 EFG	104.5 ± 6.3 EFG
11	192.3 ± 10.0 FGHI	121.0 ± 7.5 FGHI	138.7 ± 7.6 FGH	110.0 ± 5.5 FGH
12	197.6 ± 10.1 GHIJ	130.2 ± 6.7 GHIJ	148.3 ± 4.5 GH	120.8 ± 2.6 GH
T5 (crowns 13-15)				
13	203.5 ± 20.2 HIJK	135.2 ± 16.0 HIJK	156.5 ± 12.6 HI	130.2 ± 2.5 HI
14	209.6 ± 22.4 IJKL	143.5 ± 7.0 IJKL	171.6 ± 19.7 IJ	145.7 ± 5.2 IJ
15	212.9 ± 15.1 IJKL	147.8 ± 9.0 IJKL	185.6 ± 12.6 JK	146.9 ± 5.9 JK
T6 (crowns 16-18)				
16	222.9 ± 20.6 JKL	151.4 ± 19.9 JKL	189.2 ± 9.8 JK	152.5 ± 13.8 JK
17	232.4 ± 6.6 KL	153.3 ± 2.9 KL	192.1 ± 5.8 JK	155.7 ± 6.8 JK
18	239.7 ± 8.0 L	157.3 ± 3.9 L	194.8 ± 16.9 K	158.9 ± 2.4 K

[a] *Different letters compare milling periods vertically by Tukey's post hoc HSD test (p<0.05).*

tal direction for both ceramic systems in the different milling periods, followed by the Tukey honestly significant difference (HSD) test, with a confidence level of 0.05 to determine the main differences. The marginal misfit verified in the different directions (vertical and horizontal) and the ceramic systems (IPS e.max CAD and Rosetta SM) were not considered for multiple comparisons in the analysis. The analysis for the marginal misfit was performed only on the milling periods for the ceramic systems individually, in the vertical and horizontal directions separately. All tests were performed with a statistical software package (SigmaPlot 12.0 for Windows, Systat Software Inc., Chicago, IL, USA). The data for the morphologic characterization of the diamond burs were descriptively analyzed.

RESULTS

The data for the marginal misfit measurements were tabulated and subjected to the normality test (Shapiro-Wilk; $p=0.165$) and the equal variance test ($p=1.0$), presenting normal distribution. Significant differences were detected in the marginal misfit of the crowns at the different milling periods (T1-T6) for both ceramic systems, with a progressive increase in the marginal gap according to the successive millings of the ceramic crowns ($p<0.001$). The mean marginal misfit values are shown in Table 1.

The results of the morphologic characterization of the diamond burs by quantitative image analysis are shown in Table 2. Progressive loss of diamond granules from the surfaces of the burs was observed following the successive millings of the ceramic crowns, as shown by the reduction in granule count and the percentage of granules. The surface changes were observed on the morphology of the diamond burs used for milling the crowns of both ceramic systems (Figure 6A-D). Loss of the diamond granules and changes in the metallic matrix were also noted on the SEM images. Comparatively, the cylindrical bur showed more extensive morphologi-

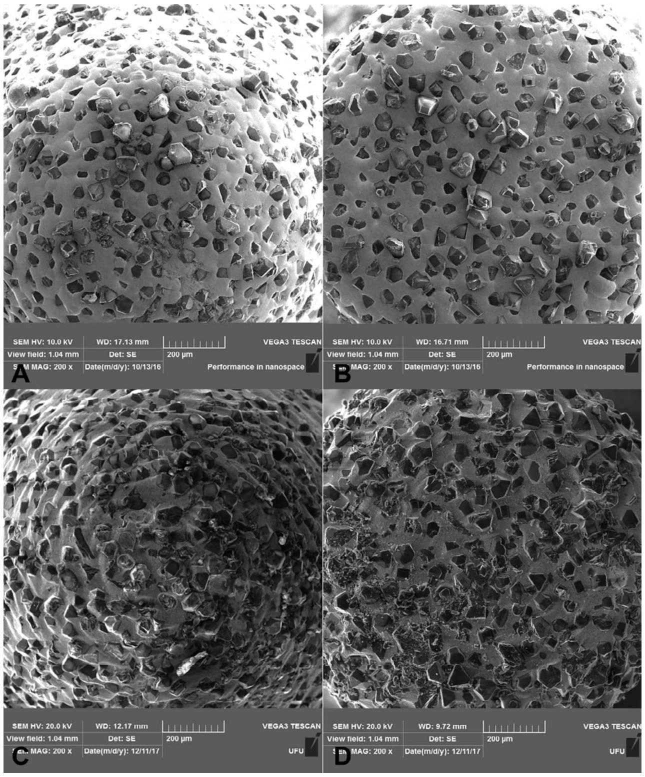


Figure 6. *(A, B): SEM images of the diamond burs before the first use—cylinder pointed bur and step bur, respectively.* (C, D): *SEM images of the diamond burs after successive millings—cylinder pointed bur and step bur, respectively.*

cal changes after successive use, such as loss/fracture of diamond grains, than the step bur (Figure 6C).

