Microcomputed Tomography Evaluation of the Marginal and Internal Fit of Crown and Inlay Restorations Fabricated via Different Digital Scanners Belonging to the Same CAD/CAM System

Zeynep Ekici, DDS
Mehmet Ali Kılıçarslan, PhD, DDS
Department of Prosthodontics, Faculty of Dentistry, Ankara University, Ankara, Turkey.

Burak Bilecenoglu, PhD, DDS
Department of Anatomy, Faculty of Medicine, Ankara Medipol University, Ankara, Turkey.

Mert Ocak, PhD
Department of Anatomy, Faculty of Dentistry, Ankara University, Ankara, Turkey.

Purpose: To evaluate the marginal and internal adaptation of all-ceramic crowns and inlays fabricated using different scanners of the same CAD/CAM system. Materials and Methods: All-ceramic crown preparations were performed on typodont maxillary first premolars, and mandibular first molars were prepared for ceramic Class II mesio-occlusal inlays. Two intraoral scanners (CEREC Bluecam and Omnicam, Dentsply Sirona) and one model scanner (CEREC inEos X5, Dentsply Sirona) were used to scan the preparations. All restorations were fabricated by milling single-feldspathic ceramic blocks (CEREC Blocs). The marginal and internal discrepancies of restorations were evaluated via microcomputed tomography (micro-CT) analyses. Results: For linear crown measurements, the marginal gaps were 63.75 μm, 88.24 μm, and 90.89 μm for Bluecam, Omnicam, and inEos X5, respectively. For crowns at central groove areas, the maximum values for Bluecam, Omnicam, and inEos X5 were found to be 144.78 μm, 165.19 μm, and 129.49 μm, respectively. For inlays, the highest range at the midpoint of the axio-pulpal line angle for Bluecam, Omnicam, and inEos X5 were determined as 138.57 μm, 184.33 μm, and 179.71 μm, respectively. In volumetric measurements, inEos X5 showed lower gaps for both crowns (11.47 mm³) and inlays (5.65 mm³) compared to both intraoral scanners. These results are within a clinically acceptable range. Conclusion: When all-ceramic crowns were evaluated, there were generally no significant differences found among scanners for the regional linear measurements, but more volumetric gaps occurred in restorations obtained with intraoral scanners. On the other hand, when the inlay restorations were evaluated, significant differences were found between groups except for the midpoint of the axio-pulpal line angle and the midpoint of the mesio-gingival margin. However, the marginal and internal gaps of both crowns and inlays presented mean values < 150 μm in many surfaces, which could be considered clinically acceptable.


In prosthetic dentistry, it is critical to ensure that the teeth and oral cavity are duplicated as accurately as possible because mistakes will have a huge impact on the quality of the final restoration. Despite improvements in impression materials, impression procedures are still considered to be uncomfortable for the patient and time-consuming for the clinicians. CAD/CAM systems in dentistry enable some manufacturing processes to be shorter and result in more acceptable restorations in dental laboratories or dental clinics.1–3

In conventional impressions, many failures are more likely to occur. Restoration failures may arise because of clinicians who do not comply with the manufacturer’s instructions or because of inappropriate storage conditions of the impression material. Another cause of restoration failure arises when technicians are not able to obtain a proper model from the impression or when they damage the model itself. Furthermore, another reason for restoration failure may be the distortion of the impression material or the impression materials’ ability to record details.1–3

Correspondence to: Dr Mehmet Ali Kılıçarslan
Ankara Üniversitesi
Dişhekimliği Fakültesi
Beşevler 06550
Ankara, Turkey.
Email: mmkilicarslan@yahoo.com

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In dental CAD/CAM systems, image acquisition is the process of making a digital impression using an image-capturing unit to collect data for the prepared teeth and adjacent tissues and then converting the data into virtual measurements. Computer-aided impressions (CAIs) are acquired by collecting the data obtained using the light reflected through the object by dental scanners. The scanning process varies according to each system, and CAIs are acquired using two different methods. The first method is by directly using the intraoral scanner, which enables the clinician to obtain data directly from the prepared tooth without any solid impressions or preparing gypsum models, resulting in a virtual model. The second method is the cast scanner that is designed for use at dental laboratories, including for scanning of dental impressions or casts. Dental scanners mainly use white light or blue light. These scanners generally use video techniques or photographic techniques to capture the image. Additionally, for CAI, properties such as scanning with or without powder, real-color display, scanning modes, and scanning principles differ for each intraoral scanner system.

