In vitro evaluation of the marginal integrity of CAD/CAM interim crowns

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The early computer-aided design and computer-aided manufacture (CAD/CAM) system (CEREC; Sirona) allowed inlays to be delivered in a single visit, reducing chairside and laboratory time. Today, using CAD/CAM technology, one can digitally mill crowns, partial removable dental prostheses, and maxillofacial prostheses, and fabricate complete dentures. Interim restorations provide esthetics during restorative procedures, during osseointegration, for partial fixed dental prostheses, and to prevent migration of retainer abutments. They are fabricated from different materials, protect the pulp, and allow the evaluation of function, esthetics, and phonetics. Interim crowns must have color stability and withstand the occlusal loads while maintaining dimensional and color stability.

ABSTRACT

Statement of problem. The accuracy of interim crowns made with computer-aided design and computer-aided manufacturing (CAD/CAM) systems has not been well investigated.

Purpose. The purpose of this in vitro study was to evaluate the marginal integrity of interim crowns made by CAD/CAM compared with that of conventional polymethylmethacrylate (PMMA) crowns.

Material and methods. A dentoform mandibular left second premolar was prepared for a ceramic crown and scanned for the fabrication of 60 stereolithical resin dies, half of which were scanned to fabricate 15 Telio CAD-CEREC and 15 Paradigm MZ100-E4D-E4D crowns. Fifteen Caulk and 15 Jet interim crowns were made on the remaining resin dies. All crowns were cemented with Tempgrip under a 17.8-N load, thermocycled for 1000 cycles, placed in 0.5% acid fuschin for 24 hours, and embedded in epoxy resin before sectioning from the mid-buccal to mid-lingual surface. The marginal discrepancy was measured using a traveling microscope, and dye penetration was measured as a percentage of the overall length under the crown.

Results. The mean vertical marginal discrepancy of the conventionally made interim crowns was greater than for the CAD/CAM crowns (P=0.006), while no difference was found for the horizontal component (P=0.276). The mean vertical marginal discrepancy at the facial surface of the Caulk crowns was significantly greater than that of the other 3 types of interim crowns (P<0.001). At the facial margin, the mean horizontal component of the Telio crowns was significantly larger than that of the other 3 types, with no difference at the lingual margins (P=0.150). The mean percentage dye penetration for the Paradigm MZ100-E4D crowns was significantly greater and for Jet crowns significantly smaller than for the other 3 crowns (P<0.001). However, the mean percentage dye penetration was significantly correlated with the vertical and horizontal marginal discrepancies of the Jet interim crowns at the facial surface and with the horizontal marginal discrepancies of the Caulk interim crowns at the lingual surface (P<0.01 in each instance).

Conclusions. A significantly smaller vertical marginal discrepancy was found with the interim crowns fabricated by CAD/CAM as compared with PMMA crowns; however, this difference was not observed for the horizontal component. The percentage dye penetration was correlated with vertical and horizontal discrepancies at the facial surface for the Jet interim crowns and with horizontal discrepancies at the lingual surface for the Caulk interim crowns. (J Prosthet Dent 2016;115:617-623)
Clinical Significance
Interim crowns fabricated by CAD/CAM had a better marginal fit than those made conventionally with PMMA, may not need as many appointments, and may be better for long term use, such as in complete mouth rehabilitation.

marginal stability. They can be produced by several different methods. Fabrication of an interim crown requires either a waxing of the restoration on a diagnostic cast or restoration of lost contours intraorally. Making diagnostic casts requires an extra appointment and adds time and cost for the patient. The clinical goal of an interim restoration is to have a minimal marginal discrepancy, protect the tooth, and prevent caries and poor gingival health. An acceptable marginal discrepancy for metal ceramic restorations should be less than 120 μm. Interim crowns should also have similar marginal discrepancies to maintain a healthy pulp and gingiva. No statistically significant differences have been reported between chamfer and shoulder margin designs for CEREC composite resin crowns, which had mean discrepancies of 70 to 90 μm. Ehrenberg et al reported that the use of polymethylmethacrylate (PMMA) and bis-acrylic composite resin crowns cemented with TempBond (Kerr Dental) significantly increased the marginal discrepancy after thermocycling, but no differences were observed between the interim materials. Although the marginal integrity of CEREC interim crowns for dental implants has been studied, no studies have reported on the difference in the marginal integrity of CEREC interim crowns compared with other interim restorative materials.

