In Vitro Evaluation of the Marginal and Internal Accuracy of Different Types of Dental Ceramic Restorations Fabricated Based on Digital and Conventional Impressions

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**Purpose:** To compare the marginal and internal gap values of different types of ceramic crowns fabricated based on digital and conventional impression methods. **Materials and Methods:** Ten noncarious extracted human teeth were prepared, and 60 restorations were made using six different impression and fabrication methods. Silicone replicas were obtained for marginal and internal gap evaluation. Statistical analyses were performed using Mann-Whitney U and Kruskal-Wallis tests (\(P < .05\)). **Results:** Statistically significant differences were found among various impression and fabrication methods. The smallest gap value was shown by the monolithic zirconia indirect digital scanning group (31.13 µm), and the largest for the lithium disilicate indirect digital scanning group (90.09 µm). **Conclusion:** The marginal and internal gap values of the restorations in the present study were 31.13 to 90.09 µm. The marginal and internal discrepancies of the tested materials were considered clinically acceptable. Int J Prosthodont 2021;34:61–69. doi: 10.11607/ijp.6443

Metal-ceramic systems are considered the standard treatment option for fixed dental restorations.1 However, increasing esthetic concerns have led to the development of new dental ceramics.2 In the last 40 years, researchers have focused on improving metal-free and all-ceramic systems and have developed superior materials.3 Nowadays, all-ceramic systems are preferred for crowns and fixed partial dentures (FPDs) due to their superior esthetic and biocompatibility properties.4 CAD/CAM systems allow the production of patient-specific restorations and prostheses in dentistry without requiring traditional dental laboratory methods.5 Since the introduction of the first CAD/CAM device by Duret,6 many innovations have been developed, and extraoral and intraoral digital impression applications have been improved. Indirect extraoral digitization begins with a conventional impression, which is then transformed into plaster and subsequently digitized in the dental laboratory. In recent years, intraoral scanners (direct digital systems) have been introduced to improve the digital workflow.7

Marginal adaptation is an important factor for the clinical success of tooth restorations.8,9 Poor marginal adaptation of restorations allows exposure of adhesive agents to the oral environment and renders restorations susceptible to microleakage and plaque retention. A larger marginal gap also increases the rate of cement dissolution.10 According to the eighth specification of the American Dental Association (ADA), a type 1 luting agent should have a cement space of no more than 25 µm in zinc phosphate film, and type 2 luting agents should have no more than 40 µm.11 However, it has been shown that these values are rarely achieved.12 Based on a study of more than 1,000 restorations over 5 years, McLean and von Fraunhofer suggested that...
120 μm was the maximum tolerable value for marginal fit in fixed restorations. Some researchers claim that values of 100 μm or less are appropriate for marginal fit, whereas others suggest that values of 75 μm or less are clinically acceptable.

The purpose of this study was to compare the marginal and internal gap values of different types of ceramic crowns produced by digital and conventional impression methods. The null hypotheses tested were: (1) that there would be no difference in the marginal or internal adaptation among lithium disilicate ceramics and monolithic zirconia ceramics scanned by intraoral (direct digital) vs extraoral (indirect digital) scanners; and (2) there would be no difference in marginal or internal adaptation among the different ceramic groups produced by different production and impression methods.

MATERIALS AND METHODS

Sample Size Calculation
A sample size of 60 was calculated based on large effects ($f = 0.975$) with 97.4% power and alpha error probability of $\alpha = .05$.

Ethical Approval
This study was approved by the Clinical Research Ethics Committee, Marmara University Faculty of Dentistry (protocol number 28.12.2015, 2015-10).

Specimen Preparation
Intact, noncarious, unrestored human mandibular first molars extracted for periodontal reasons were selected for this study to evaluate marginal and internal accuracy. Ten different extracted human teeth were used to mimic a clinical scenario instead of using a master die. Teeth of similar mesiodistal and cervicoincisal size were randomly chosen (n = 10). Immediately after extraction, the teeth were scaled (SCALEX 800, DENTAMERICA) and immersed in a germ-free 0.1% thymol solution at room temperature for 1 day. They were then stored in distilled water for no longer than 3 months before use.

