The marginal fit of E.max Press and E.max CAD lithium disilicate restorations: A critical review

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This critical review aimed to assess the vertical marginal gap that was present when E.max lithium disilicate-based restoration (Press and CAD) are fabricated in-vitro. Published articles reporting vertical marginal gap measurements of in-vitro restorations that had been fabricated from E.Max lithium disilicate were sought with an electronic search of MEDLINE (PubMed) and hand search of selected dental journals. The outcomes were reviewed qualitatively. The majority of studies that compared the marginal fit of E.max press and E.max CAD restorations, found that the E.max lithium disilicate restorations fabricated with the press technique had significantly smaller marginal gaps than those fabricated with CAD technique. This research indicates that E.max lithium disilicate restorations fabricated with the press technique have measurably smaller marginal gaps when compared with those fabricated with CAD techniques within in-vitro environments. The marginal gaps achieved by the restorations across all groups were within a clinically acceptable range.

Keywords: Marginal fit, E.max, Press, CAD, Lithium disilicate

INTRODUCTION

Introduction of the acid etched ceramic protocol for bonding to enamel in 19801-3 and the dentin adhesives in the early 1990s4-6, facilitated dental rehabilitation with all-ceramic prosthesis6.

Lithium disilicate is a glassy ceramic that consists of quartz, lithium dioxide, phosphor oxide, alumina, potassium oxide and other components7. The material has high flexural strength up to 440 MPa7. IPS E.max lithium disilicate, introduced in 2005 by Ivoclar Vivadent (AG, Schaan, Liechtenstein), is a material where lithium disilicate crystals (SiO2-Li2O) are embedded into a matrix of glass to minimize microcrack propagation8, thereby improving mechanical stability9.

IPS E.max lithium disilicate restorations can be made using either lost-wax hot pressing techniques (IPS E.max Press) or computer-aided-designed/computer-aided manufactured (CAD/CAM) milling procedures (IPS E.max CAD) either in the dental office (chairside CAD/CAM systems) or in the dental laboratory10.

CAD/CAM has been available for dental use since its development by Duret in France in the 1970s (System Duret CAD/CAM)11. Chairside CAD/CAM systems including Cerec (Sirona Dental Systems) are recognized as reliable chairside CAD/CAM systems12-14 allowing the fabrication of restorations from monolithic blocks of lithium disilicate (IPS E.max CAD)15. Following design and milling, the precrystallized restorations undergo a heat crystallization process to achieve maximum strength16. The technology allows dental practitioners to fabricate restorations in a single visit by using intraoral optical impressions and in-office milling17. This workflow avoids use of provisional cements, and it has been argued that this results in improved dentine adhesion18.

Dental laboratories can also use the lost-wax technique to fabricate pressable lithium disilicate restorations (IPS E.max Press). Ingots of lithium disilicate are heat-pressed within a porcelain furnace to mold the ceramic material into the desired shape19,20. This technique reduces processing errors that may be associated with conventional sintering and has been shown to improve mechanical stability21,22.

Marginal fit is an important factor in the success of restorations23,24. Marginal fit is related to both vertical and horizontal discrepancies. The marginal gap has been defined as the vertical distance from the internal surface of the restoration to the finish line of the preparation25. Horizontal discrepancies, such as crown overhangs, can also occur and these result in serious misfit. Horizontal overhangs can be adjusted to some degree intraorally. Vertical marginal gaps can only be sealed with luting cement. Luting cements are rough, porous, and can dissolve26. The larger the marginal discrepancy, the faster will be the rate of cement dissolution26. Therefore, clinicians seek to minimize marginal gaps to decrease the incidence of tooth staining, gingival irritation and other dental and periodontal complications accompanied with the rough surfaces present after luting cement dissolution.

There is no clinical or evidence-based consensus regarding whether a specific marginal gap may be clinically acceptable for a given patient. Some studies indicate that a marginal fit <120 microns is clinically acceptable27, but other authors showed that a marginal fit ≤100 microns is more suitable28,29. Others consider a fit ≤75 microns clinically acceptable30. However, in
additional studies, a marginal fit of between 25 and 40 microns for cemented restorations was considered to be a clinical goal\(^3\), but additional studies have shown that these levels are difficult to be achieved\(^3\).