An example of CAD/CAM interim restorative material is Telio CAD-CEREC (Ivoclar Vivadent AG), which was initially developed as an alternative to ceramic and metal restorations. This composite resin is a cross-linked PMMA block, and unlike conventional PMMA materials, has more homogeneity and strength. It does not undergo polymerization shrinkage or have an inhibitor layer, in that it is polymerized under standardized parameters at high temperature and pressure to ensure constant quality before milling, and it can be used for fabricating interim crowns and partial fixed dental prostheses. Currently, Telio CAD-CEREC can only be milled by the CEREC system.

Paradigm MZ100-E4D (3M ESPE) blocks are an alternative for ceramic restorations, are less abrasive, and are relatively strong and wear resistant. They can be used in areas where ceramics are contraindicated, for example, when opposing resin denture teeth. The E4D IntraOral Digitizer (Planmeca, E4D Technologies) uses a confocal sensor and includes a laser source coupled to a fiber optic cable, a coupler, and a detector. No studies comparing Caulk Temporary Crown and Bridge Resin (Dentsply Caulk) with other PMMA materials were found; however, Jet (Lang Dental), a PMMA, has been compared with SNAP (Parkell Inc), a polyethylmethacrylate (PEMA). The Jet crowns had a smaller marginal discrepancy and better adaptation. Ogawa et al showed that the marginal adaptation significantly improved when the PMMA material was polymerized in water at 20°C to 30°C when compared with 20°C in air. Only a few studies have compared the accuracy of the CAD/CAM systems and conventionally made interim crowns. The purpose of this study was, after aging by thermocycling, to evaluate the marginal integrity of interim crowns of Telio CAD-CEREC and Paradigm MZ100-E4D made by CAD/CAM compared with 2 other conventionally fabricated PMMA interim crowns. The first null hypothesis tested was that no difference would be found in the vertical and/or horizontal marginal fit of the interim materials fabricated by CAD/CAM or conventionally. The second null hypothesis tested was that no correlation would be found between the size of the vertical and/or horizontal marginal discrepancy and the penetration of dye after thermocycling.

MATERIAL AND METHODS
A polyvinyl siloxane putty (Aquasil; Dentsply Caulk) was used to make an impression of an unprepared mandibular dentoform (Columbia) arch. A dentoform left second mandibular premolar tooth was prepared for a ceramic crown with 1-mm axial and 2-mm occlusal reduction with a deep supragingival chamfer margin and a convergence angle of 6 degrees. The CEREC manual recommends either a deep chamfer or a modified shoulder margin. A 1-mm circumferential deep chamfer margin was selected for this study because it had been reported previously that this margin did not affect the accuracy of the CAD/CAM system or the dimensional accuracy of crown margins. The dentoform model was sprayed with a titanium dioxide powder (VITA CEREC powder with CEREC Propellant; VITA North America) to facilitate scanning with the scanner (Lava COS; 3M ESPE). The arch, the prepared tooth, the antagonist arch, and the interarch relationship were scanned from the buccal direction, and 6 stereolithic resin dies were fabricated. Die spacers allow more accurate seating of crowns with the ideal cement space reported to be in the range of about 20 to 40 μm for a cast crown. Pilot studies determined that the default settings for both the Telio CAD-CEREC and Paradigm MZ100-E4D crowns were too small to allow the crowns to be seated fully on...
the printed stereolithic dies and so were increased to 60 and 120 μm, respectively.