Before the preparations, an addition silicone (Elite HD+ Putty and Light Body Normal Set, Zhermack) impression was made for each tooth. Then, this impression was cut in a vestibulo-oral direction to assist in the removal of the tooth structure. The 10 teeth, which were relatively comparable in size, were mounted individually in acrylic resin (SC, IMICRYL). A dental surveyor (EWL, Type 990, KaVo Elektrotechniches) was placed on the dental surveyor with a 1.2-mm chamfer-style bur (6881.314, Komet Medical). All teeth were prepared according to a standardized protocol, as follows: the chamfer finish line was 1 mm above the CEJ; all sharp or internal line angles were rounded; and preparation margins were not beveled. The occlusal reduction was made without using a dental surveyor (Fig 1). Occlusal reduction of all preparations was 1.5 to 2 mm in a standardized manner. All preparations were made by one operator (H.Ö.).

Digital and conventional impressions were taken from each specimen after preparation (n = 10). For the digital impression, CEREC Omnicam (Dentsply Sirona) was used (direct digital impressions). Addition silicone was used for the conventional impression. Type 4 dental stones (Elite Stone, Zhermack) were poured into the impression using a vacuum mixer device (Twister, Renfert) according to the manufacturer’s instructions. Plaster models were scanned with an extraoral scanner (inEOS X5, Dentsply Sirona) to transfer the data to digital media (indirect digital impressions).

In this study, 10 specimens and 6 material/fabrication process combinations were used for a total of 60 ceramic restorations obtained. The tested groups were as follows (Table 1):

- **Group 1**: Lithium disilicate ceramics, extraoral scanner
- **Group 2**: Monolithic zirconia ceramics, extraoral scanner
- **Group 3**: Zirconia framework crowns, extraoral scanner
- **Group 4**: Metal-ceramics (control group), conventional impression
- **Group 5**: Lithium disilicate ceramics, intraoral scanner
- **Group 6**: Monolithic zirconia ceramics, intraoral scanner

Figure 1: Preparation of a specimen with dental surveyor.
The inEOS X5 extraoral scanner was used for groups 1 to 3 (indirect digital), and the CEREC Omnicam intraoral scanner was used for groups 5 and 6 (direct digital). The Sirona inLab SW version 15.1 program (Dentsply Sirona) was used to design the restorations, except for the metal-ceramic control group.

IPS e.max CAD (Ivoclar Vivadent) was used for the lithium disilicate ceramics for groups 1 and 5, and InCoris TZI zirconia blocks (Dentsply Sirona) were used for groups 2 and 6. InCoris TZI zirconia blocks were also used for the zirconia framework in group 3, and IPS e.max Ceram (Ivoclar Vivadent) was used as the veneer. In group 4, cobalt-chromium metal was used (Magnum Ceramic, Mesa) for the framework, and ceramic (VITA VM7, VITA Zahnfabrik) was used for the veneer.

The cement space was set at 80 μm following the manufacturer’s instructions. Sirona inLab MC X5 and Sirona MC XL (Dentsply Sirona) machines were used for the milling process.

Metal-ceramic restorations (control group) were conventionally fabricated (lost-wax technique). A 15-μm die spacer (Scheftner) was applied for these restorations. Pattern wax (Kronenwachs, Bego) was used to fabricate patterns for the copings. A sprue was attached to the completed wax coping (wax wire, Bego), and the finished lost patterns of the copings were invested (Moldavest, Heraeus, Heraeus Kulzer). The investing, burnout, and casting processes were conducted in compliance with the manufacturers’ instructions. No adjustments or corrections for the fit of the crowns were performed.

Marginal Gap Evaluation
The internal and marginal adaptation of the 60 restorations were evaluated using the silicone replica technique. Silicone replicas were used to simulate the space between the restorations and prepared teeth. To generate a replica, a super-light-body type A silicone impression material (Elite HD+ Super Light Body, Zhermack) was applied inside the restoration. Then, the restoration was placed on the master cast. Finger pressure was applied from the occlusal surface. After setting (waiting approximately 4 minutes for each specimen), the restoration was removed from the cast. This resulted in a thin super-light-body impression inside the restoration that represented the discrepancy between the restoration and the abutment. To stabilize the replica, the light-body type A silicone material was injected into the super-light-body silicone material. Putty silicone material (Elite HD+ Putty, Zhermack) was then prepared, and the restoration was embedded. Next, the restoration was removed from the silicone. Finally, a light-body silicone material (Elite HD+ Light Body Fast Set, Zhermack) was injected into the outer space of the replica for stabilization.

