Analysis of the marginal adaptation of different crowns fabricated with computer-aided technology using an intraoral digital scanner

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Aim: The aim of this study was to evaluate the marginal adaptation of ceramic and composite resin crowns fabricated with computer-aided design and computer-aided manufacturing (CAD/CAM) technology using an intraoral digital scanner. **Methods:** A human mandibular right second molar was prepared for a ceramic crown. The impressions were made using intraoral scanning device and crowns were milled. Ten crowns were fabricated for each group (n=10): GF - Feldspathic Ceramic (Cerec Blocs, Sirona), GL - Lithium Disilicate Ceramic (IPS e.max CAD, Ivoclar), GG - composite resin (Grandio Blocs, VOCO) and GB - composite resin (Brava Block, FGM). The marginal gap was measured for each specimen at 4 points under magnification with a stereomicroscope. All data were statistically analyzed using one-way ANOVA followed by the Tukey's test (α=.05). **Results:** The lowest marginal discrepancy value was observed in GB (60.95 ± 13.64 µm), which was statistically different from the GL (84.22 ± 20.86 µm). However, there was no statistically significant difference between these groups when compared with the other groups, GF (73.26 ± 8.19 µm) and GG (68.42 ± 11.31 µm). **Conclusion:** It can be concluded that the composite resin presented the lowest variance compared to the lithium disilicate glass ceramic, although the marginal gap of all materials tested was within the acceptable clinical limit (120 µm).

Keywords: Computer-aided design. Crowns. Dental marginal adaptation. Ceramics. Composite resins.

Introduction

In recent years, newer technologies have been developed in dentistry with the purpose of improving the outcome of indirect restorations[1]. As the name suggests, the computer-aided design and manufacturing (CAD/CAM) system is an innovative technology, wherein planning and fabrication of prostheses are performed using a computer[2]. With this technology, it is possible to create a virtual model of the prosthetic preparation, occlusal relationship of the arches, and plan the restoration. After virtual planning, fabrication of the restoration is carried out without intermediate manufacturing steps, thereby decreasing the cost, time, and risk of contamination during the interim restoration phase[3].

There are two main types of dental CAD/CAM scanners namely intraoral and extraoral scanners. Intraoral scanners are used chairside to scan the dental arches of patients; while extraoral scanners are used in the dental laboratory to scan casts[4]. The extraoral technique may lead to errors during the final impression stage and master cast production. Intraoral scanners aim to eliminate dimensional changes of the impression materials and expansion of the dental stone[5,6]; however, certain factors in the oral environment, such as saliva, sulcular fluid, patient movement, or limited space may interfere in obtaining the digital model[7,8]. In order to be considered an acceptable alternative to conventional impression methods, intraoral scanning devices should yield crowns with similar or better clinical success[3,9].

For the success of prosthetic crowns, good marginal adaptation is essential[9-11]. Marginal gap can be defined as the distance from edge of the finish line of the prepared tooth to cervical margin of the restoration[12]. Presence of marginal gaps contributes to exposure of cement to the oral environment, thereby raising the possibility of dissolution, biofilm accumulation, secondary caries, pulp and periodontal inflammation[10,13-15]. Reference values for a clinically acceptable marginal discrepancy have been described in the literature as less than 120 µm[16], and the recommended threshold for CAD/CAM crowns is between 50 and 100 µm[17-20].

Several factors may influence marginal adaptation, including design of the preparation, location of the margin, impression and waxing techniques[21], accuracy of the milling system, size of the milling bur, thickness of the cementation space and restorative material[22,23]. As chairside CAD/CAM technology is gaining a foothold in dentistry, several restorative materials such as ceramics and composite resins are being increasingly developed and marketed[24].