The fit of restorations is usually evaluated on the marginal ridges, axial walls, and occlusal surfaces of the prepared teeth. A good marginal fit and internal adaptation are important in the long-term success of fixed dental restorations. In spite of the fact that several studies have evaluated the clinically acceptable marginal gap, there is no full consensus on this issue yet. Some studies have shown that a marginal fit of ≤ 120 μm is clinically acceptable, but others have concluded that the marginal suitability of 100 to 150 μm was more generalized and appropriate for crown restorations. In addition, various studies have been performed in recent years showing that the marginal and internal cement thickness values can be between 20 and 200 μm for inlay or onlay restorations. However, the ceramic inlays and onlays produced by a chairside CAD/CAM system (CEREC, Dentsply Sirona) initially showed a marginal discrepancy between 140 and 256 μm. In 1994, partial- and full-coverage crowns with a marginal fit of 50 to 150 μm were developed with the CEREC 2 system. Recent studies in which powder application was performed before scanning showed that the CEREC Bluecam system achieved restorations with a 39.2-μm marginal fit with 3D image acquisition. Powder use improved image quality and created a matte surface in different materials that improved the restoration’s adaptation. CEREC introduced different scanners called Omnicam and Primescan, which form a 3D image using a video camera in real color and with powder-free scanning. Scanning should be performed under dry conditions, and the camera should be kept as close to the tooth as possible to achieve a suitable digital intraoral scan. Software updates for the system have also reduced scanning errors, and the development of the CAD/CAM system has generally minimized marginal disharmony. However, anti-reflection powder that is used during image acquisition may influence the compliance values by applying a thickness over the preparation, causing higher misfit values.

The aim of this in vitro study was to compare the marginal fit and internal adaptation of all-ceramic crowns and ceramic inlays fabricated with the use of different scanners of the same CAD/CAM system with micro-computed tomography (micro-CT). The null hypothesis of this study is that the restorations from all digital scanners used in the CAI method will display similar misfit values regardless of using or not using powder. It should be noted that anti-reflection powder that is used during image acquisition may influence compliance values by applying a thickness over the preparation, causing higher misfit values.

**MATERIALS AND METHODS**

Twelve maxillary left first premolars and 12 mandibular right first molars (AG-3 ZSDP, frasaco) of the typodont enamel-dentin-pulp–based type were used for the preparations. Since extracted natural teeth cannot be standardized in shape, the standardized typodont teeth with the same morphologic properties were used instead. In a dental model (Standard Model AG3; frasaco), standard all-ceramic crown preparations performed on premolar teeth and molar teeth were used for the ceramic inlay preparations. Restorations were fabricated using CAI with three different scanners of the same system (Table 1).

**All-Ceramic Crown and Inlay Preparations**

Standard all-ceramic crown preparations were performed supragingivally by a single clinician (Z.E.) on typodont maxillary first premolars with the following specifications: 1.5-mm axial reduction depth; 2-mm occlusal reduction depth; 1-mm–wide shoulder margins with rounded axiogingival angles; and a 12-degree taper angle. In the preparation, a moderate diamond grain drill set was used (Perfect Tooth Preparation II Extended Set, Intensiv). Inlay preparations were performed on typodont mandibular first molars. Typodont mandibular first molars (n = 12) were prepared for a ceramic mesio-occlusal inlay using an inlay bur set (FG Inlay Set III Extended Set, Intensiv). The preparation design was performed considering a 3-mm–deep occlusal box, a 3-mm–wide isthmus, and an overall convergence angle of approximately 8 degrees. The proximal gingival margin was located in the cementoenamel junction. The occlusogingival dimension of the proximal box was 3.5 mm. All internal angles of the cavity were slightly rounded.
structures with radiolucent paraffin tape. For scanning for each substructure were fitted and fixed on their sub-
crowns and inlay samples that were specially designed er) with high-resolution scanning capacity was used.