To obtain standard sectioning, the middle of the abutments and the buccal and mesial sides were marked on the replica (Fig 2). Replicas were sectioned with a surgical blade (No. 15; Swann-Morton) in two directions: mesiodistally and buccolingually. Marginal, intermarginal, axial wall, and occlusal points were determined for each section (two marginal, two intermarginal, four axial, two occlusal). A total of 20 points were measured for each specimen. Three measurements were made for each specimen.
point, and the mean gap values were obtained. Thus, a total of 60 measurements were made for each replica, totaling 3,600 measurements for the 60 specimens. A light microscope (Leica) at ×50 magnification was used for all measurements (Fig 3).

Statistical Analyses
Statistical analysis was performed using SPSS for Windows (version 21.0, IBM). Mann-Whitney U test and Kruskal-Wallis test were used for statistical analyses. The results were deemed significant at a level of $P < .05$ (95% confidence interval).

RESULTS
The mean, SD, and median values for all groups are shown in Table 2.

Marginal gap values and differences are shown in Fig 4a and Table 3. The lowest gap value was found in group 2 (31.13 µm), and the highest gap value was found in group 4 (66.69 µm).

The marginal gap value in group 1 (56.73 µm) was higher than in group 2 (31.13 µm) and group 3 (33.45 µm). The marginal gap value for group 4 (66.69 µm) was higher than in group 3 (33.45 µm), group 6 (50.38 µm), and group 2 (31.13 µm). The gap value for group 6 (50.38 µm) was higher than for group 2 (31.13 µm) and group 3 (33.45 µm) ($P < .05$).

The intermarginal gap values and differences are shown in Fig 4b and Table 4. The lowest gap value was found in group 2, and the highest gap value was found in group 4 (54.64 µm).

The mean intermarginal gap value for group 4 (54.64 µm) was higher than those for group 2, group 1 (39.67 µm), group 5 (43.83 µm), and group 6 (51.58 µm). The gap value for group 5 (48.41 µm) was higher than for group 2 (31.13 µm) and group 6 (50.38 µm) ($P < .05$).

The axial gap values and differences are shown in Fig 4c and Table 5. The lowest gap value was found in group 2 (37.99 µm), and the highest gap value was found in group 4 (54.07 µm).

The axial gap value in group 1 (39.60 µm) was higher than in group 2 (37.99 µm) and group 3 (38.60 µm). The axial gap value for group 4 (54.07 µm) was higher than in group 3 (38.60 µm), group 6 (43.83 µm), and group 2 (37.99 µm). The gap value for group 6 (51.58 µm) was higher than for group 2 (37.99 µm) and group 3 (38.60 µm) ($P < .05$).

The occlusal gap values and differences are shown in Fig 4d and Table 6. The lowest gap value was found in group 2 (48.47 µm), and the highest gap value was found in group 4 (55.79 µm).

The occlusal gap value in group 1 (90.09 µm) was higher than in group 2 (48.47 µm) and group 3 (50.53 µm). The occlusal gap value for group 4 (55.79 µm) was higher than in group 3 (50.53 µm), group 6 (67.08 µm), and group 2 (48.47 µm). The gap value for group 6 (55.79 µm) was higher than for group 2 (48.47 µm) and group 3 (50.53 µm) ($P < .05$).

Table 2  Gap Values (µm) for all Groups

<table>
<thead>
<tr>
<th>Region</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
<th>Group 6</th>
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<tr>
<td>Marginal</td>
<td>56.73 ± 21.77 (60.9)</td>
<td>31.13 ± 5.5 (29.98)</td>
<td>33.45 ± 7.54 (33.49)</td>
<td>66.69 ± 15.9 (65.46)</td>
<td>56.83 ± 16.01 (53.03)</td>
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<tr>
<td>Intermarginal</td>
<td>39.67 ± 13.74 (38.94)</td>
<td>31.78 ± 4.81 (32.47)</td>
<td>34.5 ± 8.81 (33.05)</td>
<td>54.64 ± 11.43 (51.58)</td>
<td>48.41 ± 13.74 (49.32)</td>
<td>51.58 ± 10.23 (50.14)</td>
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<tr>
<td>Axial</td>
<td>39.6 ± 12.38 (36.08)</td>
<td>37.99 ± 7.58 (37.52)</td>
<td>38.6 ± 8.28 (36.86)</td>
<td>31.79 ± 11.62 (28.22)</td>
<td>43.83 ± 11.07 (43.28)</td>
<td>54.07 ± 5.79 (55.97)</td>
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<tr>
<td>Occlusal</td>
<td>90.09 ± 23.36 (97.8)</td>
<td>48.47 ± 7.61 (49.09)</td>
<td>50.53 ± 8.57 (48.45)</td>
<td>51.45 ± 14.01 (48.75)</td>
<td>67.08 ± 19.95 (59.91)</td>
<td>55.79 ± 13.38 (55.98)</td>
</tr>
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</table>