Many studies have been published on the marginal fit of E.max press and CAD lithium disilicate restorations. However, no critical review has been undertaken to explore the collective findings of these studies.

The aim of this study was to undertake a critical review to explore the collective findings of studies that reported on the vertical marginal discrepancy, the marginal gap, when restorations were fabricated from E.max lithium disiclate.

**MATERIALS AND METHODS**

An electronic search of MEDLINE (PubMed) was conducted by two independent reviewers. All terms were entered as keywords. The search strategy is outlined in Fig. 1. In addition, a hand search of Journal of Prosthetic Dentistry, Journal of Dental Materials, International Journal of Prosthodontics, European Journal of Dentistry, Journal of Operative Dentistry, Journal of Brazilian Oral Research, and Journal of Dentistry from January 2005 until December 2014 was completed. The search commenced from the year 2005, as this was the year when E.max lithium disilicate material was introduced by the manufacturing company, Ivoclar Vivadent. Unpublished manuscripts and grey literature were not sought. Duplicate studies were excluded \(n=6\).

Eligibility criteria included in-vitro studies, published after 2005 in English, regarding the vertical marginal fit of E.max lithium disilicate restorations. Exclusion criteria included articles measuring the marginal gap with in-vivo methods, articles in languages other than English.

The flow diagram of the search is provided in Fig. 2. Out of the seventy-six articles identified, all underwent

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**Example search:**

| MEDLINE (PubMed) |
|---|---|
| (lithium disilicate) AND (press) OR | (lithium disilicate) AND (CAD) OR |
| (lithium disilicate) AND (Marginal fit) OR | (lithium disilicate) AND (E.Max) OR |
| (press) AND (CAD) OR | (press) AND (marginal fit) OR |
| (press) AND (E.Max) OR | (CAD) AND (Marginal fit) OR |
| (CAD) AND (E.Max) OR | (marginal fit) AND E.Max |

\( ( ) \) indicates keyword

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Fig. 1  Example search for MEDLINE (PubMed) database.

Fig. 2  Flow chart of search strategy.
<table>
<thead>
<tr>
<th>Authors</th>
<th>Material and technique</th>
<th>Mean Marginal gap ( Microns )</th>
<th>Type of restoration</th>
<th>Size of sample</th>
<th>Year of publication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anadioti et al.</td>
<td>E.max CAD+conventional impression (PVS)</td>
<td>3D measurement: 88±24</td>
<td>Crown</td>
<td>15</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>E.max CAD+Digital impression (Lava™ C.O.S.)</td>
<td>3D measurement: 84±21</td>
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<tr>
<td></td>
<td>E.max Press+conventional impression (PVS)</td>
<td>3D measurement: 48±9</td>
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<tr>
<td></td>
<td>E.max Press+Digital impression (Lava™ C.O.S.)</td>
<td>3D measurement: 89±20</td>
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<td></td>
<td></td>
<td>(Standard deviation 25.04)</td>
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<td></td>
<td></td>
<td>After cementation: 137.82</td>
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<td></td>
<td></td>
<td>(Standard deviation 44.44)</td>
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<tr>
<td></td>
<td></td>
<td>After cementation: 190–310</td>
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<tr>
<td></td>
<td>E.max press+Shoulder 90º</td>
<td>Before cementation: 70–160</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>After cementation: 140–220</td>
<td></td>
<td></td>
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<tr>
<td>Guess et al.</td>
<td>E.max press</td>
<td>Before cementation: 45.51</td>
<td>Onlay</td>
<td>24</td>
<td>2014</td>
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<td></td>
<td></td>
<td>(42.04–48.98)</td>
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<td></td>
<td></td>
<td>After cementation: 62.86</td>
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<td>(57.42–68.31)</td>
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<td>After fatigue: 58.59</td>
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<td></td>
<td></td>
<td>(51.78–65.41)</td>
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<tr>
<td>Hamza et al.</td>
<td>E.max CAD CEREC in lab</td>
<td>40.2±6.7</td>
<td>Crown</td>
<td>10</td>
<td>2013</td>
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<td>E.max CAD Everest</td>
<td>28.1±7.9</td>
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<td>Mously et al.</td>
<td>E.max CAD (E4D) with spacer 30 microns</td>
<td>55.18 (50.70–76.25)</td>
<td>Crown</td>
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<td>2014</td>
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<td></td>
<td>E.max CAD (E4D) with spacer 60 microns</td>
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<tr>
<td></td>
<td>E.max CAD (E4D) with spacer 100 microns</td>
<td>46.65 (30.55–58.15)</td>
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<tr>
<td></td>
<td>E.max press</td>
<td>30.80 (24.35–41.75)</td>
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<tr>
<td>Neves et al.</td>
<td>E.max CAD (CEREC 3D)</td>
<td>39.2±8.7</td>
<td>Crown</td>
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<td>2014</td>
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<tr>
<td></td>
<td>E.max CAD (E4D)</td>
<td>66.9±31.9</td>
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<tr>
<td></td>
<td>E.max press</td>
<td>36.8±13.9</td>
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Table 1 continued