**Micro-CT Analyses**

A total of 72 digitalized images were designed using the biogenic design option, including 36 crowns and 36 inlays, using CEREC version 15.1.1 software. To maintain consistency in the samples, in all-ceramic crown designs, the radial and occlusal cement widths were 100 μm, and in the inlay designs, preparation parameters were determined and applied in such a way that the radial and occlusal cement widths were 120 μm. The CAI of the preparations for each optical scanner was checked using the “Edit Model” option. To designate the restoration finish lines, preparation margins were identified using “Draw Margin.” The path of placement was approved to ensure the most comfortable and best fit of the restoration on the tooth. Restoration parameters were entered into the system so that they were the same in all-ceramic crowns and inlays.

All restorations were fabricated using milling single feldspathic ceramic blocks (CEREC Blocs, Dentsply Sirona; VITA Feldspathic Ceramic Blocs, VITA Zahnfabrik) in a common milling unit belonging to the same system for all three scanners (CEREC inLab MC XL, Dentsply Sirona) (Table 1).

**CAI and CAD/CAM**

Two intraoral scanners (CEREC Omnicam and CEREC Bluecam, Dentsply Sirona) and one extraoral model scanner (inEos X5, Dentsply Sirona) were used to scan the preparations. Unlike with the CEREC Omnicam, an opaque powder coating of titanium dioxide (CEREC Optispray, Dentsply Sirona) was applied on the prepared teeth while scanning with CEREC Bluecam. In this manner, the uniform light distribution and scanning efficiency were obtained on the teeth. However, scanning was performed by attaching the model to the holder of the CEREC inEos X5 scanner.

A total of 72 digitalized images were designed using the biogenic design option, including 36 crowns and 36 inlays, using CEREC version 15.1.1 software. To maintain consistency in the samples, in all-ceramic crown designs, the radial and occlusal cement widths were 100 μm, and in the inlay designs, preparation parameters were determined and applied in such a way that the radial and occlusal cement widths were 120 μm. The CAI of the preparations for each optical scanner was checked using the “Edit Model” option. To designate the restoration finish lines, preparation margins were identified using “Draw Margin.” The path of placement was approved to ensure the most comfortable and best fit of the restoration on the tooth. Restoration parameters were entered into the system so that they were the same in all-ceramic crowns and inlays.

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**Micro-CT Analyses**

For micro-CT analyses, a Skyscan 1275 device (Bru- er) with high-resolution scanning capacity was used. Crowns and inlay samples that were specially designed for each substructure were fitted and fixed on their sub-
structures with radiolucent paraffin tape. For scanning parameters, the rotation step was determined to be 0.2 at a size of 125 kvp, 80 mA, and 24-μm pixel size. To pre-vent radiologic artifacts that may occur during scanning, a 1-mm–thick aluminum filter was used. Each scanned sample was later reconstructed separately using NRecon (version 1.6.4.8, Bruker microCT) software. Other radio-
logic artifacts that may have occurred during scanning were also fixed using this software. The dimensional axial projection of the reconstruction samples was obtained. These 2D axial projections were then transferred to CTAn software (version 1.14.4.1, Bruker microCT) to perform quantitative analyses.

**Linear Measurements**

For 2D measurements, DataViewer (version 1.5.6.2, Bruker microCT) software was used. Axially reconstruc-
eded images were examined in 2D coronal and sagittal planes. For samples used in crowns, images of mid-
coronal and mid-sagittal sections from DataViewer were obtained, and images of mid-coronal sections for inlay samples were obtained. These images were taken back to the CTAn software, and 2D linear measurements were performed. To evaluate both the marginal and internal fit of restorations with an omega thickness in microns for the all-ceramic crown preparations, 18 reference measurement points (9 in the sagittal section and 9 in the coronal section) were used (Fig 1). To evaluate marginal and internal compliance of the inlay restora-
tions, 7 measurement points were used in the sagittal position (Fig 2).

**Volumetric Measurements**

Substructure parts where each sample came into contact with the crown-inlay restorations were included in the region of interest (ROI) area by applying adaptive inter-
polation. The ROI was then binarized using gray color values. The amount of matter in the ROI revealed the solid volume of the sample and the gap between the amounts of space in the ROI. The ROI gap values were compared statistically. Using CTVox and CTVol software (Bruker microCT), color and 3D images were obtained.
Statistical Analysis
Statistical analysis of the obtained data was performed using SPSS Statistic software version 25 (IBM). Hypothesis controls were realized at a level of $\alpha = .05$. One-way analysis of variance (ANOVA) was used to statistically compare the data. Kolmogorov-Smirnov test was used for nonhomogenous values, while Tukey-Kramer comparison test was used for multiple comparisons of the averages.