Data are reported as mean ± SD (median).
µm), and group 3 (34.5 µm). The intermarginal gap value for group 2 was lower than for group 5 (48.41 µm) and group 6 (51.58 µm), and that for group 3 (34.5 µm) was lower than those for group 5 (48.41 µm) and group 6 (51.58 µm) (P < .05).

The axial gap values and differences are shown in Fig 4c and Table 5. The lowest gap value was found in group 4 (31.79 µm), and the highest gap value was found in group 6 (54.07 µm).

The mean axial gap value for group 4 (31.79 µm) was lower than for group 1 (39.6 µm), group 2 (37.99 µm), group 3 (38.6 µm), group 5 (43.83 µm), and group 6 (54.07 µm). The values in group 6 (54.07 µm) were higher than for group 2 (37.99 µm), group 5 (43.83 µm), and group 3 (38.6 µm) (P < .05).

The occlusal gap values and differences are shown in Fig 4d and Table 6. The lowest gap value was found in group 2 (48.47 µm), and the highest gap value was found in group 1 (90.09 µm).

The mean occlusal gap value for group 1 (90.09 µm) was higher than those for group 5 (67.08 µm), group 6 (55.79 µm), group 4 (51.45 µm), and group 3 (50.53 µm). Finally, the mean occlusal gap value for group 5 (67.08 µm) was higher than for group 2 (48.47 µm) and group 3 (50.53 µm) (P < .05).

**DISCUSSION**

Marginal adaptation has a major impact on the long-term clinical success of fixed prosthetic treatments. A marginal discrepancy may cause the adhesive cement to be exposed to oral fluids, which may in turn dissolve the cement, leading to caries formation, dental plaque accumulation, and periodontal problems. These conditions can adversely affect the long-term clinical success of the restoration.30

No standardized technique is yet available for analyzing the marginal and internal gaps of restorations. In vivo and in vitro studies have been carried out to determine marginal and internal adaptation. However, it is not possible to achieve standardization in in vivo studies. Furthermore, in vivo studies are more difficult to perform...
than in vitro studies. The gap values obtained by in vitro methods do not fully reflect the values obtained by in vivo methods, but they provide useful information to guide clinical practice.31

The replica method presents an affordable and reliable way to measure the thickness of the cement. For that reason, several authors have adopted it in the past.14,22,25,32 Studies have shown that using super-light silicone to measure the thickness of the cement is a reliable method for evaluating adaptation and also allows reproducible measurements to be made, as samples cannot be cut and stored.33

Kahramanoğlu and Kulak-Ozkan took buccolingual and mesiodistal sections from their specimens and identified marginal, intermarginal, axial, and occlusal points (10 points per section; 20 points per specimen) on each section.29 Measurements made just after cementation do not allow assessment of the relative effects of cementation on marginal fit.34 Furthermore, the marginal fit should be investigated before cementation, as many researchers have done previously.22,26

Marginal gap studies have employed light microscopes, digital microscopy, stereomicroscopy, and scanning electron microscopy (SEM).22,35 Different magnifications have also been used.26,29 Att et al used a stereomicroscope and ×250 magnification.33

In the present study, the silicone replica technique was applied to teeth sectioned buccolingually and mesiodistally. Twenty points were measured on each specimen. To examine replicas, a light microscope at ×50 magnification was used.

Artificial teeth, extracted human teeth, or a metal master die can be used to investigate marginal adaptation in in vitro studies. In the present study, extracted human teeth were used to approximate the oral environment.18–20

### Table 3: Differences Between Groups in Marginal Gap

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Significant (P < .05) values are in bold. Kruskal-Wallis and Mann-Whitney U tests.