The CEREC 3 was used to scan 15 resin dies to fabricate the 15 Telio CAD-CEREC interim crowns with an internal space of 60 μm. Similar interim Paradigm MZ100-E4D crowns were fabricated using the E4D scanner and its milling system. Fifteen separate scans were completed on the 15 sets of resin dies to mill 15 Paradigm MZ100-E4D interim crowns with an internal spacer width of 120 μm. A thin layer of petroleum jelly (Vaseline; Unilever) was applied on the remaining stereolithic casts. Autopolymerizing resin interim crowns were fabricated in 2 representative resins Caulk Temporary Crown and Bridge Resin (Dentsply Caulk); Jet (Lang Dental) were fabricated by mixing the resin according to the manufacturer’s specification and loading the resin into a polyvinyl siloxane (Aquasil; Dentsply Caulk) matrix, which was placed over the die when the resin was in its doughy stage. After 10 minutes the crowns were trimmed with acrylic resin trimming burs using ×3 magnification loupes. Fifteen of each type were made on their respective resin dies. All interim crowns were cemented onto their dies with an interim luting agent (Tempgrip; Dentsply Caulk) under a 17.8 N load to simulate the force generated when constant finger pressure is applied on an interim crown intraorally. The interim crowns were embedded in clear epoxy resin (Pelco; Ted Pella) to prevent dislodging before sectioning with a diamond disk (Buehler Diamond Wafering Blade; Buehler USA) in the mid-buccal to mid-lingual direction. The percentage of dye penetration was calculated by measuring the distance of dye penetration at ×1 magnification with software (Image Pro Plus v5.1; Media Cybernetics) divided by the overall length under the crown and multiplied by 100 (Fig. 1A). The marginal discrepancy was measured with a polarized light traveling microscope (Olympus BX50; Olympus Optical Co Ltd) at ×4 magnification, and the images were collected with a dedicated PC using Image Pro Plus software. Measurements were made at the facial and lingual margins by measuring the vertical and horizontal marginal discrepancy as shown in Fig. 1B. The vertical marginal discrepancy was determined by measuring the void from the base of the interim crown to the surface of the die along the long axis of the tooth. The horizontal marginal discrepancy was measured from the base of the vertical edge of the crown to the edge of the die as shown in Fig. 1B.

Descriptive statistics were computed. One-way ANOVA with the post hoc Tukey-Kramer test was used to determine any statistically significant difference in the mean vertical or horizontal marginal discrepancies among the 4 interim crowns at either the facial or lingual margins and to detect the difference in mean percentage of dye penetration among the 4 types of crowns. A Pearson correlation test was conducted to evaluate whether a relationship existed between percentage of dye penetration and vertical or horizontal marginal
discrepancy for the facial and lingual surfaces. When CAD/CAM crowns were compared with the conventional interim crowns, a 2-sample Student t test was used to determine whether a difference existed in the mean vertical and horizontal marginal discrepancy between CAD/CAM interim crowns and the conventionally made interim crowns at the facial and lingual surfaces \((\alpha=.05)\). Software (SAS for Windows v9.4; SAS Institute Inc) was used for the data analysis.

A sample size of 60 crowns \((n=15)\) was selected for this study, based on previous published studies\(^{17,32,53}\). Previous in vitro studies\(^{17,32,53}\) of interim crowns found statistically significant differences among various types of crowns,\(^{29,49,50}\) even with fewer than 15 crowns per group. Intraobserver reliability was evaluated by using a random number table to select 16 interim crowns (4 from each group) to remeasure 1 month after the initial measurement. The intraclass correlation coefficient of 0.86 \((P<.001)\) indicated a strong agreement between the 2 measurements made by the same observer.

### RESULTS

Of the 60 specimens examined, 1 specimen from the Paradigm MZ100-E4D group dislodged during thermocycling and was removed from the study. A statistically significant difference was found between the CAD/CAM interim crowns and the conventionally made interim crowns for the mean vertical component of the facial and lingual marginal discrepancies \((P=.006)\) but not for the horizontal component \((P=.150)\) (Tables 1, 2). The combined vertical components of the conventionally made interim crowns had a significantly greater mean marginal discrepancy than that observed for the CAD/CAM crowns \((0.17 \text{ mm versus } 0.12 \text{ mm})\).

A statistically significant difference was found among the 4 types of interim crowns when the mean vertical component of the marginal discrepancy at the facial surface for the crowns made from Caulk resin was statistically significantly greater than the other 3 types of crowns, \((P<.05)\) while no difference was found among the 3 types of crowns \((P>.05)\) in each instance.

A statistically significant difference was found among the 4 types of interim crowns for the mean horizontal component of the marginal discrepancy at the facial surface \((F[3,55]=17.14; P<.001; 1\text{-way ANOVA})\) (Table 2). The mean horizontal component of the marginal discrepancy at the facial surface for Telio CAD-CEREC crowns was significantly larger than that of the other 3 types of crown. No statistically significant difference was found between the crowns made with Paradigm MZ100-E4D and Caulk. However, those made with Jet had a statistically significant smaller horizontal discrepancy at the facial surface than the other 3 \((P<.05)\).

Furthermore, no statistically significant difference was found among the 4 types of interim crowns when the mean vertical component of marginal discrepancy at the lingual surface \((F[3,55]=1.85; P=.150; 1\text{-way ANOVA})\) was evaluated. Although the crowns made from Caulk had the largest discrepancies, and CEREC the smallest discrepancies no statistically significant differences were found among the 4 types of interim crowns \((P>.05)\) for all instances as listed in Table 1.