<table>
<thead>
<tr>
<th>Authors</th>
<th>Material</th>
<th>Technique</th>
<th>Mean Marginal Gap (microns)</th>
<th>Number</th>
<th>Year</th>
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<td>Ng et al. 34</td>
<td>E.max CAD (Lava™ C.O.S.)</td>
<td>E.max press</td>
<td>48±25</td>
<td>Crown</td>
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<td>Renne et al. 17</td>
<td>E.max CAD (E4D)+Ideal preparation</td>
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<td>38.5 (Standard deviation 9)</td>
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<tr>
<td></td>
<td>E.max CAD (E4D)+Fair preparation</td>
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<td>58.3 (Standard deviation 12)</td>
<td>Crown</td>
<td>34</td>
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<tr>
<td></td>
<td>E.max CAD (E4D)+Poor preparation</td>
<td></td>
<td>90.1 (Standard deviation 23)</td>
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<tr>
<td>Schaefer et al. 19</td>
<td>E.max press</td>
<td></td>
<td>78 (Standard deviation 23)</td>
<td>Partial-coverage crowns</td>
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<td>Schaefer et al. 30</td>
<td>E.max press+One step impression/Single viscosity</td>
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<td>70 (Standard deviation 11)</td>
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<tr>
<td></td>
<td>E.max press+Two step impression/Dual viscosity</td>
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<td>107 (Standard deviation 12)</td>
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<tr>
<td>Subasi et al. 20</td>
<td>E.max press+Chamfer</td>
<td></td>
<td>105.2±21.33</td>
<td>Coping</td>
<td>10</td>
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<tr>
<td></td>
<td>E.max press+Shoulder</td>
<td></td>
<td>98.5±26.04</td>
<td></td>
<td>10</td>
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<tr>
<td>Yuksel and Zaimoglu 36</td>
<td>E.max press</td>
<td></td>
<td>92.6±4</td>
<td>Crown</td>
<td>12</td>
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</table>

Full text screening (Kappa=0.81, indicating excellent agreement) and thirteen were included in the study. Of the 63 exclusions, 2 used in-vivo methods to assess the marginal gap, 6 were duplicates, 9 were published prior to 2005, 22 did not report the marginal gaps of lithium disiclate, and 24 did not report the vertical marginal gap.

Full texts of the articles matching the inclusion criteria were read carefully by the same reviewers. Data extracted included the material, technique, mean marginal gap (microns), type of restoration, sample size, year of publication (Table 1).

Reported outcomes and methodological heterogeneity were explored qualitatively.

RESULTS

The search identified 13 studies that matched the inclusion criteria, with 11 studies reporting on E.max press, 7 reporting on E.max CAD, 5 reporting marginal gaps of both E.max press and E.max CAD. The studies assessed the marginal fit of complete crowns (n=9), partial veneer crowns (n=2), onlays (n=1) and copings (n=1).