RESULTS

Linear Measurements

All-ceramic crown results
For each of the crown samples, the linear space between the intaglio of the crown and the preparation surface was obtained at each measurement point. When the mean values were taken and descriptive statistics were performed, only 5 of the 18 points were statistically different between the groups, and no statistical difference was observed among the other groups. Differences were usually caused by inEos X5 (Fig 3). The range for Bluecam was 46.26 μm to 180.48 μm; for Omnicam, was 41.84 μm to 199.56 μm; and for inEos X5, was 51.23 μm to 237.40 μm (Table 2).

When internal and marginal adaptation of crown samples that were obtained from different scanners were evaluated regionally, statistical differences were found only in the marginal regions and at the top of the cusps, which were the most marginal and coronal parts of the restoration. There were no significant differences in the axial walls, finish lines, or central grooves of the restorations (Table 3).

Ceramic inlay results
Ridge and internal reference measurement points for inlay restorations were calculated by taking the mean of each scanner separately. Descriptive statistics were
completed to reveal differences between scanners. Thus, there were statistically significant differences between the groups, except for the midpoint of the axio-pulpal line angle and the midpoint of the mesiogingival margin. Statistical differences were found at all other measurement points (Fig 4). The lowest value for Bluecam was 16.05 µm at the midpoint of the disto-occlusal margin, and the maximum was 138.57 µm at the midpoint of