### Table 4: Differences Between Groups in Intermarginal Gap

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### Table 5: Differences Between Groups in Axial Gap

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Significant (P < .05) values are in bold. Kruskal-Wallis and Mann-Whitney U tests.

### Table 6: Differences Between Groups in Occlusal Gap

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Significant (P < .05) values are in bold. Kruskal-Wallis and Mann-Whitney U tests.
Design of the preparation finish line is an important factor for adaptation. Chamfer and straight-shoulde
finish lines have been examined by many researchers.\textsuperscript{36,37} In a review, Contrepois et al reported that a chamfer
marginal finish design is more suitable and success-
ful than a straight shoulder bur for all ceramics.\textsuperscript{38} In
contrast, Komine et al found no significant differences
among shoulder, rounded shoulder, and chamfer finish
line designs.\textsuperscript{39} In the present study, a 1.2-mm chamfer
bur was used for preparation.

There are many CAD/CAM systems on the market,
each with its own design program. When designing a
restoration, the technician/dentist may control the ce-
ment space settings, or the system may automatically
determine this range. In many studies, the settings of
these programs have been changed to investigate mar-
ginal and internal adaptation.\textsuperscript{40,41,42} Lee et al set the
cement space on a CEREC 3D scanner (Dentsply Sirona)
at 30 μm.\textsuperscript{17} Zeltner et al set it at 70 μm using C.O.S. Lab
(version 3.0.2, 3M ESPE) and CARES Visual software (ver-
sion 6.2, Straumann), and at 60 μm using CEREC Con-
nect software (version 4.0.3, Dentsply Sirona).\textsuperscript{43} All of
these settings were recommended by the manufacturer.
Zarauz et al also used the recommended settings.\textsuperscript{23}

Shim et al examined the same ceramic blocks and the
same scanners using different software versions and
different cement space.\textsuperscript{44} They tested CEREC Connect
software versions 3.8 and 4.2 with 40-μm and 80-μm
cement space and reported that the fit of a crown rest-
oration could be affected by the CAD/CAM software
version used, even if the scanner and milling machine
were the same. They preferred version 4.2 of the CEREC
Connect CAD/CAM software over version 3.8 for the
production of well-fitting crown restorations. Although
the 80-μm setting produced a larger gap, this setting
was recommended for version 4.2 because it has shown
good repeatability.\textsuperscript{44} In the present study, an 80-μm
cement space was used for the Sirona inLab 15.1 SW
design program. No adjustments or corrections were
made to the crown fit for this study. Lee at al also made
no adjustment,\textsuperscript{17} although Yildiz et al made adjustments
with a diamond bur to fit the crowns.\textsuperscript{18} A small cement
space could lead to premature contact between the
internal surface of the crown and the abutment tooth.\textsuperscript{40}
Cement space settings are related to the passive fit of the
crowns. In some studies, the obtained gap values were
lower than the cement space settings,\textsuperscript{41,45,46} while in
others they were higher.\textsuperscript{18,43,44,47}

In their review, Contrepois et al reported that in 54
articles published between 1994 and 2012, 94.9% of
the marginal gap values were equal to or less than 120
μm; the highest value was 174 μm, and the lowest was
3.7 μm.\textsuperscript{38} In the present study, all tested gap values
were less than 100 μm; these values are appropriate for
marginal fit and clinically acceptable outcomes.\textsuperscript{13,15}

Indirect digitization can be done by scanning the im-
pression or the stone model. Ahberg et al reported that
an intraoral scanner resulted in better marginal adapta-
tion than indirect digitization.\textsuperscript{48} In another study, Syrek
et al reported median marginal gaps of 49 and 71 μm in
their directly and indirectly digitized groups, respective-
ly.\textsuperscript{49} Conversely, in a study by Luthardt et al, the indirect
digital method showed better marginal adaptation.\textsuperscript{35}
Another study evaluated two different digital scanners
and a conventional impression and found no signifi-
cant difference in the marginal fit of crowns fabricated
with digital impressions compared to the conventional
impression.\textsuperscript{50} A systematic review and meta-analysis
reported that the digital impression and conventional
impression techniques resulted in statistically similar
marginal discrepancies.\textsuperscript{51} Similarly, in another systematic
review and meta-analysis, Tsirogiannis et al examined
studies published from 1989 to 2014 and reported no
significant difference between digital and conventional
impression methods.\textsuperscript{52}

In the present study, a significant difference in the
occlusal gap of lithium disilicate ceramics was observed
between direct digital (67.08 μm) and indirect digital
methods (90.09 μm), but no significant difference was
found in marginal, intermarginal, or axial gap values.
However, the monolithic zirconia group showed a sig-
nificant difference between direct and indirect digital
methods, with indirect digital methods showing bet-
ter marginal, intermarginal, and axial adaptation. Thus,
the first study hypothesis must be rejected: the results
revealed a significant difference among digital impres-
sion types, although all values were clinically acceptable.