Ceramics are highly aesthetic, with optical characteristics of translucency and opalescence superior to resinous materials. Moreover, ceramics have high fracture resistance and low material wear[25,26]; however, may have a potential abrasive effect on opposing dentition[27]. Resin composites consist of a polymeric matrix reinforced by fillers that could be inorganic (ceramics, glass-ceramics, or glasses), organic, or composite[28,29]. According to Awada et al.[24] (2015) polymer-based materials appear capable of producing acceptable margins with more conservative preparations, possibly due to relatively high flexural strength combined with low flexural modulus. Polymer-based materials appear to exhibit smoother milled margins compared to ceramic materi-

als[24]. In addition, resinous composites are easy to fabricate, repairable intraorally, and allow for less visible intra-oral repair of minor defects induced by function[29].

There are controversial data in the literature regarding marginal adaptation of crowns fabricated with resin composites and lithium disilicate ceramics. A study by de Paula Silveira et al.[2] (2017) showed no difference among these materials. Tabata et al.[1] (2020) found that the composite resin presented significantly lower values of marginal discrepancy (56 ± 27 mm) than ceramic (71 ± 35 mm), however, El Ghoul et al.[30] (2020) reported that ceramic-based groups showed smaller gaps than resin-based groups.

Further studies are required on marginal adaptation of CAD/CAM restorative materials considering the lack of sufficient data. Thus, the purpose of this *in vitro* study was to evaluate the marginal adaptation of ceramic and composite resin crowns fabricated with CAD/CAM technology using intraoral digital scanner. The null hypothesis was that marginal adaptation values of crowns are not influenced by the type of material.

Material and methods

The Research Ethics Committee of the Faculty of Dentistry of the Federal University of Bahia approved this study (number 3,082,332). One caries-free human mandibular molar was selected, cleaned by scaling, and stored in 0.01% Thymol to prevent bacterial proliferation. The tooth was stored in a metal box with a damp sponge to prevent it from drying and becoming brittle, throughout the study.

The human mandibular right second molar was mounted with its adjacent teeth on a typodont and prepared to receive an all-ceramic crown with chamfer finish line. The tooth preparation was as follows: 2 mm reduction of the occlusal surface, convergence angle of approximately 6 degrees, 1.0 to 1.5 mm axial reduction, and location of the finish line was above the cementoenamel junction. Diamond tips were used for the tooth preparation adapted on a multiplier contra-angle T3-Line handpiece (Sirona Dental Systems GmbH, Bensheim, Germany) in the following sequence: diamond tip FG 3216 (KG Sorensen, Cotia, Brazil) for delimitation of the buccal, lingual and occlusal orientation grooves and union of the grooves, diamond tip FG 3203 (KG Sorensen, Cotia, Brazil) was used to make contact point rupture, FG 3216 (KG Sorensen, Cotia, Brazil) was used to create a chamfer finish line and diamond tip FG 4138 was used for finishing (KG Sorensen, Cotia, Brazil).

The composition and information regarding manufacturer of the tested materials are listed in Table 1.

Table 1. Type, composition, and manufacturer of the four tested materials

Material	Composition	Manufacturer
CEREC Blocs	Feldspathic Ceramic – GF	Sirona (Bad Säckingen – Bensheim – Germany)
IPS e.max CAD	Lithium Dissilicate Glass Ceramic – GL	Ivoclar Vivadent (Schaan – Liechtenstein).
Grandio Blocs	Resin composite (hybrid nano ceramic) – GG	VOCO (Cuxhaven – Germany)
Brava Block	Resin composite (glass ceramic composite) – GB	FGM (Joinville – Santa Catarina – Brazil)

Ten digital impressions of the prepared tooth were made for each group using the CEREC Omnicam intraoral scanner (Sirona Dental Systems GmbH, Bensheim, Germany). The appropriate software CEREC inLab SW 4.5 (Sirona Dental Systems GmbH, Bensheim, Germany) was used to design the crowns on the virtual model. The operator determined design parameters were as follows: radial and occlusal spacer = 80 μm, resistance of proximal contacts = -25 μm, resistance of occlusal contacts = -25 mm, dynamic contact force = -25 μm, minimum thickness (radial) = 700 μm, minimum thickness (occlusal) = 900 μm, and margin thickness = 80 μm. All restorations were designed to have similar occlusal anatomy and the same occlusogingival height. After each crown was designed, the information was exported to the milling unit CEREC inLab MCXL ((Sirona Dental Systems GmbH, Bensheim, Germany).