### Table 2 Linear Measurements of Crown Samples at Each Reference Point for Sagittal and Coronal Sections (µm)

<table>
<thead>
<tr>
<th>Point</th>
<th>Bluecam</th>
<th></th>
<th>Omnicam</th>
<th></th>
<th>inEos X5</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>95% CI</td>
<td>Mean ± SD</td>
<td>95% CI</td>
<td>Mean ± SD</td>
<td>95% CI</td>
</tr>
<tr>
<td>A1: S</td>
<td>63.60 ± 31.74a</td>
<td>43.43–83.77</td>
<td>61.99 ± 15.99a</td>
<td>51.82–72.15</td>
<td>89.22 ± 22.11b</td>
<td>75.17–103.28</td>
</tr>
<tr>
<td>A1: C</td>
<td>53.68 ± 12.38a</td>
<td>45.81–61.55</td>
<td>83.52 ± 51.58a</td>
<td>50.75–116.30</td>
<td>81.43 ± 31.39a</td>
<td>61.49–101.39</td>
</tr>
<tr>
<td>B1: S</td>
<td>129.49 ± 95.04a</td>
<td>69.10–189.88</td>
<td>90.72 ± 26.79a</td>
<td>73.70–107.75</td>
<td>107.26 ± 31.18a</td>
<td>87.43–127.07</td>
</tr>
<tr>
<td>B1: C</td>
<td>91.29 ± 61.02a</td>
<td>52.51–130.06</td>
<td>76.30 ± 32.36a</td>
<td>55.73–96.86</td>
<td>92.00 ± 25.57a</td>
<td>75.75–108.26</td>
</tr>
<tr>
<td>C1: S</td>
<td>48.88 ± 17.34a</td>
<td>37.85–59.90</td>
<td>46.41 ± 11.49a</td>
<td>39.11–53.71</td>
<td>56.47 ± 19.36a</td>
<td>44.17–68.78</td>
</tr>
<tr>
<td>C1: C</td>
<td>49.63 ± 16.10a</td>
<td>39.40–59.86</td>
<td>45.16 ± 11.67a</td>
<td>37.74–52.58</td>
<td>51.23 ± 19.65a</td>
<td>38.75–63.72</td>
</tr>
<tr>
<td>D: S</td>
<td>65.42 ± 43.57a</td>
<td>37.73–93.11</td>
<td>77.83 ± 34.07a</td>
<td>56.19–99.48</td>
<td>65.02 ± 8.62a</td>
<td>59.54–70.50</td>
</tr>
<tr>
<td>D: C</td>
<td>66.67 ± 35.54ab</td>
<td>44.08–89.25</td>
<td>55.10 ± 28.06a</td>
<td>37.27–72.93</td>
<td>95.25 ± 27.80a</td>
<td>77.58–112.92</td>
</tr>
<tr>
<td>E: S</td>
<td>109.08 ± 46.14a</td>
<td>79.77–138.4</td>
<td>199.56 ± 138.23ab</td>
<td>111.74–287.39</td>
<td>237.40 ± 66.33b</td>
<td>195.25–279.54</td>
</tr>
<tr>
<td>E: C</td>
<td>180.48 ± 47.36a</td>
<td>150.39–210.58</td>
<td>130.82 ± 56.03a</td>
<td>95.21–166.43</td>
<td>149.89 ± 39.50a</td>
<td>124.79–174.99</td>
</tr>
<tr>
<td>F: S</td>
<td>51.50 ± 14.61a</td>
<td>42.21–60.79</td>
<td>65.35 ± 17.12ab</td>
<td>54.47–76.23</td>
<td>67.79 ± 13.16a</td>
<td>59.43–76.16</td>
</tr>
<tr>
<td>F: C</td>
<td>63.80 ± 34.99a</td>
<td>41.57–86.04</td>
<td>53.29 ± 29.14a</td>
<td>34.77–71.81</td>
<td>87.50 ± 35.37a</td>
<td>65.02–109.98</td>
</tr>
<tr>
<td>C2: S</td>
<td>46.26 ± 18.99a</td>
<td>34.19–58.33</td>
<td>52.82 ± 18.92a</td>
<td>40.80–64.84</td>
<td>54.52 ± 16.88a</td>
<td>43.8–65.25</td>
</tr>
<tr>
<td>C2: C</td>
<td>54.72 ± 28.44a</td>
<td>36.65–72.79</td>
<td>41.84 ± 4.15a</td>
<td>39.20–44.48</td>
<td>52.77 ± 17.76a</td>
<td>41.48–64.06</td>
</tr>
<tr>
<td>B2: S</td>
<td>127.62 ± 86.22a</td>
<td>72.84–182.41</td>
<td>100.62 ± 67.92a</td>
<td>57.46–143.78</td>
<td>129.32 ± 51.10a</td>
<td>96.84–161.79</td>
</tr>
<tr>
<td>B2: C</td>
<td>79.60 ± 37.30a</td>
<td>55.89–103.31</td>
<td>72.22 ± 46.13a</td>
<td>42.91–101.54</td>
<td>83.44 ± 23.95a</td>
<td>68.22–98.66</td>
</tr>
<tr>
<td>A2: S</td>
<td>82.69 ± 70.25a</td>
<td>38.05–127.33</td>
<td>113.12 ± 36.23a</td>
<td>90.09–136.14</td>
<td>100.97 ± 34.66a</td>
<td>78.94–122.99</td>
</tr>
<tr>
<td>A2: C</td>
<td>55.02 ± 17.99a</td>
<td>43.59–66.45</td>
<td>94.33 ± 86.51a</td>
<td>39.36–149.30</td>
<td>91.92 ± 41.70a</td>
<td>65.43–118.42</td>
</tr>
</tbody>
</table>

S = sagittal section; C = coronal section.
Groups with the same superscript letters did not exhibit a statistical significance between scanners.
the axio-pulpal line angle. For Omnicam and inEos X5, these values were, respectively, 91.45 µm at the mid-point of the gingival wall to 161.62 µm at the midpoint of the pulpal wall, and 33.37 µm at the midpoint of the intersection of disto-pulpal and distal line angles to 179.71 µm at the midpoint of the axio-pulpal line angle. The largest gap for inlay restorations was found at the midpoint of the axio-pulpal line angle for all scanner groups (Table 4).

**Volumetric Measurements**

The crown and inlay samples were evaluated for the micro-gap volume between the intaglio surface of the restoration and the preparation on micro-CT. When the mean values were obtained and descriptive statistics were performed, there was no statistical difference between Bluecam and Omnicam for each crown. However, inEos X5 showed a statistically smaller cement gap compared to both intraoral scanners. For inlay restorations, there was no statistical difference between Bluecam and inEOS X5, and they also had a statistically smaller cement gap compared to Omnicam (Table 5).