Guess and colleagues 33 studied the marginal fit of E.max press and E.max CAD (CEREC 3D InLab) onlays. The marginal gap before cementation, after cementation, and after exposure to thermomechanical cycling (cycles of thermomechanical fatigue in a computer-controlled chewing simulator, Wilytec, Munich, Germany, under clinically relevant conditions) was studied. Measurements were undertaken with a stereomicroscope at 200x magnification (Zeiss Axioskop Zeiss, Oberkochen, Germany), a 3 CCD-colour videocamera (Sony 3CCD, Sony, Koln, Germany), and image analysis program (cell Imaging Software for Life Sciences Microscopy, Olympus Soft Imaging Solutions, Munster, Germany). The mean marginal gap for the E.max press group was 45.51 (95% CI 42.04–48.98) microns before cementation, 62.86 (95% CI 57.42–68.31) microns after cementation, and 58.59 (95% CI 51.78–65.41) microns after thermomechanical cycling. The mean marginal gap for the E.max CAD group was 50.09 (95% CI 47.18–52.99) microns before cementation, 54.05 (95% CI 52.26–55.84) microns after cementation, and 50.54 (95% CI 48.63–52.46) microns after thermomechanical cycling. The difference in the mean marginal gap was not statistically significant between the two groups before cementation (p-value 0.29) and after thermomechanical cycling (p-value>0.05). In contrast to the outcomes reported before cementation, or after thermomechanical cycling, Guess and colleagues found that onlays fabricated with the press technique had significantly higher marginal gaps than those fabricated with the CAD technique after cementation (p-value 0.024). The authors concluded that cementation increased the marginal gap significantly, while the
thermomechanical fatigue had no significant effect\(^{33}\).

Ng and colleagues\(^{34}\) compared the marginal gap of E.max press and E.max CAD (LAVA C.O.S. scanning unit) crowns. The marginal gap was measured using a stereomicroscope at 40\(\times\) magnification with a digital camera (5D Mark II 21-mp, Canon) mounted on the stereomicroscope (Edmund E-Zoom, Edmund Optics) and a software for photos calibration and measurements (Image J 1.32, U.S. National Institutes of Health). The mean marginal gap was 48\(\pm\)25 SD (standard deviation) microns for the E.max CAD group, and 74\(\pm\)47 SD microns for the E.max Press group. Similarly to the outcomes of the cemented CAD Cerec 3D onlays studied by Guess and Colleagues, the mean marginal gap of the uncemented crowns were significantly higher for the E.max press group compared to the E.max CAD LAVA group\(^{34}\).

Borges and colleagues\(^{35}\) studied the marginal fit of E.max press crowns in combination with two types of luting cements (Resin cement, resin-modified glass ionomer cement). The marginal gap was measured using an optical microscope at 50\(\times\) magnification. The mean marginal gap was 83.13\(\pm\)25.04 SD microns for the resin-modified glass ionomer group before cementation and 137.82\(\pm\)44.44 SD microns after cementation. The mean marginal gap was 101.50\(\pm\)21.20 SD microns for the resin cement group before cementation and 138.10\(\pm\)38.13 SD microns after cementation. The authors concluded that no significant differences were found between the cements (p-value\(<\)0.05), but the mean marginal gap increased significantly after cementation\(^{35}\), which agrees with the results of Guess and colleagues.

Yuksel and colleagues\(^{36}\) studied the marginal fit of E.max press crowns (n=12 crowns) with two types of luting cements (Glass ionomer cement (n=6), Self-adhesive resin cement (n=6). Measurements of the marginal gap were achieved after sectioning the specimens and digital photography under a stereomicroscope at 50\(\times\) magnification. The mean marginal gap was 92.64\(\pm\)4 microns with slightly higher values for the glass ionomer cement group, but with no significant differences\(^{36}\). The variance in this study is not clear from the original article, if it is a standard deviation or a standard error. These results are in agreement with those reported by Borges and colleagues.

Demir and colleagues\(^{37}\) studied the marginal fit of E.max press crowns in combination with 2 types of finishing lines (Shoulder 90° and chamfer 135°) across 10 specimens per group. The marginal gap was measured with micro-CT and (CTan) software before cementation and after cementation and thermal cycling. The results were shown in tables:

- E.max press crowns with shoulder finish line before cementation: 70–160 microns
- E.max press crowns with chamfer finish line before cementation: 80–130 microns
- E.max press crowns with shoulder finish line after cementation: 140–220 microns
- E.max press crowns with chamfer finish line after cementation: 190–310 microns

The authors did not express the difference in the marginal gap after cementation of specimens with different marginal designs clearly. However, across both marginal designs, the authors concluded that the marginal gap increased significantly after cementation, p-value\(<\)0.05 (The exact p-value was not reported), which agrees with the results of Borges and colleagues, and Guess and colleagues, except in the shoulder preparation (sagittal buccal region), where no significant increase was noticed\(^{38}\).