Ten crowns were fabricated for each group (n = 10): GF - Feldspathic Ceramic, GL - Lithium Disilicate Ceramic, GG - composite resin (Grandio Blocs) and GB - composite resin (Brava Block). Following the manufacturers' instructions, specimens in group GL were subjected to the crystallization process (Programat CS2; Ivoclar Vivadent, Schaan, Liechtenstein), while specimens in GF, GG and GB groups did not need any crystallization firing.

Analysis of marginal discrepancy

The crowns were adapted to the prepared dental unit (mandibular right second molar) with the aid of a "C" clamp and maintained in a standardized position during the analysis in a stereomicroscope lupe[31] (Optima MDCE-5ª 2.0, Hiperquímica, Santo André, Brazil) (figure 1). Photographs were obtained at 45X magnification from the buccal, lingual, mesial, and distal surfaces, and images were transferred to the CorelDraw X7 program. Marginal discrepancy was determined by measuring the space (marginal opening) between margin of the crowns and finish line of the human mandibular right second molar. For each crown, the measurements were made at four vertical reference lines previously marked at the midpoint of the dental unit finish line (figure 2) at four locations to represent the buccal, lingual, mesial, and distal surfaces of tooth[32]. The measurements were made thrice along the long axis of the tooth at each of the four reference points. The arithmetic mean of twelve readings (three on each face) was calculated for each specimen. All procedures were performed by one calibrated operator.

Figure 1. Crown adapted to the prepared dental unit and maintained in a standardized position during the analysis in a stereomicroscope lupe.

Figure 2. Crown adapted to the prepared dental unit (see vertical reference lines) with the aid of a "C" clamp.

Statistical analysis

The normality and variance homogeneity assumptions were verified using the Shapiro-Wilk and Levene tests, neither of which violated this assumption. The amounts of marginal discrepancy were compared between the four materials with the one-way analysis of variance (ANOVA) followed by the Tukey's test for multiple comparisons (a=.05). The analyses were performed using the statistical program, SPSS Statistics v19.0 (IBM Corp Chicago, United States).

Results

Means and standard deviations of marginal adaptation are described in Table 2.

Table 2. Means and standard deviation (SD) of marginal discrepancy (values in micrometer - μm) within each of four groups tested

Group	Material	Marginal discrepancy Mean ±SD (mm)
GF	Feldspathic Ceramic	73.26 ± 18.19 [AB]
GL	Lithium Disilicate Ceramic	84.22 ± 20.86 [A .]
GG	Resin composite – Grandio Blocs	68.42 ± 11.31 [AB]
GB	Resin composite – Brava Block	60.95 ± 13.64 [B]

1-way ANOVA test and post-hoc Tukey test (p <0.05). Averages followed by distinct letters represent significant differences.

The lowest marginal discrepancy value was observed in GB (60.95 ± 13.64 μm) which was statistically different from the GL (84.22 ± 20.86 μm), that showed the highest value of marginal discrepancy. However, there was no statistically significant difference

between these groups when compared with the other groups GF (73.26 ± 8.19 μm) and GG (68.42 ± 11.31 μm). All groups showed marginal discrepancies within the clinically acceptable value.

Discussion

The null hypothesis that marginal adaptation values of crowns are not influenced by the type of material was rejected because a significant difference was observed between the lithium disilicate ceramic and composite resin (Brava Block). However, it was verified that there was no statistically significant difference when these materials were individually compared with feldspathic ceramic and composite resin (Grandio Blocs).