Volumetric measurement describes an entire gap, while linear measurements show the discrepancy at a described fixed point only. Therefore, when the restorations are evaluated holistically, volumetric measurements may differ from the marginal gap or finish line gap measurements in particular.
DISCUSSION

Previous studies have mostly evaluated the influence of conventional impressions and CAI or different intraoral scanners on restoration fit. Some investigations also compared only crowns or inlays/onlays separately. The aim of the present study was to evaluate the marginal and internal adaptation of both crown and inlay restorations manufactured using the same CAD/CAM system. According to these comprehensive results, fewer gaps were observed at the axial walls for all crown groups. Crowns obtained from scanning with inEos X5 showed statistically more marginal gaps than the intraoral scanners (Table 3), and Bluecam especially exhibited the best marginal fit (63.75 μm). Therefore, the null hypothesis was rejected because the restorations from all digital scanners used displayed different misfit values. However, the hypothesis as to whether anti-reflection powder would influence the worse-fit values was also rejected because Bluecam (with anti-reflection powder) showed the lowest misfit value.

Although there is no consensus on this issue, several studies have evaluated the clinically acceptable marginal gap, and most authors consider a clinically acceptable marginal gap to be less than 150 μm.9–17 Thus, the present data are generally within this acceptable range. Previous studies that evaluated the fit of the inlays fabricated using CAI reported larger mean gap values than the present findings.21,22 Because slight differences in study design cause large variations in results, the present study was conducted on 12 different preparations, which differs from previous studies because it reflects diversity in the clinical implications and variability in preparation.

Currently, CAD/CAM technology plays an important role in restorative and prosthetic dentistry. Internal and marginal fit of restorations is closely related to the clinical survival of restorations.1,14,18,33 Historically, every stage and innovation in the CAD/CAM systems, from optical measurement to mechanical processing, has a positive effect on the marginal and internal compliance of restorations.3

In recent years, the accuracy of model impressions was compared by Lee et al.6 who stated that Omnicam was found to have a similar accuracy level but a better sensitivity level than a model scanner for video image impressions. In addition, Renne et al.24 evaluated the accuracy of six intraoral scanners and one laboratory scanner (seven digital scanners) and reported that the PlanScan (Planmeca) had the best accuracy (48.4 μm) and the D800 (3Shape) had the best precision (79.0 μm). In addition to these studies concerned with the accuracy of the scanners, much research has been conducted that is interested in internal gaps and cement thickness of crown and inlay restorations manufactured by CAD/CAM systems.5,13,17,18,21,22 In the present study, the purpose was to compare the marginal fit and internal adaptation of ceramic crowns and ceramic inlays fabricated by different scanners of the same CAD/CAM system with micro-CT.

Prudente et al.17 compared the effects of CAD/CAM scanner powder application on the internal adaptation of restorations. Three different scanning techniques were used: (1) CEREC Bluecam scanner (B) with titanium dioxide powder; (2) digital scans (O) using powder-free CEREC Omnicam scanner; and (3) the Omnicam scanner with powder (OP). Two additional groups, in which the internal adjustment was applied to the scanning performed with Bluecam using powder and to the powder-free scans with the Omnicam, were also included in the study. To measure volumetric 3D internal compliance with the vertical and horizontal internal harmony of each cavity, examples were evaluated using micro-CT. Results obtained from the Bluecam group were significantly different from the other test groups. The volumetric 3D internal fit values were as follows: group B: 9.4 ± 1.3 mm³; group O: 11.8 ± 2.1 mm³; and group OP: 9.6 ± 0.9 mm³. The authors stated that the type of intraoral scanner, powder application, and internal adjustments influenced the marginal discrepancy values of the restorations. Crowns produced with the Omnicam have been found to have higher vertical misfit values compared to those produced with the Bluecam. For restorations made with the Omnicam, only the vertical fit has been improved by adjusting the intaglio surface. Powder application before Omnicam screening improved the vertical adjustments of the crowns and reduced volumetric 3D internal harmony. In the present study, the volumetric internal fit values were found to be 16.39 ± 4.01 mm³ in the Bluecam group and 16.90 ± 3.73 mm³ in the Omnicam group, which are higher than in Prudente et al.,17 but with no statistically significant difference between them. In the present study, the biggest gaps were found in the central grooves of the samples, resembling Prudente et al.,17 who concluded that intaglio adjustments influenced the marginal discrepancy values and vertical fit of the crowns.