Subasi and colleagues\(^{39}\) studied the marginal fit of E.max press copings after cementation in combination with two types of finishing lines (shoulder and chamfer). The measurements of the marginal gap were achieved using stereomicroscope at 46\(\times\) magnification and a computer software (Leica StereoExplorer software, Leica Microsystems). The mean marginal gap was 105.2\(\pm\)21.33 microns for the chamfer group, and 98.5\(\pm\)26.04 microns for the shoulder group, with no significant differences between the two groups (p-value 0.36). These variances were unclear from the original article, if they are standard errors or standard deviations\(^{39}\).

Mously and colleagues\(^{40}\) compared the marginal fit of E.max press and E.max CAD crowns (E4D scanner). Four groups were assessed: Group 1: E.max CAD with a 30 micron spacer, group 2: E.max CAD with a 60 micron spacer, group 3: E.max CAD with a 100 micron spacer, group 4: E.max press. The marginal gap was measured using microcomputed tomography, micro-XCT (mCT 40, Scanco Medical) and a program for analyzing images (Image J software, National Institutes of Health). The results for the median marginal gap were: Group 1: 55.18 (50.70–76.25) microns, group 2: 49.35 (32.30–56.10) microns, group 3: 46.65 (30.55–58.15) microns, group 4: 30.80 (24.35–41.75) microns. The marginal gap was significantly lower in the E.max press group than the E.max CAD groups (p-value=0.005)\(^{40}\). In contrast with the results reported by Ng and colleagues regarding marginal gaps before cementation, and the results of Guess and colleagues regarding marginal gaps after cementation, this study concluded that the marginal gaps of the E.max press specimens were significantly lower than the E.max CAD specimens. This may be attributed to the differences in the CAD systems used in these studies, CEREC-Inlab 3D system in the study of Guess and colleagues, DMG/Mori Seiki system in the study of Ng and colleagues, and E4D system in the study of Mously and colleagues.

Neves and colleagues\(^{41}\) compared the marginal fit of E.max press and E.max CAD crowns. Three groups were assessed: Group 1 (E.max CAD CEREC 3D bluecam scanner), group 2 (E.max CAD E4D laser scanner), group 3 (E.max Press). The marginal gap was measured by processing software (v1.12.0.0, Sky-Scan) after micro CT scanning. The mean marginal gap was 39.24±8.7 SD microns for group 1, 66.9±31.9 SD microns for group 2, and 36.3±13.9 SD microns for group 3. E.max Lithium disilicate crowns fabricated with either the —Cerec 3D Bluecam scanner CAD/CAM or heat-press technique—achieved significantly smaller marginal gaps than crowns.
fabricated with the —CAD/CAM E4D Laser scanner— (p-value 0.046)\(^9\). These results compare favourably with the CAD E4D results of Mously and colleagues. They indicate that the E.max press technique is superior to the E4D, and that different CAD techniques such as the CEREC 3D bluecam scanner or alternative technologies studied by other authors may produce superior outcomes for CAD/CAM fabricated prostheses.

Hamza and colleagues\(^{10}\) measured the marginal gap of E.max CAD crowns using two different CAD/CAM systems (CEREC InLab, Kavo Everest). Digital images were taken at a 100× magnification and the marginal gap was measured with computer software (Optimas 6.5, Media Cybernetics, Rockville, MD, USA). The Everest CAD/CAM system specimens showed significantly lower marginal gap (28.1±7.9 SD microns) than those of the Cerec InLab system specimens (40.2±6.7 SD microns) (p-value<0.05)\(^5\). The authors attributed this difference to the 3-axis milling unit of the Cerec InLab, compared to the 5-axis unit of the Everest system. However, in the study of Neves and colleagues, both the Cerec 3D system and the E4D system had a 3-axis milling unit, and the results were significantly different between the 2 systems.