A statistically significant difference was found among the interim crowns for the mean horizontal component of the marginal discrepancy at the lingual surface \((F[3,55]=6.58; P<.001; 1\text{-way ANOVA})\) (Table 2). This difference for Caulk and Jet was significantly greater than that observed for Telio CAD-CEREC and Paradigm MZ100-E4D. No statistically significant difference was found between Caulk and Jet or between Telio CAD-CEREC and Paradigm MZ100-E4D, as listed in Table 2.

To evaluate the effect of aging on the seal of the crowns by the cement, the crowns were thermocycled and placed in 0.5% acid fuchsin dye. The difference in the percentage depth of penetration of the dye among the

### Table 1. Vertical component of marginal discrepancy of interim crowns

<table>
<thead>
<tr>
<th>Crown Type</th>
<th>N</th>
<th>Facial (mm), mean (SD)</th>
<th>Lingual (mm), mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telio CAD-CEREC</td>
<td>15</td>
<td>0.18 (0.07)*a</td>
<td>0.09 (0.04)*a</td>
</tr>
<tr>
<td>Paradigm MZ100-E4D</td>
<td>14</td>
<td>0.13 (0.06)*a</td>
<td>0.09 (0.04)*a</td>
</tr>
<tr>
<td>Caulk</td>
<td>15</td>
<td>0.29 (0.14)*a</td>
<td>0.13 (0.07)*a</td>
</tr>
<tr>
<td>Jet</td>
<td>15</td>
<td>0.15 (0.06)*a</td>
<td>0.11 (0.06)*a</td>
</tr>
<tr>
<td>Combined vertical of CAD/CAM</td>
<td>29</td>
<td>0.12 (0.04)*a</td>
<td>0.08 (0.04)*a</td>
</tr>
<tr>
<td>Combined vertical of polymethylmethacrylate</td>
<td>30</td>
<td>0.17 (0.08)*a</td>
<td>0.10 (0.09)*a</td>
</tr>
</tbody>
</table>

*Means with same superscript letter not significantly different using post hoc Tukey-Kramer test \((P>.05)\).

**Means with same superscript letter not significantly different using two-sample test \((P>.05)\).

### Table 2. Horizontal component of marginal discrepancy of interim crowns

<table>
<thead>
<tr>
<th>Crown Type</th>
<th>N</th>
<th>Facial (mm), mean (SD)</th>
<th>Lingual (mm), mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telio CAD-CEREC</td>
<td>15</td>
<td>0.18 (0.05)*a</td>
<td>0.03 (0.05)*a</td>
</tr>
<tr>
<td>Paradigm MZ100-E4D</td>
<td>14</td>
<td>0.10 (0.05)*a</td>
<td>0.02 (0.03)*a</td>
</tr>
<tr>
<td>Caulk</td>
<td>15</td>
<td>0.10 (0.08)*a</td>
<td>0.16 (0.18)*a</td>
</tr>
<tr>
<td>Jet</td>
<td>15</td>
<td>0.02 (0.04)*a</td>
<td>0.13 (0.09)*a</td>
</tr>
<tr>
<td>Combined horizontal of CAD/CAM</td>
<td>29</td>
<td>0.08 (0.04)*a</td>
<td>0.10 (0.09)*a</td>
</tr>
<tr>
<td>Combined horizontal of polymethyl methacrylate</td>
<td>30</td>
<td>0.10 (0.09)*a</td>
<td>0.10 (0.09)*a</td>
</tr>
</tbody>
</table>

*Means with same superscript letter not significantly different using post hoc Tukey-Kramer test \((P>.05)\).

**Means with same superscript letter not significantly different using the two-sample test \((P>.05)\).
4 types of crown is listed in Table 3. A 1-way ANOVA revealed a statistically significant difference between the crowns for the depth of dye penetration (F[3,55]=39.06; P<.001). Dye penetration for Paradigm MZ100-E4D crowns was significantly greater than that observed for the other 3 crown groups. No significant differences were found between Telio CAD-CEREC and Caulk. However, for Jet crowns, it was statistically significantly smaller than for the other 3 crowns (Table 3).