In a study conducted by Uzgur et al.,21 the cement thickness of mesio-occlusal-distal (MOD) molar inlays made of different materials was examined using 3D radiographic micro-CT. The authors indicated that MOD inlays made of different CAD/CAM materials presented similar cement thicknesses (< 100 μm), and the smallest mean marginal gap was between 67.54 ± 10.16 μm and 95.18 ± 10.58 μm. In the present study, three different scanners of the same system, independent of the inlay material, were used, and the marginal gap was found to be 84.47 ± 30.04 μm in the Bluecam group, 121.51 ± 61.10 μm in the Omnicam group, and 83.77 ± 16.46 μm in the inEos X5 group. Both the Bluecam group and the inEos X5 group showed marginal gaps < 100
μm, showing similarities with Uzgur et al. They also evaluated the internal cement thicknesses in the same study and found the smallest mean internal gap to be between 54.85 ± 6.94 μm and 77.53 ± 12.13 μm. In the present study, the internal cement thickness was 72.94 ± 36.61 μm in the Bluecam group, 161.62 ± 110.51 μm in the Omnicam group, and 145.44 ± 66.75 μm in the inEos X5 group. Internal gap and marginal gap values of the Bluecam group were very similar to Uzgur et al. The differences in other groups in both studies may be explained by the different scanning parameters and system (3Shape) that Uzgur et al used in their study.

Similarly, Alajaji et al examined discrepancies in the premolar MOD cavity preparations at 120 different points per inlay using radiographic micro-CT with different manufacturing methods: a three-axis milling machine, a five-axis milling machine, and a heat-press group. Considering the marginal gap, there was no statistical difference between the three-axis machined CAD/CAM group (67.67 ± 14.04 μm) and the five-axis group (56.19 ± 12.32 μm). However, the heat-press group (35.48 ± 8.12 μm) was found to be statistically different and smaller than both CAD/CAM groups. A five-axis milling machine was used in the present study, and the following marginal gaps were found: 84.47 μm in the Bluecam group; 121.51 μm in the Omnicam group; and 83.77 ± 16.49 μm in the inEos X5 group, which were higher than in Alajaji et al, probably due to the micro-CT scanning parameters.

A clinically acceptable marginal gap of fixed restorations is yet to be formally identified; however, American Dental Association (ADA) Specification No. 8 states that the thickness of luting cement used to bond a crown should not exceed 40 μm when using different types of luting agents. According to existing research in this area, marginal/internal gap values between 20 and 200 μm are found to be largely clinically acceptable. In the present study, the internal gap is adjusted as 100 μm for crowns and 120 μm for inlays by the software, and all parameters calculated were in the clinically acceptable range despite some statistical differences between them.

The present study only assessed three different scanners. Other scanning systems may show different results, and more studies must be conducted to evaluate the effects of powdering prior to scanning. Although Bluecam with powdering is a former way of scanning, it is still widely used. In crown samples, marginal gaps and gaps at the cusp apexes were smaller in the Bluecam group. In addition, in inlay groups, gaps in the disto-occlusal margin and pulpal wall were statistically smaller in the Bluecam group compared to the other groups.

CONCLUSIONS

When CAI was performed using different scanners with different light sources and image-capture methods from a CAD/CAM system using the same design software, the following results were determined within the limitations of this in vitro study:

1. Using 3D micro-CT, marginal and internal gaps of crowns and inlays scanned with three different systems presented mean values < 150 μm in many surfaces, which could be considered clinically acceptable.
2. When the crowns were evaluated regionally, the maximum gap was found in the occlusal central fossa region for all groups, and the smallest gap was found in the axial walls.
3. The largest gap for inlay restorations was found at the midpoint of the axio-pulpal line angle for all scanner groups.
4. Although Bluecam with powdering is an old-fashioned system with some application difficulties, this type of scanning still shows promising and acceptable results.

Thus, it is suggested that all CAIs can be used frequently in dental clinical practices. However, these in vitro studies should be supported by controlled clinical studies.

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REFERENCES

Could be a valuable preventive measure for CRC.

Further studies are needed to assess causality. Hence, effective periodontal treatment that significantly increases the risk of CRC by 44% (RR = 1.44, 95% CI = 1.18–1.76; I² = 55.2%). An association between PD and CRC was found. PD can be a potential risk indicator for CRC.

References:

4. Lin Li, linli@cmu.edu.cn —

Volume 34, Number 3, 2021

389

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