Anadioti and colleagues\(^{10}\) compared the marginal fit of E.max press and E.max CAD crowns in combination with conventional (PVS) and optical impressions (LavaTM C.O.S). The study was divided into 4 groups: Group 1 (PVS+Press), group 2 (PVS+CAD), group 3 (Optical+Press), group 4 (Optical+CAD). The marginal fit was measured in 3 dimensions and 2 dimensions computer software (Geomagic Qualify 2012, Research Triangle Park, NC, USA) after digitizing the sample using a laser scanner (Laser Design, GKS, Minneapolis, MN, USA). The mean marginal gap was:

- **Group 1**: 3D measurement (48±9 SD microns), 2D measurement (40±9 SD microns),
- **Group 2**: 3D measurement (88±24 SD microns), 2D measurement (76±23 SD microns),
- **Group 3**: 3D measurement (89±20 SD microns), 2D measurement (75±15 SD microns),
- **Group 4**: 3D measurement (84±21 SD microns), 2D measurement (74±26 SD microns).

The smallest marginal gap was measured in the first group (Conventional impression +E.max press) 3D (48 microns) and 2D (40 microns), which was significantly smaller than in the other groups (p-value<0.0001)\(^{10}\). These results are in agreement with Mously and colleagues, which also showed that the E.max press restorations achieved by silicon impressions had minimal marginal gaps.

Schaefer and colleagues\(^{10}\) studied the marginal fit of E.max press partial coverage crowns fabricated from master casts when different impression techniques were used. Group 1: One step single viscosity, vinyl siloxanether material (Identium, Kettenbach), group 2: One step dual viscosity, vinyl siloxanether material (Identium, Kettenbach), group 3: Two step dual viscosity, vinyl polysiloxane material (Panasil, Kettenbach). Measurements were undertaken with computer software (Qualify 12, Geomagic, Stuttgart, Germany) after digitizing the prepared tooth and the partial coverage crown by a white-light scanner. The mean marginal gap was:

- **Group 1**: 70±11 SD microns, group 2: 78±15 SD microns, group 3: 107±12 SD microns.

The authors concluded that the one step impression technique resulted in significantly less marginal gap than the two step impression technique (p-value 0.006)\(^{39}\).

In a different study, Schaefer and colleagues\(^{19}\) studied the marginal fit of E.max press partial coverage crowns. Measurements were completed using computer software (Qualify 12, Geomagic) after digitizing the prepared tooth and the partial coverage crown by a structured light scanner (Flex 3A, Otto Vision Technology, Jena, Germany). The mean marginal gap was 78±23 SD microns\(^{19}\). The results achieved in this study agrees with all the other studies included in this review, in terms of having a mean marginal gap below 120 microns.

Renne and colleagues\(^{17}\) studied the marginal gap of E.max CAD (E4D scanning unit) crowns in combination with three categories of preparation: Ideal (n=25), fair (n=34), and poor (n=15). The authors considered both heavy chamfer and modified shoulder preparations as acceptable. The marginal fit was measured using the replica technique, where a green light body VPS impression material (Genie, Sultan Healthcare, Englewood, NJ, USA) was injected into the crowns before placing them on the corresponding die with finger pressure to replicate the marginal gap. Thus, no cementation was applied in this study. The authors used a microscope at 100× magnification, a digital camera and a digital software (Omnimet 8.8.1, Buehler). The mean marginal gap was 38.5 microns with a standard deviation 9 microns for the ideal preparation group, 58.3 microns with a standard deviation 12 microns for the fair preparation group, and 90.1 microns with a standard deviation 23 microns for the poor preparation group.

The authors concluded that the category of preparation affected significantly the marginal fit of E.max CAD crowns (p-value<0.001)\(^{17}\)

**DISCUSSION**

This critical review collated information from the published literature regarding the marginal fit of E.max lithium disilicate restorations (Press and CAD). These techniques are becoming more common for fabrication of dental restorations in clinical practice\(^{40}\), but advances in technology and laboratory techniques mean that the techniques are regularly evolving. Marginal gaps will always be present when indirect restorations are fabricated, and the presence of such gaps can be related to ongoing cement dissolution, dental caries and periodontal complications\(^{40}\).

The search identified 13 studies that met the inclusion criteria. Out of the 5 studies that compared the marginal fit of E.max press and E.max CAD restorations, the majority (n=3) found that the E.max
lithium disilicate restorations fabricated with the press technique had significantly smaller marginal gaps than those fabricated with CAD technique15,37,38. This finding may be related to the scanning device accuracy, software design, spacer settings, and milling machine accuracy41-43.