DISCUSSION

According to the results of the present in vitro study, the first null hypothesis was rejected, since significant differences were detected in the marginal fit of the monolithic ceramic crowns obtained in the different milling periods for both ceramic systems. The second null hypothesis was also rejected, since changes were observed in the surface morphology of the CAD/CAM diamond burs after successive millings of monolithic ceramic crowns for both ceramic systems, as observed by the decreased quantity of diamond granules. It seems that the marginal misfit of the ceramic crowns is directly related to the quality of diamond burs.

Since the tooth preparation design performed freehand may influence the marginal misfit of indirect restorations, standardized composite resin dies were used in the present study to reduce variables related to the operator and to avoid interference with the scanning procedure, besides allowing for the insertion of the crowns onto the dies to be performed accurately and reproducibly.[27] To avoid unadvertised wearing of a master resin die during the insertion and removal of the ceramic crowns, which could influence the marginal misfit assessments along the study, individual identical resin dies were produced by additive manufacturing instead of using a single die. The literature supports termination in shoulder with rounded axiogingival angles, since this design presents acceptable marginal misfit values.[26] The composite resin material used for obtaining the standardized dies presents distinct radiopacity properties when compared with those of dental ceramics, which are useful when measurements are performed by tomographic assessments, since it simplifies readings between/among the different structures. The occlusal and axial anatomy of the ceramic crowns produced was also standardized, but the software was allowed to calculate the best design for the cervical termination. The crowns tested in this study were not adhesively luted to the composite resin dies to avoid any possible influence in the marginal adaptation

Table 2: *Morphologic Characterization of the Diamond Burs Used for Obtaining the Lithium Disilicate Full-Ceramic Crowns According to the Ceramic System and Milling Periods: Mean of Diamond Granules per Area (μm), Percentage of Diamond Granules per Area (%), and Diamond Granules Count per Area (GC)*

Milling Period	IPS e.max CAD						Rosetta SM					
	Cylinder Bur			Step Bur			Cylinder Bur			Step Bur		
	Mean (μm)	Area %	GC	Mean (μm)	Area %	GC	Mean (μm)	Area %	GC	Mean (μm)	Area %	GC
T0	105.0	41.2	38	90.6	35.5	45	102.2	40.1	36	90.3	35.4	38
T1	92.0	36.1	32	71.7	28.1	36	98.9	38.8	33	87.3	34.2	37
T2	91.2	35.7	32	81.0	31.8	35	83.2	32.6	33	65.1	25.5	35
T3	75.5	29.6	30	84.9	33.3	31	82.3	32.25	31	64.6	25.3	32
T4	59.8	23.5	29	88.8	34.8	27	81.4	31.9	30	64.1	25.1	30
T5	66.0	25.9	22	71.2	27.9	26	71.9	28.2	27	60.8	23.9	30
T6	57.0	22.3	20	59.6	23.4	26	61.5	24.1	27	59.7	23.4	28

caused by the luting materials due to factors such as cement type, viscosity, composition, radiopacity, shrinkage stress, and fixation techniques.[14] Rather, the crowns were stabilized using only a thin layer of a vinylpolysiloxane material prior to marginal misfit assessments. As well, no polishing, glazing, or internal adjustments of the crowns were made for any of the specimens to avoid influence of those techniques.

The use of different CAD/CAM systems,[3] scanning cameras, and the application of opacifier powders may also influence the marginal misfit values, as demonstrated by previous investigations.[2,28] Therefore, in this study, all of these factors and even the operator were standardized to perform the scanning of all dies without further interference. During the pilot tests, the necessity for standardized scanning of the resin dies was noted, since this process was critical to be performed because of the die instability when it was held freehand. Thus, a custom device was developed by the authors for die stabilization as previously described, making the scanning procedure reproducible for all specimens. This change in the digitizing protocol resulted in increased accuracy of scanning with reduced marginal misfit values compared with the pilot specimens that were scanned freehand, showing that the cast scanning procedure must be performed rigorously.

The morphologic characterization of the diamond burs showed loss of the superficial diamond granules and changes in the metallic matrix following the successive millings of the ceramic crowns for both ceramic systems (Figure 6A-D). As seen, these findings may be related to previous results reporting progressive increases in the marginal misfit of ceramic crowns milled in CAD/CAM systems and the damage caused by the diamond burs on the ceramic surfaces,[6,15] which is also in accordance with the marginal misfit results found in the present investigation. Despite the fact that the previous study cited was performed with Y-TZP–based restorations showing that burs were similar after 30 successive millings, the main surface roughness values were significantly different after 27 millings for Y-TZP–based restorations with cyclic fatigue and after 24 millings for restorations without cycling fatigue.[6] Other studies using composite or glass ceramic CAD/CAM blocks also showed no differences in surface roughness of the materials after successive millings.[7–9]

The surface roughness of the ceramic crowns was not evaluated in the present study, but SEM images showed changes in the morphology of the diamond granules of the burs immediately after the first milling period (three crowns). Thus, the images of the diamond burs were quantitatively evaluated as a complementary analysis based on the total area of the images. The image analysis of the diamond burs showed progressive loss of the superficial diamond granules following successive millings of the ceramic crowns, as shown by the reduction in the percentage of granules (Table 2). The cylindrical bur showed increased morphological changes after the successive uses, such as loss/fracture of the diamond grains compared with those on the step bur (Figure 6C). This probably occurred because the diamond bur has a more severe regimen of use, since the occlusal anatomy of the crown is defined by this instrument, as described by the manufacturer.