A Pearson correlation coefficient was calculated to examine the relationship of the percentage of penetration of acid fuchsin dye and the marginal discrepancy and is listed in Tables 4, 5. No significant correlations were found between the percentage of dye penetration and the vertical component of the facial or lingual marginal discrepancies (P>.05), except for Jet interim crowns. The Pearson correlation coefficient of 0.64 indicated a moderate positive relationship between the 2 variables as listed in Table 4. The correlation between the percentage of dye penetration and the horizontal component of the marginal discrepancy is listed in Table 5. However, no significant correlations were found between the percentage of dye penetration and the facial or lingual horizontal component of the marginal discrepancies (P>.05), except for the lingual margin of Caulk (P<.01) and the facial margin of Jet (P<.01). The Pearson correlation coefficient of 0.67 and 0.74 indicated a moderate positive relationship between the 2 variables.

**DISCUSSION**

The first hypothesis tested was whether a difference existed in the vertical and/or horizontal marginal fit between the interim crowns made by the CAD/CAM systems compared with those made conventionally with PMMA. The vertical discrepancy (Fig. 1B) is clinically important because it exposes the luting cement and potentially the tooth structure to the oral environment. The horizontal discrepancy (Fig. 1B) is also clinically significant because it results in a step defect between the crown and the tooth, which influences the ability of the patient to clean the margin and prevent increased plaque accumulation.6,11,12 Therefore, because a statistically significant difference was found in marginal discrepancy between the crowns made by the CAD/CAM systems and those made by the conventional methodology, the first null hypothesis was rejected.

The average vertical marginal discrepancy found in this study ranged from 110 µm for Paradigm MZ100–E4D to 210 µm for Caulk resin. In the horizontal direction, the measurements were less, and the range was from 60 µm for Paradigm MZ100–E4D to 130 µm for Caulk (Tables 1, 2). These numbers were higher than those reported by Akbar et al21 (65.9 ±38.7 µm); however, his group evaluated the chamfer and shoulder margins of Paradigm MZ100–E4D crowns without thermocycling. In this study, the marginal discrepancies were smaller than those reported by Ehrenberg et al22 (152.1 ±69.6 µm) or Ehrenberg and Weiner31 (460.4 ±155.1 µm), but they stressed their specimens by serially loading them before thermocycling. The methodologies used in these 2 studies22,31 varied in the cementation technique, in how the specimens were serially loaded, and in the way the marginal discrepancies were measured, which ranged from a replication technique to the use of an electron microscope.

The need to increase the default space for the CAD/CAM crowns may be due to the increased roughness of the stereolithic dies compared with that of a stone die. The effect of the degree of axial wall convergence, margin, and luting space has not previously been discussed nor could we find any discussion of the influence of the surfaces of the printed stereolithic dies on the fit of crowns. Although the ideal cement space is in the

<table>
<thead>
<tr>
<th>CROWN TYPE</th>
<th>N</th>
<th>DEPTH OF DYE PENETRATION (%)</th>
<th>MEAN (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paradigm MZ100-E4D</td>
<td>14</td>
<td>72.38 (15.86)A</td>
<td></td>
</tr>
<tr>
<td>Telio CAD-CEREC</td>
<td>15</td>
<td>32.71 (9.42)B</td>
<td></td>
</tr>
<tr>
<td>Caulk</td>
<td>15</td>
<td>31.54 (16.42)B</td>
<td></td>
</tr>
<tr>
<td>Jet</td>
<td>15</td>
<td>18.95 (13.44)C</td>
<td></td>
</tr>
</tbody>
</table>

*Means with same superscript letter not significantly different using post hoc Tukey-Kramer test (P>.05).

**Table 3. Depths of penetration of acid fuchsin after thermocycling as percentage of crown for different types of crowns**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>CORRELATION COEFFICIENT</th>
<th>P</th>
<th>CORRELATION COEFFICIENT</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paradigm MZ100-E4D</td>
<td>-0.17</td>
<td>.56</td>
<td>-0.05</td>
<td>.84</td>
</tr>
<tr>
<td>Telio CAD-CEREC</td>
<td>-0.10</td>
<td>.73</td>
<td>-0.24</td>
<td>.40</td>
</tr>
<tr>
<td>Caulk</td>
<td>0.03</td>
<td>.91</td>
<td>-0.24</td>
<td>.40</td>
</tr>
<tr>
<td>Jet</td>
<td>0.64</td>
<td>&lt;.01**</td>
<td>-0.37</td>
<td>.18</td>
</tr>
</tbody>
</table>

*Pearson correlation coefficient given to describe strength of relationship between 2 variables.
**Significant relationship between two variables at P=.05 using Pearson correlation test.