Most of the included studies had some possible drawbacks, which might have affected the outcomes. Mously and colleagues37 were among the authors that found that the E.max lithium disilicate restorations fabricated with the press technique had significantly smaller marginal gaps than those fabricated with CAD technique. The authors used Micro-CT to measure the marginal gap. The disadvantages of this method include the low capacity of discrimination of CT microtomography compared to the optical or electron microscope44. A major drawback of this technique is radiation artifacts, which are caused by the differences in the coefficient of radiation absorption among the different materials used35. This technique was also used in the study of Demir and colleagues which showed that marginal gap of E.max press crowns increased significantly after cementation9. The use of this method of measurement in these two studies may have affected the reliability of the results.

Anadioti and colleagues40 measured the marginal gap using a new scanner, and its reliable use would have been subject to a learning curve by the researchers. In addition, errors might take place during the multiple scanning phases: 1) The prepared dentoform tooth (master die), 2) the intaglio of all each-ceramic crown and 3) each crown on the dentoform tooth in a final position. These errors are likely to occur and may affect the final result significantly.

Neves and colleagues38 showed a significantly smaller marginal gap of E.max Lithium disilicate crowns fabricated with (Cerec 3D Bluecam scanner CAD/CAM system) or the heat-press technique than E.max Lithium disilicate crowns fabricated with (CAD/ CAM E4D Laser scanner)36. However, the sample size of this study was very small (5 specimens per group) compared to other studies like Guess and colleagues (24 specimens per group), which could be inadequate to give a significant result. In addition, a silicon material was used to fix the crowns on the die model, which could affect the accuracy of the marginal gap measurement.

Conversely, one study showed no significant difference in the mean marginal gap between the E.max CAD and E.max press restorations38, while another study showed that the E.max CAD restorations had significantly smaller marginal gap than the E.max press restorations44.

The findings of the latter study could be explained by the following: E.max press restorations require an accurate negative replica of the dentition with an elastomeric impression material46,47. Transporting the impression to the dental laboratory subjects the impression to a large variation in temperature, which could result in dimensional changes48. In addition, the length of time between impression making and pouring of the stone cast, as well as disinfection may cause an additional distortion40,42. The application of a die hardener and die spacer, the fabrication of a wax pattern of the restoration, and the investment and pressing process may also be source of errors31,32. However, the measurements conducted by Ng and colleagues34 were made at only 8 locations per specimen, which might be inadequate. Groten et al. suggested that, ideally, 50 or at least 20–25 measurements are required to obtain clinically relevant information about the gap size30.

The Cerec 3D system (Sirona, Bensheim, Germany) and the Everest system (Kavo, Bismarckring, Germany) use different software and milling systems to fabricate ceramic restorations15. Hamza et al. concluded that the Everest CAD system crowns showed significantly lower marginal gap than those of the Cerec InLab system15. However, the measurements were also made at only 8 locations per specimen, which might be inadequate to give accurate results.

Schaefer and colleagues concluded that the one step impression technique resulted in a significantly lower marginal gap of the E.max press partial-coverage crowns than the two step impression technique9. However, impressions were made on an acrylic resin model, which differs from dentine and enamel. In addition, soft tissue, saliva, crevicular fluid, humidity and temperature would differ between the intraoral and the laboratory environments.

The quality of preparation (ideal, fair, poor) had a significant effect on the marginal fit of E.max CAD crowns before cementation as shown by Renne et al.17. Despite the fact that the evaluators in the study of Renne and colleagues used magnifying loupes 2.5× for evaluating the quality of preparations, the preparation quality was assessed with a subjective method, using visual inspection to determine the extent that preparations differed from the ideal. This method could contribute to allocation bias in this study.

In additional research relating to preparation design, the mean marginal gap of E.max press crowns was not affected by the design of the finishing line (Shovel vs chamfer) as shown by Subasi et al. after cementation20 and Demir et al. before and after cementation9.