A gap between 50 and 100 μm has been considered acceptable for adequate marginal adaptation of CAD/CAM restorations[17-20]. In this study, the mean value of marginal discrepancy of the four groups (GF, GL, GG, and GB) was in the range of 60.95 ± 13,64 μm to 84.22 ±20,86 μm; therefore, were clinically acceptable. Group GL displayed the largest gaps while group GB displayed the smallest gaps. Some studies[2,24] have reported that resin materials demonstrated better machinability and adaptation. According to Awada et al.[24] (2015) these materials tend to be less brittle and more flexible probably due to the resin component.

Tabata et al.[1] (2020) evaluated the marginal adaptation of crowns fabricated with two materials (ceramic and composite resin) and two internal spacings using the CAD/CAM system. They reported statistically significant difference between materials for marginal adaptation with spacing of 80 μm. This result is consistent with that of the present study, wherein the same internal spacing measure was used and a difference was observed between the lithium disilicate ceramic and composite resin (Brava Block), although there was no difference between the former and composite resin (Grandio Blocs).

El Ghoul et al.[30] (2020) compared the marginal adaptation of lithium disilicate ceramic crown (IPS e.max CAD) and resin composite endocrown (Cerasmat) fabricated using the CAD/CAM system and observed that there was a statistically significant difference between the tested groups. However, the composite resin crown showed higher marginal discrepancy values (143.0 ± 21.7 μm) than lithium disilicate ceramics (104.8 ± 14.1 μm). In the present study, resin composites showed smaller marginal discrepancy than the tested ceramics, with a statistically significant difference between the lithium disilicate ceramic and resin composite (Brava Block).

de Paula Silveira et al.[2] (2017) evaluated the marginal adaptation of lithium disilicate (IPS e.max CAD) and composite resin (Lava Ultimate) total crowns fabricated by CAD/CAM technology using intraoral digital scanner and reported no statistically significant difference between the materials. These data partially corroborate with the present study, wherein there was no statistically significant difference between lithium disilicate ceramics and the composite resin (Grandio Blocs). However, statistically significant difference was observed when compared to the other composite resin (Brava Block).

In the present study, photographs were taken at 45X magnification using stereoscopic magnifying glass, while in the studies by Tabata et al.[1] (2020) and de Paula Silveira et al.[2] (2017) the method used was microtomography. Variations may also be related to the different resin composite materials tested, namely Lava Ultimate, Cerasmat, Brava Block, and Grandio Blocs. The manufacturing method, scanning, and milling system accuracy could also influence the observations.

When comparing the materials used in the present study with those in other studies, the resin composite Grandio Blocs had 86% inorganic filler particles in a polymer matrix, but the particle size was not reported[33] whereas Brava Block had 80% inorganic filler encased in a resin matrix with particle size ranging from of 40 nanometers (nm) to 5 µm[34]. In the other studies, the resin composite used (Lava Ultimate) had 80% inorganic fillers by weight with individual particles in the size range of 4 to 20 nm[35]. The variation in particle size may be related to the differences between the materials and results obtained.

Few other studies have compared the marginal adaptation of feldspathic ceramic crowns with other restorative materials. das Neves et al.[36] (2014) evaluated the marginal adaptation of feldspathic ceramic total crowns manufactured by the CAD/CAM system and found that the marginal discrepancy was 62.6 ± 65.2 µm. This was within close range of the values observed in the present study, wherein marginal adaptation of feldspathic ceramic was 73.26 ± 18.19 µm.

The in vitro nature of this study could be considered a limitation, the results of which may differ from a clinical study, where the scanning and processing would be less precise due to constraints such as presence of saliva and limited access of the scanner in the oral cavity.

Within the limitations of this study, it can be concluded that the composite resin Brava Block presented the lowest variance when compared with the lithium disilicate glass ceramic, although the marginal gap of all materials tested was within the acceptable clinical limit (120 µm).

Acknowledgments

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