**Table 4. Correlation between dye penetration and facial and lingual horizontal discrepancies**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>CORRELATION COEFFICIENT</th>
<th>P</th>
<th>CORRELATION COEFFICIENT</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paradigm MZ100-E4D</td>
<td>-0.24</td>
<td>.39</td>
<td>-0.01</td>
<td>.96</td>
</tr>
<tr>
<td>Telio CAD-CEREC</td>
<td>-0.18</td>
<td>.54</td>
<td>0.04</td>
<td>.89</td>
</tr>
<tr>
<td>Caulk</td>
<td>0.07</td>
<td>.80</td>
<td>0.67</td>
<td>&lt;.01**</td>
</tr>
<tr>
<td>Jet</td>
<td>0.74</td>
<td>&lt;.01**</td>
<td>0.13</td>
<td>.65</td>
</tr>
</tbody>
</table>

*Pearson correlation coefficient given to describe strength of relationship between 2 variables.
**Significant relationship between 2 variables using Pearson correlation test.

**Table 5. Correlation between dye penetration and facial and lingual horizontal discrepancies**
The present study did not use occlusal loading. The second hypothesis tested whether a relationship existed between the marginal discrepancy and the penetration of the dye after thermocycling. Thermocycling increases the marginal discrepancy size of interim crowns, and simultaneous occlusal loading and thermocycling increases marginal discrepancy sizes even more. The present study did not use occlusal loading but all specimens had dye penetration between the die and the cement. Paradigm MZ100-E4D interim crowns had significantly greater dye penetration (72.38%), Jet, the least (18.95%), and Telio CAD-CEREC and Caulk interim crowns were similar (Table 3). Greater dye penetration with Paradigm MZ100-E4D could be because the internal cement space had to be increased to 120 μm to seat the crowns. A positive but moderate relationship was found between dye penetration and the horizontal and vertical marginal discrepancy on the facial aspect of Jet interim crowns and the horizontal marginal discrepancy on the lingual aspect of Caulk interim crowns. The second null hypothesis testing the correlation between discrepancy size and dye penetration was also rejected.

Another question investigated was whether a difference could be found among the interim crowns made from different materials. The greatest discrepancy in the vertical component of the marginal discrepancy was found with Caulk interim crowns, while Jet interim crowns did not differ from the CAD/CAM crowns. A study by Ehrenberg et al compared Jet, which is a PMMA, and SNAP, which is a PEMA. The Jet crowns had a smaller marginal discrepancy and better adaptation, which may explain why Jet was more accurate than Caulk.

The larger marginal discrepancy in the vertical component at the facial surface of the Caulk interim crowns could have been due to shrinkage when the crowns were polymerized in air. Ogawa et al showed that the marginal adaptation significantly improved when the interim PMMA material was polymerized in water at 20°C to 30°C. In this study, marginal discrepancy differences were found between the materials when they were measured separately at the facial and lingual surface and when measured in the vertical and horizontal directions. Although there was no clear pattern, Caulk seemed to have the largest marginal discrepancy at all sites except on the horizontal component of the facial surface. Paradigm MZ100-E4D was found to have the smallest marginal discrepancy except in the horizontal component at the facial surface. Because few studies have evaluated both the horizontal and vertical component of the marginal discrepancies, comparing our findings with other studies is difficult.

**CONCLUSION**

Within the limits of this study, the following conclusions can be drawn:

1. The vertical component of the marginal fit of the PMMA conventionally made crowns was significantly greater than that of the CAD/CAM interim crowns.
2. The depth of dye penetration after thermocycling was greater in crowns made from Paradigm MZ100-E4D and was significantly less in crowns made with Jet.
3. The interim crowns made from Caulk had the largest mean marginal discrepancy at all sites except on the horizontal component of the facial and lingual surface. Also, crowns made with Paradigm MZ100-E4D had the smallest mean marginal discrepancy, both at the facial and lingual surface.
4. The vertical component of the mean marginal discrepancy was significantly larger at the facial surface for all crowns, and the horizontal component of the marginal discrepancy for Caulk and Jet interim crowns was significantly larger at the lingual surface.
5. A significant relationship exists between the size of the vertical and/or horizontal component of the marginal discrepancies of the interim crowns and dye penetration after thermocycling.

**REFERENCES**


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