The major drawback of the study made by Subasi and colleagues is that the measurements were only made after cementation, with no measurements achieved before cementation as done by Guess and colleagues. Regarding the measurements after cementation, it does not show the fit of the restorative material without the cement layer. The cement layer may increase the marginal gap uncontrollably and unequally depending on the cement type and viscosity. Therefore, it is better to measure the marginal fit either before cementation, or before and after cementation. It has been reported that the marginal gap increased by 13 to 22 µm when the crown was luted with cement54,55. In our review, all the studies that tested the effect of cementation on the marginal gap of E.max restorations, had similar conclusion, that the cementation increased the marginal gap significantly56,57,58.
Borges and colleagues found no significant effect of the cement type (resin cement, Variolink II or resin-modified glass ionomer cement, Rely X), on the marginal fit of E.max press crowns. However, the study was conducted on extracted bovine teeth, which could have different characteristics and reaction with the fixating cements from those of vital human teeth, which in turn could have affected the results of the study.

Despite the drawbacks found in the studies included in our critical review, there were also positive methodological decisions which contributed to strong findings of individual studies. The sample size was sufficiently large to avoid type II errors, and allow confidence in the significant results reported by Borges and colleagues, Renne and colleagues, and Guess and colleagues. The studies of Yuksel and colleagues, Demir and colleagues, and Guess and colleagues were achieved on extracted human teeth and this allowed the behavior of the teeth under experimental investigations to be as similar as possible to the intraoral environment. One out of the thirteen studies measured the marginal gap at 50 or more locations for each restoration in the study, Neves and colleagues, minimizing measurement error and allowing the circumferential fit of the restoration to be estimated with the highest accuracy.

The results from studies evaluating the marginal fit of different all-ceramic restorations, show great variations within the same restorative material and technique. This might be explained by the following factors: Measurement of cemented or non-cemented restorations, the material from which the die model is fabricated from (acrylic, metal, zircon, human teeth and bovine teeth), the type of scanner and milling device, the thickness of the die spacer used, the type of microscope, the amount of magnification used for the measurement, and the number of measurements. Despite these differences, the mean marginal gap of all E.max lithium disilicate restorations in the studies appraised in this critical review, regardless of technique, was within the clinically acceptable range.

The results of this critical review are limited by aspects of its methodology. Studies published in languages other than English were excluded, grey literature was not sought, the electronic search strategy excluded indexing terms, and multiple bibliographic databases were not consulted. Therefore, it is likely that relevant articles were excluded from this critical review. The authors aimed to collate articles from the published literature at large. It is known that the exclusions listed above increase the chance that small studies, especially those with non-significant results, are not identified as part of the appraisal. However, the authors did not seek to complete a systematic review, and did not seek to combine the results quantitatively with meta-analytic techniques. The critical appraisal of the collated material completed in this review provides clinicians and researchers with an important resource to guide clinical decisions and to assist in the design of ongoing research. The authors acknowledge the limitations, but also espouse the contribution that this review has made to the knowledge base in this growing field.

This critical review provides information about the dimensions of vertical marginal gaps that can be achieved under experimental conditions in the in-vitro environment with E.max lithium disilicate. However, these in-vitro measurements do not necessarily reflect clinical reality. The studies have been designed to maximize internal consistency, allowing the data to be collated in a repeatable manner and understood within the context of each study. However, each in-vitro study environment differs considerably from everyday clinical practice. Differences may include (the existence of saliva and soft tissues make intraoral tooth preparation and impression making much more complicated than in-vitro ones, the prepared teeth in in-vitro studies might be fabricated from different materials that might have different characteristics than natural teeth, and other factors), which means that the results have reduced external validity. Despite this limitation, the information reported provides researchers with a “proof of concept”, and an important starting point to guide hypotheses for future clinical studies. Further research is required in three separate domains: (1) to determine whether these marginal gap dimensions can be routinely achieved in a clinical environment; (2) the clinical consequences that such marginal gaps have on the longevity and complication burden of restorations; and (3) to review such outcomes across different restorative materials.

CONCLUSIONS

Within the scope of this critical review, the following conclusions were drawn:

1. The majority of studies showed that E.max lithium disilicate restorations fabricated with the press technique have measurably smaller marginal gaps when compared with those fabricated with CAD techniques.
2. The marginal gaps achieved by the restorations across all groups were within a clinically acceptable range.

CONFLICTS OF INTEREST

None of the authors report any conflict of interests.

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