Yeo et al investigated the marginal adaptation of
three different all-ceramic systems with metal-ceramic
restorations as a control group.\textsuperscript{53} They reported a sta-
tistically significant difference between the lithium di-
silicate group and the control group. Furthermore, IPS
Empress 2 (lithium disilicate) exhibited minimal marginal
discrepancy compared to other systems.\textsuperscript{53} Martins et al
compared a metal-ceramic group (control) to all-ceramic
groups (slip-cast technique and CAD/CAM). They found
that the axial (83.12 μm) and occlusal (95.42 μm) gap
values for the metal-ceramic group were lower than the
values for the other groups.\textsuperscript{25}

In the present study, the mean axial value for metal-
ceramic crowns (group 4, 31.79 μm) was lower than
those for all other groups. However, the mean marginal
value for metal-ceramic crowns (66.69 μm) was higher
than those for the indirect monolithic zirconia (group 2,
31.13 μm), zirconia framework crown (group 3, 33.45
μm), and direct monolithic zirconia (group 6, 50.38 μm).
The metal-ceramic group values were higher than those
for the indirect digital lithium disilicate (group 1) and
indirect zirconia (group 3) in the intermarginal area.
Thus, the second hypothesis must also be rejected, as
the results showed significant differences among the different production and impression methods, although all of these values were clinically acceptable.

In the present study, the highest gap value was found in the occlusal area in the indirect lithium disilicate group (group 1, 90.09 µm). Tinschert et al explained the accuracy of CAD/CAM processing of digital data by showing differences in the internal gap in the occlusal, axial, and occlusal-axial regions.9 Bornemann et al described the increased amount of internal space at the rounded edges as reflecting the limited resolution of the scanner in CAD/CAM systems.54 This situation may lead to premature contact in the incisal or occlusal internal area; to address this, either the technician must manually adjust the restorations during production, or the spacer parameters recommended by CAD/CAM system manufacturers should be entered into the system.54 Reich et al pointed out that virtual overrides near the edges of the preparation were an important factor affecting internal adaptation; ie, the “overshoot” phenomenon, which is the result of interruptions in reflections during optical sensor detection.55 Another physical phenomenon is the distal shadow phenomenon, which can be observed on intraoral scanners (eg, CEREC Omnicam, DigiDent, LAVA) that operate according to the active triangulation principle. Mou et al reported that the triangular space between the axial wall and the margin is not perceived by the camera between the transmitted and reflected light in the CEREC system—especially in the posterior region—due to the camera angle, and this affects the internal fit.56

Although the methodology of the present study could not exactly simulate the oral conditions, in vitro studies may inform about the effect of digital and conventional impressions on the marginal and internal fit of different restorations fabricated with different methods. In vitro studies including direct or indirect digital scanning, marginal and internal gap evaluation of different ceramic types, and digital and conventional workflows can be done in the future. In addition, further clinical studies are needed to compare the clinical survival of restorations fabricated using digital and conventional impressions.

CONCLUSIONS

In this study, the accuracy of the marginal and internal fit was compared among ceramic crowns manufactured using different impression and production methods. Within the limitations of this study, the following conclusions could be drawn:

1. A significant difference (P = .034) in the occlusal gap of lithium disilicate crowns was found between direct digital and indirect digital impressions. Occlusal gap values of indirect digital lithium disilicate crowns (90.09 µm) were found to be higher than for direct digital lithium disilicate crowns (67.08 µm).
2. No significant differences (P > .05) in the marginal, intermarginal, or axial gap of lithium disilicate crowns were observed between direct digital and indirect digital impressions.
3. The marginal, intermarginal, and axial gap values of direct digital monolithic zirconia crowns were found to be higher than for indirect digital monolithic zirconia crowns, and these comparisons were statistically significant (P < .05).
4. Although significant differences were seen among the different production and impression methods, all values were at clinically acceptable levels.

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