The efficiency of the diamond burs was sequentially reduced following the successive millings of the lithium disilicate crowns, and a progressive increase in the marginal misfit of the full-ceramic crowns obtained was observed for both experimental groups. This behavior may have resulted from reductions in the cutting efficiency of the diamond instruments, as could be observed with the progressive loss of diamond granules on the surfaces of the burs. Reports in the literature support the separation of the diamond granules at the beginning of the cut, leaving fewer particles and a large number of diamond-shaped holes in the metal matrix on the surfaces of the CAD/CAM diamond burs.[5] Thus, the degradation of the diamond burs can be intimately associated with increased marginal misfit for the ceramic crowns milled, as observed in the present investigation. In addition, it can be assumed that the time required for milling the monolithic lithium disilicate ceramic crowns in CAD/CAM systems may increase with the sequential use and reduced efficiency of the diamond burs. Pilot measurements of the time taken for milling the crowns were performed in this study, and this assumption seems to be adequate, since increased milling time was observed for the crowns obtained in the last milling periods. Not only may this depend on the quantity of diamond granules remaining on the burs, but it also may be influenced by factors such as the cooling system and the performance of the electric motors of the CAM unit. Thus, further studies are needed.

Some studies have described that, despite the fact that micro-CT methodology was seldom used for the measurement of marginal adaptation, this is a reliable technique that allows two-dimensional and three-dimensional measurements to be made from any angle or position of the specimen.[1,2,18] A previous investigation reported significant differences in the marginal adaptation of restorations produced by different CAD/CAM systems.[26] Therefore, in this study, a single CAD/CAM system and software were used to ensure that the marginal misfit values of ceramic crowns were obtained in equivalent form.

A marginal gap of less than 120 μm has been described as being clinically acceptable for indirect restorations.[19] Although this misfit value is supported by the literature, recent studies have indicated that the maximum level of vertical misadjustment should stand below the 75-μm limit,[1,2] which is a smaller misfit value than those found for the crowns of both experimental groups in the present study. Considering the marginal misfit values found in this study, the maximum number of subsequent millings per diamond bur set to produce indirect restorations with acceptable misfit in the vertical direction would be 11 and 12 for IPS e.max CAD and Rosetta SM ceramic systems, respectively. On the other hand, if the horizontal direction was considered, only six and eight millings would be performed for IPS e.max CAD and Rosetta SM, respectively. Any further milling with the same bur set resulted in increased marginal misfit values, higher than 120 μm. However, if 120 μm is considered the maximum acceptable misfit value for the marginal gap, after 12 lithium disilicate crown millings, the diamond bur set should no longer be used, since the next milling would result in increased misfit values that may jeopardize the success of the restorative procedure.

The present in vitro study has some intrinsic limitations, such as the absence of adjacent and antagonist teeth during the scanning procedures. Also, the influence of the crystallization process was not taken into consideration, and only a chairside CAD/CAM system was evaluated. Thus, further studies are needed to investigate additional variables. Regarding the increase in the milling irregularity demonstrated by the successive use of the diamond burs in the marginal misfit produced by these instruments, more studies about surface roughness and fracture resistance should be performed. Little information is available from the manufacturers about the number of milling cycles that can be performed before the diamond burs need to be replaced. The manufacturer of the CAD/CAM used in this study established that a new set of diamond burs is capable of milling up to 15 consecutive indirect restorations, regardless of the extension and restorative material; however, still no evidence is available to support this information.[8] As shown, the decision to change the diamond bur set is usually defined by the CAD/CAM unit, but ideally, this decision should also be made by the operator. More information is needed about these issues, and a better understanding of the criteria for replacing the diamond bur set is necessary to improve the quality of the ceramic restorations produced by chairside CAD/CAM systems.

CONCLUSIONS

Within the limitations of the present in vitro study, it was observed that the milling efficiency of the diamond bur set used in a chairside CAD/CAM system was progressively reduced with the sequential milling of lithium disilicate ceramic crowns for both ceramic systems evaluated. The reduced efficiency of the CAD/CAM diamond burs affected the cervical adaptation of the ceramic restorations, with a sequential increase in the mean marginal misfit. Inappropriate milling of new full lithium disilicate ceramic crowns occurred after 11 successive millings for IPS e.max CAD and 12 for Rosetta SM under the parameters tested.

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Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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